Technological Advisory Committee

Welcome to September 22, 2020 Meeting

Agenda

10am – 10:15am	Introduction and Opening Remarks
10:15-10:30am	Announcements and Roll Call
10:30am ~ 11:15am	Artificial Intelligence WG
11:15am-12:00pm	Future of Unlicensed Operations WG
12:00pm – 1:00pm	Lunch Break
1pm – 1:45pm	5G RAN Technology WG
1:45pm-2:30pm	5G IOT WG
2:30pm-3:00pm	Closing Remarks
3pm	Adjourned

FCC TAC AI and Computing WG
Artificial Intelligence

Chairs: Lisa Guess, Cradlepoint
Adam Drobot, OpenTechWorks, Inc.

FCC Liaisons: Michael Ha, Mark Bykowsky, Monisha Ghosh, Martin Doczkat, Robert Pavlak, Chrysanthos Chrysanthou, Gulmira Mustapaeva

Date: September 22, 2020

Agenda

- Artificial Intelligence (AI) and Computing WG Members
- Calendar Year 2020 WG Charter and Objectives
- List of Speaker Presentations
- Findings
  - Artificial Intelligence (AI and ML)
  - Data
  - Federal Investments in AI
  - Broadband Mapping
  - Projects of Interest to the FCC
- Draft Areas of Recommendation
- Deliverables
- Thoughts for Next Year

2020 Work Group Team Members

- Shahid Ahmed, Independent
- Sujata Banerjee, VMware
- Nomi Bergman, Advance
- Brian Daly, ATT
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- James Goel, Qualcomm
- Lisa Guess, Cradlepoint
- Russ Gyurek, Cisco
- Dale Hatfield, Univ of Colorado
- Stephen Hayes, Ericsson
- Mark Hess, Comcast
- Nageen Himayat, Intel
- Steve Lanning, Viasat
- Gabriel Lennon, Intern Univ of Colorado
- Kevin Leddy, Charter
- Anne Lee, Nokia
- Brian Markwalter, CTA
- Lynn Merrill, NTCA
- Michael Nawrocki, ATIS
- Dennis Roberson, entigenlogic
- Marvin Sirbu, SGE
- David Tennenhouse, VMware
- Jack Nasielski, Qualcomm

Artificial Intelligence WG - 2020 Charter

The Artificial Intelligence (AI) and Computing working group will continue its work on analyzing the ability of AI to improve the performance of telecommunications networks and the services enabled by these networks.

To that end, the working group will focus on the following questions as outlined in the subsequent slides:

Objective 1

- How can the results from recent programs in AI for spectrum and networking, such as the DARPA Spectrum Collaboration Challenge (SC2) and the NSF/Intel joint solicitation on Machine Learning for Wireless Networking Systems (MLWiNS), be leveraged for real-world systems and applications and for investigating new applications?
- Examples:
    - Understand spectrum usage techniques to automatically identify signals, detect and understand violations
    - Assist with enforcement to prevent interference
    - Improve physical layer protocols and signal processing
- Actions:
    - Schedule top 3 winners from challenge as SME speakers – (lessons learned and formulation of use cases)
    - Use and exploit results from federally funded research programs

https://www.spectrumcollaborationchallenge.com/ - DARPA Spectrum Challenge
https://www.nsf.gov/events/event_summ.jsp?cntn_id=299111&org=CISE - MLWiNS

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Objective 2

- AI relies on curated and labeled data sets being available for algorithm development and testing: what should the parameters of such data sets be?
- Issues and questions to be answered:
  - What data sets are already available?
    - Use cases helpful to the FCC such as Broadband America
    - Datasets for congestion, provisioning, advertising, marketing are other examples
    - Center for Applied Internet Data Analysis (CAIDA) at UCSD curated data sets on Internet traffic and network routing which could be helpful for AI (And experience with collecting, disseminating, and curating Data)
  - How can new data sets be collected and made available to the community?
    - What is the purpose of the data?
    - Where can the data be used and by whom?
    - How can carriers be incented to share data and information for mutual improvement?
    - How can location data be shared without violating privacy (it's tricky!).
    - Helpful application example is CV tracking. (Israel is using cellphone surveillance to warn citizens who may be affected by individuals already infected – WP article)

Objective 3

- How can AI be used to extract meaningful information from data that are either already available (e.g. from the Measuring Broadband America (MBA) program) or may become available, to determine the following:
  - Coverage at a more granular level
  - Service parameters available in smaller coverage areas than census blocks
  - Merged or Aggregated with other data to detect fraudulent activities such as unauthorized spectrum usage

Objective 4

- As legitimate applications of AI start proliferating, what risks should be evaluated and what AI tools exist or should be developed to identify and mitigate harms that might arise from the proliferation of AI?
  - How to promote safe use of AI?
  - How to deter deleterious use of AI?
  - How to build in robustness into the AI Methods and Techniques used?

Summary of Speaker Presentations

List of Speaker Presentations

Speaker	Affiliation	Presentation Title
Ulrika Jägare	Ericsson	“How AI is Shaping Telecom Operations”
Mazin E. Gilbert **Jack Murray**	AT&T Research	“AI for Autonomous Networks”
Mukarram Bin Tariq **Nandita Dukkipati**	Google	“Optimization of Computing and Communication Resources Using AI”
Rakesh Misra	Vmware (Uhana)	“Subscriber-Centric ML/AI in Mobile Radio Access Networks”
Jason Martin	Intel (and Georgia Tech)	“Machine Learning Security & Privacy”
Berge Ayvazian	Wireless 20|20	“Breakthroughs from Synergy Between AI and 5G”

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List of Speaker Presentations - Continued

Speaker	Affiliation	Presentation Title
Tan F. Wong **John M. Shea**	University of Florida	“Dynamic Spectrum Sharing: Lessons from the DARPA Spectrum Collaboration Challenge”
Peter Volgyesi, Miklos Maroti, Peter Horvath, Sandor Szilvasi	Vanderbilt University	“Spectrum Collaboration - Building Prize-Winning Radios”
Harry Surden	U of Colorado Law School	“Artificial Intelligence, Government and Ethics”
Martin Zoltick **Jennifer Maisel**	Rothwell Figg	“Legal and Regulatory Considerations: Application of Artificial Intelligence to Telecommunications and the FCC”
Ramana Jampala	Avlino	“Predictive Modeling & Machine learning-based optimization of network operations”
Jeff Alstott **Alexander Sprintson**	IARPA NSF	**“Security of AI Systems”** “Impacts of AI in the Wireless Networking domain”

List of Speaker Presentations - Continued

Speaker	Affiliation	Presentation Title
Elham Tabassi	NIST - ITL	"Artificial Intelligence: A NIST strategic priority"
Rafail Ostrovsky	UCLA Stealth Software	"Stewardship of Private Data with Cryptography"
Russell Stuart	UC Berkeley	"Artificial Intelligence: History and Future"
Stephen Dennis **Sridhar Kowdley**	DHS S&T	" Artificial Intelligence and Machine Learning"
Ajay Vikram Singh	Nokia	" Artificial Intelligence as a Service - AIaaS"
Petros Mouchtaris	Prospecta Labs	" AI/ML Research with Applications in Telecommunications"
Thyagarajan Nandagopal	NSF	"The NSF PAWR Initiative"

Upcoming Speaker Presentations

Speaker	Affiliation	Subject
Michael Cotton	NTIA - ITS	EM Propagation Data, AI, and 801.22.3
Kumar Navulur	DigitalGlobe - Maxar	GIS Systems for Telecomms and AI
Danny Weitzner	MIT - CSAIL	The Internet and AI
Russell Stuart	UC Berkley	Return Visit – AI and Control

Danny Weitzner

Kumar Navulur

Michael Cotton

Findings

Findings: AI and ML

Findings – Artificial Intelligence (Machine Learning and Other Methods)

- Artificial Intelligence as a term describes computational techniques consisting of multiple major branches each focused on different methods, approaches, or areas of application.
- Since the term "Artificial Intelligence" was coined in the mid 1950s there have been successive waves of deployment of applications that are now routine (such as Optical Character Recognition) or have been widely adopted (among others in areas such as machine vision, speech recognition, natural language processing, knowledge systems, classification systems, and applications including: noise cancellation; search; customer relationship management, chatbots for customer facing services; facial recognition; gaming, control systems; and analysis of high dimensional data)
- Within the family of AI techniques Machine Learning (ML) and its sub-branches have recently seen a dramatic surge of investment, activity, and popularity across multiple domains including those that may be of interest to the FCC, with significant impact now, in the near-term, and potentially profound impact in the long term.

Findings – Artificial Intelligence (Machine Learning and Other Methods)

- The various flavors of ML hold significant promise for dealing with the complex problems that are important to network planning and design, control and operation of networks, the management of resources such as spectrum, for the technologies used as the building blocks of network architectures, components, devices, and applications, and lastly for customer services and automation of customer interactions through chatbots.
- With the continued growth of demand for digital traffic, Networks now connect over 4 Billion people on the planet and 10's of Billions of devices. ML as a tool set is important because the increasing level of complexity is outpacing the ability of well-established methods in reliably delivering solutions and ML offers a potential approach for conquering that complexity. It is particularly important for machine-to-machine communications characteristic of Industrial uses, the Internet of Things, and the increased heterogeneity of digital traffic on the Network.
- The sheer scale and new exacting requirements for network performance are compounding the problem. There is a widely recognized need for a higher level of automation of Network Functions to deliver efficient and in some sense near optimal solutions. (Examples can be found in areas such as: spectrum sharing; network access control; security and privacy, management of 5G Networks; siting and operational aspects of wireless Network Densification, and in specific new capabilities such as Network Slicing). AI is not just a tool it has the potential of being a gamechanger!

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Findings – Artificial Intelligence (Machine Learning and Other Methods)

- A basic aspect of traditional techniques (Analytics, Simulation, Modelling, and Statistical Methods) is to build up the understanding of phenomena and behaviors at a cause and effect level. That understanding is then applied for control or decision making, typically using reduced models that have undergone rigorous testing. Progress along this path is made possible by exploiting the underlying advances in science and engineering principles. As with ML, advances depend on improvements in computational capabilities. They also depend on better data from improved instrumentation and observations at a more and more granular scale.
- In contrast, what is different about ML is that it is built on pattern recognition and critically depends on training. That in turn requires massive amounts of data that accurately, and as completely as possible, cover the range of conditions possible in an application. It requires powerful computational capabilities for accomplishing the training. ML does not provide cause and effect results! ML can overcome aspects of complexity where no other tools to deal with it exist, yet at the same time, it has limitations which are not well understood today.

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Findings – Artificial Intelligence (Machine Learning and Other Methods)

- A key feature of ML is the significant asymmetry in the computational resources needed for training vs those needed for execution of ML Models. It is typical that training will be conducted in large cloud like facilities, but the ML Model execution on connected fast edge devices - Inference Engines (that run at rates 4-6 orders of magnitude faster than the training).
- One of the allures of ML based solutions is the relative simplicity of ML Models and the fact that the edge devices (Inference Engines) can execute many different ML Models on the same hardware. In addition the settings of the parameters in the Model can be tuned to capture improvements from additional data or new data used for training.
- It is important to say that AI methods are far from achieving what is referred to as ”General AI” – that is the ability to reason like human beings and to be able to make the kind of generalizations, that human beings are capable of, or common sense reasoning in the face of ambiguity or previously unencountered conditions. There are however techniques and methods within AI, such as Reasoning, Rule Based, and Knowledge Based Systems (Narrow AI) that significantly exceed human performance.
- Based on presentations from our expert speakers and a review of literature, in addressing applications it is important to consider a mixture of AI Techniques, not just ML, along with an appropriate mixture of traditional methods.

Findings – Artificial Intelligence (Machine Learning and Other Methods)

- It is highly likely that ML will be used extensively within the Network to perform critical and important functions. Aspects of ML and AI have already been adopted by operators, especially where ML/AI are used with human-in-the-loop, to recommend options, for engineering, backend, and consumer facing applications and it is again likely that such use will only increase over time. Our speakers have repeatedly presented examples of ML Models displaying unpredictable or grossly incorrect results. While these phenomena do not occur frequently, they are not well understood. With surprises not welcome – this is an important area to examine for what is acceptable and what is not.
- Within the cycle of ML Model preparation, testing, deployment, and operation there are unique new vulnerabilities that affect security, privacy, and trust regimes. This combined with inherent limitations of AI/ML Models leads to two important questions:
    - How can AI/ML be used safely and reliably within the Nations Networks and as part of Service Offerings
    - Knowing that AI/ML performance is not perfect, what are the appropriate metrics for acceptability?

Findings – Artificial Intelligence (Machine Learning and Other Methods)

- For an organization like the FCC to deal with the opportunities and challenges posed by the wide adoption of AI there needs to be a cadre of experienced staff with knowledge of AI Technologies, and familiarity with the emerging AI ecosystem.
- The motivation for this statement comes from identifying areas where AI can be used for activities within the FCC and the resources needed for success. It also includes where policies from the FCC and emerging legislation impact the use of AI/ML by the Telecommunication Industry, and the end-users of Telecommunication Services by Commercial Firms and the Public. We provide a list of promising areas for AI later in this briefing.

Findings – Artificial Intelligence (Machine Learning and Other Methods)

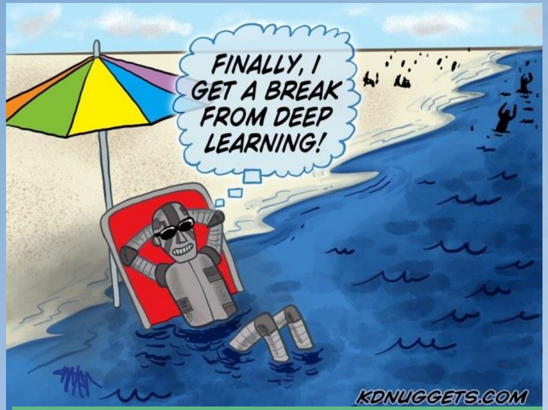
Summary

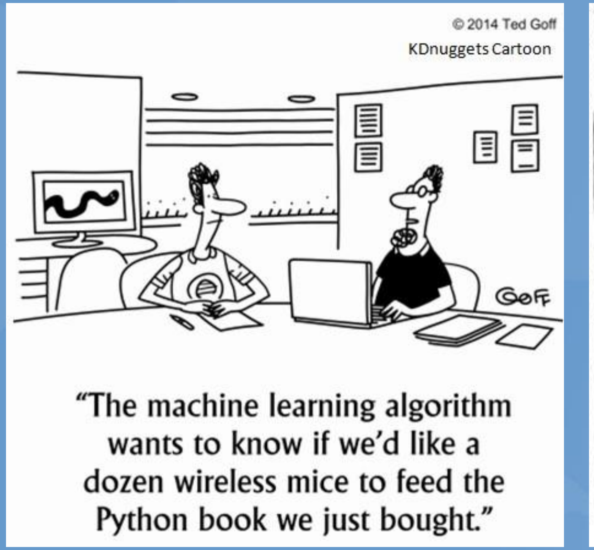
We have identified the following priority issues in the findings on AI and ML:

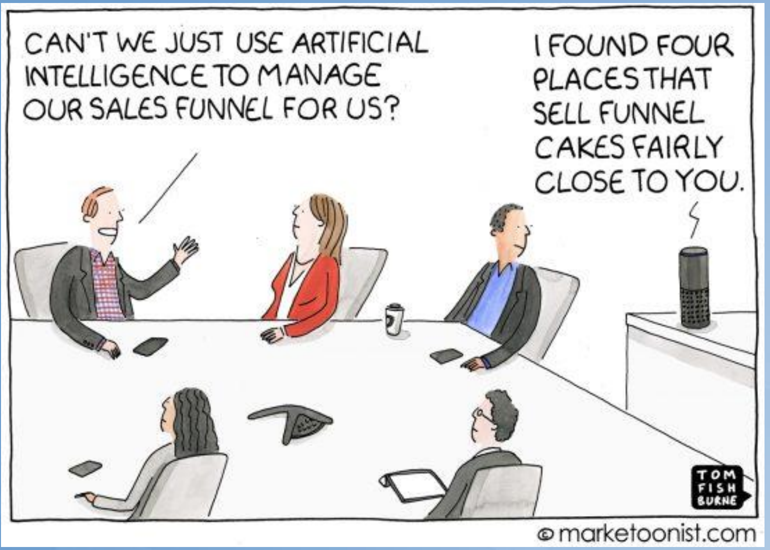
- The first is the importance and criticality of Data and its availability across the AI ecosystem. The FCC can play a positive role that ranges from accelerating progress in the evolution of AI Technologies, to a positive impact on the Nations Networks to better serve Government Organizations, the competitiveness of the Telecommunications Industry, and the needs of the Public.
- Anticipating the transition of the Nations Networks to be dominated by Machine-Machine traffic where telecommunications connectivity and access to Computing and Data Storage resources is broadly available – from Edge to Cloud!
- Establishing well thought through approaches and criteria for the Safe use of AI and ML Technologies as they are increasingly incorporated in the Nations Networks and the accompanying Services and Applications.

Findings – Artificial Intelligence (Machine Learning and Other Methods)

A measure of acceptance of AI/ML and its maturity as measured by popular humor!







Findings: Data

Findings – Importance of Data and the Data Lifecycle for AI applications

- Oversimplifying by using a general abstract label such as "Data" does not convey the essence of what the data can mean. It also does not capture the diversity and the variety of data types, the completeness of the data, what specific requirements the data is associated with, the importance of the data to the FCC, the impact it can have on the ecosystem (the large number of stakeholders that have an interest and need for the data), the dependence on the data of third parties doing business with FCC and the dependence of the FCC on data in the hands of third parties, and lastly the essential and central role that data plays in extracting value from AI/ML applications.
- One way of saying this is that making headway with AI/ML requires relevant data that is reliable and verified and allows the community and stakeholders to have faith in the data and its provenance and clear rules for how the data may be used. To invest and deploy AI solutions, the community must have some certainty for the basis on which they can build their plans and their businesses. This is good for the economy, good for further technology advancement and good for the country and its competitiveness.
- We have identified the availability of relevant "Data Sets" and the uncertainty of the business models and polices surrounding such "Data Sets" as the single most important impediment to progress.

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Findings – Importance of Data and the Data Lifecycle for AI applications

- In large-scale AI/ML deployments the typical allocation of resources to Data and its processing runs between 50% and 80% of the budget:
- It includes:
  - Identification of Relevant Data
  - Feature Selection
  - Input of Raw Data (Many Sources)
  - Collection and Transmission
  - Cleaning and Annotation
  - Storage and Management
  - Analysis and Training
  - Sharing and Distribution
  - Updates and Corrections

Source: Mark Cusack, Teradata

- Successful project require considerable resources, domain expertise, domain knowledge, and time! According to studies by McKinsey and others a large fraction of projects succeed in pilots but fail to achieve their goals in deployment!

Findings – Importance of Data and the Data Lifecycle for AI applications

- Data, as alluded to previously, comes in many diverse forms and it is useful to bin the type of data and what it is useful for, its characteristics, the source of the data and its ownership, and the rules that may apply to it. Examples below

Type	Characteristics	Source	Ownership	Regimes
Technical	Volume	Sensors/Devices	Public Domain	Private Person Info
Operational	Velocity	Logs	Open Source	Protected
Performance	Variety	Media	Government	Restricted
Customer	Variability	Crowdsourced	The FCC	Open Source License
Documentation	Veracity	Specific Projects	Operators	Private Proprietary
Survey	Value	Reporting Req.	Vendors	Commercially Available
Legal	Visualization	Purchased	Restricted	Sensitive

Findings – Importance of Data and the Data Lifecycle for AI applications

- The oversight of Data carries responsibilities for the Data's Security, Cyber-security, Privacy, Trust, and a long list of requirements that deal with its availability, reliability, and assurance of access, among others. There are emerging technologies and techniques in this area that may alleviate some of the constraints. These include Blockchains, Homomorphic Computing (Where the Data is encrypted but it is possible to obtain aggregated results without revealing the underlying Data), and shared-secret methods. Several of these techniques have been applied in conjunction with AI Inference Engines.
- The access to relevant and significant Data Sets is important to the Basic and Applied Research Communities. We found a significant number of programs working on a wide array of AI applications to problems in Networking, Wireless Systems, and Characterization of RF and mmWave phenomenology. In general Data for what would be meaningful in a commercially significant situation is not available (The exception is individual investigators or laboratories working directly with major operators or equipment suppliers where the Data use and outcomes are restricted) This is an important issue to address, having long term implications for maintaining a competitive and pre-eminent Telecommunication Industry in the US.

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Findings – Importance of Data and the Data Lifecycle for AI applications

- The FCC has a lead role to ensure the nation has a competitive and outstanding best-in-class Telecommunications System. In this role, there is data that the FCC should be responsible for. This includes generating and collecting, data the FCC needs access to, and to ensure other entities in the ecosystem also have appropriate levels of access to the data (Federal Agencies and Departments, Local and State Governments, Operators, Suppliers, Consumers, Industrial Enterprises, and Small and Medium Sized Businesses, the Research Community, as well as AI/ML mechanisms that allow for shared learning of results/outcomes between owners of data while keeping the data private)

  Examples

  - Broadband usage and availability
  - Spectrum usage , efficiency of usage, and occupancy
  - Location of interconnect points
  - Outage reporting

- The Curation of Data Sets is an important aspect of operationalizing AI/ML applications. Curated Data becomes an assets with multiple, meaningful uses and its value often increases when it is easy to fuse Data from multiple Data Sets and to provide tools for searching, displaying, and analyzing the Data and providing common Data services (an example would be notifications that Data of interest to a user has been modified and augmented, configurable maps for displaying overlays from multiple Data Sets, time series displays, and compatibility with and interfaces to widely used Data tools)

Findings – Importance of Data and the Data Lifecycle for AI applications

- Data fuels AI in terms of its usefulness but requires consistent and trusted guardrails
  - Personal Private Information Protection
  - Visibility into and Validation of Data used for significant decisions
  - Analysis and Testing of AI used for control in critical network systems

- Consistent Approach to Meta-Data (Identity, Meaning, Time, Source Identification, Labelling, Definitions and Standards……..
  - Examples
    - Technical Data related to Network Management and Control
    - Technical Data for Network Assets
    - Data necessary for the National Broadband map
    - Data received by the FCC in response to NPRMs (Searchable Text Files with tools for analysis)
    - Data related to auctions and licenses (including Historical Data)

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Findings – Importance of Data and the Data Lifecycle for AI applications

- There are standards bodies working on frameworks to help address the Data issue. Perhaps, some of these frameworks like Network Data Analytics Function(NWDAF) introduced into 5G several years ago, can alleviate the data issues for AI agents working within wireless systems. However, there may be a time gap from now until when these frameworks are in place in the field. In the meantime, it may be good to have an alternate solution(s) for providing the data that would keep AI/ML progress moving forward, esp. if the U.S. wants to maintain leadership in the world.
- The Linux Foundation in collaboration with Telecommunication Operators is also formulating approaches that lay the groundwork for open sharing of ML models for Network Control and Management Functions.

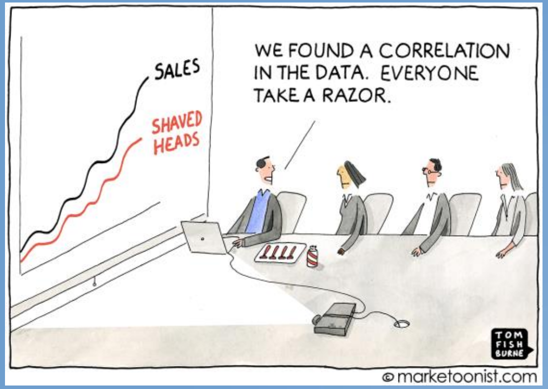
Findings – Importance of Data and the Data Lifecycle for AI applications

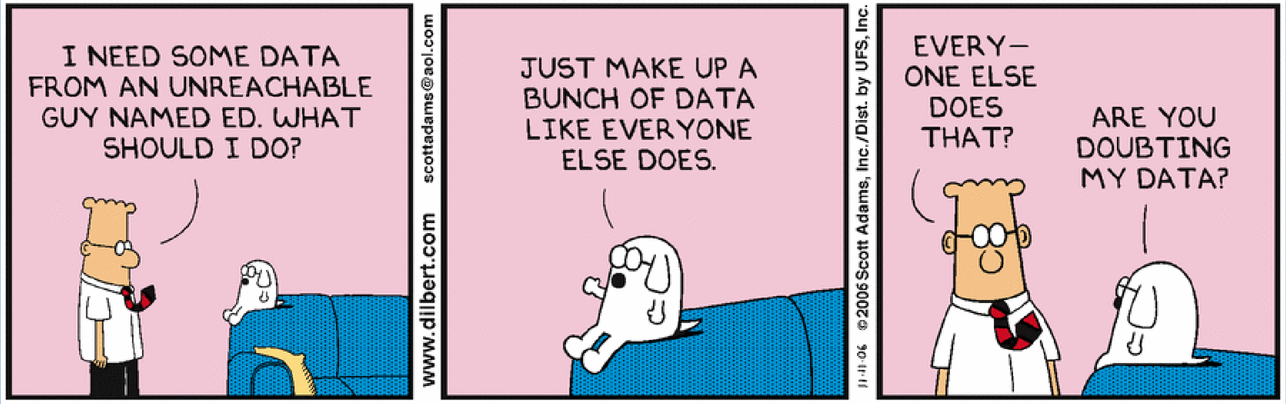
Summary

- The FCC needs a clear policy and approach for the sharing and dissemination of Data. A clear policy and a business model that will work well for the FCC to determines what is best for the FCC to do on its own, what Data should be handled by Industry Bodies and Consortia, what Data is best procured on a Commercial Basis and what Data could be available through a Data Exchange. As important is how the FCC can best promote the sharing of Data across the ecosystem to ensure advancement and where appropriate adoption of AI/ML Technologies.(An example would be availability of Data for the Research Community, availability of Data for Small and Medium Sized Businesses, Data to assist unserved and underserved communities)
- The Acquisition and Curation of meaningful Data Sets is a critical aspect of obtaining the benefits from AI/ML technologies. This can be done in stove-pipes one project at a time, but experience has shown that developing a Data Curation infrastructure and a Data Centric mindset is functionally more effective and in the long runs shortens the time to value for individual projects.
- Developing a Data regime that serves the FCC and National needs in providing a reliable and competitive Network Infrastructure requires– Staffing, Expertise, Time and Money.

Findings – Importance of Data and the Data Lifecycle for AI applications

Public attitudes towards Data and its Analysis as seen in Humor!





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Findings:

Federal Investments in AI

Broadband Mapping

Projects of Interest to the FCC

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Findings - Federal Investments in AI

- The AIWG has heard from a broad range of experts responsible for basic research, standards, and other initiatives. Regarding the basic and applied research our general observation is that the programs we reviewed are attempting to leverage AI to it's fullest, and attacking important issues, but uniformly the missing piece is access to high quality, current, labeled, and curated Data. It's in the interest of the FCC to help mature the investments in AI/ML relevant to Communications and Operational issues. This cannot be done without the availability of Data , the Sharing of AI/ML Models.
- While the research agencies are willing to provide some level of funding for data gathering and collection, by tradition they are unlikely to support the funding for longer term maintenance and curation of the data and the steps that would make the data useful outside the scope of individual programs and projects. This leaves a hole in the larger ecosystem for the contribution that the investments could make to US leadership in Telecommunications.

Findings - Federal Investments in AI

- The AIWG also examined significant and innovative AI projects that focused on important issues such as spectrum sharing, the automated categorization and identification of EM emission sources and the use of AI to improve Wireless Network Protocols and Access Methods. The work was suggestive of what would be possible in a commercial setting. We perceived a need for a much closer collaboration between the funding agencies. the FCC and Industry, with the objective of steering the research to include conditions likely to be encountered in actual Networks.
- We also found that Agencies working on Standards, Advanced Prototypes, and Deployments have important capabilities and facilities relevant to the FCC. These include Frameworks for Data Governance, Security and Privacy, etc. Many of these were developed in consortia with Industry. It may be of value for the FCC to be an active partner and participant.

Broadband Mapping RFI

- The development of a Broadband Map has multiple aspects to it and is a major undertaking. It involves capturing the drivers and constraints for the scope, an understanding of and fleshing out of the requirements at a detailed level, operational considerations for how it will be used and by whom, and provisions for eventual operation and sustainment. There are multiple approaches possible and the development, for what it entails, will most likely include a systematic analysis of the trade-offs for how it may be developed, what technologies will be involved, and a concrete plan for how the work will be accomplished (a constructive step by step plan with timelines, milestones, and a budget) and eventually operationalized.
- In presentations to the AIWG we heard from a number of experts that a significant application of AI/ML technologies is already being used with success for network planning. The requirements for such planning in all likelihood parallel many of the requirements for the Broadband Map as do the requirements for data collection.

Broadband Mapping RFI

- The overall project will also require integration skills, have significant number of components and elements, field teams, and including data from many different sources.
- There is significant capability available commercially and within academic institutions that a well-crafted Request for Information (RFI) will be informative to the FCC. It can help identify technologies available, sources of data, approaches for architecting a solution, approaches for development and eventual deployment, and most importantly providing a factual basis for estimating of the budgets required for different lifecycle stages.
- The results of the response would be followed by an analysis of what role the FCC choses for itself and what items would be procured and competed for through an RFP.

Findings - Areas of interest to the FCC

- The AIWG held several sessions collecting ideas for where AI/ML may have significant impact and could be of importance to the FCC's missions. This is an incomplete list but indicative of what is possible. We intend to present a much more complete list in the year end TAC meeting in December.

Area	Benefit
Improved Propagation Models	Increase in Spectrum Utilization
Identification of Interference Sources	Automation of Enforcement Functions
Trading Models for Data Sharing	Accelerating Technology Development for Network Elements
Analysis of Outage Data	Elimination of likely causes

Findings - Areas of interest to the FCC - Continued

Area	Benefit
Analysis of Comments to FCC Actions	Better understanding of positions and auto generated material
FCC Data Bases and Website	Improved service for FCC Customers and The Public
Network Security and Privacy	Decreased Threat Exposure
Spectrum Sharing	More Dynamic Sharing and Development of spot Markets
Robo-calls and other annoyances	Identification of violations
Emergency Response	Faster service restoration
Preventing Adversarial use of AI	Get ahead of the curve on a rapidly emerging problem - AISEC
…………………………………..	

Draft Recommendations

Draft Recommendations – Strategic Plan

- FCC should have a strategic plan for AI and Data that explicitly deals with the potential AI impacts across all bureaus and offices
  - The AIWG will be specific about what should be considered in the plan
  - The Plan should define boundaries where AI is helpful as it relates to interests of the FCC and exclude where it is not helpful
  - Caretaking of AI requires considerable resources so the FCC must be judicious in the areas of application
  - Caution must be exercised to avoid “hype” and to focus on where specific deliverables can be achieved in a defined time frame
- The Plan should include the FCC’s vision for AI which is still to be defined
  - Include how the FCC embraces AI for its own use
  - This should include outlining the need for internal resources with significant AI experience, both theoretically and experientially
  - Define what immediate, defined and bounded projects the FCC may undertake to build up expertise and experience as an organization
  - The strategic plan should include a comprehensive strategy for all aspects around ”Data”

Draft Recommendations – Strategic Plan

- AI as a Tool should be included in the Plan
  - While many people consider AI as just a tool, there is a solid reason to believe that the tools under the AI label have profound effects, will likely have more in the future, and impact almost all the functions that the FCC performs. Some of that Future has already arrived with the emphasis on the Network traffic shifting to connected devices and machine-to-machine communications.
- Having a solid updated plan helps ground the FCC to understand what to do internally or when to leverage a third party
- The Plan should define why AI is important for the network, and have a particular focus in this area
- The Plan should also refer to areas where AI/ML are in use today with positive benefits and promise
- The Plan should also address what Tools and infrastructure the FCC may share with or develop to address common problems across multiple Agencies.

Draft Recommendation: Federal Investments

- There are many opportunities to leverage federal investments and research in AI
- There are many early state experimentations underway with positive yet isolated results that the FCC can help shepherd
  - A common finding was that fundamental challenges existed around access to data, and in sharing data
  - FCC would be a good mediator for the entities (NSF, DARPA)
- The FCC has applicable use cases internally that can benefit from AI
- The FCC should also focus on areas to partner with other entities such as the NIST and NSF
- Engaging the research community is important to move this area forward.

Draft Recommendations: Data

- Data Issues
  - AIWG plans for recommendations on Data structure and the positive role FCC can bring to bear in fostering a curated Data structure
  - Clear policy is needed but must be considered in the context of other organizations so as not to duplicate effort but to work in tandem
  - Partnership with other entities to leverage good frameworks is beneficial. Care should be taken to re-use and leverage and align with these frameworks.
- The FCC Itself is a keeper of many databases that are useful for the research community. The FCC should provide this information, curate the information, and understand when to leverage third parties

Draft Recommendation: Safe Use of AI

- Safe use of AI
  - AI will become entangled with network systems and this brings danger
  - The FCC must think through how AI is being used, and ensure that AI does not introduce compromise into the Network
  - What does the notion of "Safe use of AI" include? Below are a few examples:
    - Ethical – bias, using inappropriately collected data
    - Resistance to attacks
    - Integrity of data
- A key point from our speakers - The more powerful AI is, the more adverse the consequences it can enable.
  - Should we create systems that aren't so independent and require human intervention? This is an example of an area the FCC should explore
  - There are already examples of Adversarial use of AI, and it is important to develop defenses now!

Draft Recommendation: The Broadband Map RFI

- The AIWG will recommend that the FCC issue an RFI for the generation of a granular Broadband Map
  - This is a specific opportunity to learn where can AI can contribute by focusing on a specific, bounded and relevant, beneficial issue
  - The recommendation will outline at a high level what should be included in the RFI with suggestions on types of potential participants
- This exercise will provide several critical deliverables
  - Facilitate learning with an actual hands-on relevant project
  - Provide a vehicle to define specific resources to be allocated (funding, expertise)
  - Provide valuable data progressing toward a granular Broadband Map
  - Increase understanding of where to leverage third parties, where to perform the work internally, and where to apply a hybrid approach
- We feel there are third parties who would take on the task and illuminate technologies that already exist to produce the map
- The Broadband Map itself is an important asset that can be leveraged by many parties for the benefit of business, the community, and in informing future actions

Draft Recommendation: Focused action in areas of interest to the FCC

- Create task forces, workshops or forums in specific relevant areas
  - Focus on areas where learning can occur while delivering output of tangible value
- Conduct Pilots in these areas where most relevant
- The AIWG will provide a meaningful list of areas in the December presentation

December Deliverables

- Final Recommendations
- White Paper
- Appendix of current AI research
- Thoughts for next year
  - Potentially form a working group focused on the broad topic of Data
  - Potentially form a working group to explore and define the Safe Use of AI

Thank You.

Appendix 1.
Speaker Biographies

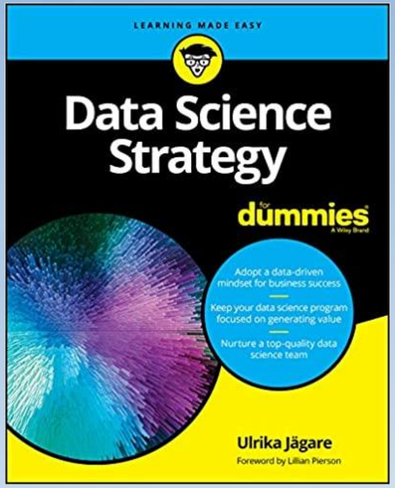
Ulrika Jägare

ERICSSON

Head of AI/ML Strategy Execution at Ericsson

“How AI is Shaping Telecom Operations”

- **Ulrika Jägare** is an M.Sc. Director at Ericsson AB. With a decade of experience in analytics and machine intelligence and 19 years in telecommunications, she has held leadership positions in R&D and product management. Ulrika was key to the Ericsson’s Machine Intelligence strategy and the recent Ericsson Operations Engine launch – a new data and AI driven operational model for Network Operations in telecommunications. She is the Head of AI/ML Strategy Execution at Ericsson.



Mazin E. Gilbert

AT&T

Vice President of Technology and Innovation AT&T Research

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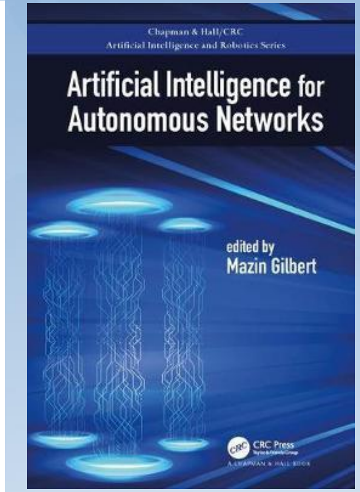
- **Mazin E. Gilbert,** Ph.D., MBA leads AT&T’s research and advanced development for a software-defined network, overseeing advancements in networking and IP network management, network virtualization, big data, speech and multimedia technologies, information systems and visualization, algorithms and optimization, and scalable, reliable software systems. His business areas of focus include product strategy and development, entrepreneurship, and corporate finance. He is the recipient of the AT&T Science and Technology Medal Award (2006).



Mukarram Bin Tariq
Nandita Dukkipati

Software Engineers at Google Inc.

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- **Nandita Dukkipati** is a Principal Engineer, leading Congestion Control and end-to-end Telemetry systems at Google. Her mission at Google is to deliver excellent end-to-end network performance for applications through making better use of shared capacity, smarter scheduling systems / QOS, providing end-to-end visibility into application behavior and making network control schemes work well at scale. She has published ward-winning papers in premier Networking conferences with fundamental contributions to Congestion Control, traffic shaping, and Bandwidth Management. She received her PhD from Stanford University in Electrical Engineering in 2008.
- **Muhammad Mukarram Bin Tariq** leads the network systems management area at Google. His team is responsible for the systems that make critical network changes to meet the ever-increasing network and compute capacity needs for Google and its customers. This is enabled through high velocity in operations while simultaneously maintaining the highest standards of availability and safety. In his ten years at Google, Mukarram has made numerous contributions to Google's cluster and edge networking, enabling new capabilities, high performance for our users, and allowing Google to scale. Some of these contributions are published, e.g., the Espresso work in Sigcomm 2015. Mukarram received his PhD in Computer Science from Georgia Tech in 2010.

Petros Mouchtaris, Ph.D.

perspecta LABS

President, Perspecta Labs

- Dr. Petros Mouchtaris is president of Perspecta Labs, providing the vision and leadership for transformative applied research across the organization. He has more than 30 years of experience in research and development, both as a technologist and a senior manager.
- Prior to being appointed as president, he served as vice president of applied research and played a key role in growing the organization and setting its strategic direction. In particular, he has led the entry into advanced security for wireless ad hoc networks and served as principal investigator for various projects funded by two of the organization's biggest customers—the Defense Advanced Research Projects Agency (DARPA) and the U.S. Army Communications, Electronics, Research, Development and Engineering Center (CERDEC).
- In previous roles he has been assistant vice president of Telcordia Technologies' Network Systems Laboratory, director of Oracle's Product Development and technical director at Pacific Bell (now AT&T).
- Mouchtaris has been published extensively in the areas of wireless networks, cybersecurity, voice-over-IP and smart grid security, and he is co-author of the book "Security for Wireless Ad Hoc Networks." He was named by Billing & OSS World as one of the "25 Most Influential People in Telecom Software" and in 2011 he was elected a Telcordia Fellow.
- Mouchtaris holds a bachelor's degree in electrical engineering from the National Technical University of Athens, Greece, as well as a Master of Science and doctorate in electrical engineering from the California Institute of Technology

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Rakesh Misra

Co-Founder Uhana (now part of Vmware)

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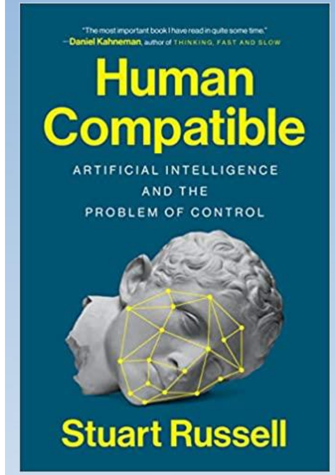
- **Rakesh Misra** is Co-founder Uhana Inc (now part of VMWare). He received his PhD from Stanford University, and B.Tech & M.Tech from IIT Madras. He was born/and grew up in Bhubaneswar/Berhampur, Odisha.

Stuart Russell

Professor of EE and CS at the University of California at Berkeley

Stuart Russell received his B.A. with first-class honours in physics from Oxford University in 1982 and his Ph.D. in computer science from Stanford in 1986. He then joined the faculty of the University of California at Berkeley, where he is Professor (and formerly Chair) of Electrical Engineering and Computer Sciences, holder of the Smith-Zadeh Chair in Engineering, and Director of the Center for Human-Compatible AI. He has served as an Adjunct Professor of Neurological Surgery at UC San Francisco and as Vice-Chair of the World Economic Forum's Council on AI and Robotics. He is a recipient of the Presidential Young Investigator Award of the National Science Foundation, the IJCAI Computers and Thought Award, the World Technology Award (Policy category), the Mitchell Prize of the American Statistical Association, the Feigenbaum Prize of the Association for the Advancement of Artificial Intelligence, and Outstanding Educator Awards from both ACM and AAAI. From 2012 to 2014 he held the Chaire Blaise Pascal in Paris, and he has been awarded the Andrew Carnegie Fellowship for 2019 to 2021. He is an Honorary Fellow of Wadham College, Oxford; Distinguished Fellow of the Stanford Institute for Human-Centered AI; Associate Fellow of the Royal Institute for International Affairs (Chatham House); and Fellow of the Association for the Advancement of Artificial Intelligence, the Association for Computing Machinery, and the American Association for the Advancement of Science. His book "Artificial Intelligence: A Modern Approach" (with Peter Norvig) is the standard text in AI; it has been translated into 14 languages and is used in over 1400 universities in 128 countries. His research covers a wide range of topics in artificial intelligence including machine learning, probabilistic reasoning, knowledge representation, planning, real-time decision making, multitarget tracking, computer vision, computational physiology, and philosophical foundations. He also works for the United Nations, developing a new global seismic monitoring system for the nuclear-test-ban treaty. His current concerns include the threat of autonomous weapons and the long-term future of artificial intelligence and its relation to humanity. The latter topic is the subject of his new book, "Human Compatible: AI and the Problem of Control" (Viking/Penguin, 2019).



Jason Martin

intel

Principal Engineer, Intel

"Improving cyber-defenses against deception attacks on machine learning models" **DARPA GARD Program**

- **Jason Martin** is a Senior Staff Research Scientist in the Security Solutions Lab and manager of the Secure Intelligence Team at Intel Labs. He leads a team of diverse researchers to investigate machine learning security in a way that incorporates the latest research findings and Intel products. Jason's interests include machine learning, authentication and identity, trusted execution technology, wearable computing, mobile security, and privacy. Prior to Intel labs he spent several years as a security researcher performing security evaluations and penetration tests on Intel's products. Jason is a co-inventor on 19 patents and received his BS in Computer Science from the University of Illinois at Urbana-Champaign.

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Berge Ayvazian

Senior Analyst/Consultant at Wireless 20|20

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- **Berge Ayvazian** Berge Ayvazian is a senior telecom industry analyst and consultant, with a 30-year career including more than 20 years with Yankee Group where he served as CEO. As a Senior Analyst and Consultant with Wireless 20/20, he leads an integrated practice to help operators secure 5G spectrum and work with vendors to develop their wireless technology roadmaps and build a complete WiROI™ Business Case.
- Ayvazian is currently conducting research on Wireless Networks, IoT and AI Strategies, and how the wireless industry can harness AI and machine learning in the climb to 5G networks. Ayvazian has also served a frequent speaker and program director for mobile and telecom industry events worldwide, including Big 5G, AI World, 5G North America, Tower & Small Cell Summit and 4G World and Mobile Internet World conferences. The following are some articles written last year for AI Trends.
- 5G Wireless Networks And AI Will Power Enterprise Digital Transformation
- Employing AI to Enhance Returns on 5G Network Investments
- AI at the 5G Wireless Network Edge
- Mobile Visions: IBM’s Plans for AI, Cloud Computing, 5G Networks
- What is the Potential ROI from AI in 5G Wireless Networks?

Tan F. Wong
John M. Shea

UF UNIVERSITY of FLORIDA

GatorWings Team – DARPA Spectrum Challenge

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- **Tan F. Wong** is a Professor of electrical and computer engineering at the University of Florida. His research activities mainly aim towards achieving intelligent and secure use of the radio spectrum. Tan recently led Team GatorWings, a team of students and professors, to win the DARPA Spectrum Collaboration Challenge, in which competing teams employed AI technologies to share the radio spectrum with each other and incumbent networks autonomously and efficiently.
- **John M. Shea** is a Professor of electrical and computer engineering at the University of Florida. His research is in the areas of wireless communications and networking, with emphasis on military communications, software-defined radio, networked autonomous systems, and security and privacy in communications. He was co-leader of Team GatorWings, the overall winner of the DARPA Spectrum Collaboration Challenge.

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Peter Volgyesi, Miklos Maroti, Peter Horvath, Sandor Szilvasi

VANDERBILT UNIVERSITY

MarmotE Team DARPA Spectrum Challenge

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- **Péter Völgyesi** is a Research Scientist at the Institute for Software Integrated Systems, Vanderbilt University. His current research interests include wireless sensor networks and domain specific modeling environments. He received an M.Sc. in Computer Science from the Budapest University of Technology and Economics.
- **Miklos Maroti** a former EECS research associate professor, is an associate professor at the University of Szeged, Hungary.
- **Peter Horvath** a former postdoctoral scholar at ISIS, is an associate professor at Budapest University of Technology.
- **Sandor Szilvasi** PhD’14 and former ISIS research assistant, is a radio frequency and FPGA (field-programmable gate array) engineer in Atlanta.

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Harry Surden

University of Colorado Boulder

Associate Professor, University of Colorado at Boulder

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- **Harry Surden** Harry Surden is an Associate Professor of Law at the University of Colorado Law School. He joined the faculty in 2008. His scholarship focuses upon legal informatics, artificial intelligence and law (including machine learning and law), legal automation, and issues concerning self-driving/autonomous vehicles. He also studies intellectual property law with a substantive focus on patents and copyright, and information privacy law. Prior to joining CU, Professor Surden was a resident fellow at the Stanford Center for Legal Informatics (CodeX) at Stanford Law School. In that capacity, Professor Surden conducted interdisciplinary research with collaborators from the Stanford School of Engineering exploring the application of computer technology towards improving the legal system. He was also a member of the Stanford Intellectual Property Litigation Clearinghouse and the director of the Computer Science and Law Initiative. Professor Surden was law clerk to the Honorable Martin J. Jenkins of the United States District Court for the Northern District of California in San Francisco. He received his law degree from Stanford Law School with honors and was the recipient of the Stanford Law Intellectual Property Writing Award. Prior to law school, Professor Surden worked as a software engineer for Cisco Systems and Bloomberg L.P. He received his undergraduate degree with honors from Cornell University.

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Martin Zoltick
Jennifer Maisel

ROTHWELL FIGG

IP Professionals

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- **Martin M. Zoltick** is a technology lawyer with more than 30 years of experience representing inventors, innovators, entrepreneurs, and investors. Marty has a degree in computer science and, prior to attending law school, he worked for several years as a software developer and engineer. His formal training in computer science and technical experience as a practicing software developer and engineer has enabled him to handle complex software-related legal matters successfully in a cost-effective and efficient manner. Marty’s practice is focused primarily on intellectual property (IP) matters, transactions, and privacy, data protection, and cybersecurity. He is a registered patent attorney, and a substantial part of his practice involves drafting and prosecuting patent applications and, along with that, developing with his clients IP strategic plans designed to maximize value and satisfy both legal and business objectives. Marty also has significant experience handling contested cases and disputes on behalf of his clients. He regularly serves as trial counsel in major patent disputes in the U.S. federal district courts and as lead counsel in post-grant proceedings before the U.S. Patent and Trademark Office Patent Trial and Appeal Board.

- **Jennifer Maisel** An emerging thought leader on the intersection of artificial intelligence and the law, Jen makes use of her technical background in information science and operations research in her practice focusing on intellectual property and privacy law issues involving cutting edge technology. Her practice encompasses all aspects of intellectual property law including litigation, patent prosecution, transactions, opinions, and counselling. She is also a Certified Information Privacy Professional in the United States (CIPP/US) and counsels clients on privacy and data security matters. She has been selected to the Washington, DC Super Lawyers "Rising Star" list in 2018, 2019, and 2020. Jen joined the firm full time in 2012 after graduating with honors from The George Washington University Law School. She also graduated *cum laude* from Cornell University's College of Engineering with a B.S. degree in Information Science, Systems, and Technology with a specialization in Operations Research and Information Engineering. She is registered to practice before the United States Patent and Trademark Office.

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Ramana Jampala

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- In the past 2 decades **Ramana Jampala** has founded, led investments, or was a Board of Director of numerous technology companies in Silicon Valley and New York/New Jersey in the United States. Ramana is currently the founding President and CEO of Avlino Inc – an AI and Data Analytics company. Prior to Avlino, Ramana was the President and CEO of Altior Inc – a Big Bata pioneering company, which was acquired by Exar (NYSE: EXAR). Earlier Ramana was a General Partner with SAS Investors, a Venture Capital fund in New York City. Ramana has invested in or served as the Board of Director on many of SAS portfolio investments including Tacit Networks (acquired by Packateer), Velox Semiconductors (acquired by Power Semiconductors), HydroGlobe (acquired by Graver Technologies), Textronics (acquired by Adidas), Protonex (public company) and Enpirion (acquired by Altera). Prior to SAS Investors, Ramana worked with Viant (NASDAQ: VIAN) as a Strategy Lead in San Francisco. He had his initial career with Rockwell Automation (Allen-Bradley) in the Control and Communications Group. Well recognized for his accomplishments, Ramana was awarded the “Financier of the Year” by New Jersey Technology Council, for leading more than $250M Investments in early stage companies in New Jersey. Ramana frequently teaches Technology Entrepreneurship at leading Business Schools in the United States, and is a Board of Advisors of numerous academic institutions. Ramana holds an MBA from London Business School, and graduated with distinction with a BS in Electronics Engineering from Pune University, India.

Keith Gremban

University of Colorado Boulder

Research Professor University of Colorado at Boulder

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- **Keith Gremban** is a Research Professor in the Technology, Cybersecurity, and Policy (TCP) Program at the University of Colorado Boulder. Keith has been involved in systems engineering and advanced technology development for over thirty years.
- Prior to joining the University of Colorado, Keith was the Director of the Institute for Telecommunication Sciences (ITS), which is the research and engineering laboratory for the National Telecommunications and Information Administration (NTIA). Keith was also a Program Manager at the Defense Advanced Research Projects Agency (DARPA) where he managed a portfolio of programs in the areas of wireless communications and electronic warfare. Prior to DARPA, Keith worked at a variety of companies and research organizations, managing and leading research and systems engineering projects, including a diverse collection of unmanned systems and command-and-control applications.
- Keith received his Ph.D. and M.S. in Computer Science from Carnegie Mellon University, and his M.S. in Applied Mathematics and B.S. in Mathematics from Michigan State University.

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Jeff Alstott
Alexander Sprintson

Program Directors
IARPA and NSF

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- **Dr. Jeff Alstott** is a program manager at IARPA (the Intelligence Advanced Research Projects Activity). He previously worked for MIT, Singapore University of Technology and Design, the World Bank and the University of Chicago. He obtained his PhD studying complex networks at the University of Cambridge, and his MBA and bachelor’s degrees from Indiana University. He has published research in such areas as animal behavior, computational neuroscience, complex networks, design science, statistical methods, and S&T forecasting.

- **Alexander Sprintson** is a faculty member in the Department of Electrical and Computer Engineering, at Texas A&M University, College Station, where he conducts research on wireless networks, distributed storage, and software-defined networking. Dr. Sprintson received the Wolf Award for Distinguished Ph.D. students, the Viterbi Postdoctoral Fellowship, the TAMU College of Engineering Outstanding Contribution award, and the NSF CAREER award. From 2013 and 2019 he served as an Associate Editor of the IEEE Transactions on Wireless Communications. He has been a member of the Technical Program Committee for the IEEE Infocom 2006--2020. He joined NSF in September 2018 where he currently serves as a Program Director in the Directorate of Computer & Information Science and Engineering (CISE). He manages networking research within the Networking Technologies and Systems (NeTS) and Secure and Trustworthy Cyberspace (SaTC) programs.

Elham Tabassi

National Institute of Standards and Technology
U.S. Department of Commerce

Chief of Staff in the Information Technology Laboratory (ITL) at NIST

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- **Elham Tabassi** is the acting Chief of Staff in the Information Technology Laboratory (ITL) at the National Institute of Standards and Technology (NIST). ITL, one of six research Laboratories within NIST, supports NIST’s mission, to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. ITL conducts fundamental and applied research in computer science and engineering, mathematics, and statistics that cultivates trust in information technology and metrology by developing and disseminating standards, measurements, and testing for interoperability, security, usability, and reliability of information systems.
- As a scientist she has been working on various computer vision research projects with applications in biometrics evaluation and standards since 1999. She is the principal architect of NIST Fingerprint Image Quality (NFIQ) which is now an international standard for measuring fingerprint image quality and has been deployed in many large-scale biometric applications worldwide. She received the Department of Commerce Gold Medal in 2003, the Department of Commerce Bronze Medal in 2007, and 2010, ANSI’s 2012 Next Generation Award, and the Women in Biometrics Award in 2016 for her contributions to biometrics. She is a member of OSAC Friction Ridge subcommittee and co-chairs FIDO Biometrics Certification working group.

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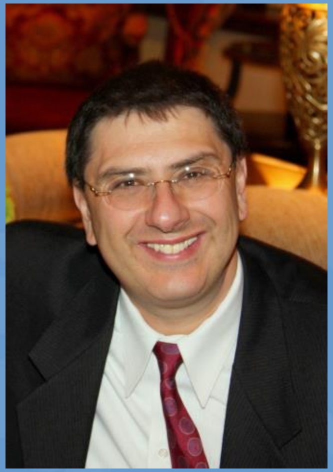
Rafail Ostrovsky

Distinguished Professor at UCLA And Founder Stealth Software Technologies



" Preservation of Privacy in Data and Computing"

- **Rafail Ostrovsky** is a Distinguished Professor of Computer Science and Distinguished Professor of Mathematics at UCLA. Prof. Ostrovsky joined UCLA in 2003 as a full tenured professor, coming from Bell Communications Research where he was a Senior Research Scientist. Prior to beginning his career at Bellcore, he was an NSF Mathematical Sciences Postdoctoral Research Fellow at UC Berkeley. Dr. Ostrovsky received his Ph.D. in computer science from MIT in 1992, (advisor: Silvio Micali, thesis: Software Protection and Simulation on Oblivious RAM), supported by IBM Graduate Fellowship. Prof. Ostrovsky is a Fellow of IEEE; Fellow of IACR; and a foreign member of Academia Europaea. He has 14 U.S. patents issued and over 300 papers published in refereed journals and conferences. Dr. Ostrovsky has served as a Chair of the IEEE Technical Committee on Mathematical Foundations of Computing from 2015-2018 and has served on over 40 international conference Program Committees including serving as PC chair of FOCS 2011. He is a member of the Editorial Board of Journal of ACM; Editorial Board of Algorithmica; and the Editorial Board of Journal of Cryptology and is the recipient of multiple awards and honors including the 2017 IEEE Computer Society Technical Achievement Award and the 2018 RSA Conference *Excellence in the Field of Mathematics* lifetime achievement Award. At UCLA, Prof. Ostrovsky heads the Center of Information and Computation Security (CICS) a multi-disciplinary Research Center (http://www.cs.ucla.edu/security/) at Henry Samueli School of Engineering and Applied Science.

Ajay Vikram Singh

NOKIA

Senior Director of Product Management
Global Analytics Business at Nokia

Experience Profile:
(https://www.linkedin.com/in/ajaynetwork/)

Current:
Title: Global Business Leader - Cognitive Operations
Focus: Enabling Telco/I4.0 onboard AI based digital transformation.
Assets created: IP - Telco AI Data Products. AI as a service business model. Cloud native delivery model.
Business segment: Global CSP OPEX & Enterprise Productivity

Last assignments: Ajay is an Analytics, Software, and services professional, and has played several hands on and leadership roles in large and small software/services companies in Telco Business. Lived and worked in Asia, North America and Europe

Present interest are exploring ML/AI frontiers, consulting startups and conducting primary school students on the magic of AI!

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Future of Unlicensed Operations
Q3 2020 Report

WG Chairs: Kevin Leddy, Charter & Brian Markwalter, CTA

Date: 9/22/2020
Meeting: Virtual

2020 Working Group Team Members

FCC Liaisons

Monisha Ghosh
Michael Ha
Nick Oros
Bahman Badipour
Mark Bykowski
Chrys Chrysanthou

Working Group Members

Kevin Leddy (Chair), Charter
Brian Markwalter (Chair), CTA
Brian Daly, AT&T
Jeff Foerster, Intel
Steve Lanning, ViaSat
Chris Richards, Ericsson
Lynn Merrill, NTCA
Mark Hess, Comcast

Peter Ecclesine, Cisco
Aleks Damnjanovic, Qualcomm
Lynn Claudy, NAB
Nomi Bergman, Advance/Newhouse Investment Partnership
Michael Tseytlin, Facebook

Future of Unlicensed Operations Agenda

- Working Group Charter
- Subject Matter Experts
- Walkthrough of Findings and Updates
- Looking Ahead

FCC Charter for Unlicensed Spectrum Operations Working Group

- **(1)** How do unlicensed operations continue to complement or compete with licensed services?
- **(2)** How can unlicensed operations improve the user experience and potentially become more competitive?
- **(3)** What are the new services and novel applications of unlicensed (i.e. Wi-Fi 6 and 7, low power IOT, personal radar, unlicensed LTE/5G NR, UWB etc.)? Are there new protocols that may improve the spectrum sharing among various services and applications? Should the Commission reevaluate certain regulations to promote such novel applications?
- **(4)** How can we enhance the use of unlicensed operations while sharing with radars (i.e. DFS in 5GHz) and what are the enabling technologies that may allow more unlicensed operations in more bands?

3rd Quarter Topics

1. Industry Standards Setting

2. Coexistence and Spectrum Sharing

3. 60 GHz Use Cases and Coexistence

Standards Presentation Summaries

Organization	Topic	Speaker	Summary
intel	Wi-Fi 7	Carlos Cordeiro	• Wi-Fi 7 builds on Wi-Fi 6/6E – seeks to drastically increase throughput (4X over Wi-Fi 6), reduce latency, improve network energy efficiency and connection density • Multi-link operation and Multi AP technology will drastically improve Wi-Fi performance • **Recommendation:** Intel recommends reevaluating rules for radar and communication coexistence in 60 GHz, and to encourage standards bodies to support coexistence scenarios (3GPP v. IEEE)
ERICSSON	3GPP Technologies in Unlicensed Spectrum	Havish Koorapaty	• 5G NR represents the architectural design of 5G radios. 5G NR-U is the design of radios capable of supporting unlicensed spectrum. 3GPP Release 16 was finalized and ratified on July 3rd 2020. Release 16 includes the NR-U workstream • NR-U = 5G NR + LBT: NR-U incorporates several design features to support unlicensed rules and coexistence, including lower EIRP levels and listen-before-talk • Energy detection thresholds have traditionally been an area of disagreement between IEEE and 3GPP, which determines transmitter behavior during periods of interference. IEEE/Wi-Fi has two thresholds and 3GPP only has one for NR-U. This results in Wi-Fi devices treating non-Wi-Fi devices differently than 3GPP

Coexistence Presentation Summaries

Organization	Topic	Speaker	Summary
CableLabs	Cable's Future of Unlicensed Operations	Rob Alderfer	• COVID-19 has been an unplanned stress test to the cable infrastructure and forced ~1 year of traffic growth over the course of a few weeks. The cable industry has been able to support the COVID-related traffic increases • DOCSIS 4.0 is the latest specification for broadband transmission over cable. Extends usable spectrum (from 1.2 to 1.8 GHz) and uses noise cancellation to enable simultaneous upstream and downstream transmission • ETSI BRAN recently approved a common energy detect threshold of -72 dBm for 6 GHz and voted to not require a preamble

The University of Chicago	Measurement Study of LTE-LAA and Wi-Fi in Chicago	Monisha Ghosh	• Wi-Fi performance was negatively impacted by having unaligned ED thresholds in the presence of LTE-LAA traffic. Led the team to recommend two possible solutions: Wi-Fi and LTE-LAA be capable of detecting each other's preamble/signal @ -82dBm, or Wi-Fi and LTE-LAA have a common preamble. This combined with 6 ms TXOP was the most equitable approach observed for coexistence
			• The team deployed APs in Chicago to evaluate LTE-LAA behavior across the major carriers
			  ◦ Observed that each carrier uses three primary LTE-LAA channels, with infrequent use of other channels. Live streaming traffic was not pushed through LTE-LAA channels
			  ◦ Did not observe dynamic allocation of LTE-LAA channels – it appeared to be a static assignment, and U-NII-2 was not used by carriers

Spectrum Sharing Presentation Summaries

Organization	Topic	Speaker	Summary
Google	Spectrum Sharing and Propagation Modeling	Andy Clegg	• TVWS suffers from a few key challenges: limited support due to past regulatory uncertainty, complexity and lack of international market, limited support for use cases (no mobility), challenging economic model • Google's SAS manages tens of thousands of GAA CBSDs despite COVID 19 delays . 6 GHz AFC presents a simpler database-driven sharing model that does not require coordination. Statistical model shows very low probability of AP interference • **Recommendation:** The FCC should evaluate and adopt modern propagation modeling techniques. Additionally, certification processes by FCC for CBRS, TVWS, and AFC is lengthy and overly cumbersome. Needs to improve to accelerate growth and adoption
federated wireless	SAS Data and Reporting Q&A with Kurt Schaubach	Kurt Schaubach	• SAS vendors have responsibility for ensuring proper operation of the SAS, and the FCC Enforcement Bureau would manage cases where protection measures were insufficient or issues with statistical modeling • SAS operators synchronize nightly to ensure full knowledge of all CBSDs operating regardless of the SAS vendor • **Recommendation:** FCC does not yet require periodic reporting from SAS operators. Federated recommends the FCC consider requiring periodic reporting
Cambium Networks	CBRS Rural Experience	Matt Mangriotis	• Cambium Networks offers a broad range of different wireless solutions – includes LTE and Point-to-Multi-Points software defined CBRS radios. Cambium's radios are largely based on proprietary technology, but are compatible with standards-based radios • Cambium offers a service to their customers for CBRS devices – rather than customers working through a SAS operator directly, Cambium manages the SAS engagement and serves as the troubleshoot point-of-contact for a premium fee (typically a ~30% mark-up over SAS service rates) • **Recommendation:** Cambium has experienced interference issues in CBRS – stems from a disconnect between SAS operators. Cambium would like to see better coexistence between the SAS operators

60 GHz Presentation Summaries

Organization	Topic	Speaker	Summary
Google	Motion Sense and Radar Technologies at 57-64 GHz	Nihar Jindal, Megan Stul, Gary Wong	• Motion Sense is a technology that allows users to have touchless interaction with devices using radar. Soli is an implementation of Motion Sense that was designed for space-constrained battery operated devices • Google was granted a waiver to operate its Soli chip in 60 GHz under the following conditions: increase the peak transmitter conducted output power from -10dBm to 10dBm and peak EIRP from 10dBm to 13dBm with maximum 10% duty cycle • Coexistence lab testing and analysis shows that Soli causes minimal impact to other devices operating in 60 GHz
facebook Qualcomm intel	60 GHz Band: Potential & Coexistence Challenges	Carlos Cordeiro, Intel Corporation Bin Tian, Qualcomm Inc. Alan Norman, Facebook	• 60 GHz can address several use cases, with AR/VR, wireless backhaul, and radar/sensing being ideally suited for 60 GHz • 802.11ay is the next generation 60 GHz / WiGig standard. Will support data rates up to 200 Gbps. 802.11ay will also support sensing use cases and implements multiple mechanisms to coexist between sensing and communications– LBT, channelization, beamforming. ETA late 2020 / early 2021 • **Recommendation:** FCC should consider issuing an NPRM to modify the 60 GHz rules to promote radar applications and coexistence with communications systems

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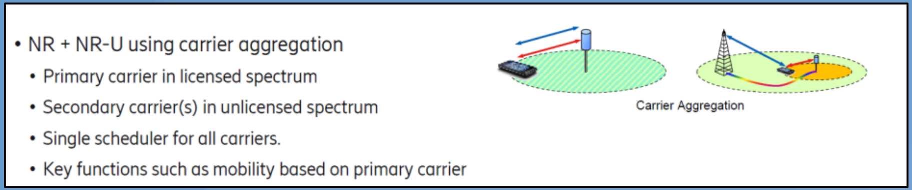
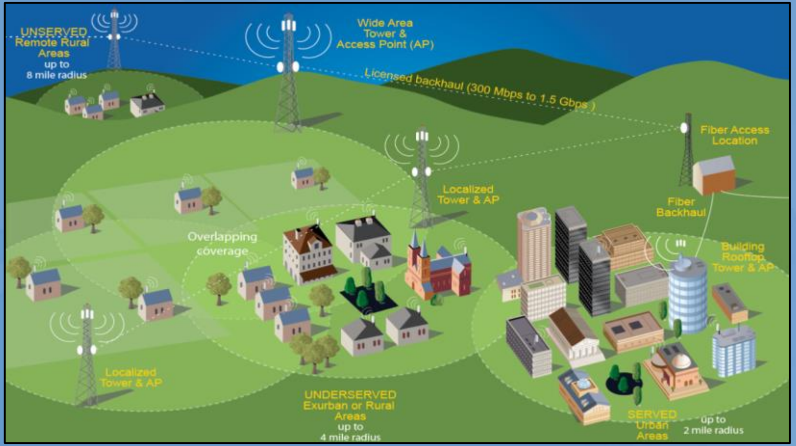
Question 1: How does Unlicensed Complement or Compete With Licensed?

Unlicensed Spectrum Can Augment and Complement Licensed Operations



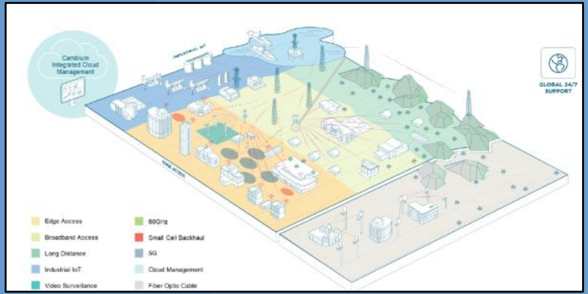
Source: Ericsson



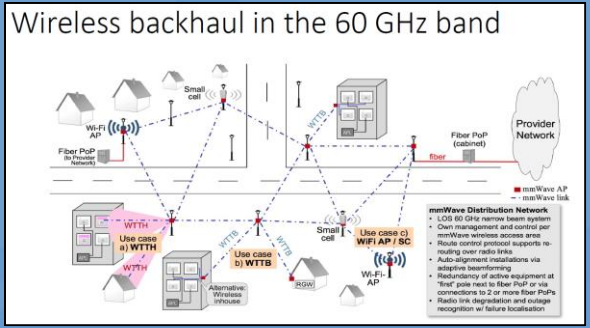
Source: WISPA

- MNOs use a blend of licensed and unlicensed spectrum in their network, and leverage unlicensed for in-home connectivity
  - >50% of mobile traffic offloads to unlicensed spectrum
- WISPs are opportunistic and will leverage both licensed and unlicensed systems in their network
- Wireline broadband providers' last 20 meters is over unlicensed Wi-Fi in the home

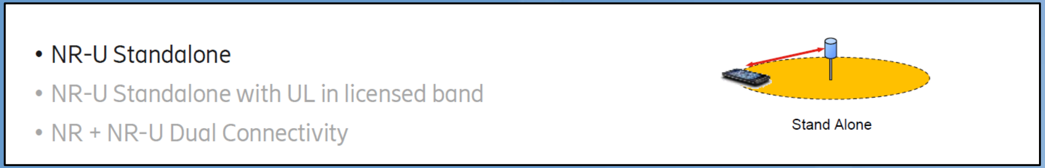
Unlicensed Spectrum Creates Competitive Opportunities



Source: Cambium



Source: Intel

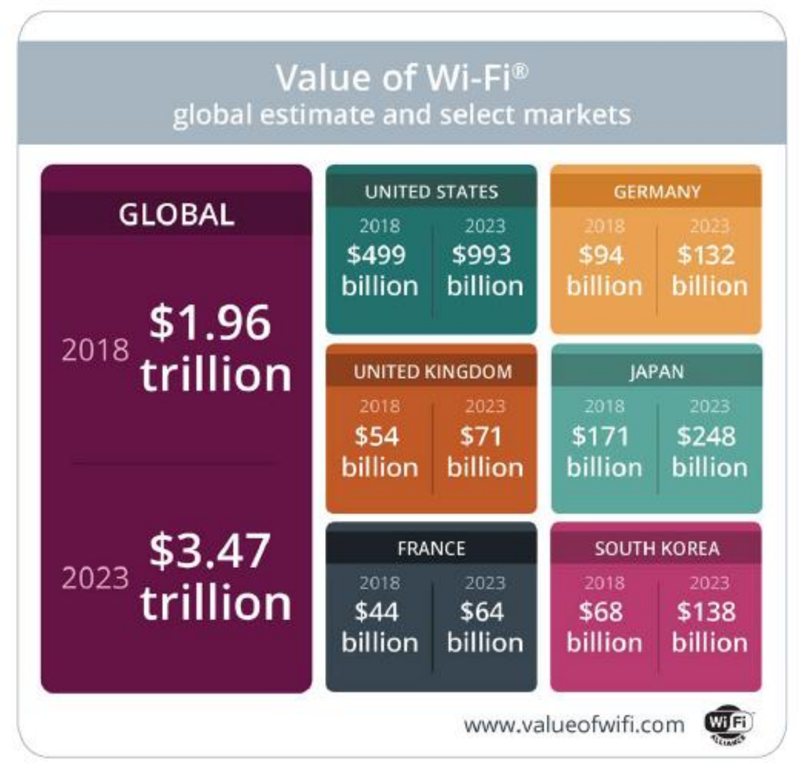


Source: Ericsson

- WISPs and FWA providers leverage unlicensed spectrum to offer a competitive service to wireline ISPs
- Wi-Fi hotspots use unlicensed to reduce dependency on mobile networks and improve MVNO economics
- 5G NR-U enables a RAN 100% on unlicensed spectrum

Unlicensed Spectrum is Incredibly Valuable to the Industry and Economy

- Healthy tension is expected when deciding which spectrum to allocate for licensed vs shared vs unlicensed use. However, the value of unlicensed spectrum is significant
- Clearly, access to unlicensed and shared spectrum is good for the US businesses and consumers
- Considerations for Future TAC Evaluation:
  - International unlicensed and shared spectrum / technology trends
  - Progress and trends in the WISP community



Question 2: How Can Unlicensed Improve the User Experience?

Question 3: What are the New Services, New Protocols, Regulations to Promote Unlicensed?

Current Wireless Standards and Capabilities

Wi-Fi 6 / 6e Use Cases and Benefits

- Wi-Fi 6 / 802.11ax improves performance to address growing video streaming, gaming, and data throughput demands
- Greater scalability via OFDMA, which **will improve AP efficiency**
- **Reduced interference** in dense deployments with BSS coloring
  - OFDMA combined with BSS coloring will **lower latency**
- Use of WPA3 will **enhance device security**
- **Faster performance** by enabling 1024 QAM across 160 MHz channels
- 802.11ax is expected to be approved in Q4 2020

Wi-Fi CERTIFIED 6 feature	Benefit
Uplink and downlink Orthogonal Frequency Division Multiple Access (OFDMA)	Increases network efficiency by allowing simultaneous access for multiple devices Lowers latency. More deterministic. Ideal for low bandwidth applications
Multi-User Multiple Input Multiple Output (MU-MIMO)	Increases capacity: More data transferred at once Higher speeds per user Increases network efficiency by allowing simultaneous access for multiple devices Ideal for high bandwidth high capacity applications
Transmit beamforming	Enables higher data rates at a given range Enhanced performance at the network's edge Greater network capacity
1024 Quadrature Amplitude Modulation mode (1024-QAM)	Increases throughput per available spectrum
Target Wake Time (TWT)	Improves network efficiency by scheduling access by device Significantly improves battery life e.g. for Internet of Things (IoT) devices
Basic Service Set (BSS) coloring	Improves coexistence Enables better spectral re-use

Source: Wi-Fi Alliance

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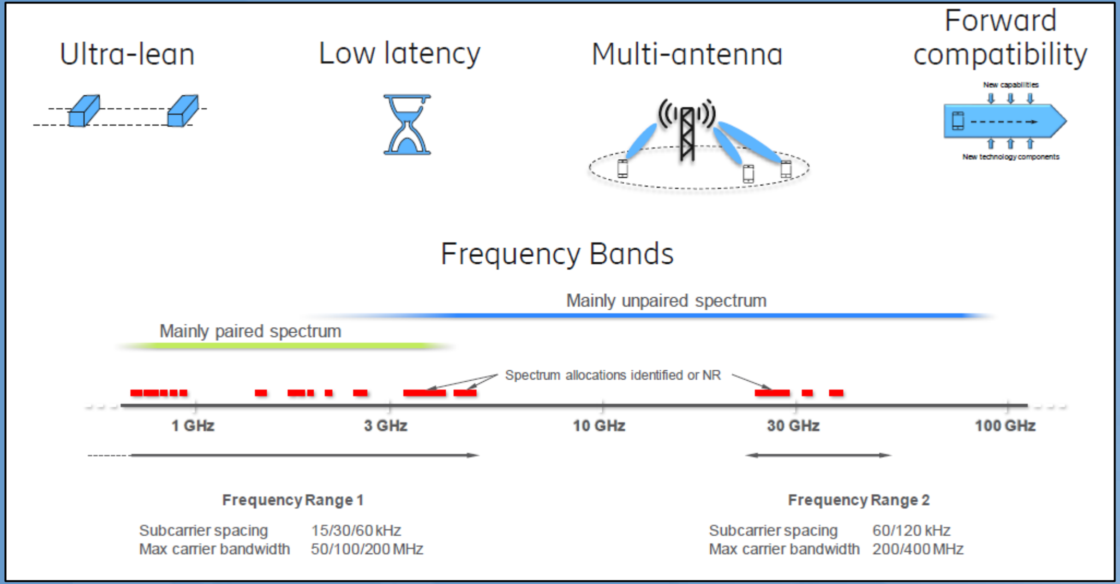
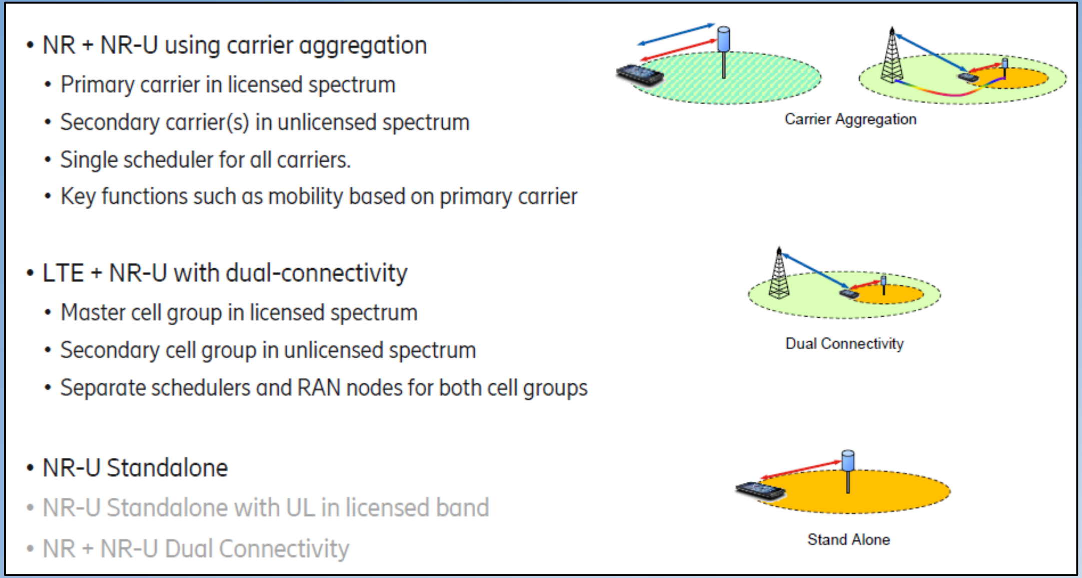
5G NR-U Use Cases and Benefits



Source: Ericsson



Source: Ericsson

- 5G NR-U = 5G NR + Listen-Before-Talk
- Designed to handle highly congested channels

- Supports multiple scenarios including: NR = NR-U using carrier aggregation, LTE + NR-U with dual connectivity, and NR-U standalone

60 GHz Use Cases and Benefits

- 60 GHz has two broad categories of ideal uses:
  1. Multi-Gigabit @ low latency and low power communication
     - Wireless AR/VR, wireless backhaul
  2. Sensing / radar with fine spatial resolution
     - Proximity detection, gesture recognition, presence detection, health monitoring, robot 3D vision
- 802.11ay is the upcoming wireless standard specific to 60 GHz
  - Builds on top of and is backward compatible to 11ad
  - Supports rates in excess of 200 Gbps for indoor & outdoor usages
  - 802.11ay will deliver the following technical features:
    - Channel bonding: 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels
    - MIMO operation, up to 8 streams, and downlink multi user (MU) transmissions
    - New medium access scheme for fixed wireless access applications
    - Time division duplex (TDD) service period
    - Supports Facebook Terragraph , multi hop backhaul 60 GHz system for street level deployments
    - Enhanced beamforming protocols, support to multi channel operation and MIMO
- 802.11ay is expected to be approved in Q4 2020

Ultra Short Range (USR) Communications
8K UHD Transfer at smart home
Augmented Reality/Virtual Reality
Data Center inter-rack connectivity -Indoor backhaul with multihop -backup interfaces for fiber optics failure
Video/Mass-Data Distribution/VoD -Multicast Streaming/Downloading for dense hotspots
Mobile Offloading and Multi-Band Operation - Stationary or low mobility for offloading
Mobile Fronthauling
Wireless Backhauling: - Single hop and Multi-hop
Wireless office docking
mmWave distribution network
Ultra short range wireless docking

Source: Intel

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Future Wireless Roadmap

Pipeline of Unlicensed Standards and Use Cases

- **Wi-Fi 7** builds on Wi-Fi 6/6E – seeks to drastically increase throughput (4X over Wi-Fi 6), reduce latency, improve network energy efficiency and connection density
  - New features include 320 MHz channels, puncturing (will allow radios to notch out restricted channels), Multi-link operation and Multi AP technology will drastically improve Wi-Fi performance

- 5G NR-U Future Releases / Features
  - As part of **3GPP Release 17**, spectrum support will be extended to up to 71 GHz. It will include any physical-layer procedures and protocol aspects required for operation in unlicensed bands between 52.6 GHz and 71 GHz.

- WLAN Sensing and Radar
  - 802.11 WLAN Sensing Study Group and separate industry 60 GHz coexistence effort

Coexistence Summary

- Received feedback from University of Chicago, Boingo, CableLabs, and Ericsson about wireless coexistence, with an emphasis on LTE-LAA / 5G NR-U and 802.11ac/ax use cases
  - Boingo observed deployment challenges where LTE-LAA and Wi-Fi shared the same channels, often resulting in LTE-LAA not getting fair channel access
  - University of Chicago study noted the lack of airtime fairness between LTE-LAA and Wi-Fi in 5 GHz
- For now, industry is sorting out via standards bodies – 6 GHz will use a common energy detection threshold of -72 dBm, which was largely due to the ETSI harmonized standard negotiation between IEEE and 3GPP
- The FCC should continue to defer technical specification to industry standards bodies, but monitor as needed

Latest agreement in ETSI BRAN achieves alignment for all technologies at -72 dBm for 6 GHz

Source: Ericsson – specific to energy detection

- Wi-Fi and LTE-LAA have improved throughput and latency performance when the detection threshold used by Wi-Fi in the presence of LTE is lowered to -82 dBm, and LTE-LAA does the same.

- In order for Wi-Fi to distinguish between LTE-LAA and other signals, Wi-Fi would need to implement LTE detection, which can be easily implemented by detecting the LTE synchronization signals, and LTE-LAA would need to detect the Wi-Fi preamble. Common preambles may be another option.
- A TXOP of 6 ms along with symmetric detection threshold leads to equitable throughput.

Source: University of Chicago

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Spectrum Sharing

Sharing Summary

- Multiple industry experts came in to discuss spectrum sharing. Overall, sentiment was very positive but challenges exist
  - Complexity – CBRS rules and SAS certification processes are cumbersome and complex
  - Coexistence – inconsistences between SAS operators lead to coexistence challenges
  - Interference – interference issues persist, but are largely manageable. Propagation modeling enhancements may be one method for improving interference issues
  - Metrics – opportunities to improve industry metrics and KPIs across sharing schemes
- More work is needed to understand the topic, opportunities, and challenges
- As part of the Q4 report, we will summarize all spectrum sharing findings collected this year
- TAC Working Group Leads recommend a dedicated 2021 spectrum sharing working group

Propagation Modeling


Manhattan


How Longley-Rice Sees Manhattan

Source: Google

- Advances in imagery, building material data, and terrain modeling may help improve unlicensed regulation and operations

Question 4: What Sharing Technologies Enable Use with Personal Radar or Additional Bands?

60 GHz Findings

60 GHz Coexistence: Communications and Radar/Sensing

- Growing interest in 60 GHz for two reasons:

  - Wide bandwidth allows high throughput/low latency and fine spatial resolution

  - Short wavelength allows small antenna arrays and low power at short range

- … and in two application areas:

  - Communications at multi Gbps, low latency and low power (802.11ad/ay 5G NR-U)

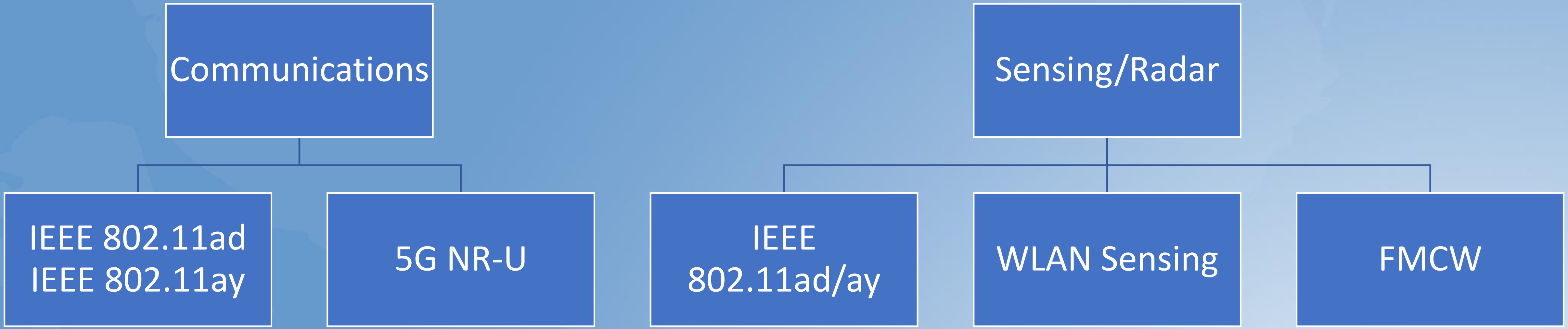
  - Radar and sensing from room scale to gesture control (FMCW radar, WLAN sensing)

Use Cases

- Ultra Short-Range communications for loading mobile device
- VR headsets
- Office docking
- Short distance fronthaul and backhaul

- Presence detection
- Gesture recognition, e.g. Google Soli technology
- Aliveness detection
- Contactless interfaces

Industry/Standards Activity

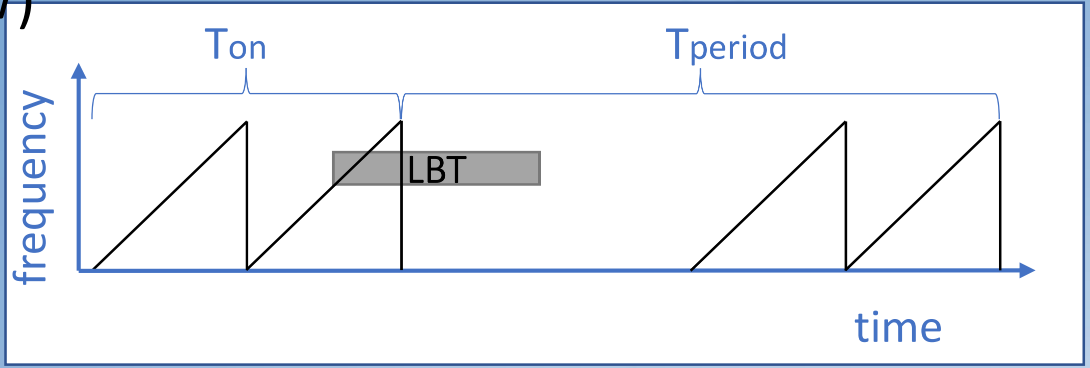


Regulatory Background

- 60 GHz band (57-71 GHz) regulated as unlicensed intentional radiator through 47 CFR 15.255
- For personal radar, *FCC 15.255(c)(3)*: "short-range devices for interactive motion sensing, the peak transmitter conducted output power shall not exceed –10 dBm and the peak EIRP level shall not exceed 10 dBm."
- A number of waiver requests have been submitted to the FCC to permit operation at higher power levels and aboard aircraft.
  - Google Project Soli field disturbance sensor, is instructive because the FCC has acted on it in DA-18-1308A1
  - But also Vayyar Imaging Ltd, Leica Geosystems AG's and recently Tesla Motors

Radar and Communications Coexistence

- Frequency-modulated continuous wave (FMCW)
  - Bandwidth determines spatial resolution
  - Motion resolution related to sweep time and repetition rate



- Communication systems, like 802.11 ad/ay
  - Listen-Before-Talk
  - Channelization

DA-18-1308A1 Grant of Google Waiver Request

- The waiver for Google included the following requirements for Soli:
  - "…allow the device to operate in the 57-64 GHz band at a maximum +13 dBm EIRP, +10 dBm transmitter conducted output power, and +13 dBm/MHz power spectral density"
  - "operate with a maximum transmit duty cycle of 10 percent in any 33 milliseconds (ms) interval"
  - Waiver "not to be considered to apply generally to other field disturbance sensors"

Industry Consensus to Improve Regulations for 60 GHz Band

- Our working group had briefings from Google, Facebook, Intel and Qualcomm
- Industry has formed a 60 GHz Coexistence Study Group for Communications and Radar (above companies plus Infineon, Samsung and Socionext America) on record with the FCC in Leica and Vayyar waivers (filing of February 3, 2020)
- All indicate that it is time to start a rulemaking proceeding to permit higher power levels for radars and preserve coexistence between radars and communication systems

Potential Areas for Public Comment Recommended by Intel, Facebook, and Qualcomm

1. Should FCC rules allow greater radiated power for radar applications than currently permitted?
2. Should the parameters for Google Soli, for which other entities have filed “me too” requests, be included in the rules?
3. What changes to the recent waiver parameters are needed to improve sharing with communications applications?
4. Should the FCC require communications applications (and radar applications) to use a contention based protocol?
5. Should radar applications that perform LBT be allowed to use the same power levels as communications applications in this band?

Recommendation

- The FCC should start a rulemaking proceeding to examine 60 GHz rules in 47 C.F.R. 15.255 to address issues raised by waiver requests for field disturbance systems
  - Power levels for radar applications, including potential for equivalent power levels to communication systems for LBT radar
  - Coexistence mechanisms, including duty cycle requirements and contention-based protocols

Summary and Next Steps

Recommendations Summary

1. **60 GHz Evaluation:** Open a rulemaking proceeding to examine 60 GHz rules in 47 C.F.R. 15.255 to address issues raised by waiver requests
2. **Spectrum Sharing TAC Topic:** Consider spectrum sharing as a dedicated TAC working group in 2021
   - Consider industry recommendation for clarification around KPIs and metrics for SAS and AFC
3. **Industry Led Technical Rule-Setting:** After review of international regulatory rule-setting, the FCC should continue a light touch approach and defer technical specification to industry standards bodies

4th Quarter Work Plan

- Spectrum Sharing Evaluation
  - Comparison of sharing techniques
  - Sharing with incumbents (including satellite bands, etc)
  - Additional unlicensed spectrum opportunities based on limitations such as indoor-use only
- Evaluate Additional Unlicensed Use Cases (i.e. UWB and Low Power IoT)
- Complete Final Report

Technological Advisory Committee

September 22, 2020 Meeting

- Lunch Break -

5G RAN Technology Working Group
Readout to the TAC

WG Chairs: Tom Sawanobori, CTIA & Kevin Sparks, Nokia

Date: September 22 2020
Meeting: TAC virtual meeting

Outline

- Intro (charter, members, speakers)
- 5G RAN evolution
  - Major architecture, technology & spectrum evolutions
  - Areas for FCC to watch
- Advanced RAN/Antenna technology
  - AAS/MIMO/Beamforming/Beam steering – taxonomy, benefits, challenges
  - Potential ways to address challenges
- Mitigating interference
  - Interference Management in C Band (5G and earth stations)
  - Leverage C Band Multi-stakeholder work (FSS satellites, CBRS, Altimeters) to minimize interference
  - Using propagation/modelling tools to predict and minimize possible interference
- WG plans for rest of year
  - Summary of recommendation areas
  - Main areas for further focus

5G RAN Technology WG: 2020 Charter

Broad Areas:
UE - RF - Fronthaul - vRAN/BBU → Spectrum Mgmt./Interference

Explore advanced technologies that may be used in 5G/6G radios, both at base stations and client devices.

1. What is the roadmap of RAN architecture evolution in 5G/6G radios and how does it compare to the previous generations?
2. How does the potentially disruptive network virtualization proposed by O-RAN affect the development of RF front-end and fronthaul technologies?
3. What are the broader implications of the convergence of the use of advanced RF/RAN system components and spectrum management policies?
   - RF front end: advanced multi-band antennas, filtering technology, feed networks, amplifier efficiency, A/D converters, etc.
   - Baseband Processing: vRAN technology & architectures
   - RAN systems: self-optimization & configurability of advanced components, fronthaul technologies, eMBB/URLLC/mMTC performance optimization
4. Does incorporation of these advanced technologies and capabilities into radio equipment warrant a reexamination by the Commission of its policies and procedures pertaining to spectrum management?
5. How can the Commission best characterize the use of advanced RF system components in the analysis of in-band and out-of-band emissions to optimize efficient use of spectrum?
6. How can propagation modeling tools be better utilized to predict interference between systems?
7. How might equipment authorization procedures need to be modified to better address these advanced features, especially as the worst-case configuration used during testing continues to deviate from expected performance under normal operations?
8. What is the potential for interference risks as more dynamic components and features are introduced into advanced wireless systems, which could result in widely varying interference potential over time, particularly across broad geographic areas.

2020 5G RAN Technology Working Group Team Members

- Shahid Ahmed, Imagine Wireless
- Ahmad Armand*, T-Mobile
- Kumar Balachandran*, Ericsson
- Mark Bayliss, Visualink
- Lynn Claudy, NAB
- Brian Daly, AT&T
- Satish Dhanasekaran, Keysight
- Russ Gyurek, Cisco
- Dale Hatfield, Univ of Colorado
- Stephen Hayes, Ericsson
- Frank Korinek*, Motorola Solutions
- Greg Lapin, ARRL
- Brian Markwalter, CTA
- Lynn Merrill, NTCA
- Khurram Muhammed*, Samsung
- Jack Nasielski, Qualcomm
- Madeleine Noland, ATSC
- Jesse Russell, incNetworks
- Travis Russell, Oracle
- David Tennenhouse, VMWare
- David Young, Verizon

- Dennis Roberson, entigenlogic
- Michael Ha, FCC
- Monisha Ghosh, FCC

*SME participant

FCC Liaisons: Bahman Badipour, Reza Biazaran, Bob Pavlak, Ken Baker, Kamran Etemad, Sean Yun, Sean Spivey, Charles Mathias

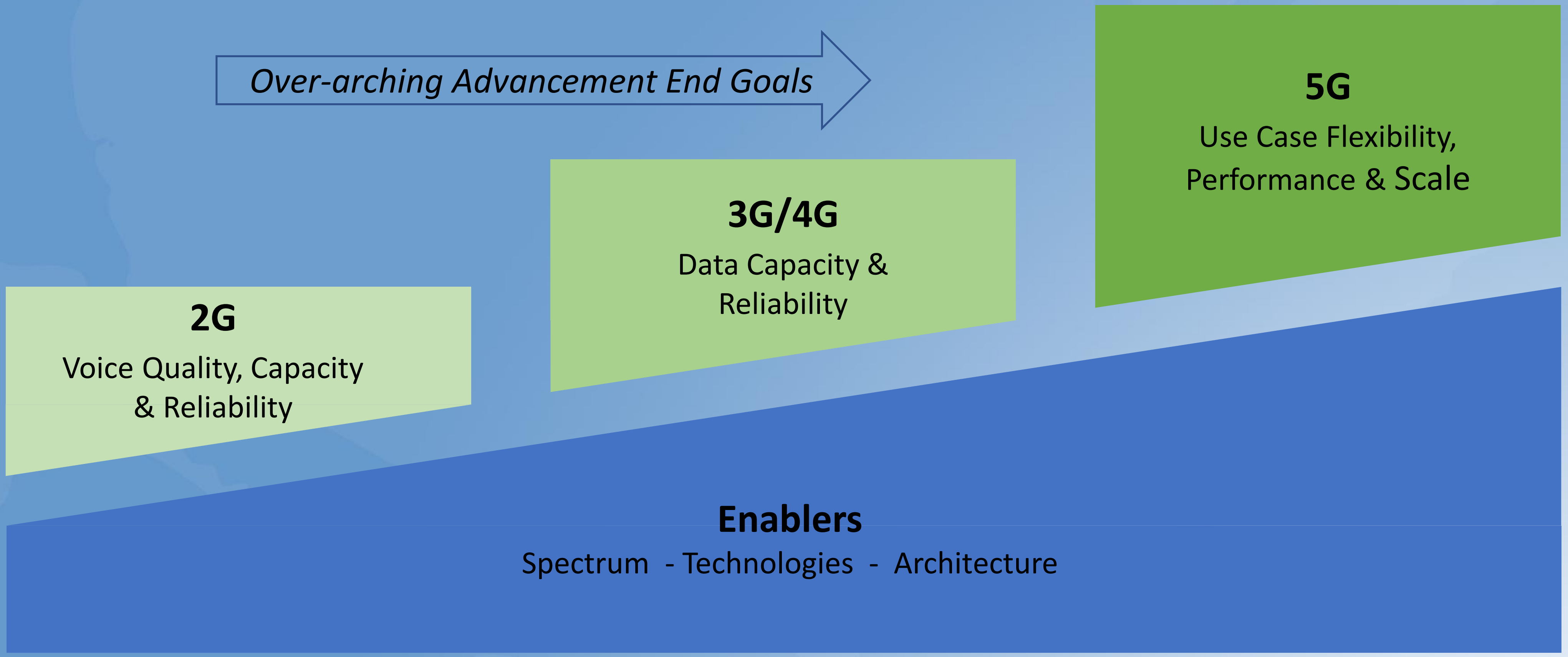
Speakers and Key Observations (Up to June TAC)

Topic	Speaker	Key Observations
E2E RAN components & flexibility overview	Greg Wright (NOKIA)	End-to-end 5G RAN component architecture Flexibility feasibility varies – radio unit (i.e. SDR) not practical, distributed unit (vDU) challenging, and centralized unit (vCU) straightforward
vRAN technology evolution	Rob Soni (NOKIA)	V-RAN closely related to edge cloud and O-RAN Cloud scaling and feature velocity bigger driver than TCO savings Multiple types of vRAN w/varying pros & cons
RF: A/D converters	Boris Murmann	Filtering essential to reducing dynamic range for converters Improving performance, but must consider power consumption Further ADC technology scaling brings mainly density
vRAN technology evolution	Udayan Mukherjee (intel)	Progress being made on real-time optimizations for vRAN System integrator is key consideration vRAN/O-RAN in greenfield claim ~30% TCO savings (Rakuten)
5G/UE technology evolution	John Smee (QUALCOMM)	Proliferation of bands for 5G – in addition 4G, other technologies Subsystem modularity is key to manage more bands and interference
mMIMO (especially EIRP/interference aspects)	Moray Rumney (KEYSIGHT TECHNOLOGIES)	Massive MIMO – beam steering and beam forming provide different benefits across low/mid/high bands Challenges measuring interference and Total Radiated Power

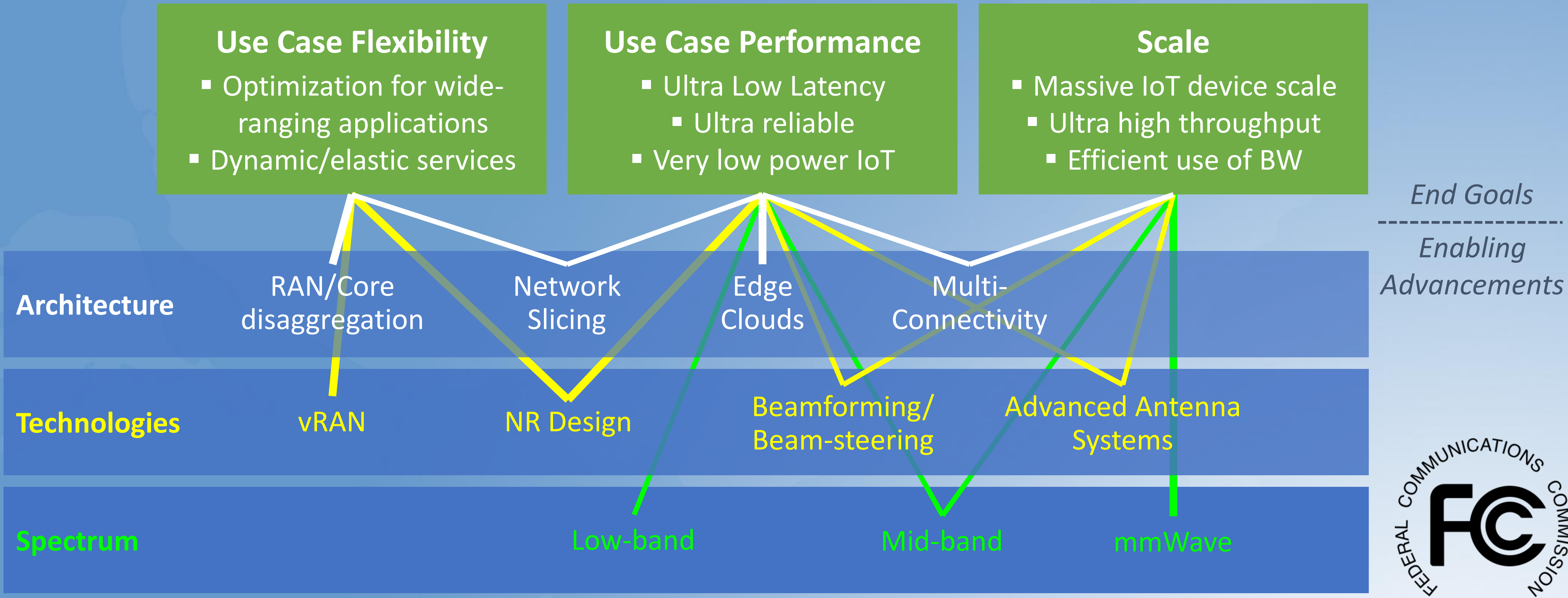
Speakers and Key Observations (Since June TAC)

Topic	Speaker	Key Observations
Mm wave deployments	Arda Aksu (verizon)	mmWave does provide high capacity/throughput, but short range Fixed initially, but adding sites and optimizing for mobility Ecosystem needs repeaters and other tools to make more robust
Interference Management	Scott Townley (verizon)	Blocking, OOBE can be addressed through distance, OOBE limits Beamforming helps mitigate Small cells may help mitigate mobile interference using power control
MIMO and beamforming	(ERICSSON) Kumar Balachandran	Taxonomy/tutorial on Advanced Antenna Systems and MIMO/Beamforming Diversity vs. array gain varies by band & corresponding channel characteristics Digital vs. analog beamforming tradeoffs likewise very band-dependent
Interference Management	Kamran Etemad (FCC)	5G NR introduces many new enabling tools useful for coexistence and sharing Sensing and measurement reporting is key to enable closed-loop modeling Coordination, AI/ML, & closed-loop can/will help mitigate/avoid interference
C Band Multi stakeholder Group	Admad Armand (T-Mobile), Kumar B. (E///), Raj S (CTIA)	Coordinating with FSS earth stations to mitigate interference Most altimeters should be fine (evaluating corner cases of helicopters) C Band and CBRS may be assisted by TDD synchronization
Propagation tools to minimize interference	Preston Marshall (Google)	Many existing tools rely primarily on terrain modeling Machine learning, large geographic data sets, and crowd sourcing are promising technologies to address buildings, foliage, and terrain considerations.

RAN Evolution Dimensions over Generations



5G RAN Evolution – A much more Multi-Dimensional affair



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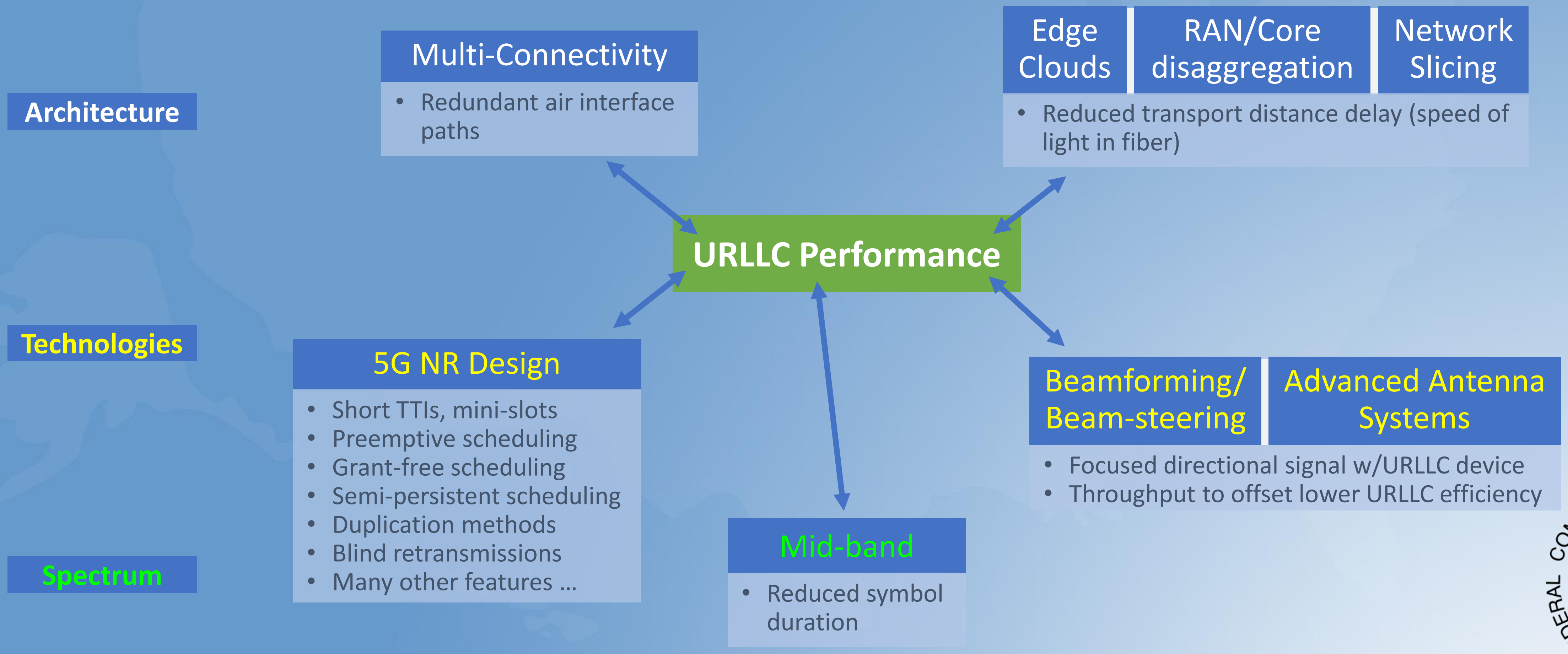
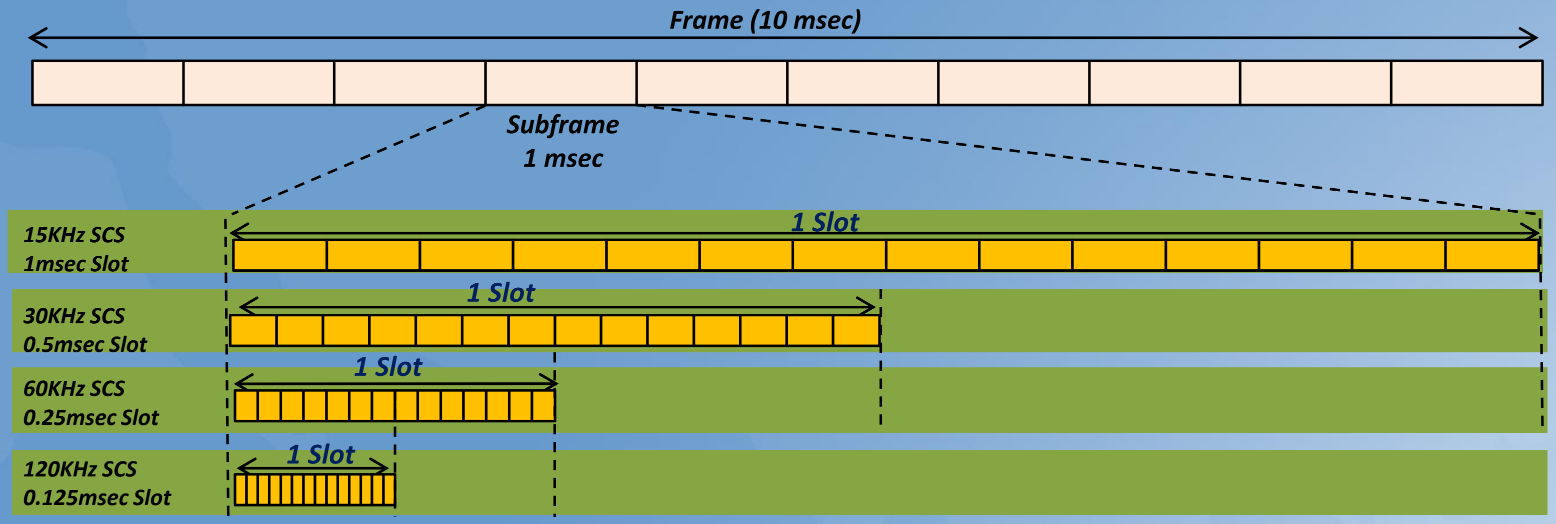
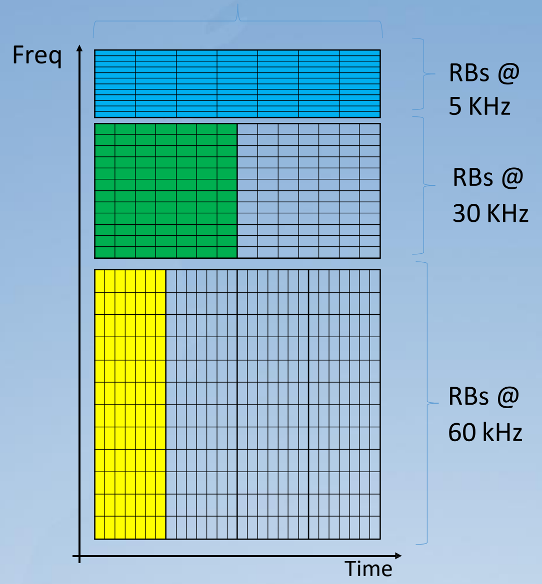
5G Evolution – Architecture, Technology & New Spectrum in Concert – URLLC Example



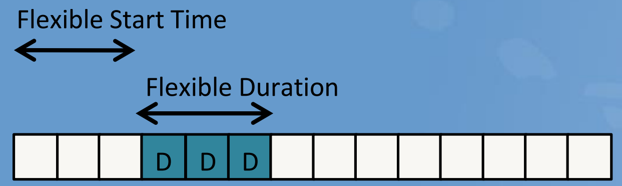
5G Evolution – Drill down on 5G NR Design: Flexible resource blocks

- Each 1ms subframe consists of 2^{μ} slots of 14 OFDM symbols each.
  - The length of a slot in ms and the number of slots per subframe depend on the numerology.
- In order to support various deployment scenarios and wide range of carrier frequencies, NR supports multiple subcarrier spacing (SCS)





NR supports mixed numerologies in both frequency domain & time domain



Mini-Slot Allocations (DL Example)
can be carried out over 2, 4 or 7 OFDM symbols

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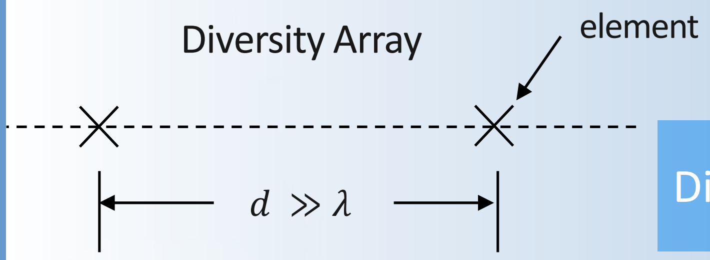
MIMO/Beamforming Taxonomy

Advanced antenna systems: an umbrella term that encompasses MIMO and beamforming

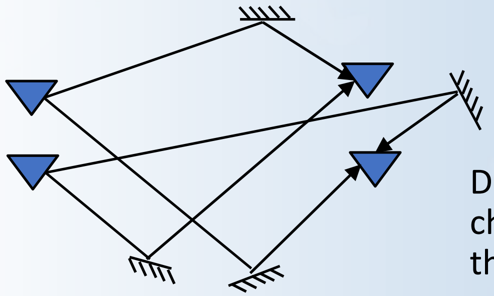
Multiple Antenna Techniques

- Diversity techniques
  - Transmit and Receive Diversity
  - Spatial multiplexing
- MIMO/Beamforming/Beam-steering Techniques
  - Spatial multiplexing
  - Reconfigurable Antenna Systems or Beam-shaping

Diversity Array

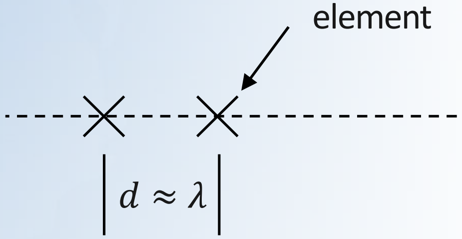


Channel from the Tx to the Rx looks different, or uncorrelated, to each antenna element

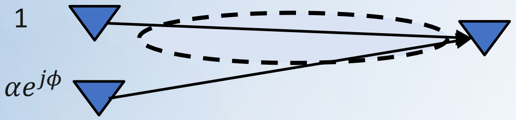


Diversity refers to different channel modes that can match the antenna to the channel

Phased Array

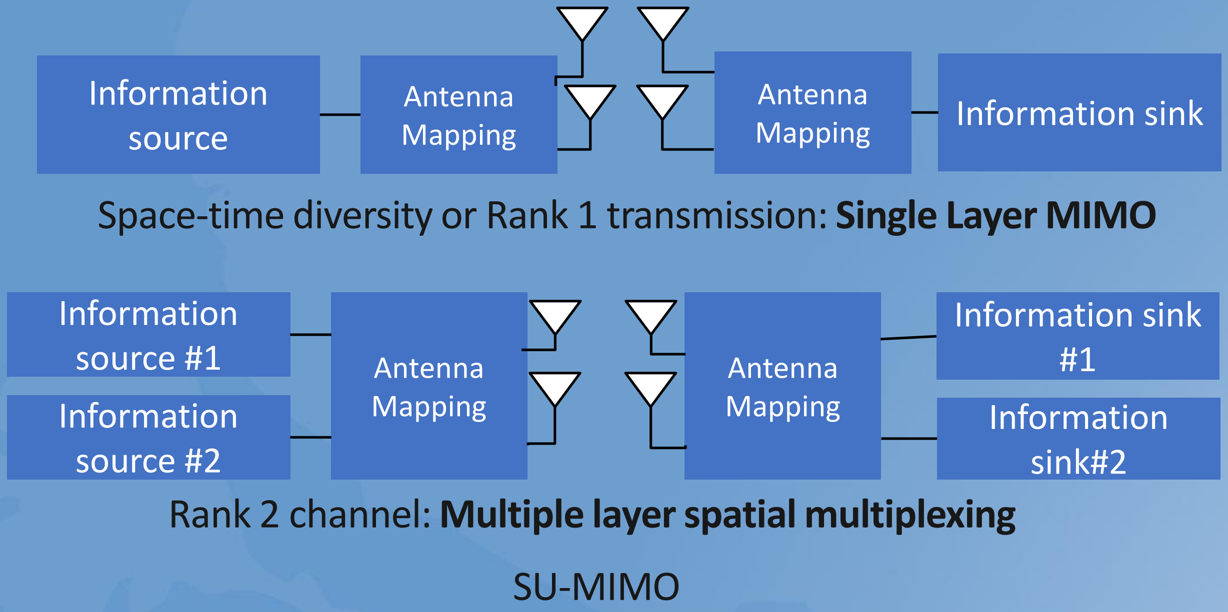


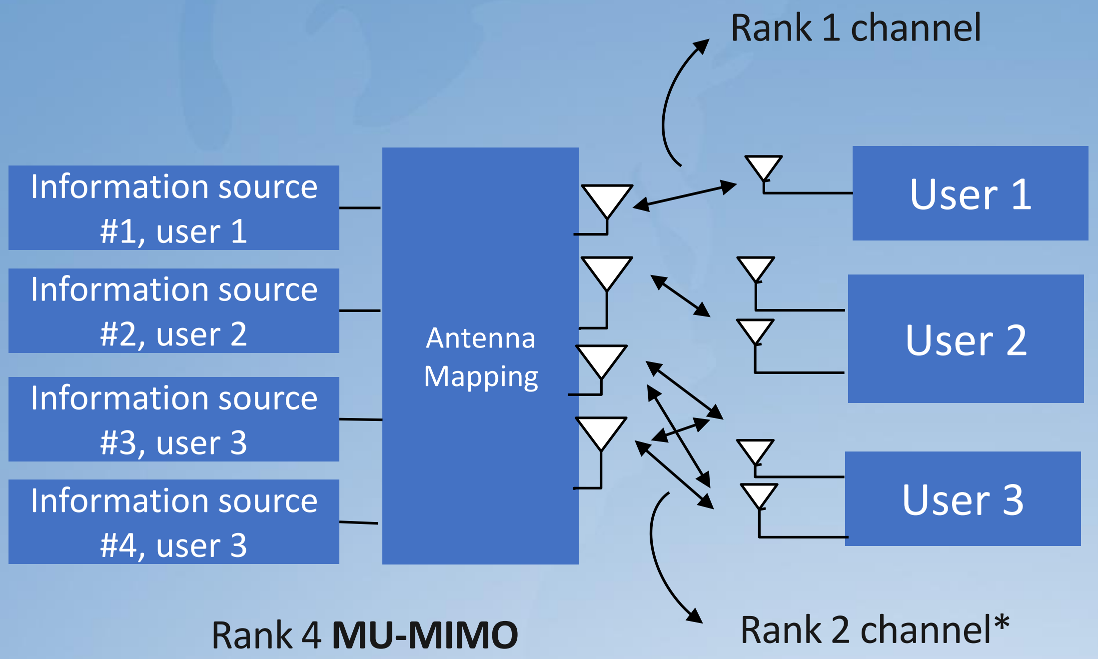
Channel from the transmitter to the receiver looks the same to each antenna element



Array gain can increase the effective area or aperture of an antenna and narrow the spatial spread of energy

MIMO Variations



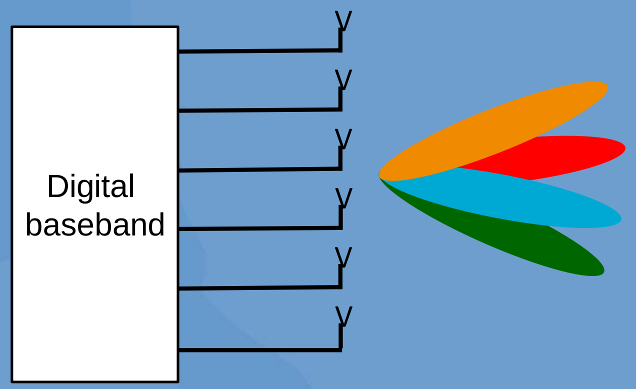


Massive MIMO: an AAS system with a very large number of Tx antennas and a relatively small number of Rx antennas

- Similar to MIMO, but as number of elements grows, effective channel becomes averaged, more benign
- Simple solution becomes closer to optimal…
  … and can allow transmission of the entire bandwidth to every terminal served
- Depends on channel characteristics being accurately known, and interference sufficiently suppressed

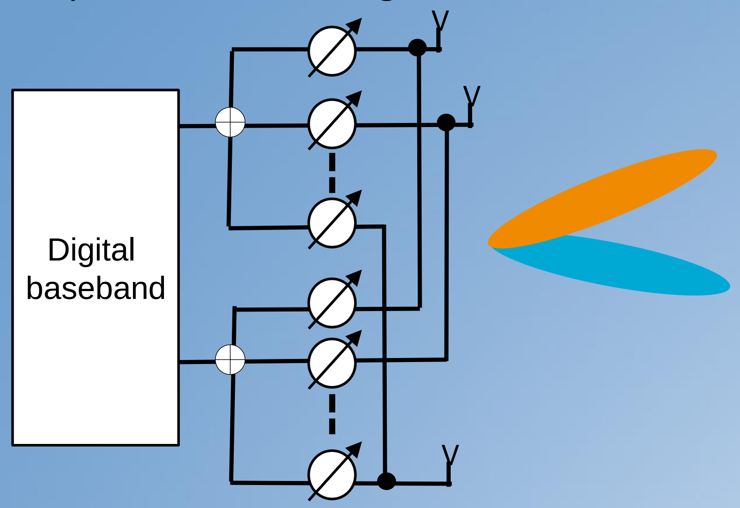
Beamforming/Beam-steering Variations

Digital beamforming



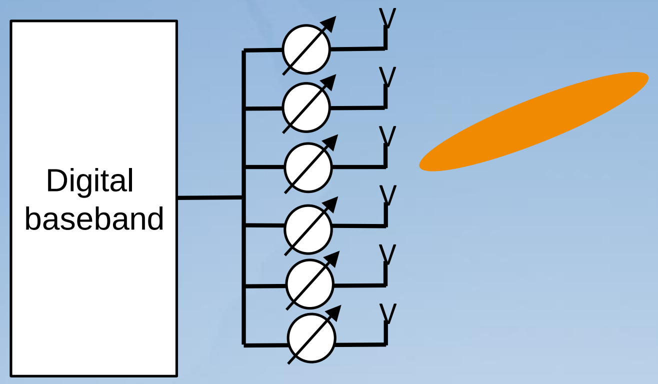
Full flexibility, multiple beams per time unit
Adaptable to multi-path and frequency-selective fading, e.g with eigen-beamforming

Hybrid beamforming



A few beams per time unit
Not adapted to multi-path or frequency-selective fading

Analog beamforming/beamsteering



One beam per time unit per polarization for the entire frequency band

Performance/BW efficiency
Cost & Complexity

Pros & cons are very band-dependent

Power efficiency
Simplicity & Economy

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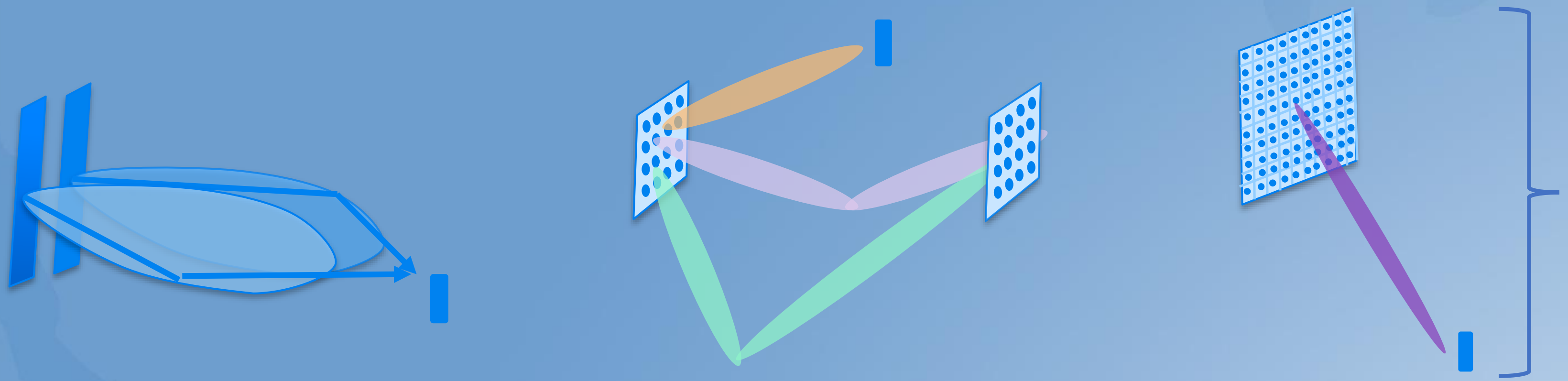
MIMO/Beamforming Application to Different Bands



Channel feedback is instrumental in choosing the best match between transmit and receiver arrays

Low bands < 2 GHz

- Single antennas have large aperture
- Channel is rich if antennas are uncorrelated, e.g. polarization
- Multiple antennas are spaced wide apart
- **Diversity transmission** and reception is relied on with channel or precoder feedback

Mid bands 2-6 GHz

- Channel feedback for FDD, reciprocity for TDD
- Single antennas have medium aperture and smaller size
- Multiple antennas can **trade off diversity and array gain**
- Channels are rich
- Frequency bands are suitable for **digital or hybrid beamforming**

High bands ≫ 6 GHz

- TDD, beam index feedback
- Single antennas have very small aperture
- Propagation tends to favor near LoS with one dominant mode
- Transmission and reception relies on **array gain**
- Antennas tend to rely on **analog beamforming**

MIMO/Beamforming Benefits & Challenges

Key Benefits

- Significant RAN capacity/efficiency and coverage gains
- Enabling technology for practical utilization of mmWave spectrum
- New degrees of freedom for optimizing RAN performance, and potential future dynamic interference mitigation

Challenges

- More dynamic power distribution, channel conditions and cell edge overlap environment
- Complicates measurement of radiated power, and modeling of in-band and out-of-band interference
- Digital beamforming increases base station power consumption

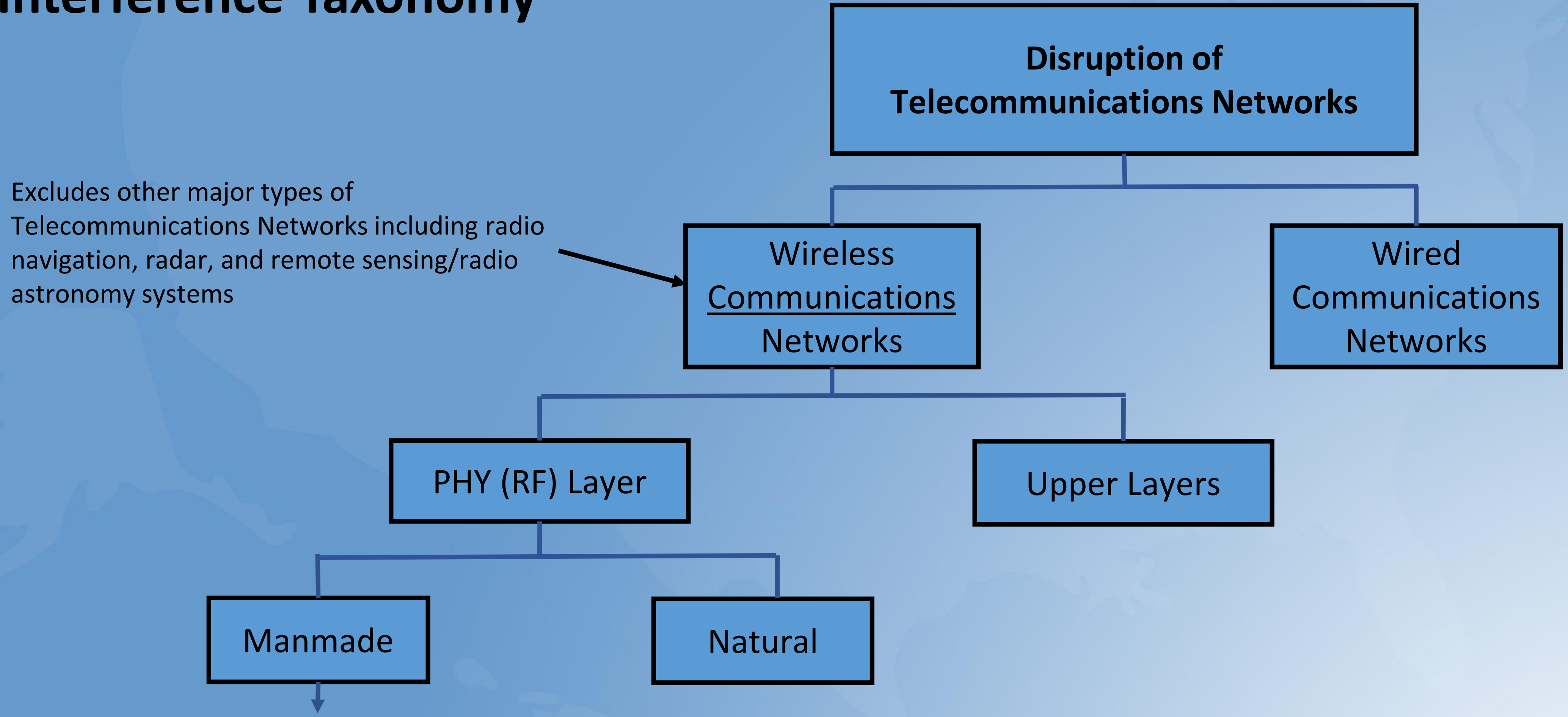
Potential Recommendation Areas

- Changes to how RF is measured & modeled for inter-cell interference and co-existence purposes
- Interference mitigation – Closed-loop approaches, compatibility analysis, TDD impacts, sharing

Interference Taxonomy

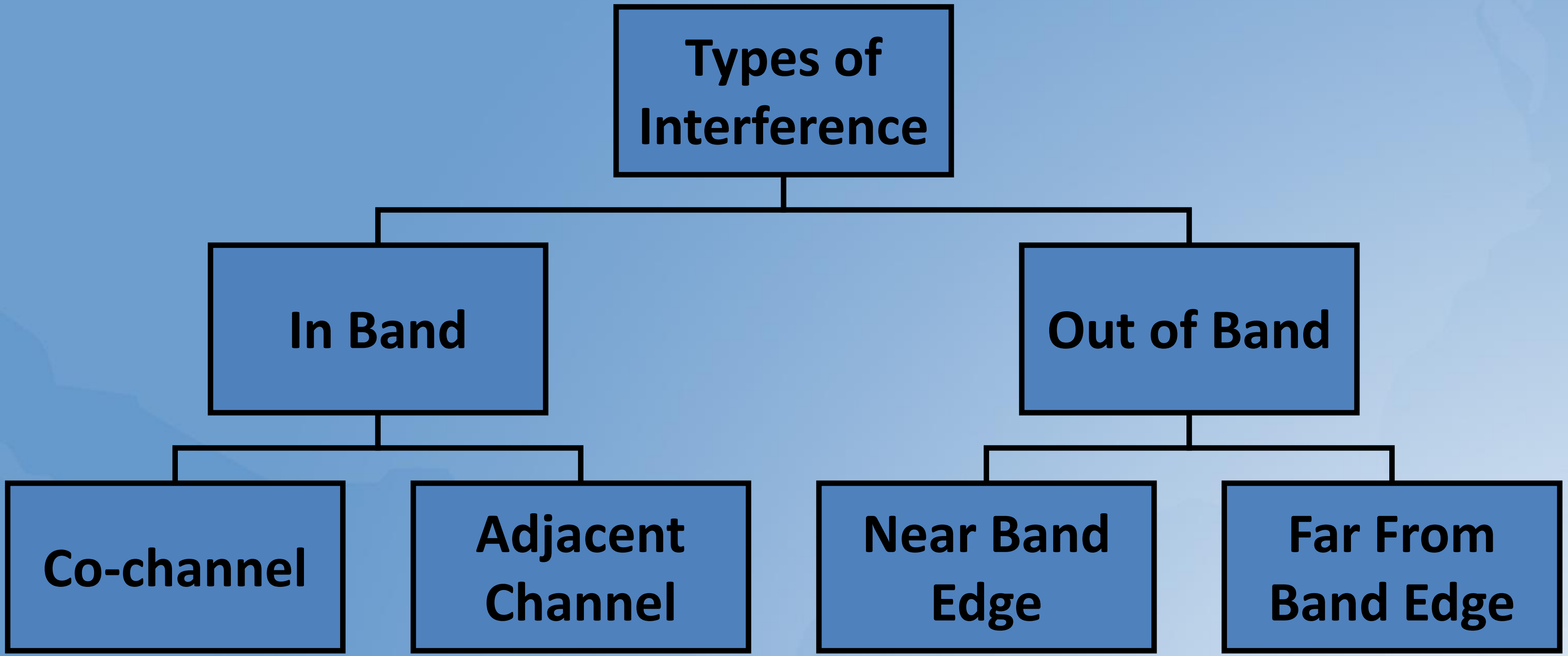
- There are significant benefits to using taxonomies in aligning terminology and in understanding and addressing complex domains like interference
- The WG is looking to leverage previous taxonomies (from TAC and researchers) to develop a more comprehensive interference taxonomy for WG as well as broader TAC use
- This may also be helpful to the Commission in developing interference-related assignments for the next TAC
- The following two slides represent a high level starting point leveraging prior work

Interference Taxonomy



Types of Interference defined by IEEE P1900.2/D2.22.

Interference Taxonomy



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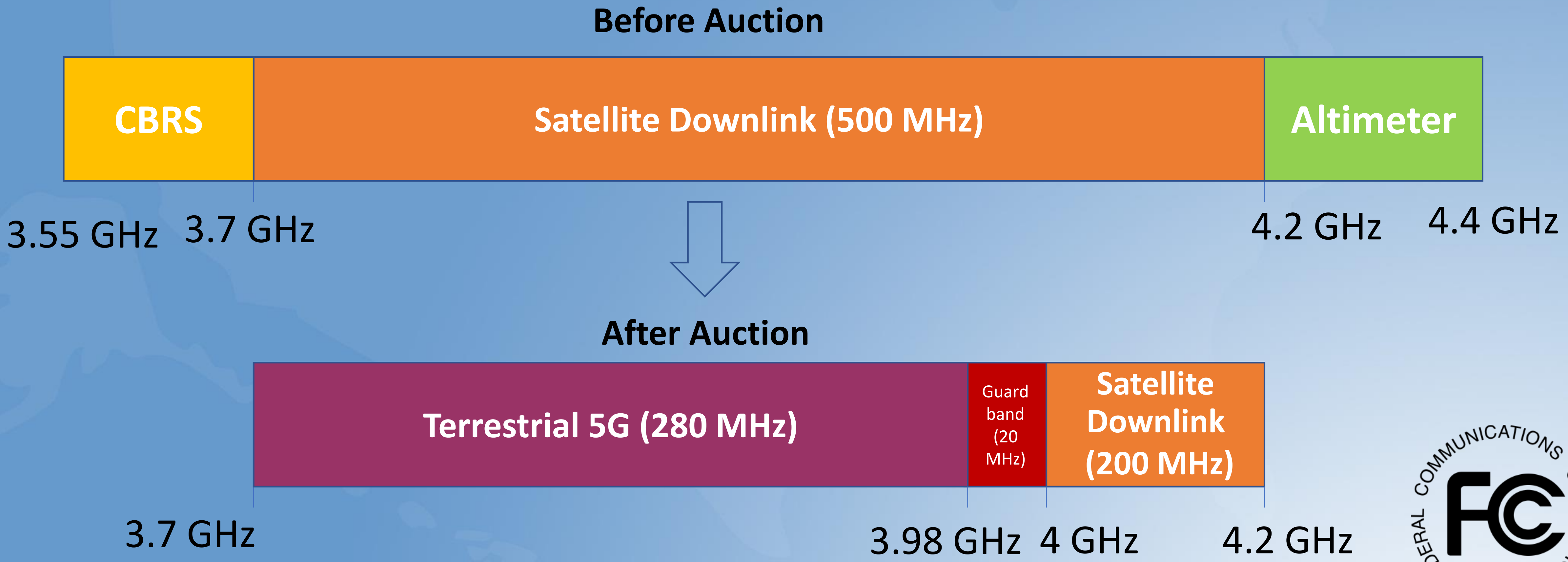
C-Band Spectrum and Interference Management



Interference Management in C Band (5G and earth stations) (Scott Townley - VZ)

- 5G signals have the potential to interfere, but can be mitigated
  - Lower part of the band – filtering at the FSS input
  - OOBE in C Band – limit OOBE
- Antenna types provide different opportunities
  - Massive MIMO 64 x 64, 32 x 32; Beamforming or SDMA with Remote Radio Heads (RRH)
  - Beams can be omitted or reduced in power
    - Additional transmit filtering, as appropriate
  - Deploying a small cell, which utilizes power control functionality, to limit device OOBE

Configuration	Blocking	gNB OOBE	UE OOBE
64T64R 32T32R	Generally none needed. Distance where issues arise with unfiltered FSS locations within adjacent Ph2 PEAs.	Distance	UE Power Control, Small Cell, Beam Omission
Beamforming	"	Distance, Filtering	UE Power Control, Small Cell
SDMA	"	Distance, Filtering, Beam Omission	UE Power Control, Small Cell, Beam Power/Omission

C Band Multi-stakeholder Technical Working Groups

- ~60 companies and associations representing aviation, broadband/CBRS, broadcaster, filter companies, MVPDs, programmers, satellite companies, and wireless service providers and manufacturers.

- TWG-1- Terrestrial and FSS Coexistence During and After the Transition
  - Interference mitigation approaches
  - Interference notification procedures and resolution

- TWG-2 - FSS Relocation to upper portion of the C Band
  - Best practices
  - Procedures
  - Other technical considerations related to relocating FSS

- TWG-3 - Terrestrial-Aeronautical Coexistence
  - Study aeronautical radionavigation equipment performance
  - Assess interference cases
  - Model use cases for aeronautical radionavigation operating in the 4.2-4.4 GHz band

- TWG-4 -Terrestrial-CBRS Coexistence
  - Technical considerations related to C-Band terrestrial operations and operations below 3.7 GHz

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TWG-1: Terrestrial-Satellite Coexistence

- **The 3.7 GHz Order** specifies limits on receiver (earth station) blocking and on OOBE
- **Preventing Interference**
  - Understand best practices that 3.7 GHz Service licensees use to predict interference
  - Preliminary findings: Filtering at earth station input (lower part of band), set OOBE equipment limits, beamforming/steering, deploy 5G small cell (power control)
- **Interference Detection and Mitigation**
  - Develop a process for positively identifying (or excluding) sources of interference
  - Develop a process to address situations where the PFD limits are determined to be compliant
- **Interference Resolution**
  - Define a process for earth station operators seeking resolution of potential interference
  - Can the resolution process can be expedited through the use of approved third-party firms?

TWG#3 - Terrestrial Aeronautical Co-existence

- The FCC indicated it expects the aviation industry to take account of the RF environment that is evolving below the 3980 MHz band edge and take appropriate action, if necessary, to ensure protection of such devices.
- **Scope**: Group is studying aeronautical radio navigation equipment performance, assessing interference cases, and evaluating possible use cases
  - Most altimeters seem to be adequately protected

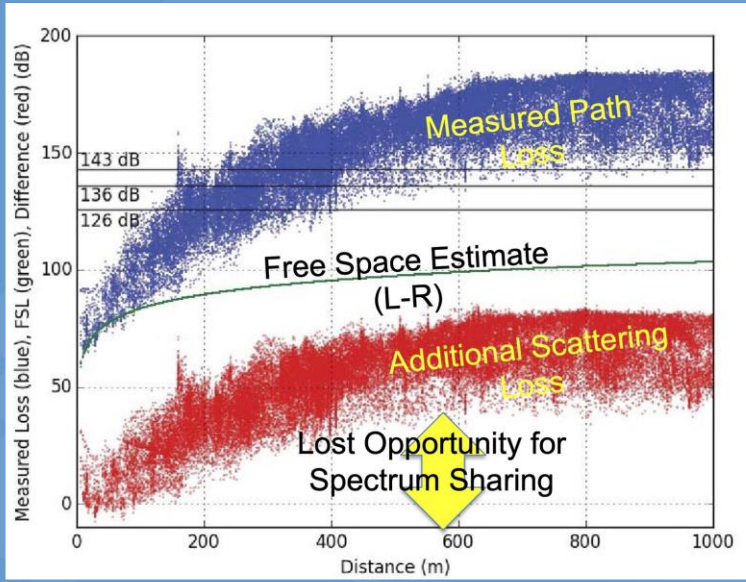
TWG#4 – C-Band and CBRS Co-existence

- **FCC:** "Mobile Out-of-Band Emissions. As with base station out-of-band emission limits, the Commission adopts mobile emission limits similar to the standard emission limits."
- **Scope:** Studying TDD synchronization, OOBE impact, receiver overload issues, non-3GPP equipment in CBRS, impact to the Environmental Sensing Capability (ESC).
  - Preliminary findings: TDD synchronization may help mitigate interference.
  - Most systems expected to be TDD. CBRS Alliance agreements provide for TDD synchronization and coordination.

Optimizing Communications By Considering Propagation

- Goal: Maximize utility of spectrum in shared frequency environment
- Problems:
  - Existing models rely primarily on terrain modeling
    - Do not account for environment-specific clutter, multi-path propagation, diffraction, etc.
  - Propagation changes over time and atmospheric conditions
    - Tropospheric Ducting can increase propagation distance
    - Rain Scatter can increase propagation distance
- Current Solution: Limit transmit power to not interfere, assuming maximum possible propagation conditions (i.e. too conservative worst-case protection limits)
- Possible Future Solutions:
  - More granular & accurate models based on closed-loop AI/ML acting on large field data sets
  - Dynamically adjust transmit characteristics based on current propagation conditions

Advantages of Actual Propagation Distances vs Modeled



Source: Preston Marshall, Google

Overly simple models can cause:

- Coverage and capacity requirements: inaccurate investment projections when used to determine infrastructure
- For spectrum sharing: Loss of spectrum opportunities
  - Early Google path loss experiments show large deviation from free space estimates (graph)
  - Large model errors can force significantly greater cell spacings

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Determining Propagation From Real-Time Measurements

Machine Learning	Provides scalable framework to incorporate billions of measurements, both to understand paths and environments.
Nano-Scale Geo-Data	Leverage the availability of nano-scale geodata on buildings, terrain, foliage, and other features
Crowdsourcing	Acquire massive training sets through utilizing collateral collection by deployed devices, to provide the essential scale, and to avoid cost of standalone collections.

Source: Preston Marshall, Google

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Interference Source Identification

- One of the key problems identified in various sharing and coexistence studies
- A possible approach is use of a broadcast beacon which could identify the type/location/ technology used by a transmitter to help with interference detection and mitigation
- Such beacon transmissions which be narrow band / low rate may be defined at RF layer, physical layer or higher layer with different trade offs
- Some such ideas are introduced in 5G for intra-system Remote Interference management (RIM) due to ducting
- There are also studies in CSMAC on unique identifiers needs and challenges which the WG plans to review and discuss for potential recommendations

Potential Recommendation Areas

Advanced Antenna Systems (AAS) & Beamforming

- Changes to how RF transmission is measured & modeled for managing interference and co-existence
- Changes to how RF interference is measured at receiver
- Impact of beamforming on OOBE

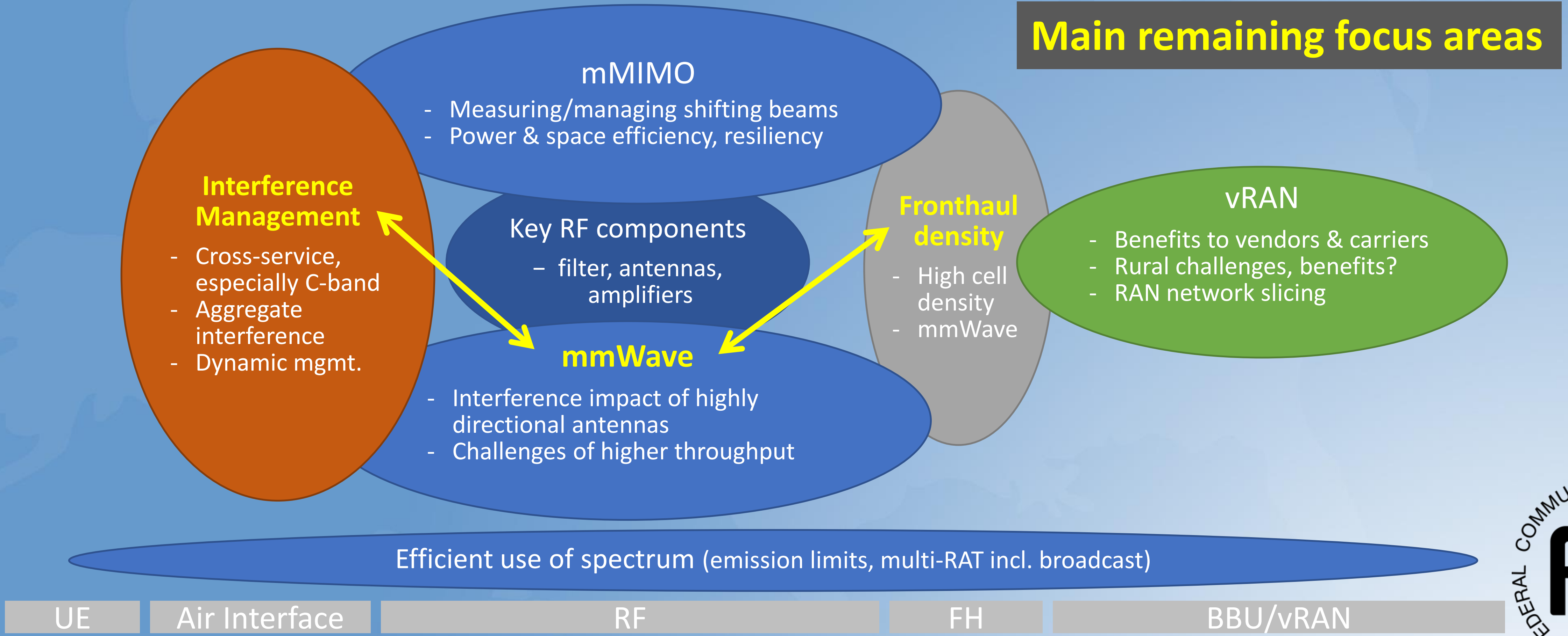
Interference mitigation techniques

- Near term methods from current experiences (C Band w/FSS and CBRS with incumbents)
- Learnings/approaches from C-Band multi-stakeholder group to other bands, as appropriate
- TDD synchronization

Dynamic spectrum management opportunities

- Dynamic interference characterization
  - Crowdsourcing environmental & measurement data
  - AI/ML
- Dynamic interference migration (long-term)
  - Closed-loop propagation modeling for greater spectrum utilization

‘Heat Map’ of High Impact, High Interest Areas



WG plans for rest of year

- Address main remaining focus areas
  - mmWave: interference challenges & mitigation
  - Fronthaul technologies & implications
  - Equipment authorization aspects
- Firm up conclusions & recommendations across all topics

Thank You!

5G/IoT/O-RAN Working Group 2020
Third Quarter Readout

WG Chairs: Russ Gyurek, Cisco & Brian Daly, AT&T

Date: September 22, 2020

Outline for FCC Formal Readout: Sept 22, 2020

- WG participants
- Charter
- Summary of SMEs and topics past quarter
- Standards update
- Key observations
- Potential areas for recommendations
- Request for input

2020 Working Group Team Members

- Ahmad Armand, T-Mobile
- Mark Bayliss, Visualink
- Marty Cooper, Dyna
- Bill Check, NCTA
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- Dale Hatfield, Univ of Colorado
- Haseeb Akhtar, Ericsson
- Steve Lanning, Viasat
- Greg Lapin, ARRL
- Lynn Merrill, NTCA
- Robert Miller, inc Networks
- Jack Nasielski, Qualcomm
- Milo Medin, Google
- Mike Nawrocki, ATIS
- Charlie Zhang, Samsung
- Dennis Roberson, entigenlogic
- Scott Robohn, Juniper
- Jesse Russell, incNetworks
- Travis Russell, Oracle
- Kevin Sparks, Nokia Bell Labs
- Marvin Sirbu, Spec. Gov. Emp.
- Tom Sawanobori, CTIA
- Paul Steinberg, Motorola
- David Young, Verizon
- David Tennenhouse, VMware

FCC Liaisons: Michael Ha, Padma Krishnaswamy, Charles Mathias, Ken Baker, Sean Spivey, Nicholas Oros, Monisha Ghosh

2020 Charter from FCC

5G in low/mid/high frequency bands - critically important to the communications industry, our economy, and U.S. international competitiveness

5G systems are now being deployed, and **6G is being discussed**

- Provide information on the development and deployment of this technology, make recommendations, and provide technical insights on new developments that have arisen

Recent industry developments in the **virtualized radio access network (RAN)** space, such as those undertaken by the O-RAN Alliance, have the potential to disrupt conventional cellular network design and deployment

- How scalable are such approaches and what time frames should be anticipated before scalability is achieved?
- How can v-RAN help large and small companies to become more efficient or competitive?
- What are the key challenges of disaggregating the network among multiple vendors?
- How can such disruptive technologies be tested and deployed in realistic environments?
- How will they evolve to keep pace with the ever increasing bandwidth requirements of cellular systems?

Other topics for this Working Group include:

- How can 5G services over mmWave bands be made **more robust**?
- **How will** 5G coexist with Wi-Fi in bands with existing and new unlicensed devices?
- What is the status of the deployment of service by verticals such as transportation, energy, health care, etc. and is any Commission action needed to encourage this deployment?
- Is dedicated or shared spectrum needed to support industrial IoT applications, what spectrum would be suitable for this purpose, and what are the enabling technologies to consider? Are there any other communication technology trends about which the Commission should be aware to prepare for the future beyond 5G?

Speakers: Key Insights pg.1

Organization	Topic	Speaker	Summary
ERICSSON	O-RAN Alliance Deep Technical Review	Dr. Brenda Connor 6/18	• RAN programmability through near-RT & non-RT RICs- this has high value • O-RAN has opened up the RAN network: includes radiohead, cloud and virtualized functions. Limited pre-commercial tier 1 deployments (option 7-2x)
SMALL CELL FORUM	Small Cell Forum- Chair (Russ/Brian)	Prabhakar Chitrapu 6/25 and on 7/16	• SCF has a history of disruption and is driving openness across SCN's • Focus is on enabling verticals the build and use macro-cellular networks • Open-nFAPI is a foundational network protocol for connecting the PHF to VNF
analysys mason	US Spectrum Report Findings	Janette Stewart 7/9	• US plans for mid-band spectrum are solid with 3.45-4.0 • Analysys report predated some actions, called US mid-band a bit low • Additional mid-band such as 3.45-3.55 GHz will drive faster deployments
PAWR Project Office	RAN slicing and NSF PAWR/ Colosseum	Tommaso Melodia (NE U) 7/23	• Need work on Open Architectures, Algorithmic frameworks, Testbeds, Meas • Propose: Cellular Operating System (CellOS) programmatic network control • Need spectrum Coexistence Between U-LTE and Wi-Fi
QUALCOMM	NR-U (overall and 3GPP R17)	Aleksander Damjanovic 7/30	• Synchronization is the key enabler for more efficient sharing of the spectrum • Synchronous sensing mechanism can be viewed as more flexible alternative to the database-controlled access • Synchronous access allows priority based channel use for mobile scenarios
ASU Arizona State University	Smart Campus: IoT (Brian)	Chris Richardson 8/6	• Universities are leveraging 5G for production and research needs • City scale projects help define non-operator size requirements and services • Not a one-size-fits-all approach, but an integration of a multiple technologies

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Speakers: Key Insights pg.2

Organization	Topic	Speaker	Summary
QUALCOMM	NB-IoT, REDCAP	Lorenzo Casaccia 8/13	• 3GPP Release 17 will have a focus on the mid-range IoT devices- REDCAP • exercise of subtraction: what can be removed from NR to address this segment • Goal: reduce complexity/cost thru device constraints, reduced Rx/Tx antennas
atis	ATIS, AT&T and Samsung, preso & panel	Mike Nawrocki, Brian D., Charlie Z. 8/20	• 6G is expected to launch as early as 2028. From “Massive” to “Extreme” • 6G encompasses smart connectivity systems as a platform for NG Internet • Integration of Human-machine, hi-QoS comms, cyber-physical fusion/ D. Twins
CBRS	CBRS Auction Results and next steps	WG team 8/27	• Observation: Large SP presence in the CBRS PAL auction • Very limited number of bidders from enterprise/industrial- determinism? • Team discussion on license size; would smaller geographies help business use
Google	[X-WG] Spectrum sharing	Preston Marshall 9/1	• Spectrum sharing: modeling propagation with ML, Geo-data, and crowdsource • It is time to move from trusting analysis to trusting real data • Current models support inefficient spectrum use and efficiency
6G	[WG] 6G preso and whitepapers	WG team 9/10	• Significant push WW focused on 6G planning and creation of framework • Some 5G topics spill onward to 6G: EC, URLLC, and AI are fundamental • Key differences are uses and vertical customization/focus
EIRP Safety	[PANEL] Lapin, CTIA, Cisco	5G Safety Panel 9/17	• NPRM 19-226 Targeted Changes to the Commission's Rules on Exposure to RF Publication of IEEE C95.1 (2019) standard • Publication of ICNIRP guidelines (2020)

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Standards, Consortia Updates

3GPP

- COVID-19 and 3GPP Meetings
  - There seems to be consensus that 3GPP meetings will continue electronically for 1H2021, with some concern that this will continue for the entirety of 2021
  - Almost continuous meetings (WGs and Plenaries) are not only significantly reducing productivity but also greatly increasing overall fatigue on the process and its delegates
  - While it is desired that only 6 Working Group meetings be held each year, 2 week electronic meetings mean almost continuous preparation for those involved in the process
  - E-Voting is still under development by 3GPP, it is planned to be ready by December
- U.S. Participation in a COVID environment
  - Increase (numbers to be posted)
- Release 16
  - All Release 16 exceptions were completed during the last WG meetings
  - Release 16 September ASN.1 generally agreed to be stable for development; was "ratified" at last week's plenary meetings

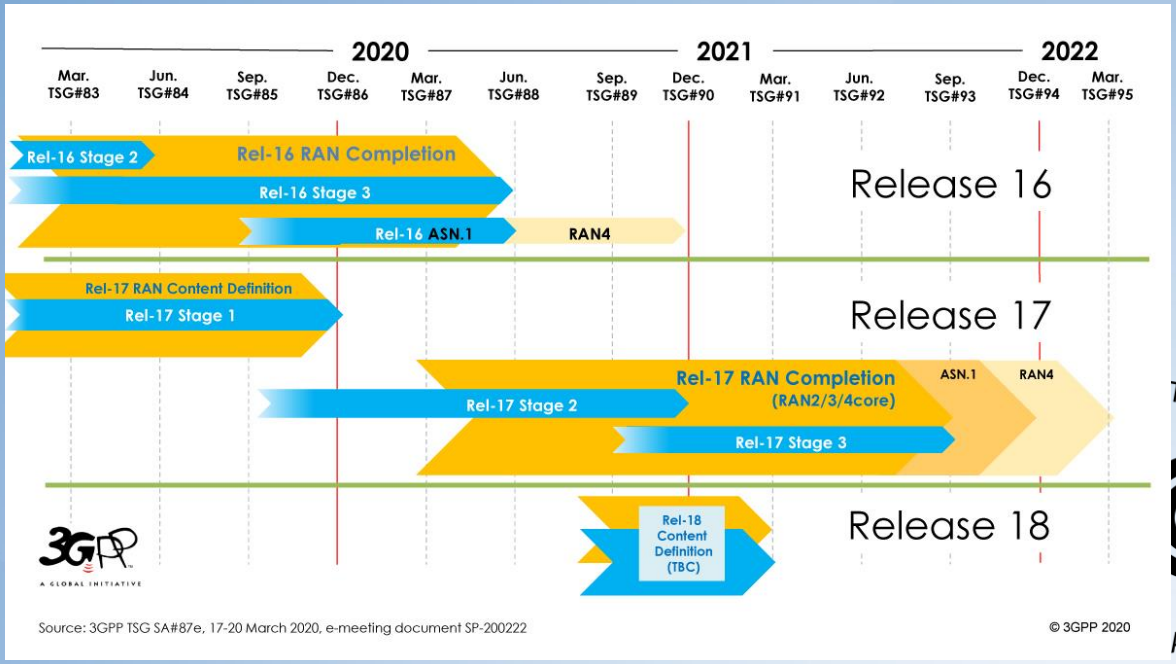
3GPP Release 17 Status

- Release 17
  - No official announcement on timing; 3GPP WG leaders will develop a detailed plan to present at December plenaries
  - However, expect a minimum 6 month delay - in reality it is likely to be longer
  - Release 17 RAN specifications clearly in 1H2022, with ASN.1 completion to follow 3 months later
  - However, given current the current e-meeting situation it is likely that Release 17 will not be completed until 2H2022
- Down Scoping of Release is still possible
  - 5G Multicast / Broadcast (MBMS) related work is currently being discussed
    - China Broadcast Network (CBN) and other Asian companies had a proposal against such down scoping
    - FirstNet needs MBMS in Release 17
- Band n96 (6 GHz)
  - NR 6 GHz band (n96) requirements not agreed in RAN4 - firm objections from Chinese.
  - The principal objections have been that Chinese requirements have not yet been defined for the band
  - Clearly blocking the regional US specification of the band

3GPP Release 18 Status

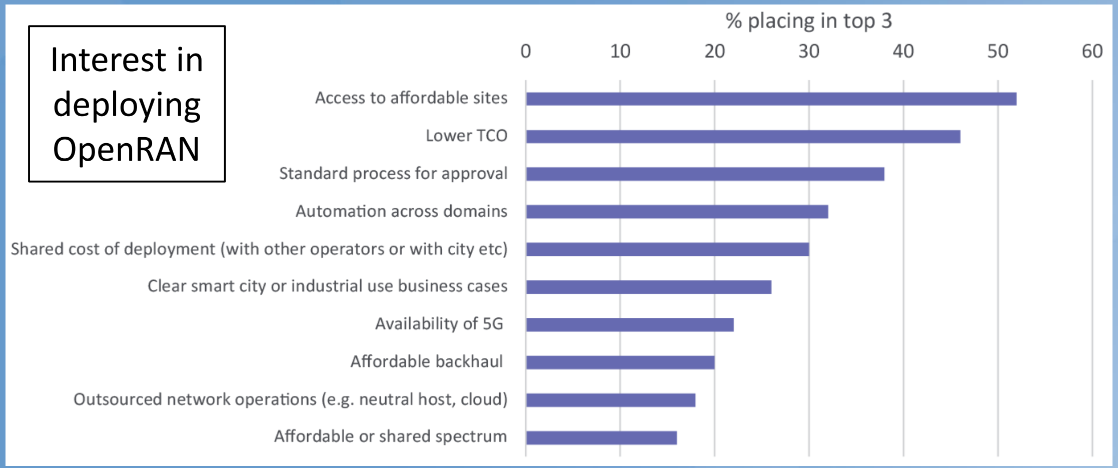
- Study on evolution of IMS multimedia telephony service
- Study on sharing administrative configuration between interconnected MCX Service systems
- Study on Supporting of Railway Smart Station Services
- Study on traffic characteristics and performance requirements for AI/ML model transfer in 5G systems
- Guidelines for Extra-territorial 5G systems
- Study of Gateway UE function for Mission Critical Communication
- Study of Interconnection and Migration Aspects for Railways
- Study on Enhanced Access to and Support of Network Slice
- Study on Off-Network for Rail
- Study on 5G Timing Resiliency System
- Study on 5G Smart Energy and Infrastructure
- Study on Ranging-based Services
- Study on Enhancements for Residential 5G

- Study on Personal IoT Networks
- Study on vehicle-mounted relays
- Study on 5G Networks Providing Access to Localized Services
- Subscriber-aware Northbound API access



OpenRAN and SCF Updates

- FCC hosted an all-day "Forum on 5G OpenRAN"
  - Focused on the development and deployment of Open RAN and expected impact on 5G technology, vendor supply chain, security, and U.S. innovation
- ONF Announces New 5G SD-RAN™ Project
  - Software Defined Radio Access Network open source software platforms and multi-vendor solutions for 4G/5G
  - Initially, the project will focus on open source Near Real-Time RAN Intelligent Controller (nRT-RIC) compatible with the O-RAN architecture (µONOS-RIC), using the E2 interface between µONOS-RIC and RAN RU/DU/CU RAN components
  - Founding members include AT&T, China Mobile, China Unicom, Deutsche Telekom, Facebook, Google, Intel, NTT, Radisys and Sercomm



- Small Cell Forum (SCF)
  - Published "Options for Indoor Cellular"
    - Assist building owners and tenants in solving the issues of poor and sub-standard cellular connectivity on their premises
  - Market Status Report 2020
    - Indoor/enterprise small cells will be a far larger market than urban small cells in the short term
    - Urban small cell networks will be slower to get to large scale, due to many stakeholders need for a common benefit; the complexity of siting and approval regulations; and macro networks often deliver 'good enough' performance outdoors, vs inside buildings
    - Roll-out of urban small cells is hampered by access to sites and approvals, but automation could be key in reducing costs

Source: SCF

ITU Updates

- ITU-R
  - Evolution of IMT-2020/5G Technology - update of Recommendation M.[IMT-2020.Specs] to incorporate 3GPP Rel 17 standards
  - "Draft new Report on terrestrial IMT for remote sparsely populated areas providing high data rate coverage"
  - Initiation of Future IMT-2020 vision for beyond 5G to stimulate global research
    - First steps leading to the next IMT (2030?)
  - Technology Trends report (to be completed in 2022)
- ITU-T SG17 (Security)
  - Completed preliminary step of creating a 5G security standard based on the Korea Internet & Security Agency (KISA) responses to attacks on 5G core networks
    - procedures for verifying the integrity of 5G communication, the denial of services through forced non-encrypting, stealing voice information and the forgery of communication contents
  - Six proposals related to quantum cryptography, blockchain (distributed ledger technology), and vehicle security, and two proposals on personal information protection and cyber security failure responses

5G Deployment Updates – Sept 2020

- **AT&T**
  - 205 million POPs and 395 markets
  - Sub 6 GHz and mm wave spectrum
- **T-Mobile**
  - 7500 towns/cities covering 250 million customers and 1.3 million square miles
  - Sub 6 GHz and mm wave
- **Verizon**
  - 36 cities deployed
  - More than 60 cities with mobile and 10 cities with FWA by EOY2020
- **US Cellular**
  - Iowa and Wisconsin launched
  - Plans to launch select areas in 11 more states this year
- **GCI (Alaska) and C Spire (Mississippi) launched**

- **Growing 5G devices** (11-13 models for national operators)
  - Smartphones: Samsung (multiple models); LG; Motorola
  - Fixed wireless routers/modems




- **China**
  - China Mobile, China Telecom, China Unicom
  - All 300 prefecture cities by EOY2020
- **South Korea**
  - SK Telecom, KT, LGU Plus
  - 115 K 5G base stations nationally
- **Japan**
  - NTT DOCOMO, KDDI, Softbank launched March 2020
  - Rakuten is deploying 5G O-RAN network
- **UK**
  - EE, Three, O2, Vodafone launched in 2019
  - Others, including MVNOs launched (BT, Tesco, Sky, VOXI)

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Open RAN Market Status

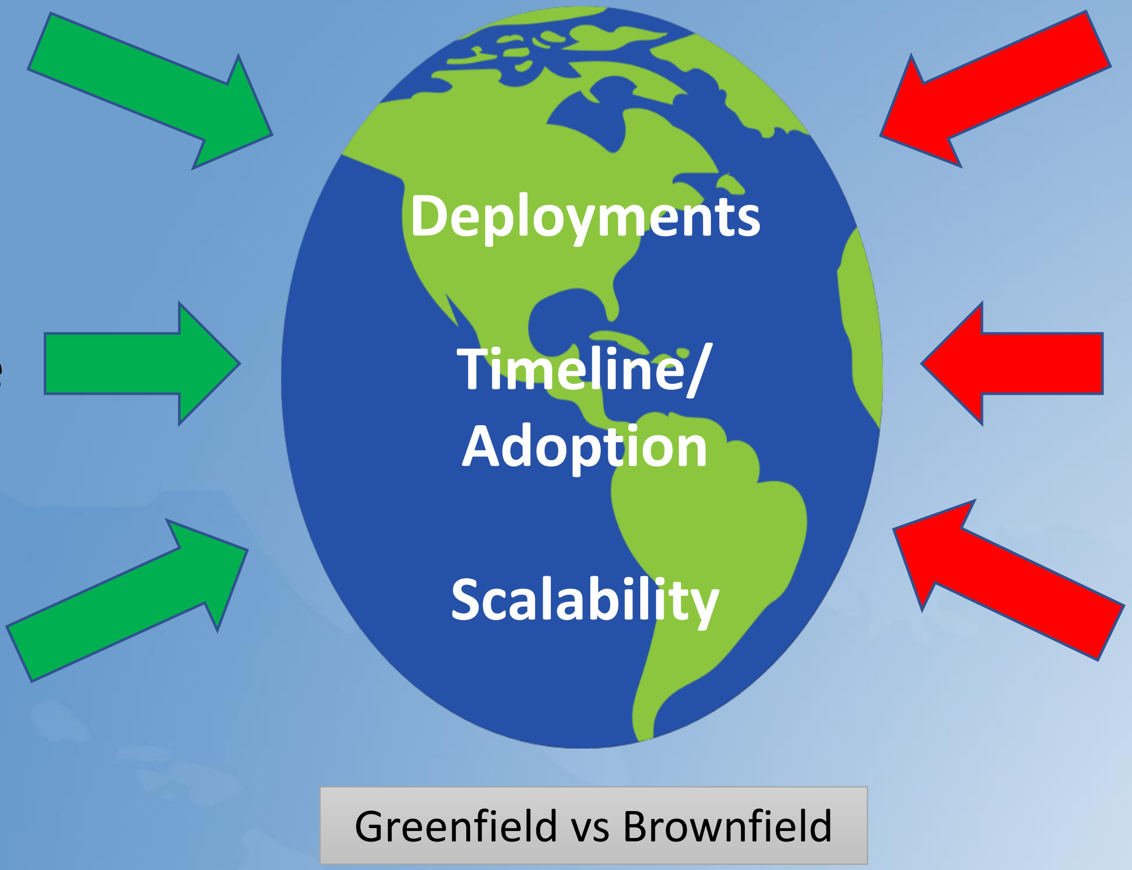
MNO	vRAN	OpenRAN	O-RAN Alliance	Radio Access Technology
Rakuten, Japan	vBBU	No	No	4G
Bharti Airtel, India	vBBU	No	No	4G
Vodafone Idea, India	vBBU	Yes	No	4G
Vodafone, UK	vBBU	Yes	No	4G
MTN, Africa	vBBU	Yes	No	4G/3G/2G
Orange, Africa (CAR)	vBBU	Yes	No	4G/3G/2G
IPT consortium (Telefonica+ FB) - Peru	vBBU	Yes	No	4G/3G/2G
NTT DoCoMo (pre-commercial trial system)	N/A	No	7-2x LLS, X2 profile	5G/4G

Estimated total worldwide deployed sites ~ 7,000

Driving Points & Observations

Summary of Open RAN, O-RAN Drivers and Issues

- Openness
- Drive innovation
- Cost savings
- US competitiveness
- Flexible architecture
- Virtualization
- Disaggregation
- SW driven
- Network-as-an-app



- Interoperability
- System integration
- Multi-vendor
- Cloud reliance
- Power efficiency
- Interface conflicts
- Legacy support
- Complexity
- Security

The "movement" continues to grow!

Open RAN POLICY COALITION

Airspan	Altiostar	American Tower	AT&T	AWS	Broadcom	Ciena	Cisco
Cohere Technologies	CommScope	Crown Castle	Deepsig	Dell Technologies	DISH Network	Facebook	Fujitsu
Gigatera	Google	Hewlett Packard Enterprise	IBM	Intel	JMA Wireless	Juniper Networks	Inseego
Ligado	Marvell Technology Group	Mavenir	Microsoft	NEC Corporation	NewEdge Signal Solutions	Nokia	NTT
NVIDIA	Oracle	Parallel Wireless	Pivotal Commware	Qualcomm	Quanta Cloud Technology	Radisys	Rakuten
Reliance Jio	Rift	Robin.io	Samsung Electronics America	Telefonica	Texas Instruments	U.S. Cellular	US Ignite
Verizon	VMWare	Vodafone	World Wide Technology	XCOM-Labs	Xilinx		As of Sept 16, 2020

Goals

- Support global development of open and interoperable wireless technologies
- Signal government support for open and interoperable solutions
- Use government procurement to support vendor diversity
- Fund research & development;
- Remove barriers to 5G deployment
- Avoid heavy-handed or prescriptive solutions.

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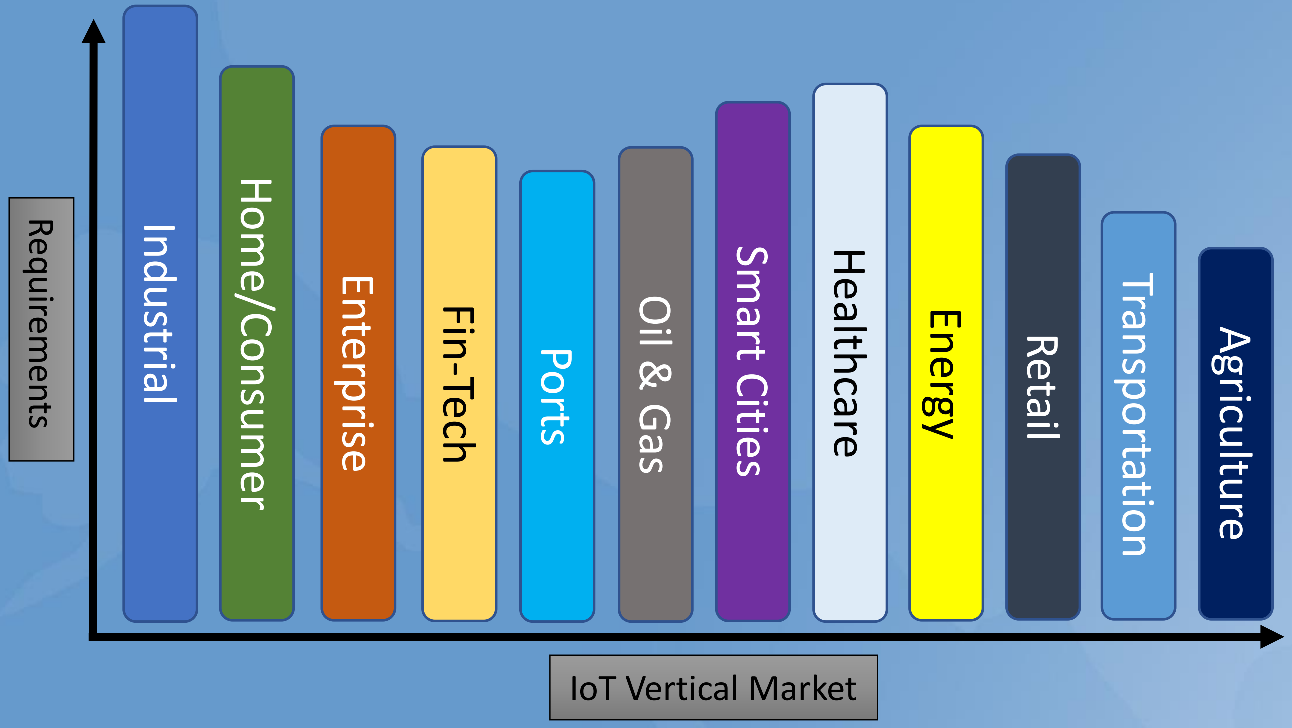
IoT Verticals have Specific Requirements Related to 5G



Requirements/Needs

Private vs Operator
Latency- URLLC
Compute- at edge
QoS: Jitter, loss, reliability
Security- Network, data
Privacy
High throughput
IT/OT Control

Opportunity to Reference ATIS Characterization work on IoT

IoT/ENT: A growing demand for private, locally licensed spectrum

Area to Explore: 5G+ Requires Fiber

- 5G does not have massive spectral efficiency improvements over LTE-Advanced. It's speed advantage comes from being able to use much more spectrum compared to LTE-A, since peak speeds are driven by channel width.
- Due to limits of availability of low and mid-band spectrum, 6G will target higher radio spectrum equating to smaller cells and greater densification
- Analyses have shown that for 3.5 GHz coverage to hit 70% of POP availability in the US, more than a million base stations would be needed. At 28 Ghz, that number grows to over 13 Million base-stations, as the frequency increases it results in even larger base-station counts. For indoor locations this issue is exacerbated with millions more base-stations
- Major challenge emerging: these type of deployment scenarios require fiber backhaul to connect base-stations to the rest of the Internet. The cost and availability of fiber will begin to challenge deployment rates and operator economics. Integrated access backhaul will partially offset need.
- When comparing the US to countries like Japan, Korea, Singapore, China, Hong Kong etc..., which have deployed utility style fiber networks have been deployed, with both broad availability and low cost, these nations have a fundamental advantage over the US in such small cell deployments. Low cost Interoffice dark fiber is necessary to enable 5G and 6G economics to work. In the US, no widespread utility dark fiber transport is available, much less affordable.
- The fundamental difference in dark fiber availability and pricing compared to other nations puts the US at a strong disadvantage not just in 5G network, but especially 6G systems that will aggregate even larger amounts of spectrum, and use even higher frequencies, as well as challenges in building out indoor coverage cost effectively where >50% of current cellular data is consumed.
- Without addressing the fiber x-haul requirements, US leadership in 5G, and more so in 6G will be nearly impossible to achieve.

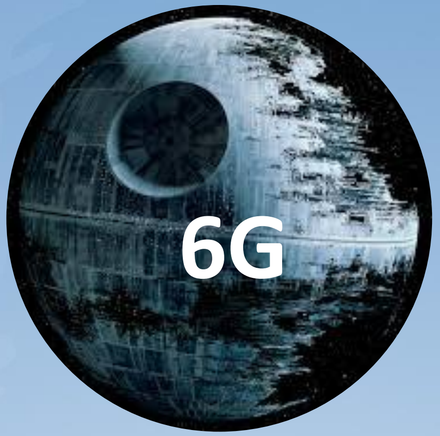
Recommendation focus areas

Key areas for recommendations: Spectrum

- Need a mix: licensed, shared, unlicensed
- WG supports latest move to open up 3.45-3.55 GHz for licensed use
- Additional use options to be explored in the 3.1-3.45 GHz bands
- Consider shared spectrum where exclusive use is not practical
  - Recommendation for spectrum sharing based on a data intense/intelligence sharing model
  - For future sharing, explore smaller geographies, ex smaller than county level
  - Interference issues related to receivers overcome
  - Sharing via non-exclusive licenses
  - Focus on spectrum efficiency, maximize use and users
  - US leadership role related to spectrum sharing with novel approaches
- Addition spectrum exploration:
  - beyond 7 GHz

Key areas for recommendations: 6G

vs.



- FCC to promote creation of a US national roadmap
  - Encourage industry engagement, R&D, and standards
  - ATIS could take leadership role
- Key 6G areas that need attention
  - Spectrum: planning to support 6G network requirements
  - Architecture: further densification may cause site location challenges
  - Fiber backhaul: will be a challenge for US overall without investment and focus
    - Examine technical options such as integrated access and backhaul
- Research: FCC should support research related to hi-frequency mmWave and THz potential use, and spectrum efficiency techs
- Multi-network service convergence: Additional efficiencies can be gained
- FCC to encourage applications, services development aligned to 6G capabilities
- FCC to bolster US competitiveness by proactively encouraging an open innovative environment for 6G eco-system

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Key areas for recommendations: IoT

- Consider private spectrum tied to IoT/Enterprise/captured spaces
  - Needs are for limited geographic areas, buildings
  - Models: lightly licensed and private
  - Potential economic disadvantage in US (many other countries leading)
  - Create specific rules on power levels for private/LLS
  - Both midband and mmWave are applicable, some trade-offs , advantages
  - Focus on re-use in closed/captured spaces
  - Shielding requirements, outside-in vs inside-in
  - limit perimeter emission
  - Optimize use of the spectrum (up/down)
- Vertical being studied
  - Industrial- Strict needs related to URLLC, control, cost, operations
  - Cities- Wide range of needs and QoS requirements for services; from critical to best effort
  - Transportation- TBD
  - Medical: TBD
- 3GPP R17 effort "RedCap" focused on "mid-level" IoT device needs, lower cost

Spectrum comparison for local-licensed needs & use

Metric	Mid-Band	mmWave
Propogation	~4-7Km	< 1 km
Bandwidth Capacity	Gbps	10's of Gbps
Location accuracy	Good	Better
Interference issues	Low	potenially higher
Low Latency support	Yes	Yes
Indoor coverage	Low path loss	Hi path loss
Relection	Limited	High
Share-ability/Re-Use	Fair	Good/excellent
Coverage ratio	High	Low-medium
Power efficiency/area	High	Low-medium

"We need private spectrum for control, economics, latency" – Bosch

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Potential recommendation areas: FCC role in driving Open RAN

- Encourage development of Open RAN and O-RAN eco-system
- Support "open" R&D opportunities
- Support interoperability through public-private events such as "plug-fests"
- Leverage enterprise and IoT verticals for rapid adoption

Open RAN is much more than CAPEX savings and efficiency

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Key areas for recommendations: Security (WiP)

- 5G security concerns
  - 5G is more secure than 4G, but some are concerned with massive IoT that security risks are greater
  - FCC CSRIC working group making recommendations on 5G security and transitioning to 5G
  - Industry is considering zero trust models
    - Verifying 'clean' supply chain components
    - 3GPP standards are increasing security capabilities
    - Network sharing and slicing security issues- interconnection, neutral host
  - Jamming and spoofing issues are real and becoming more frequent- easy and low-cost to jam
  - O-RAN potentially adds additional security threats with multi-vendor HW & SW

- Power reliability, back-up for critical services- Industry leading here
  - Reliability of power grid essential for communications infrastructure
    - Availability/capability vs economics
    - how many nines: excess requirements vs what is really needed
    - Highly robust, low-latency, what is fall-back? Over-engineering the network at increased cost, for long-tail traffic
    - Adds increased complexity
  - FCC TAC previously studied network reliability and backup power
  - Current model is industry voluntary commitment – roaming under disasters, mutual aid, consumer education, municipal readiness
    - *Potential recommendation* related to emergency roaming

Feedback, Input, Questions

Thank You!

Closing Remarks

Adjourned