Federal Communications Commission Technological Advisory Council Meeting

December 1, 2020

FCC Technological Advisory Council Agenda – December 1, 2020

10am – 10:15am	Introduction and Opening Remarks
10:15am – 10:30am	Announcements and Roll Call
10:30am – 11am	FCC Chairman's Remarks WG Recommendations (5 minutes for each WG)
11am – 11:45am	Artificial Intelligence WG
11:45am – 12:30pm	Future of Unlicensed Operations WG
12:30pm – 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

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FCC TAC
Artificial Intelligence and Computing Working Group [AIWG] – Chairman's Briefing

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: December 1, 2020

2020 FCC TAC AIWG Team Members

- Shahid Ahmed, Independent
- Sujata Banerjee, VMware
- Nomi Bergman, Advance
- William Check, NCTA
- 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
- Jack Nasielski, Qualcomm
- Michael Nawrocki, ATIS
- Dennis Roberson, entigenlogic
- Marvin Sirbu, SGE
- David Tennenhouse, VMware

FCC TAC AIWG Activities in FY2020

Issues Addressed

1. Leveraging Federal Investments in AI
2. Understanding Data needs for AI
3. Extracting value from AI and Data to address issues of importance to the FCC
4. Safe use of AI

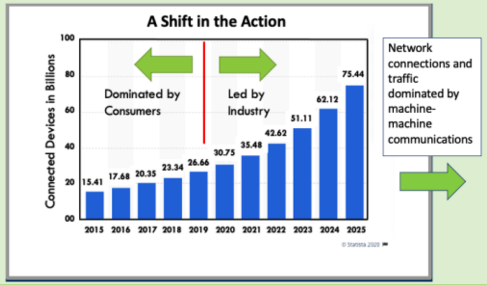
Considerations

1. The FCC's Strategic Priorities
2. Industry Trends
3. Technology Maturity
4. Timeliness
5. Impact

Strategic Priorities

1. Closing the Digital Divide
2. Promoting Innovation
3. Protecting Consumers and Public Safety
4. Reforming the FCC's Processes

Industry Trends



The FCC
Service Providers
Consumers
Industry
The Public Sector

Inputs

1. AIWG SME Discussions
2. External Presentations
3. Supporting Documents
4. FCC Liaisons

Nature of Recommendations

Lasting Impacts on the FCC

(Two) AI in FCC Strategy, and Data

Immediate Impacts on FCC, Service Providers, Consumers, Industry, and the Public Sector

(Three) Broadband Map, Safe Use of AI, and Pilot Projects

Recommendations

The FCC TAC AIWG has identified five recommendation areas:

1. **"Unlock transformational change" - The incorporation of considerations for Artificial Intelligence in the FCC Strategic Plan.**
2. **"To build knowledge, unleash the Data" - The creation of a Task Force to address how the FCC can best address important aspects of Data governance and curation for AI/ML applications to serve its internal needs, and those of industry and the public.**
3. **"Cast a wide net" - Develop a plan and strategy for designing, developing, deploying, operating, and maintaining a Broadband Map that takes advantage of the best technologies and capabilities available.**
4. **"Keep humans in control of the loop" - Policies and approaches to ensure the safe use of Artificial Intelligence as it impact the nation's networks, communication needs, and important applications.**
5. **"Get your feet wet" - Develop the FCC's capability for extracting value from Artificial Intelligence in solving issues and problems that come before the FCC by conducting pilot projects with near term return.**

Thank You!

FCC TAC
Future of Unlicensed Operations
Q4 2020 Report

Chairs: Kevin Leddy, Charter & Brian Markwalter, CTA

FCC Liaisons: Monisha Ghosh, Michael Ha, Nick Oros, Bahman Badipour, Mark Bykowski, Chrys Chrysanthou, Martin Doczkat

Date: December 1, 2020

Chairman's Summary

- We evaluated businesses and use cases and validated that **unlicensed spectrum both creates healthy competition and is a powerful tool to complement** existing licensed business models.
  - Competitive Benefits: Better competition with MNOs by improving MVNO economics; greater competition with wireline ISPs by enabling WISP business models.
  - Complementary Benefits: Mobile offload of 80%+ of traffic to Wi-Fi, LTE expansion via LAA, and extension of ISP's network via Wi-Fi.
- Further, **unlicensed spectrum has tremendous value to the US economy**. While auction revenue supports the U.S. Treasury, unlicensed spectrum creates broad economic benefit.
  - ~500 MHz of low / mid band spectrum at 900 MHz, 2.4 GHz and 5GHz is estimated to have contributed to $500 billion in economic value in the US in 2018
- **We commend the FCC for continuing to prioritize unlicensed spectrum** in recent years, including unlicensed and lightly licensed initiatives in 5.9 GHz, 6 GHz, CBRS, and 60 GHz.
- Our Working Group studied the wide variety of sharing technologies available to open more spectrum for unlicensed operations and we see great potential in sharing more bands.

Chairman’s Summary (continued)

- Recommendations – Our report includes three recommendations:

1. The FCC should continue its light touch approach to unlicensed spectrum and allow industry to collaborate to determine the best methods for sharing the airwaves. The FCC should avoid further codifying standards in regulation, and **allow industry to define technical specifications.**

2. However, when requirements and conditions evolve, so should the regulations. In particular, **we recommend a rulemaking on personal radars be opened on 60 GHz spectrum** where the FCC has received several waiver requests to use the spectrum for personal radar. The FCC needs to move from waivers to rules.

3. Finally, sharing technologies have the potential to unlock large swaths of spectrum for public use. What is clear is that there are many “tools in the tool belt” for sharing spectrum and that there must be careful alignment between technologies, incumbents, and use cases. With several sharing technologies and commercial deployments under development in 2020/2021, further study is needed and **the FCC should dedicate a TAC working group** to focus on spectrum sharing in 2021.

FCC TAC
5G RAN Technology Working Group
Final 2020 Chairman's Brief

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

FCC Liaisons: Bahman Badipour, Reza Biazaran, Bob Pavlak, Ken Baker, Kamran Etemad, Sean Yun, Charles Mathias, Monisha Ghosh, Michael Ha

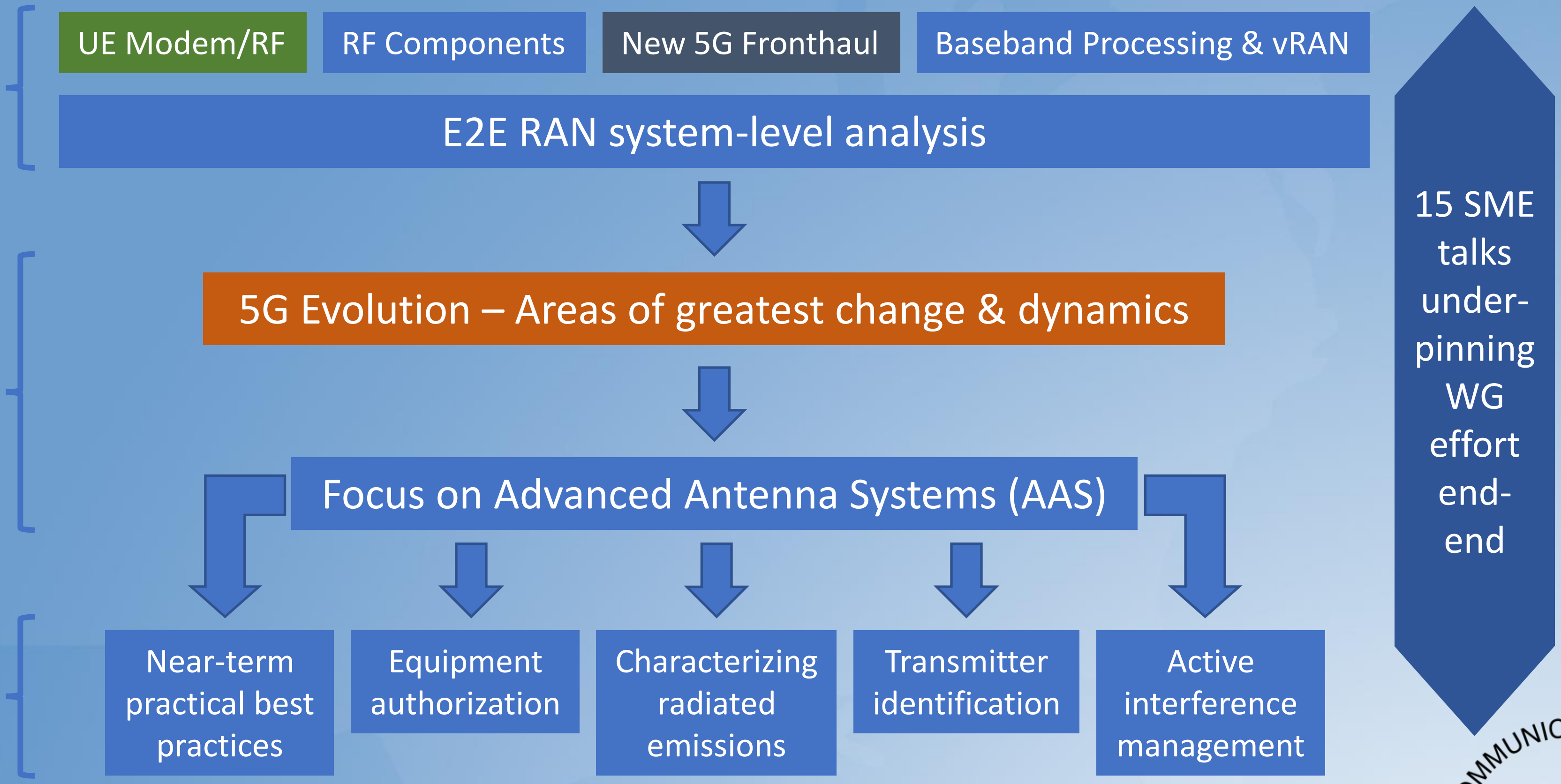
Date: December 1, 2020

Accomplishments

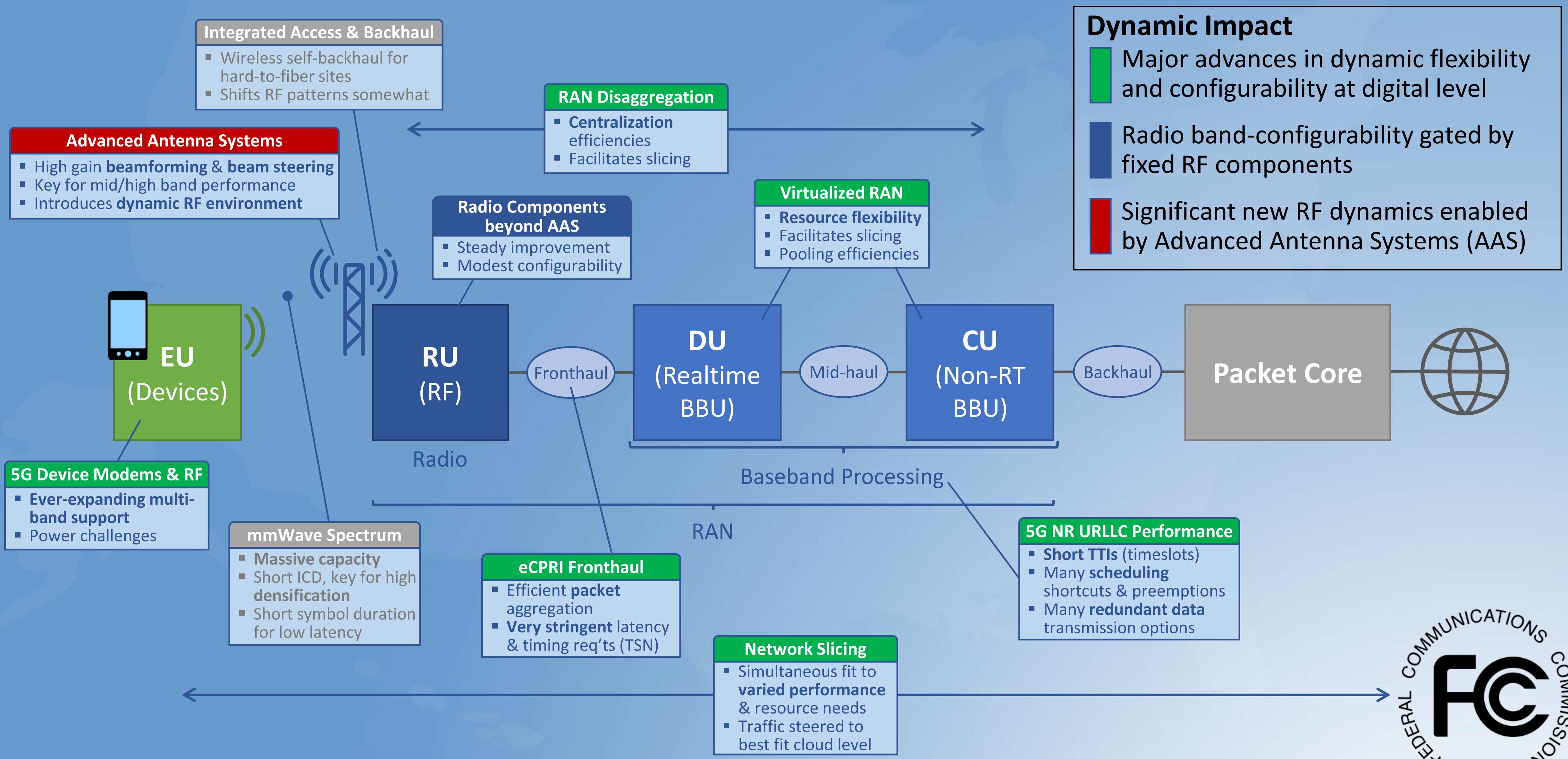
Performed component & system analysis of 5G evolution

Narrowed focus to areas of greatest impact on spectrum management

Developed recommendations on top spectrum/interference management topics



5G RAN Evolution – Main New Areas of RAN Dynamics



Recommendations

Near-term practical best practices	▪ Partial **TDD synchronization guidelines** (for future bands beyond C Band) that consider all the tradeoffs and global comparisons, applicable to 4G LTE and 5G technologies, offer an opportunity for coordination
Equipment authorization	▪ FCC Regulations should be examined in regard to adding **field strength limits** for certification of Advanced Antenna Systems, as conventional conducted power measurements not possible with AAS ▪ Areas for future study: (1) practicality of **3D probabilistic power flux** characterization to improve sharing, and (2) evaluation of the **impact of power control on out-of-band emissions**
Characterizing radiated emissions	▪ Initiate multi-stakeholder studies on application of **properly averaged radiated power** measurements for coverage/compatibility analysis purposes, considering the dynamics of AAS RF transmissions
Transmitter identification	▪ Promote a feasibility study - working with industry, SDOs, academia and federal agencies as needed - on **effective methods of identifying transmitters** (including RF fingerprinting and explicit Tx identifiers) for interference mitigation purposes
Active interference management	▪ Form multi-stakeholder expert technical group to study in detail the potential for generalization of intra-system mechanisms to **inter-system active interference management** ▪ Encourage and build, via FCC fora or similar, broad industry interest and engagement in research programs pursuing more accurate **data-driven localized propagation modeling**

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Thank You

FCC TAC 5G/IoT/O-RAN Working Group Dec. 1

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

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

WG 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

5G/IoT/Open RAN Charter

Open RAN

- Industry developments and overview
- Challenges and roadblocks
- Adoption and scalability
- Multi-vendor support in disaggregation
- Testing
- Evolution

6G

- Technology trends, planning & obstacles
- FCC engagement opportunity

IoT

- Is dedicated or shared spectrum needed to support industrial IoT applications
- IoT verticals and service requirements

Other

- Spectrum sharing- future needs, opportunities and frameworks
- 5G security, reliability and resiliency

Recommendations/Advisements

- O-RAN
  - FCC to support MV interoperability, plugfests
  - Encourage acceleration of ORAN adoption

- Security
  - Spoofing, interference are real concerns
  - System supply chain, MV systems
  - Network reliability, resilience- area to monitor

- 6G
  - Challenges: lack of fiber for x-haul, power reliability
  - Architecture changes: Mesh, evolved IAB
  - Create US roadmap- partner with industry
  - Readiness of THz is uncertain- support research

- Spectrum Sharing
  - Hi-level framework: guidelines, rules, and goals,
  - Sharing is dependent on the spectrum band; incumbents, etc
  - Interference; need to quantify, measure & enforce
  - 2021: Formal FCC TAC WG for spectrum sharing

- IIoT
  - IoT and enterprise use cases are quickly emerging
  - Demands vary widely on QoS/determinism
  - Locally licensed spectrum desired to provide necessary determinism, control, and compete with worldwide options (e.g. BNetzA)
  - Both mid-band and mmWave are suitable
    - Facilitates spectrum re-use

*IAB- Integrated Access and Backhaul

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Artificial Intelligence and Computing Working Group
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Agenda

FCC TAC Artificial Intelligence and Computing Working Group 2020 Brief

- Team Members
- Working Group Charter
- Approach and Activities in FY2020
- Trends and Patterns
- Potential Impacts of AI on the FCC
- Recommendations
- Suggestions for FY2021

Appendices
White Paper

2020 FCC TAC AIWG Team Members

- Shahid Ahmed, Independent
- Sujata Banerjee, VMware
- Nomi Bergman, Advance
- William Check, NCTA
- Brian Daly, ATT
- Adam Drobot, OpenTechWorks
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Artificial Intelligence and Computing WG (AIWG) – 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 Objectives:

  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?

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Artificial Intelligence and Computing WG (AIWG) – 2020 Charter (continued)

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?

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

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Artificial Intelligence and Computing WG (AIWG) – 2020 Charter (continued)

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?

Activities and Approach in FY2020

The AIWG started off the year by forming two sub-working groups that addressed specific aspects of the charter:

1. A SWG focused on Federal and Public Investments in AI relevant to Telecommunications and to the FCC (Objective 1): Led by Nageen Himayat. The SWG met on a weekly basis for discussions and for gathering information from external speakers. The SWG was also responsible for the development of the overall AIWG White Paper.
2. A SWG focused on safe uses of AI (Objective 4): Led by David Tennenhouse and Nomi Bergman. The SWG met as part of the main AIWG and then held several additional discussions to produce its output and contribution to recommendations.

The AIWG would like to acknowledge that the University of Colorado recruited a summer intern (Gabriel Lennon under the supervision of Dale Hatfield) who provided the SWG with an extensive survey and categorization of the peer reviewed literature for AI technologies and advances relevant to Telecommunications. The results are included in an appendix as part of the AIWG White Paper.

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Approach and Activities in FY2020 - Continued

The activities of the main AIWG consisted of:

3. Weekly meetings that included discussions relevant to the charter, preparation of presentation material, and presentations from over twenty external speakers. The AIWG held follow-up meetings to receive additional in-depth insights from several of the speakers.

4. The AIWG members also attended several presentations hosted by other TAC WGs that dealt with the use of AI as part of their agenda. Specifically this included presentations on spectrum sharing and incorporation of AI in aspects of 5G.

5. The AIWG Co-Chairs held regular discussions with the FCC Liaisons and would like to acknowledge the usefulness and insight gained from these exchanges.

The AIWG also benefited significantly from the participation of the FCC liaisons in WG discussions and in providing information about on going activities at the FCC and better insight for the AIWG to understand the FCC's areas of responsibility and current processes.

Approach and Activities in FY2020 - Continued

In its approach the AIWG considered:

1. The questions and issues posed by the charter for FY2020

2. Alignment of the effort with the FCC's current strategic priorities that include:

   - **Closing the Digital Divide**
   - **Promoting Innovation**
   - **Protecting Consumers & Public Safety (Safeguarding law enforcement communications)**
   - **Reforming the FCC's Processes**

3. The trends and patterns in the adoption of AI technologies and solutions and their effect on:

   - **The FCC's missions and responsibilities**
   - **The adoption of AI by operators and how it impacts Network performance, control, management, and the needs of consumer as well as commercial applications**
   - **The implications for future network architectures and network demand for services resulting from widespread adoption of AI**

Approach and Activities in FY2020 - Continued

In its approach the AIWG considered (continued):

4. Input in the from of presentations and discussions with expert on various aspects of AI as applied to issues that affect telecommunications networks including:

- **Projected advances and current results of AI and ML applied to technical aspects of network resource allocation, technical performance, operations,**
- **Impact of AI and ML on business models**
- **The legal landscape for dealing with AI impacts on security, privacy, sensitive private information, data sharing, and issues of fairness and transparency**

5. A broad look at the state of AI and ML technologies and the practical issues in operationalizing AI solutions, and developing effective ecosystems in terms of participation, capabilities, resources, and practices.

6. A focus on the broader ecosystem that addresses the role that the FCC may play in its priority to promote innovation by assisting the transition of basic and applied research for AI in telecommunications to practical purpose and the assuring future US leadership.

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Approach and Activities in FY2020 - Continued

In structuring its efforts the AIWG recognized two areas of study:

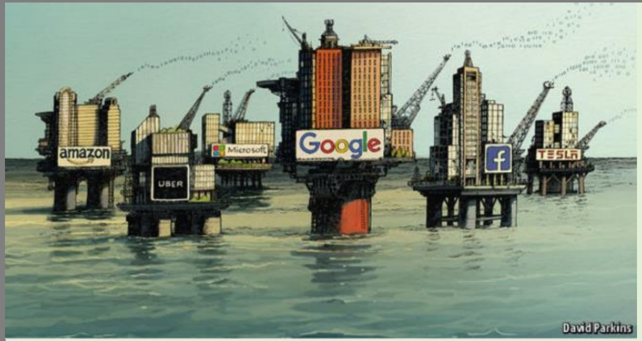
1. Strategic issues that are important for the FCC and its practices and will have long term impacts on the value that the FCC, the Telecommunications Industry, and the Nation will benefit from in addressing important issues and in promoting innovation.

   - The first of these is the incorporation of considerations for AI in the FCC's own strategic plan and building the bench strength to exploit the advances that AI offers.
   - The second is around Data, which plays a central role in extracting value from AI and often consumes the largest fraction of resources in AI/ML projects. The availability of Data is also the single most barrier to progress for the Research Community, that in turn plays an important role in the US's leadership in future Telecommunication systems.

2. Immediate issues that warrant attention or are suitable to gain early experience with AI and likely to produce results on a short time scale. These include:

   - Safe Uses of AI
   - The National Broadband Map
   - Pilot Projects relevant to current FCC interests that could take advantage of existing Federal Investments in AI/ML

Trends and Patterns



The Economist
May 6th, 2017

"The Fuel of the future – Data is giving rise to a new economy"
" The world's most valuable resource is no longer oil, but data"

Colby Proffitt
NEXTGOV
May 6th, 2017

"Data May Be The New Oil But Artificial Intelligence Is The Engine That It Fuels" - **Essential**
"Balancing benefits and risks will continue to be a challenge for federal agencies." – **Complexity and Uncertainty**

The Economist
Feb 20th, 2020

"Are Data more like oil or sunlight?"

"The question highlights the many different faces of data"

Much to be discovered

Inherent value of reuse

"Here is why data is not the new oil!"

"Data also becomes more useful the more it is used, rather than its energy being lost as heat or light, or permanently converted into another form……."

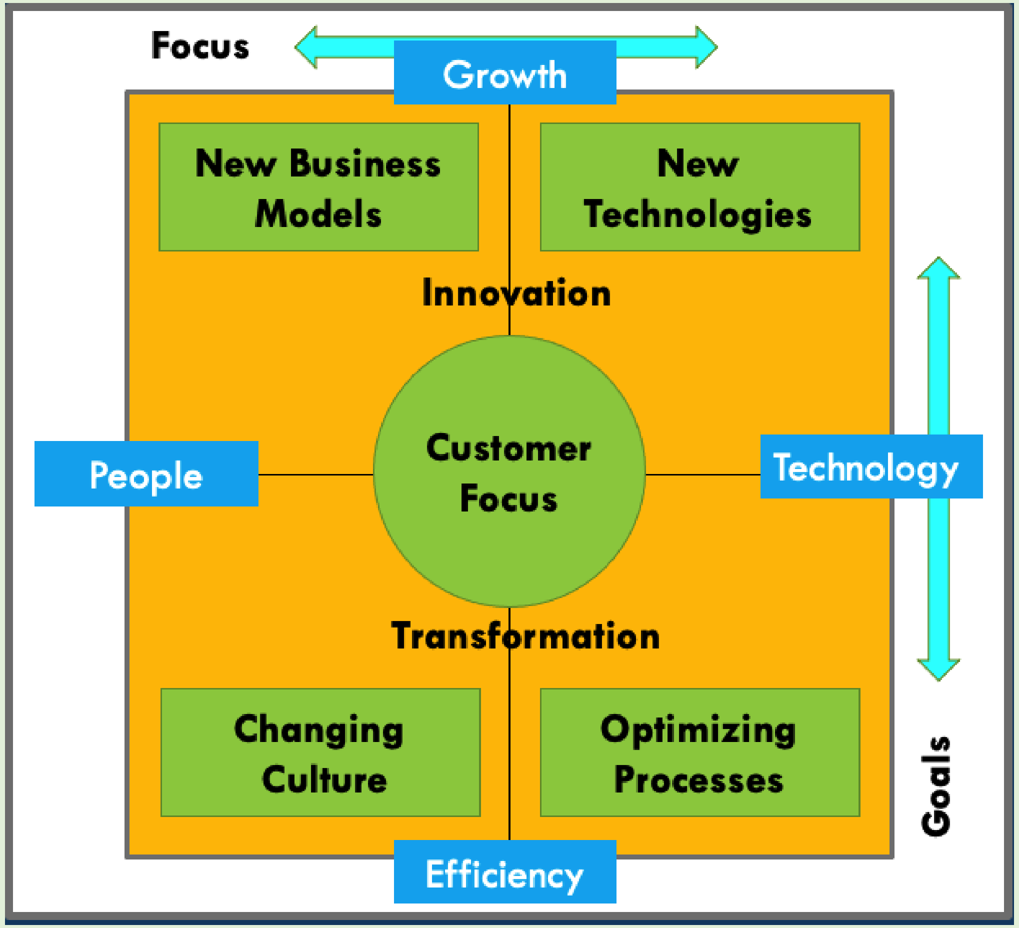
Bernard Marr
Forbes
March 5th, 2018

Trends and Patterns

Important Trends for the FCC to watch where the Network and the connectivity it provides as well as AI are essential:

- **Digital Transformation**
- **Industry 4.0**
- **Robotics**
- **The Internet of Things**
- **Digital Twins – for Manufacturing, Products, Services, and Processes**
- **Digital Sensor Networks**
- **Wide-spread use of diagnostics and prognostics for maintenance, repair, and overhaul**
- **Asset management**
- **Logistics**
- **………..**
- **………..**

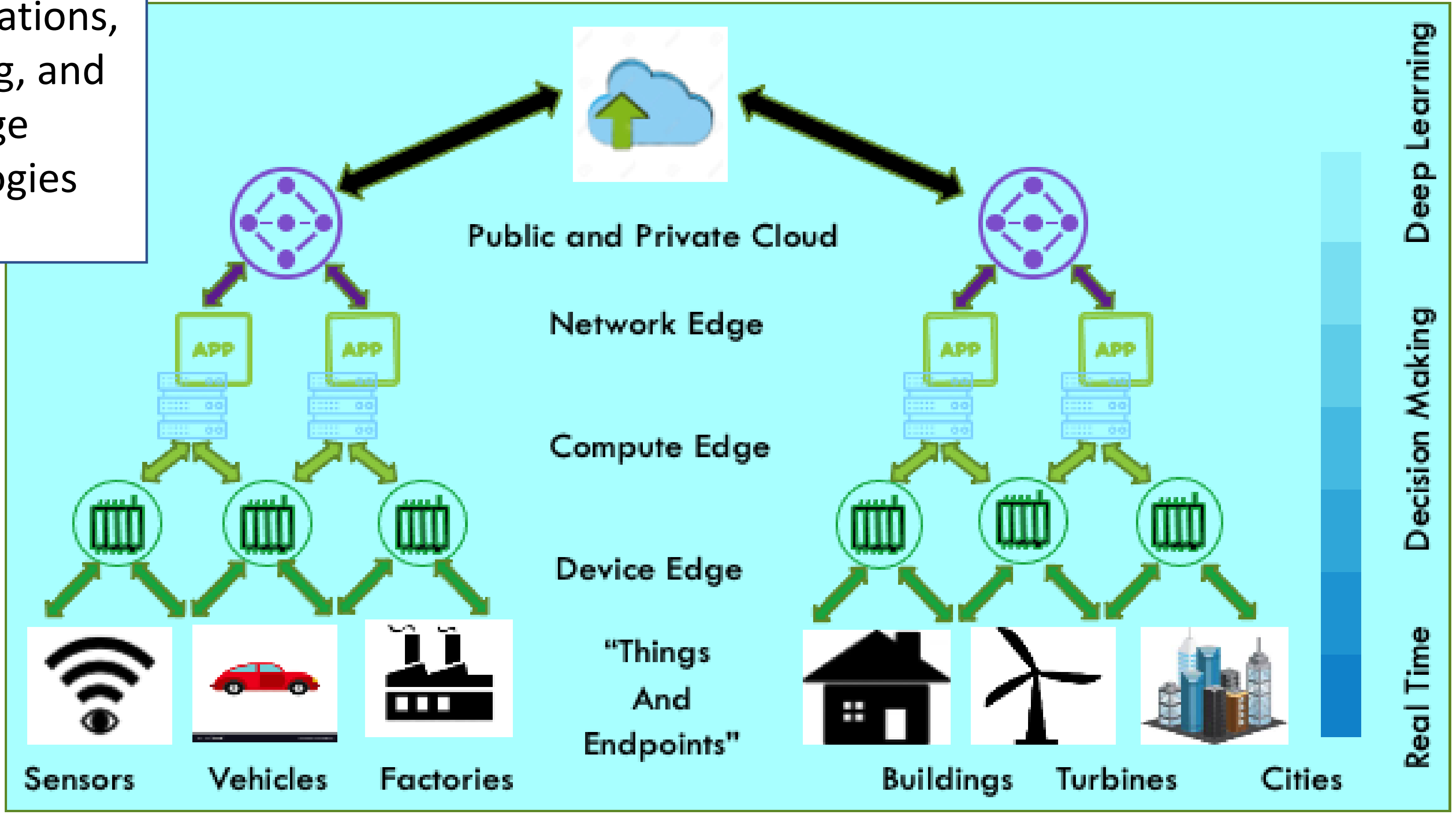
Digital Transformation



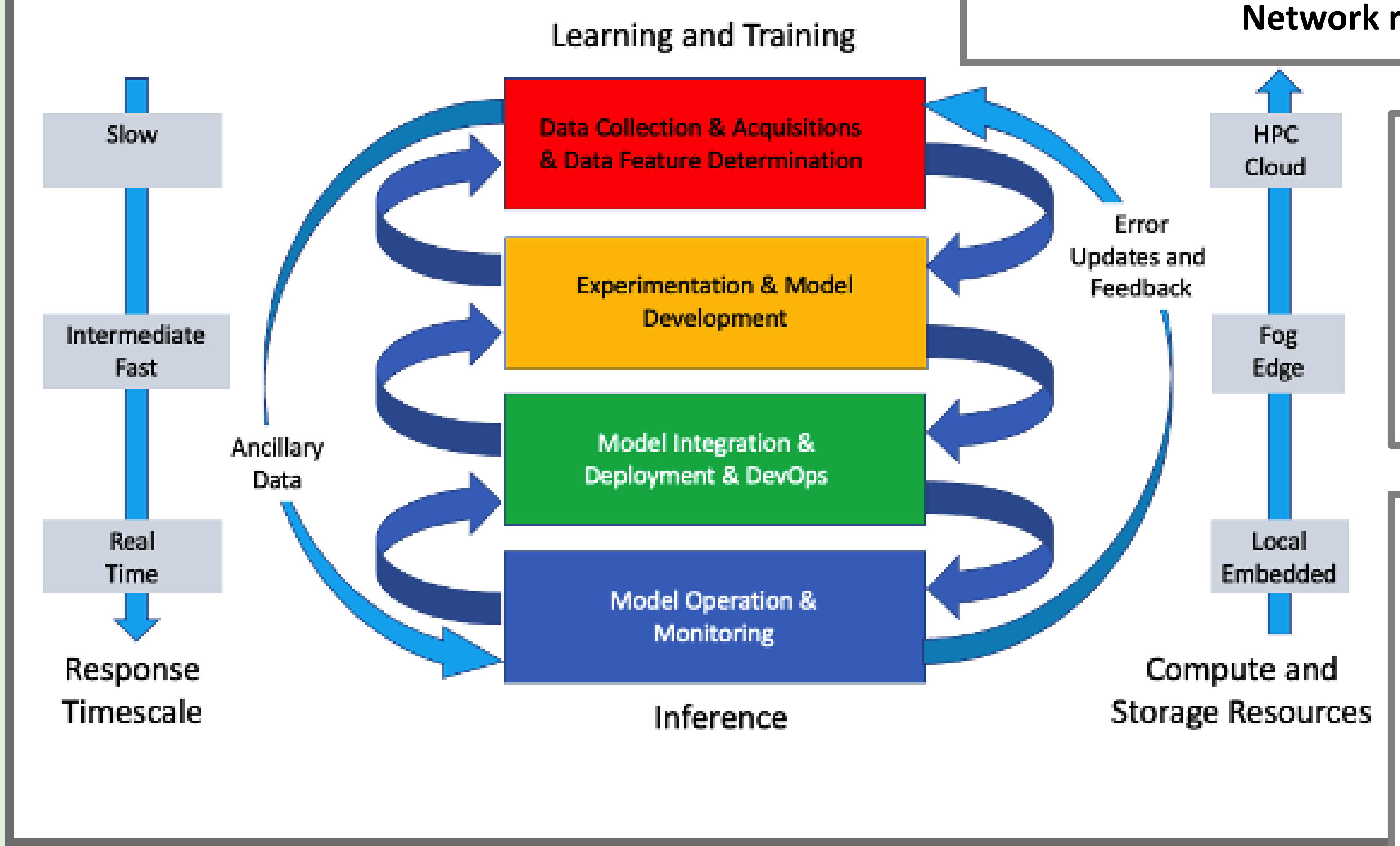
Trends and Patterns

The intertwining of Communications, Computing, and Storage Technologies

The Emerging Network Hierarchy



Trends and Patterns



Processes for AI/ML applications create new patterns for Network connectivity and access to Network resource

Typical AI/ML Application Cycle and requirements for Connectivity

Complex flows and connectivity patterns across logical, spatial and temporal dimensions

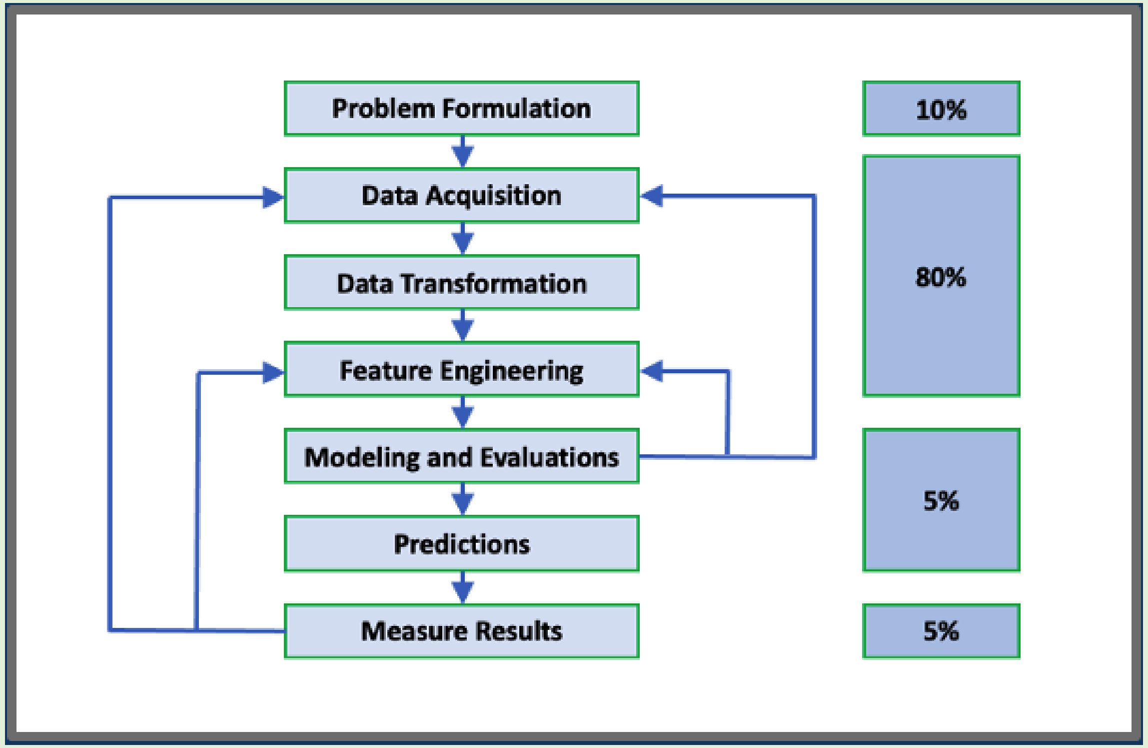
Trends and Patterns

➢A Few Factoids as a guide

- ➢ Over 90% of Data Stored Digitally was created in the last two years
- ➢Between 2% and 4% of that Data was used
- ➢Less than 0.1% of that data was analyzed
- ➢Between 25million and 50 million people around the world were involved in collecting and curating data.

➢ The experts we heard from stressed that the art of picking the ”right data” and the “right model” play a significant role solving a specific problem, but the overwhelming effort usually goes into the collection and curation of the data itself.

The AI/ML Solution Cycle

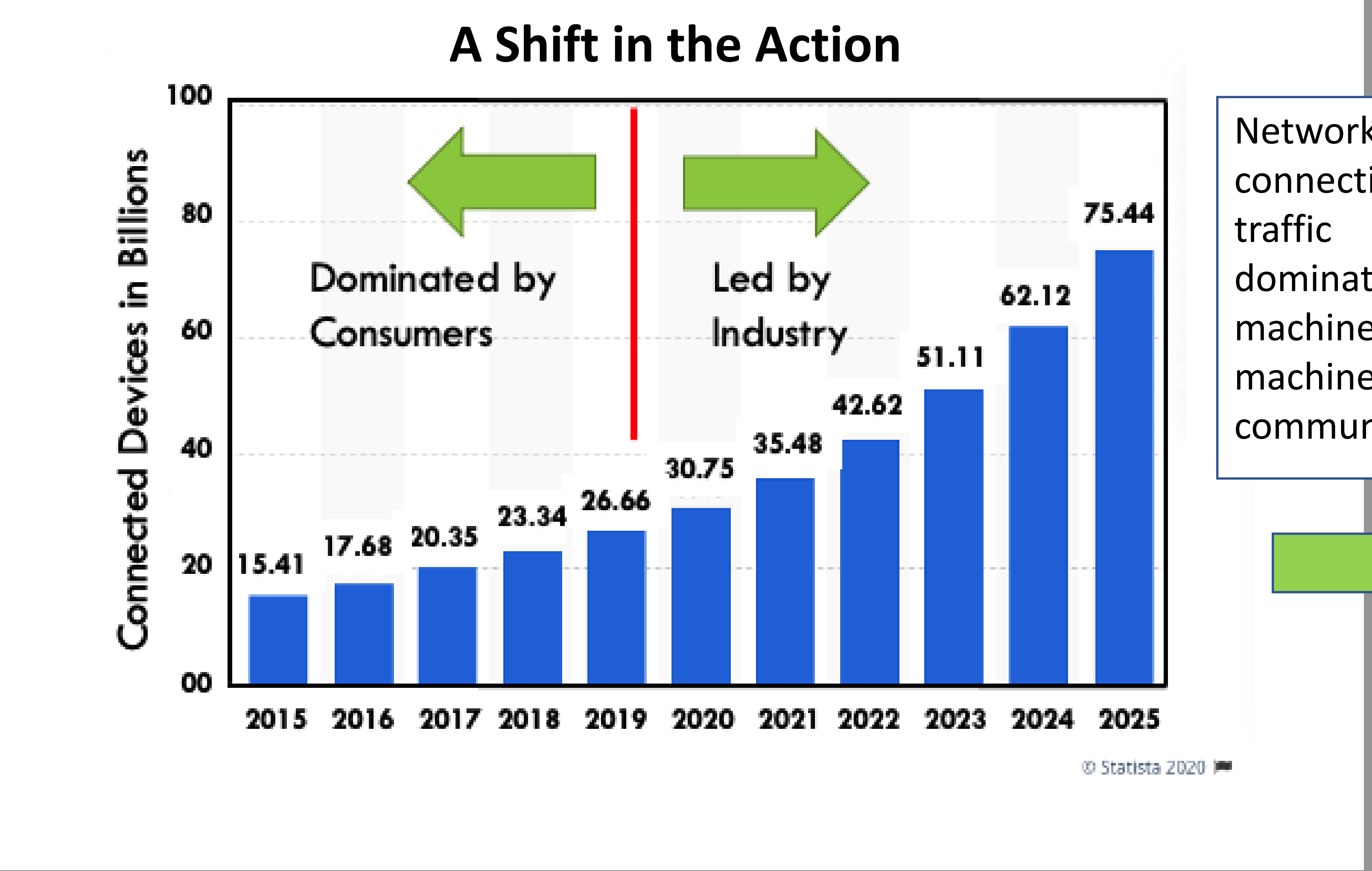


Trends and Patterns

- A Few Factoids as a guide
    - Over 90% of Data Stored Digitally was created in the last two years
    - Between 2% and 4% of that Data was used
    - Less than 0.1% of that data was analyzed
    - Between 25million and 50 million people around the world were involved in collecting and curating data.
- One approach to data reuse is to create curated data catalogs where data can be easily discovered, transformed as appropriate and merged with other data, to be used to address multiple issues – contributing to the solution of multiple objectives.

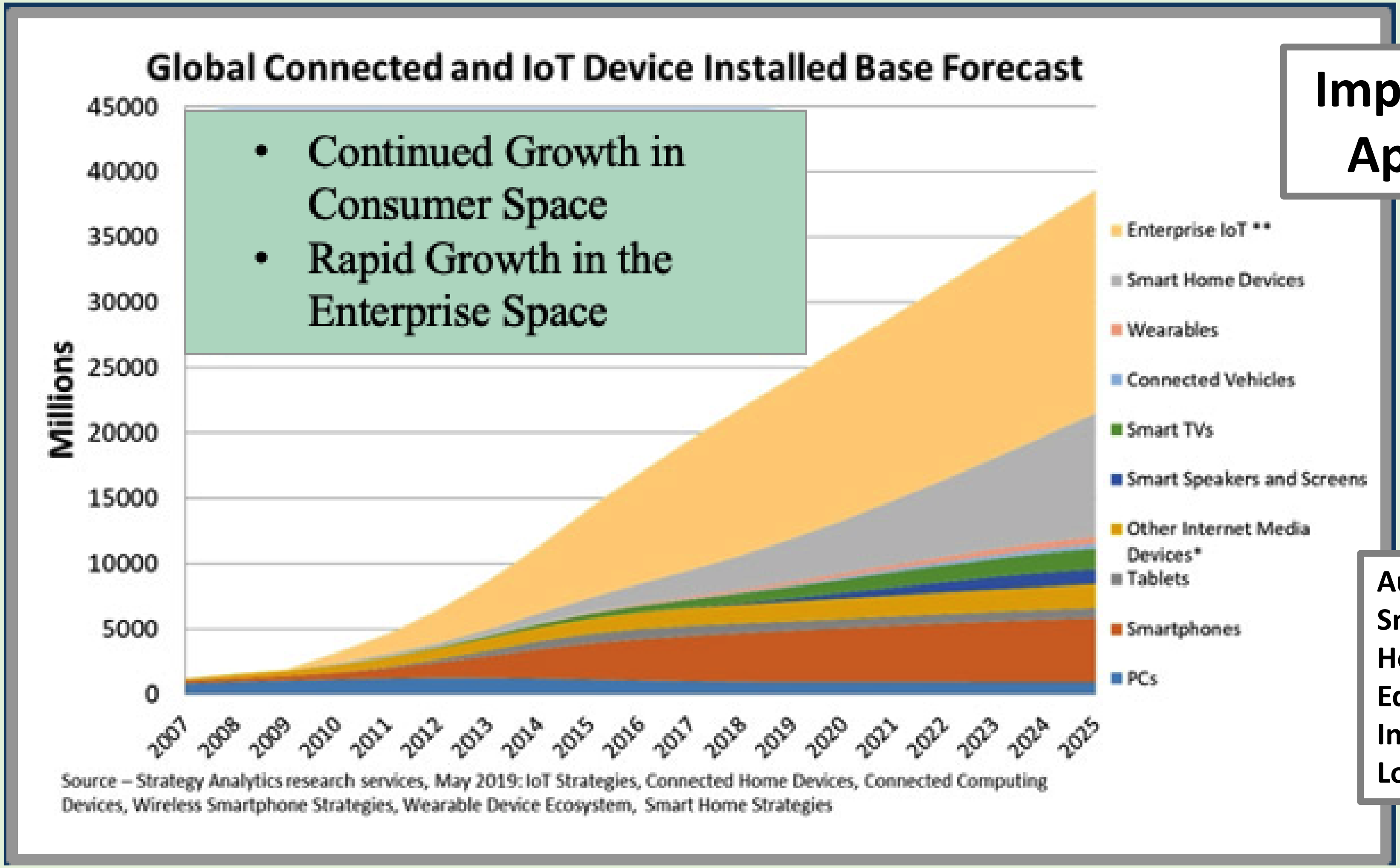
The Data Deluge

Trends and Patterns



Network connections and traffic dominated by machine-machine communications

Trends and Patterns



Important New Applications

Autonomous Cars
Smart Cities
Healthcare
Education
Industry 4.0
Logistics

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Potential Impacts of AI on the FCC

Potential Impacts of AI on the FCC

- In examining potential impacts on the FCC the AIWG considered:
  - The use of AI/ML on the FCC's internal processes
    - Interactions and Communications with Stakeholders
    - The FCC's investments in Network Services
    - Enforcement of regulations
    - Interest in basic aspects underlying network technologies
  - The implications for the FCC in the use of AI/ML by service providers
    - For Network Control, Management, and Operations
  - Consumers
  - Industry
  - The Public Sector
  - Contribution to economic competitiveness and innovation

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Potential Impacts of AI on the FCC – Safe Uses

Characteristics of Safe AI/ML

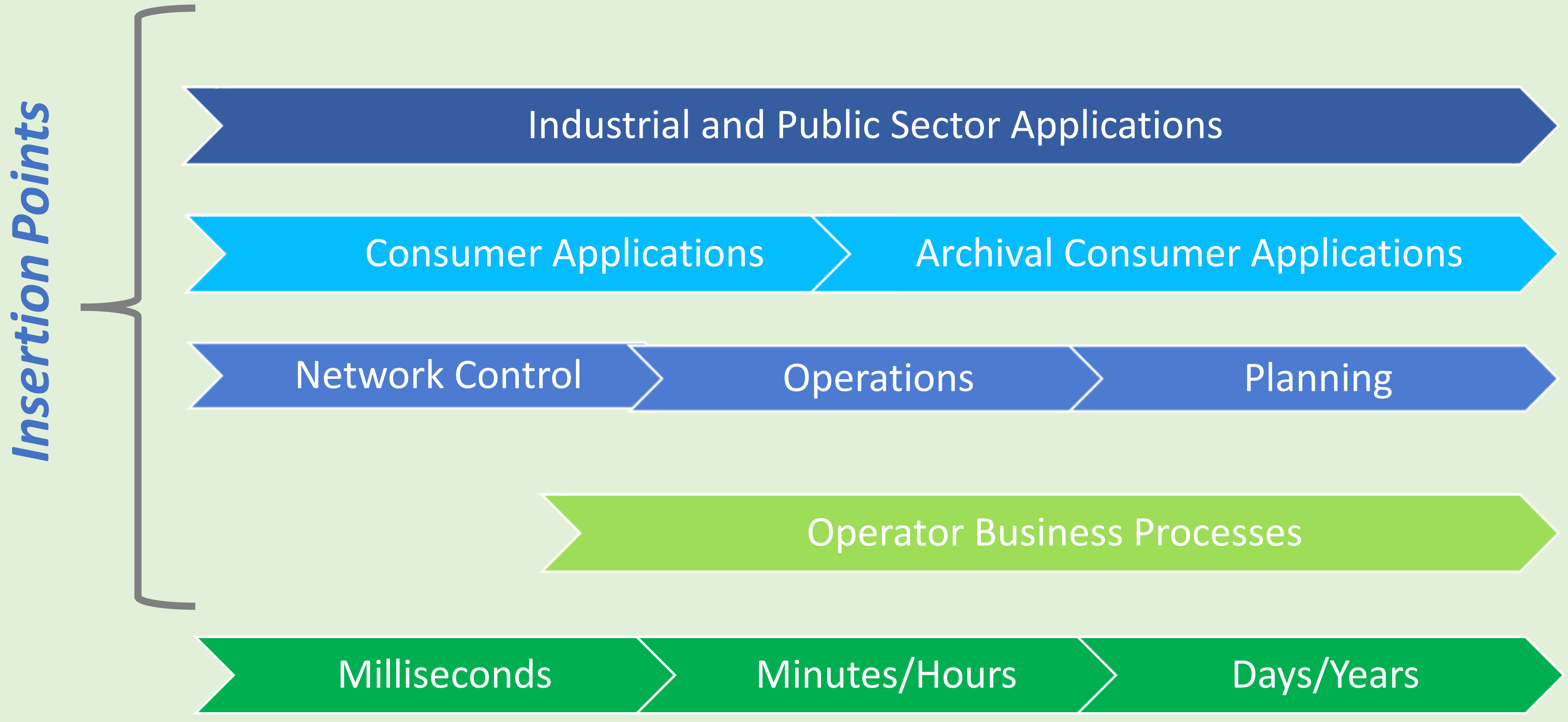
- **Fairness** – at individual, community, and societal levels
- **Transparency** - of models and training data
- **Invulnerability** – to adversarial attack
- **Accountability & Explainability** – to humans and to other AI applications
  - Guided by the judgement of domain experts
  - Human compatible AI
  - Avoids harm to users (e.g. causing addiction, bullying, affecting human behavior)
- **Robustness**
  - Prescribed operating range
  - Predictable response to unanticipated inputs
  - Interaction of multiple models (which may be geo-distributed and/or at different layers)
  - Known *blast radius (range of impacts and systemic vulnerabilities)*
  - *Ensure skillful implementation*
  - *Verification – that the implementations perform as designed and anticipated*

One of the challenge is clearly understanding how these characteristics map to insertion points where AI is used in the Network and the time scales that apply.

In a broader sense Safe AI/ML also implies that its uses are Ethical, Trustworthy, and Safe and provide adequate protection for Privacy and Security.

Potential Impacts of AI on the FCC – Safe Uses

The use of AI/ML in the Network has multiple insertion points & can be characterized by multiple time scales and constraints.



Potential Impacts of AI on the FCC – Safe Uses

Consumer Applications

Potential FCC concerns: Fairness, Transparency, Accountability, Vulnerability

Examples: Ad-insertion, content editing, real-time translation, application optimization, content analysis and indexing, record keeping, etc.

Findings:

- Network operators should obey similar guidelines to other providers of applications / content services
- Future workgroup on deliberating effects of AI/ML on impacting human behaviors with broad representation.

Operator Business Processes

Potential FCC concerns: Fairness, Transparency, Accountability, Vulnerability

Examples: Customer service, data mining, billing, customer communications, outage reporting, etc.

Findings:

- Operators should obey similar guidelines to other providers of consumer services
- FCC should encourage disclosure of information concerning macro level performance (e.g., that customer service, upsell offers, etc. are fair)
- FCC should consider merits of a requirement that humans be able to easily determine when they are communicating with a bot (vs. with another human being)

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Potential Impacts of AI on the FCC – Safe Uses

Network Planning

Potential FCC concerns: Fairness, Vulnerability

Examples: Base station site selection, backhaul capacity, service area decisions, etc

Findings:

- Operators should follow similar guidelines to other providers of critical infrastructure
- FCC should encourage operators to disclose information concerning practices used to ensure fairness, e.g., that bias in training sets/models is not a factor in network planning

Network Control

Network Operation

Potential FCC concerns: Fairness, Explainability, Accountability, Vulnerability, Robustness

Examples:

- Minutes/Hours: Automated reallocation of spectrum between cells
- Milliseconds: TCP congestion control, Prioritization of public safety traffic, security, etc

Continued on following slides …

Milliseconds → Minutes/Hours

Potential Impacts of AI on the FCC – Safe Uses

Network Control

Online AI/ML, embedded deeply within the network and operating at *faster than human* time scales, has the potential to create significant challenges with respect to the vulnerability and robustness of the network – and the ability of human operators to oversee its operation.

Findings:

- Operators (and their suppliers) should partner with providers of other types of critical infrastructure to adopt and implement best practices with respect to explainability, vulnerability and robustness. These may be similar to existing practices for safety-critical systems.
- It is important for operators to institute processes to manage their AI/ML *supply chain*, to track the provenance of models and training data used in their networks – and the mechanisms used to secure and manage timely updates to them (e.g., vulnerability patching).
- There is high value in operators sharing and disclosing the frameworks they adopted to analyze and address the vulnerability (to attack) and robustness of AI/ML models whose failure could jeopardize the operation of significant portions of the network.

Milliseconds → Minutes/Hours → Days/Years

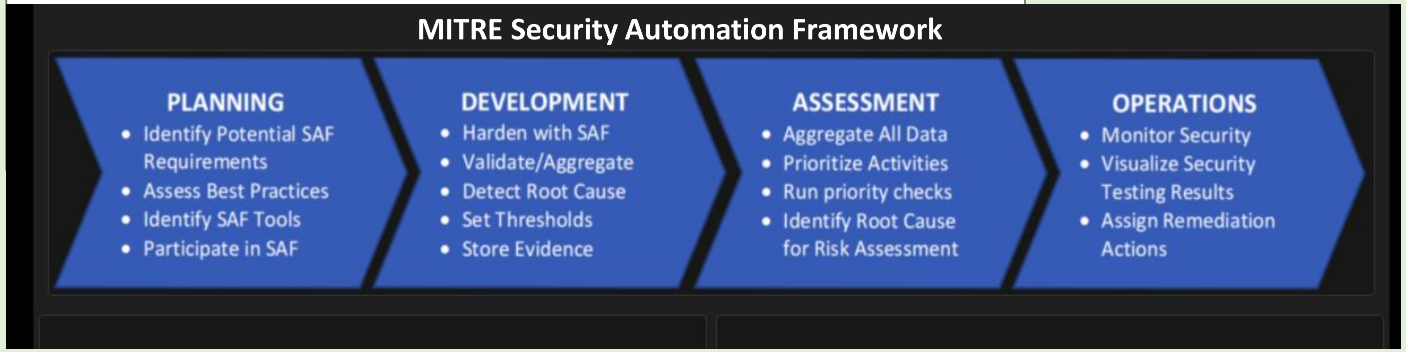
Potential Impacts of AI on the FCC – Safe Uses

Existing Risk, Security, and Process Frameworks are a starting point for addressing similar issues with AI/ML

Alberts, Christopher; & Dorofee, Audrey. ***Risk Management Framework.*** CMU/SEI-2010-TR-017. Software Engineering Institute, Carnegie Mellon University. 2010. http://resources.sei.cmu.edu/library/asset-view.cfm?AssetID=9525

Herndon, Mary Anne; Moore, Robert; Phillips, Michael; Walker, Julie; & West, Laura. *Interpreting Capability Maturity Model Integration (CMMI) for Service Organizations' Systems Engineering and Integration Services Example.* CMU/SEI-2003-TN-005 . Software Engineering Institute, Carnegie Mellon University. 2003. http://resources.sei.cmu.edu/library/asset-view.cfm?AssetID=6387

The NIST Cybersecurity Framework: https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.04162018.pdf



Framework Considerations

- Access Control
- Asset Management
- Awareness and Training
- Audit and Accountability
- Configuration Management
- Identification and Authentication
- Incident Response
- Maintenance
- Media Protection
- Personnel Security
- System and Information Integrity
- System and Communications Protection
- Situational Awareness
- Risk Assessment
- Physical Protection
- Risk Management
- Recovery

Potential Impacts of AI on the FCC – Safe Uses

Network Control

Illustrative Framework for Assessment of the Robustness of *online* AI/ML Models operating at *faster-than-human* speeds

- What is the *safe operating range* of the output parameters controlled by the model, both with respect to their absolute values and how fast they can change?
- What is the *range of inputs* to the model?
    - Are controls in place to ensure that inputs to the model do not deviate from this range?
- Is the model *safe* across the *range of inputs*?
    - For valid inputs, can the model be proven to always generate outputs within the safe operating range – or to do so within statistically acceptable bounds?
    - Alternatively, are controls in place to detect and address deviations, e.g., over-ride the AI/ML model output with those of a more robust model?
- Is there potential for multiple models to interact in ways that lead to network instability?
    - Models could be at different layers
    - Interacting models could be distributed. Example: Per-flow congestion controls whose interaction has unanticipated effects.
- Has the potential *blast radius* of failures of the model (or ensemble of models) been characterized?

  For large blast range scenarios:
    - Are there *explainability* mechanisms through which human operators can interpret the actions of the model?
    - Are processes in place to recover and learn from failures at the extreme of the blast radius?

Milliseconds → Minutes/Hours → Days/Years

Potential Impacts of AI on the FCC – National Broadband Map

The subject of a National Broadband Map is not new and has been visited many times and there have been multiple attempts to develop such a Map. The AIWG examined some of the past history, recent events, and attempts at defining what such a map may or must contain. The references that follow captures some of the past history and recent events that have led to new requirements for the National Broadband Map and its functionality.

1. **2010-2011** "NTIA Unveils National Broadband Map and New Broadband Adoption Survey Results" A composite with maps developed by each State https://www.ntia.doc.gov/press-releases/2011/commerce%C3%A2%E2%82%AC%E2%84%A2s-ntia-unveils-national-broadband-map-and-new-broadband-adoption-survey

2. **2017-2020 Broadband Deployment Advisory Committee** (BDAC or Committee), to provide advice and recommendations for the Commission on how to accelerate the deployment of high-speed Internet access. On March 1, 2019, the Commission re-chartered the BDAC for a period of two (2) years. The meeting of the re-chartered BDAC did occurred during 2019. https://www.fcc.gov/broadband-deployment-advisory-committee

Potential Impacts of AI on the FCC – National Broadband Map

3. **2020** NTIA received funding from Congress in 2018 to update the **National Broadband Availability Map (NBAM)** in coordination with the Federal Communications Commission (FCC). Congress directed NTIA to acquire and utilize data from available third-party datasets. NTIA built upon existing partnerships to identify data from federal, state, local and tribal governments, owners and operators of broadband networks, educational institutions, nonprofits, and cooperatives to create the map. https://broadbandusa.ntia.doc.gov/map
4. **2020 "Broadband Deployment Accuracy and Technological Availability ACT",** Congress Tells FCC to Fix Broadband Maps Now, https://www.benton.org/blog/congress-tells-fcc-fix-broadband-maps-now
5. **2020 FCC Broadband Mapping Report and Order** "The Order implements key provisions of the Broadband DATA Act, including requiring fixed and mobile providers to submit standardized broadband availability maps and taking steps to develop a common dataset of homes and businesses where fixed broadband networks could be deployed, over which service providers' broadband availability maps will be overlaid. https://docs.fcc.gov/public/attachments/DOC-365573A1.pdf and https://docs.fcc.gov/public/attachments/FCC-20-94A1.pdf

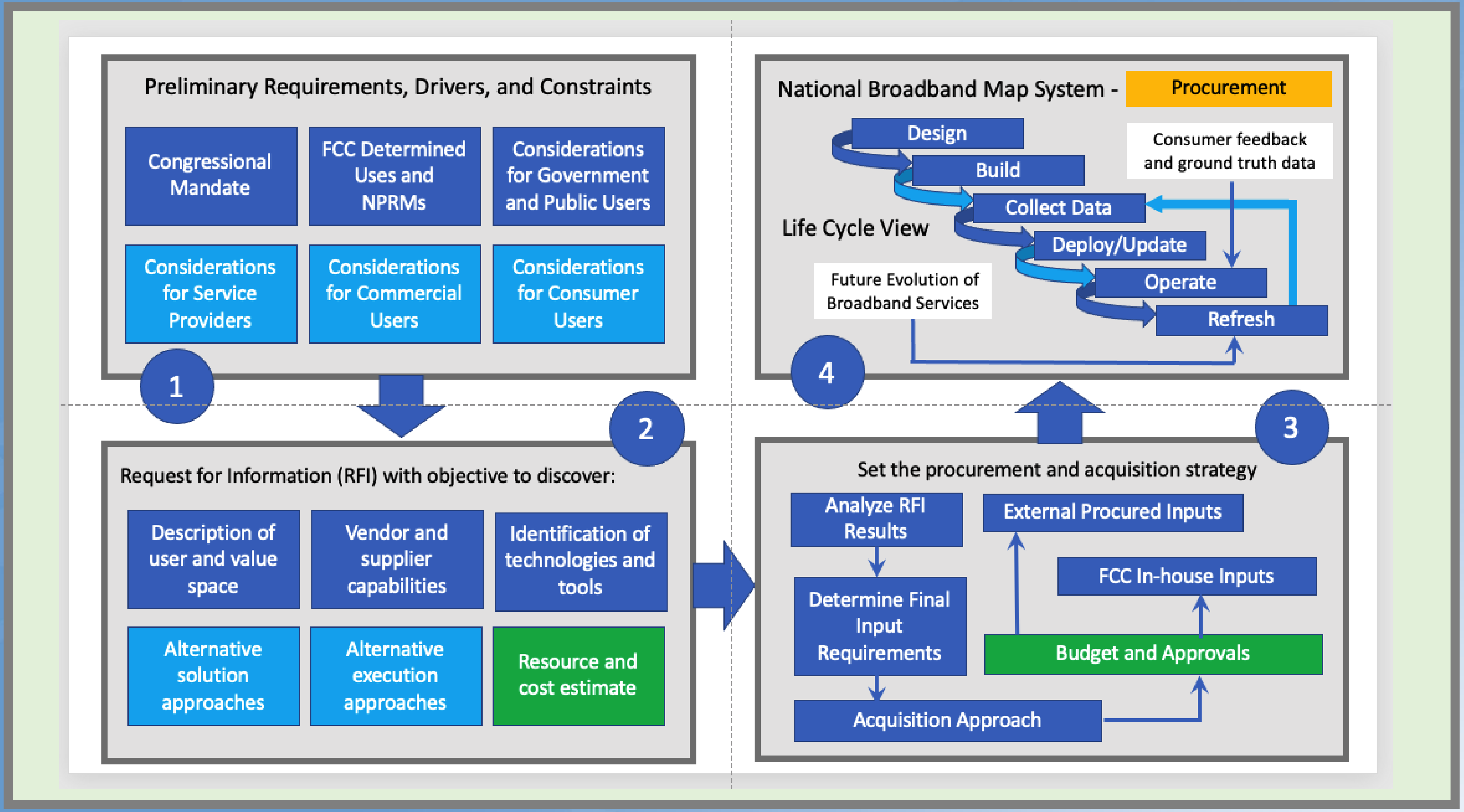
Potential Impacts of AI on the FCC – National Broadband Map

- The development of a Broadband Map has many aspects to it and is a major undertaking. It involves capturing the drivers and constraints, an understanding of and fleshing out of the requirements at a detailed level, the concepts of operation for how it will be used and by whom, and provisions for eventual deployment and sustainment. There are multiple approaches possible. The development entail, inclusion of a systematic analysis of the trade-offs for how the National Broadband Map will be built, 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.

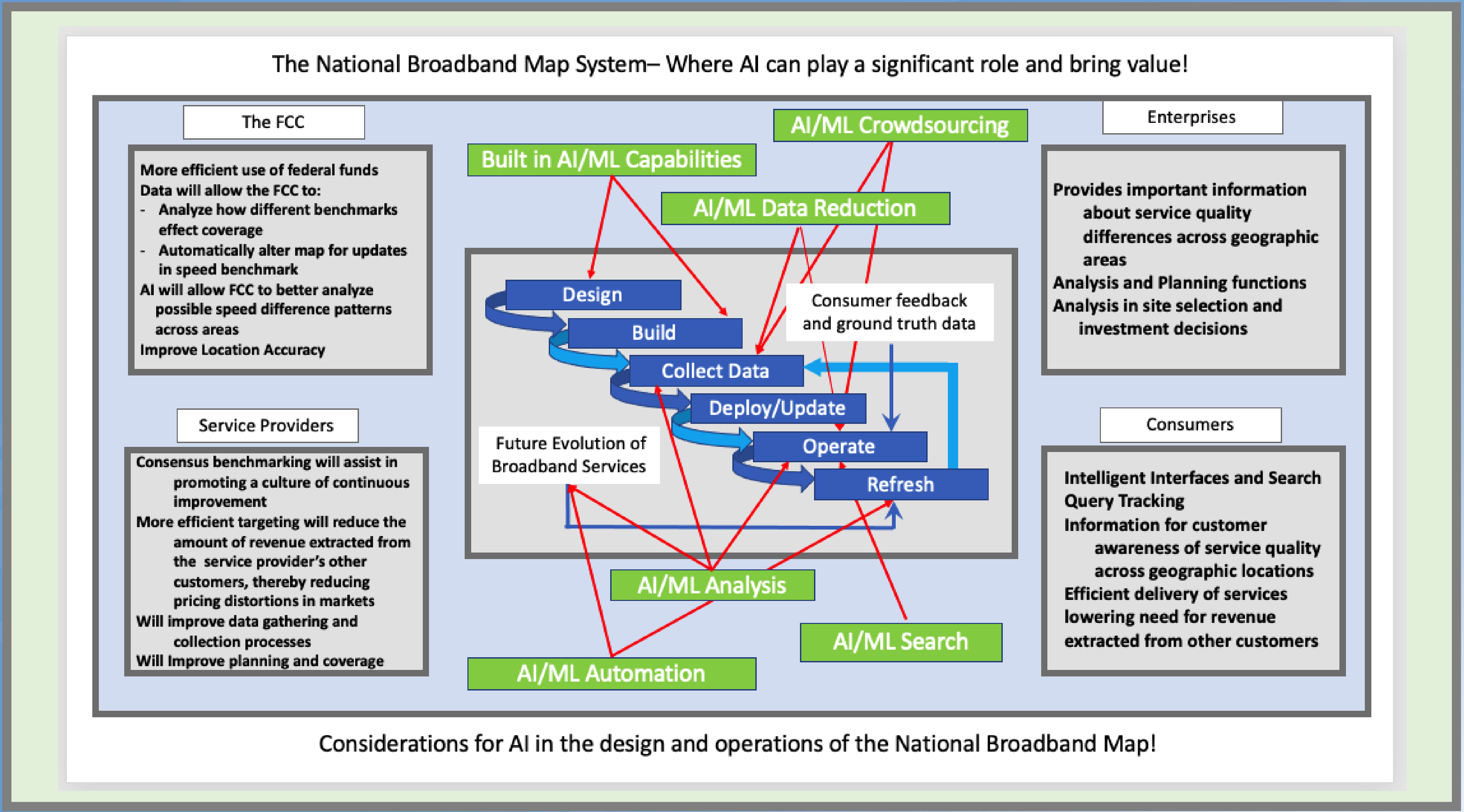
- In presentations to the AIWG we heard from a number of experts that significant applications of AI/ML technologies are already being used with success for network planning. The requirements for such planning parallels many of the requirements for the Broadband Map as do the requirements for data collection. As with planning systems, the development of the National Broadband Map should be approached holistically and recognize the breadth of technologies, integration methods, and operational considerations that must be brought to bear.

- Experience with technologies, development and integration approaches, operationalization, and management of projects of similar scope and content indicate that experienced organization to deliver a National Broadband Map System exist and could competitively offer effective solutions. Under those circumstances it would be important to understand what range of alternate solutions is possible, at what cost, and what approach to procuring the capabilities would be best for the FCC. A first step in this process is to formulate a Request for Information that casts a wide net and leads the FCC to a plan that results in a sustainable and effective solution. The approach is illustrated in the following viewgraphs.

Potential Impacts of AI on the FCC – National Broadband Map



Potential Impacts of AI on the FCC – National Broadband Map



Potential Impacts of AI on the FCC – Pilot Projects

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
Detection and Elimination of Interference	Improved detection methods and specific identification of sources (Spectrum fingerprinting)

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Potential Impacts of AI on the FCC – Pilot Projects

Area	Benefit
Self Organizing Networks (SON)	Supporting the use of automation for general high-volume applications and critical uses
An interference data exchange	A mechanism to eliminate common causes of interference
AI/ML based EM Propagation models	Improving the specifications for avoiding interference, leading to better utilization of spectrum
AI/ML Benchmarking	Transparency for understanding the performance and behavior of AI/ML models
Emulation of RF Environments	Identification of violations
Automated Testing and Certification using AI/ML Tools	Dealing with the increasing complexity of software driven devices on the network
……………….	

Potential Impacts of AI on the FCC – Data

- 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.

Potential Impacts of AI on the FCC – Data

- 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.

- The AIWG has 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.

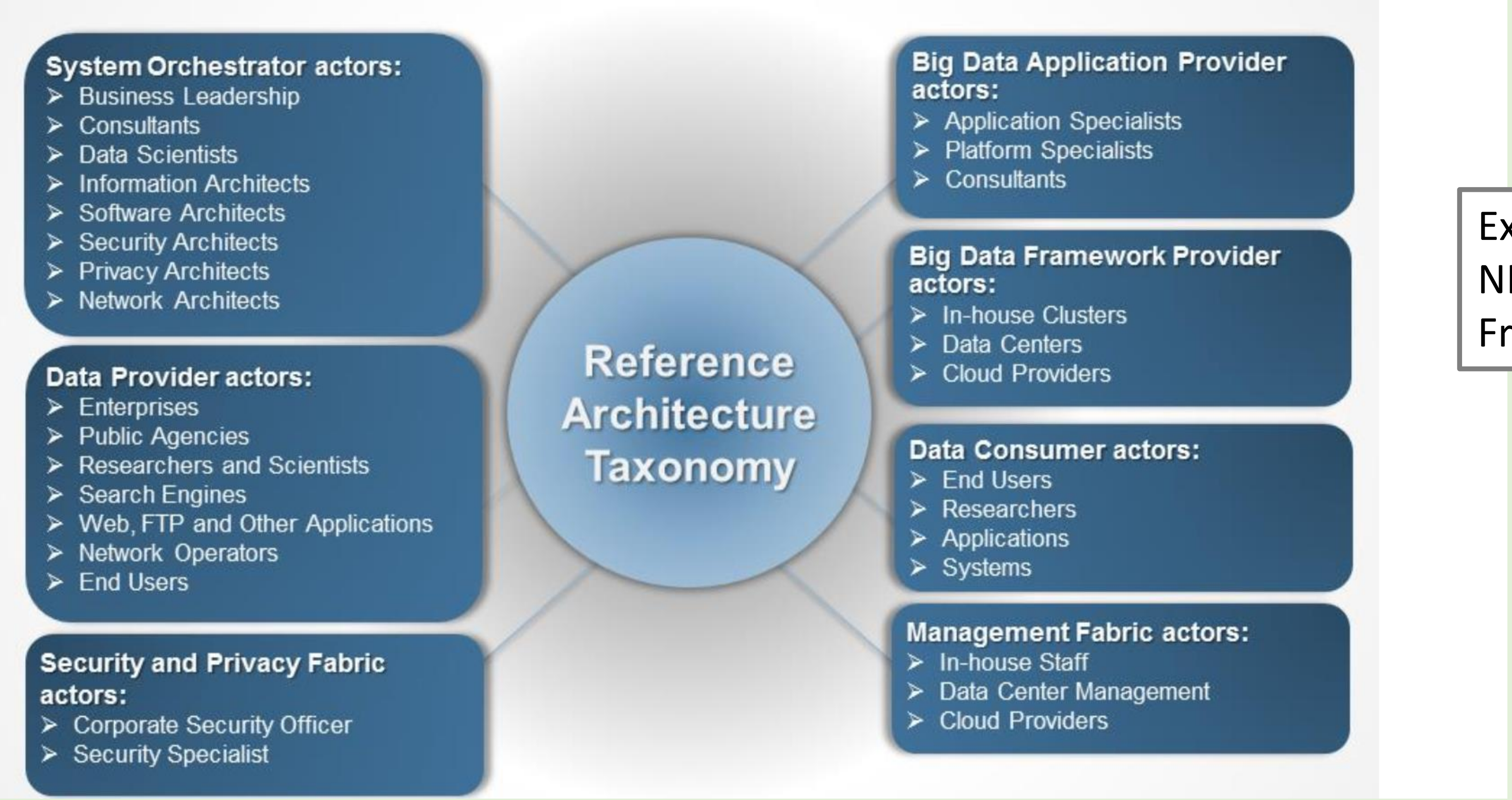
Potential Impacts of AI on the FCC – Data

Considerations for curation and use of "Data"

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

Potential Impacts of AI on the FCC – Data

- A number of Frameworks have been created recently for developing practices around the use and curation of Data. It is important that there exist such a Framework specialized to the Tele -Communications Sector



Example: The NIST Data Framework

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Potential Impacts of AI on the FCC – Data

- 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)

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Recommendations

The FCC TAC AIWG has identified five recommendation areas:

1. **“Unlock transformational change” - The incorporation of considerations for Artificial Intelligence in the FCC Strategic Plan.**
2. **”To build knowledge, unleash the Data” - The creation of a Task Force to address how the FCC can best address important aspects of Data governance and curation for AI/ML applications to serve its internal needs, and those of industry and the public.**
3. **“Cast a wide net” - Develop a plan and strategy for designing, developing, deploying, operating, and maintaining a Broadband Map that takes advantage of the best technologies and capabilities available.**
4. **“Keep humans in control of the loop” - Policies and approaches to ensure the safe use of Artificial Intelligence as it impact the nation’s networks, communication needs, and important applications.**
5. **“Get your feet wet” - Develop the FCC’s capability for extracting value from Artificial Intelligence in solving issues and problems that come before the FCC by conducting pilot projects with near term return.**

Recommendations – 1. Artificial Intelligence Strategic Plan

1. The incorporation of considerations for Artificial Intelligence in the FCC Strategic Plan

Advances in Artificial Intelligence (AI) and Machine Learning (ML) are leading to transformational changes in how telecommunications and information services are being provided and the set of the services that are being deployed for consumers, industry and the public sector. The FCC has an important role to play in the extent to which capital investments related to AI and ML by telecommunications equipment and service providers continue to stimulate growth in the economy, support innovation that positively impacts the services enjoyed by consumers and impacts the competitiveness of US based industries.

- To augment the FCC's policy goals in light of AI/ML's important role we recommend that the FCC establish a Task Force to identify relevant policy areas and, equally important, the resources the FCC needs, including specialized facilities, human resources, and partnerships to expertly analyze and implement policies for the creation of value through AI/ML

Recommendations – 1. Artificial Intelligence Strategic Plan - continued

1. The incorporation of considerations for Artificial Intelligence in the FCC Strategic Plan

- Considerations for AI/ML in the strategic plan should be framed to address the important priorities that the FCC sees in its mission and the possible value that AI/ML can contribute:

  - Closing the Digital Divide (Examples)
    - Improve the efficiency with which Federal Funds are used to close the digital divide by exploring the use of AI and ML for supporting investment decisions.

  - Promoting Innovation (Examples)
    - Deployment of new infrastructure to support Smart Cities
    - Adopt policies that facilitate the deployment and wide use of autonomous vehicles (maybe refocus to IOT or facilitate the development of smart cities)

  The examples require approaches to continuous sharing of data, ubiquitous bandwidth, and a high degree of reliability.

Recommendations – 1. Artificial Intelligence Strategic Plan - continued

1. The incorporation of considerations for Artificial Intelligence in the FCC Strategic Plan

- Considerations for AI/ML in the strategic plan should be framed to address the important priorities that the FCC sees in its mission and the possible value that AI/ML can contribute:

  - Protecting Consumer and Public Safety (Examples)
    - Policies that facilitate the development of infrastructure (and enforcement of responsible and safe use of AI)
    - Improved web-based services for access to communications and use of information provided by the FCC

  - Reforming the FCC's Processes (Examples)
    - Explore the use of AI and ML to expedite equipment authorization and certification procedures
    - Upgrade the curation of the FCC's current databases in preparation for the application of AI/ML
    - Access to AI/ML tools and facilities to perform analysis in support of policies

Recommendations – 2. Data Governance, Operations, and Curation

2. The creation of a Data Task Force to address how the FCC can best address important aspects of Data governance, operations, and curation to serve its internal needs, and those of industry and the public

Data is a key ingredient in extracting value from AI and ML applications and success in doing so effectively within an organization requires a holistic approach that is accompanied by a "data centric" mindset. *

- Establish an AI/ML Data Task Force (ADTF) with the objective of creating data governance, resource, operations, and policy procedures to improve the collection and curation of existing and future data sets to serve the internal needs of the FCC, other government entities, industry, the research community and the public. Members of the ADTF should include FCC employees with technical training in computer/data science and engineering. It should also include a few similarly trained individuals from other government organizations and the private sector whose current responsibilities relate to the objective at hand. The ADTF should complete the work within a year and provide a written plan aligned with the FCC's strategic objectives.

- https://www.mckinsey.com/business-functions/organization/our-insights/unlocking-success-in-digital-transformations

Recommendations – 2. Data Governance, Operations, and Curation – cont'd

2. The creation of a Data Task Force to address how the FCC can best address important aspects of Data governance, operations, and curation to serve its internal needs, and those of industry and the public

- For greatest impact create an AI Data team and organizational structure within the FCC to execute the plans created by the AI/ML Data Task Force. The team should be empowered to work across the entire FCC and be led by a designated Chief Officer.
- Explore approaches and mechanisms that promote the sharing of Data and AI/ML Models across the Telecommunications Industry to extract value from applications of AI in solving common technical and operational problems and to address important national economic and societal needs.
- Consider the role that the FCC may play in providing the pre-competitive research community with access to specific curated AI/ML oriented data sets that are important to innovation, technology advances, and the leadership position of the US in Telecommunications.
- Encourage the formation and use of consortia to provide widely available benchmarks for Data attributes and for the performance of AI/ML Models.

Recommendations – 3. The FCC Broadband Map

3. Develop a plan and strategy for designing, developing, deploying, operating, and maintaining a Broadband Map that takes advantage of the best technologies and capabilities available

- The AIWG recommends that the FCC develop a holistic approach and plan to satisfy the requirements for the National Broadband Map (NBM). As step in the process we would urge the FCC to issue an RFI that provides it with the necessary information to chose a procurement approach that the best fits the FCC's mandates.

  - This should include considerations for:

    - Identification of technology alternatives, integration approaches, development methods, deployment and operation approaches, and provisions for updating the NBM, as well as estimates of resources needed for each portion of the NBM's lifecycle.
    - The provisions to use Data gathered for important functions beyond the NBM itself. The purpose is to anticipate how the Data can serve the long term needs of the FCC in developing its AI/ML approaches and does not have to be regenerated. (e.g. wireless signal and propagation data)

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Recommendations – 4. Developing FCC Approaches for Safe Uses of AI

4. Policies and approaches to ensure the safe use of Artificial Intelligence as it impact the nation's networks , communication needs, and important applications

- FCC should encourage and incentivize operators (and their suppliers) to institute processes to manage their AI/ML *supply chain*, to track the provenance of models and training data used in their networks – and the mechanisms used to secure and manage timely updates to them (e.g., vulnerability patching).

- FCC should encourage and incentivize operators to disclose the framework they adopted to analyze/address the vulnerability (to attack) and robustness of AI/ML models whose failure could jeopardize the operation of significant portions of the network.

- FCC should encourage creation of consortia to develop one or more common assessment frameworks for use with the above analysis and for sharing of critical operational vulnerabilities and lessons learned.

These recommendations are applicable to the Network Control and Network Operations Functions

Recommendations – 5. Extracting Value from Artificial Intelligence for the FCC through Pilot Projects

5. Develop the FCC's capability for extracting value from Artificial Intelligence in solving issues and problems that come before the FCC by conducting pilot projects with near term return

During FY2020 the AIWG identified over twenty potential uses cases of AI/ML applications that could provide the FCC with significant value in pursuing its strategic priorities. Of these the AIWG found multiple projects that could serve as an early entry points in building the FCC's capabilities and in creating value. The criteria was to select projects that could be conducted within the span of a year.

- The AIWG urges the FCC to further prioritize the projects and to select 2-3 such projects to execute within the coming year. We further urge the FCC to partner with experienced organizations that have been conducting earl explorations in each of the subject areas identified. The list that was developed by the AIWG follows on the next page.

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Recommendations – 5. Extracting Value from Artificial Intelligence for the FCC through Pilot Projects

5. Develop the FCC's capability for extracting value from Artificial Intelligence in solving issues and problems that come before the FCC by conducting pilot projects with near term return

- Pilot for management of self organizing networks (SON) including the benchmarking of AI/ML model performance for fair execution of automation functions (e.g. Automatic radio slice life cycle management, radio network slice optimization , and radio slice resource optimization)

- Use of AI/ML for RF Fingerprinting to map the electro-magnetic environment and identify sources that contribute to interference and the noise floor.

- Improvements for navigating and using FCC's existing data bases and website with AI/ML tools for data extraction, search, and analysis.

- Working with the teams that developed the DARPA Spectrum Challenge emulator to determine the specification for an emulator that could supplement the FCC Testing Laboratories capabilities in performing analysis on wireless system issues for a commercial setting.

- Examining how AI/ML techniques could be used to realistically specify limits on electromagnetic radio signals to avoid or mitigate causes of interference, leading to significant improvements in the efficient use of spectrum

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Suggestions for FY2021

Several considerations related to AI/ML emerged as important for having a lasting impact on the FCC and its missions and maybe worthy of much deeper examination leading to significant outcomes:

- The use of AI/ML methods and techniques applied to assuring the safety and performance of network equipment, network control, and network operations in a network environment that increasing relies on automation and:
  - Is seeing a rapid growth of new network connections
  - Is increasingly digitized and sofwareized
- The implications of AI/ML adoption by edge providers and the impact on consumers, focusing on:
  - Understanding causes of and approaches to dealing with addictive behaviors
  - Understanding of uses of AI/ML that may result in modification of human behavior, to develop sound policies that encourage positive outcomes (e.g. public health measures, and other benefits) and mitigate against negative outcomes (e.g. bullying)
- The use of AI/ML methods and techniques to improve the utilization and administration of spectrum (licensed, unlicensed, and shared) by addressing the fundamental aspects of propagation, interference, signal processing, and protocols.

Thank You!

Appendices

1. List of Presentations
2. 2. Speaker Backgrounds

1. List of Presentations

List of 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"

List of 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	IARPA	"Security of AI Systems"
Alexander Sprintson	NSF	"Impacts of AI in the Wireless Networking domain"

List of 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 – AI as a Service (AIaaS)"
Petros Mouchtaris	Prospecta Labs	" AI/ML Research with Applications in Telecommunications"
Thyagarajan Nandagopal	NSF	"The NSF PAWR Initiative"

List of Presentations - Continued

Speaker	Affiliation	Subject
Michael G. Cotton Bradley Eales Douglas Boulware	NTIA - ITS	“EM Propagation Data, AI, and 801.22.3”
Kumar Navulur	DigitalGlobe - Maxar	“GIS Systems for Telecomms and AI”
Russell Stuart	UC Berkley	“Return Visit – AI and Control”
Ken Leonard	DoT – NHTSA and RITA	“Artificial Intelligence for Transportation”
Tommaso Melodia Abhimanyu Gosain	Northeastern University	“The use of AI in Telecommunications”
Preston Marshall	Google Wireless	“Propagation Modeling - Now Enabled by Machine Learning, Geo-Data and Crowdsourcing”

2. Speaker Backgrounds

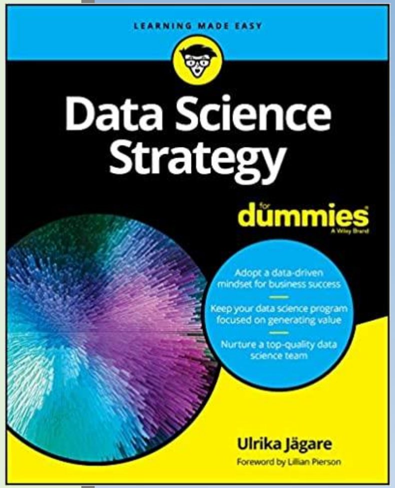
Ulrika Jägare

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.



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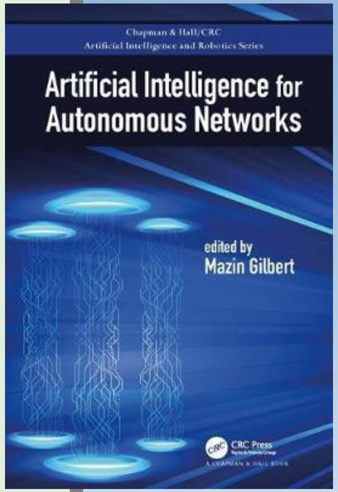
Mazin E. Gilbert

AT&T

VP of Technology and Innovation AT&T Research

“AI for Autonomous Networks”

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).



Jack Murray

AT&T

AVP Intelligent Systems, AT&T Research Labs

"AI for Autonomous Networks"

John "Jack" Murray leads the Intelligent Systems and Incubation organization which uses software, platforms, data, analytics and AI and machine learning to deliver solutions that address AT&T's needs. He is an expert in design and building advanced communications systems and is involved in key initiatives such as ONAP, Acumos, data management, and automation and communications systems.

[https://lfaidata.foundation/blog/2019/07/26/att-orange-techmahindra-adoption-of-acumos-ai-builds-foundation-for-growth/]

Nandita Dukkipati

Software Engineers at Google Inc.

"AI for Optimization of Network Resources"

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.

Mukarram Bin Tariq

Software Engineers at Google Inc.

"AI for Optimization of Network Resources"

- **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.

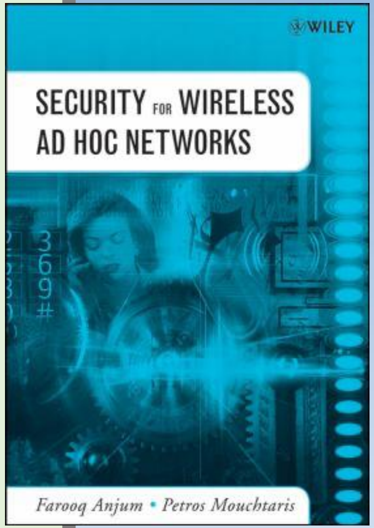
Petros Mouchtaris, Ph.D.

perspecta LABS

President, Perspecta Labs

"AI/ML research with applications in telecommunications"

Dr. Petros Mouchtaris is president of Perspecta Labs. Prior to being appointed as president, he served as VP of Applied Research and played a key role in growing the organization. He has led the entry into advanced security for wireless ad hoc networks and was principal investigator for projects funded by two of the organization's biggest customers - DARPA and the U.S. Army (CERDEC). Previously he was AVP of Telcordia Technologies' Network Systems Laboratory, director of Oracle's Product Development and Technical Director at Pacific Bell (now AT&T). He has published extensively in the areas of wireless networks and security. 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 BS in electrical engineering from the National Technical University of Athens, Greece, as well as a MS and PhD. in electrical engineering from the California Institute of Technology.



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Rakesh Misra

Co-Founder Uhana (now part of Vmware)

"Subscriber-Centric ML/AI in Mobile Radio Access Networks"

Rakesh Misra is Co-founder Uhana Inc (now part of VMWare). Uhana, is a company that has built a real-time deep learning engine to optimize carrier network operations and application quality experience, deployable in the operator private cloud or public cloud infrastructure. He received his PhD from Stanford University, and B.Tech & M.Tech from IIT Madras. He was born/and grew up in Bhubaneswar/Berhampur, in Odisha.

Stuart Russell

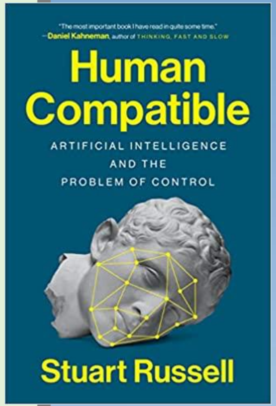
Berkeley
UNIVERSITY OF CALIFORNIA

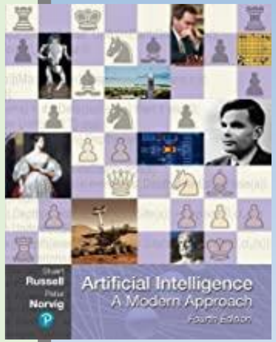
Professor of EE and CS at UC Berkeley

"AI: History and Future"

Stuart Russell received his B.A. from Oxford University in 1982 and his Ph.D. in CS from Stanford in 1986. 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 at UC Berkeley. 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 many prestigious awards. 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.

https://www2.eecs.berkeley.edu/Faculty/Homepages/russell.html





Jason Martin

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.

Berge Ayvazian

Wireless 20|20

Senior Analyst/Consultant at Wireless 20|20

"Breakthroughs from Synergy Between AI and 5G"

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

"Dynamic Spectrum Sharing: Lessons from the DARPA Spectrum Collaboration Challenge"

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

"Spectrum Collaboration - Building Prize-Winning Radios"

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

"Artificial Intelligence, Government and Ethics"

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.

Martin Zoltick

ROTHWELL FIGG

IP Professionals

"Legal and Regulatory Considerations: Application of Artificial Intelligence to Telecommunications and the FCC"

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.

FEDERAL COMMUNICATIONS COMMISSION · USA ·

Jennifer Maisel

ROTHWELL FIGG
IP Professionals

"Legal and Regulatory Considerations: Application of Artificial Intelligence to Telecommunications and the FCC"

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 counsel's 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.

Ramana Jampala

AVLINO

Founder and CEO, Avlino

"AI Solutions Transforming Telecom Network Operations"

Ramana Jampala: 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.

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Alexander Sprintson

Program Director National Science Foundation

"NSF/Intel Partnership on Machine Learning for Wireless Networking Systems"

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.

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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Jeff Alstott

Program Director IARPA

“Security of AI Systems”

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.

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Elham Tabassi

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

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

"Artificial Intelligence: A NIST strategic priority"

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

UCLA

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 at Henry Samueli School of Engineering and Applied Science. (http://www.cs.ucla.edu/security/)

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Michael G. Cotton
Bradley Eales
Douglas Boulware

Division Chief, ITS Theory Division
Data Scientist, NTIA ITS
Software Architect, NTIA ITS

“EM Propagation Data, AI, and Measurement Standards”

Michael Cotton joined NTIA/ITS in 1992. He has been involved in a broad range of research topics including applied electromagnetics, atmospheric effects on radio-wave propagation, radio channel measurement and theory, interference effects on digital receivers, ultrawideband technologies, spectrum sharing with Federal systems, and spectrum occupancy measurements. In 2002, he earned the DOC Gold Medal Award for research and engineering achievement in the development of national policies for UWB technologies. In 2010 and 2011, Mr. Cotton was the General Chair for the International Symposium on Advanced Radio Technologies (ISART) on Developing Forward-Thinking Rules and Processes to Fully Exploit Spectrum Resources. Currently, he is the project leader on NTIA’s Spectrum Monitoring Pilot Program. Michael has authored or co–authored over thirty technical publications. He received a B.S. degree in Aerospace Engineering in 1992 and an M.S. degree in Electrical Engineering with an emphasis on electromagnetics in 1999, both from the University of Colorado at Boulder.

Eales, Bradley

Data Scientist NTIA, ITS

Boulware, Douglas

Software Architect NTIA, ITS

Kumar Navulur

Sr. Director, Strategic Business Development, at MAXAR Technologies (DigitalGlobe)

"Geographic Information Systems and Artificial Intelligence for Telecommunications"

Dr. Kumar Navulur, Sr. Director of Strategic Business Development at Maxar Technologies, is on the Board of Directors of the **OPEN GEOSPATIAL CONSORTIUM** (OGC), a consortium of 500+ companies, government agencies and universities developing open standards and services for geospatial data. As location becomes integral to our daily life, whether navigating to a coffee shop or trying to find the nearest bus stop, it is paramount that location data from multiple sensors can be brought together seamlessly, processed and served to millions of customers globally. This is the mission of OGC: creating standards for all location-based data providers to follow so that end-users are able to leverage the data quickly.

Maxar has been a member of OGC for 15 years and follows several of the **STANDARDS ESTABLISHED BY OGC**. Dr. Navulur has been representing Maxar as a participant in OGC for 12 years. Maxar has been transforming the commercial remote sensing industry for decades by pushing the technology limits - with increased pixel resolution of 30 cm, increased number of spectral bands to map and monitor our changing planet, and frequent revisit - providing a comprehensive and current view of the globe.

Ken Leonard

U.S. Department of Transportation
Federal Highway Administration

Director for the Intelligent Transportation Systems JPO, DoT FHWA

“AI and Autonomous Vehicles”

Ken Leonard has over 30 years of federal government and private sector leadership experience providing solutions in transportation, energy, investment decision making, defense, environment, regulatory affairs, and information systems. As Director he serves as USDOT's primary advocate and leader for Department-wide coordination of ITS research and development. Under his leadership the ITS JPO created and is executing a five-year strategic plan, integrating connected and automated vehicles, emerging technologies such as smart cities, ITS enterprise data, interoperability and accelerated ITS deployment.

He joined the ITS JPO from the Federal Motor Carrier Safety Administration (FMCSA), where he served as a Senior Policy Advisor and Director of the Office of Analysis, Research and Technology. While there, he provided executive leadership and direction in improving FMCSA's project effectiveness and efficiency, as well as supporting the stand up of DOT's IdeaHub innovation platform. Previously, Mr. Leonard served as Federal Aviation Administration (FAA) Director of Aviation Weather, led the FAA's Technology Development Office and was the manager of Investment Analysis. While at the FAA, he provided strategic direction, advancing cornerstone aviation weather enterprise systems and emerging technologies in support of the USDOT's Next Generation Air Transportation Systems initiatives.

While serving in the private sector, Mr. Leonard provided management oversight of complex and innovative research and development programs involving multibillion-dollar projects. Additionally, he developed strategies to improve standard business practices and reduce program cost risks. Mr. Leonard is a graduate of the George Washington University School of Public and International Affairs, where he earned a bachelor's degree in international economics and completed graduate-level studies in economics and finance.

Tommaso Melodia

Northeastern University

Professor, Electrical and Computer Engineering, Northeastern University

"AI In the Open RAN: Toward Wireless Networks with a Brain?"

Tommaso Melodia is the William Lincoln Smith Chair Professor with the Department of Electrical and Computer Engineering at Northeastern University in Boston. He is also the Founding Director of the Institute for the Wireless Internet of Things and the Director of Research for the PAWR Project Office. He received his Laurea (integrated BS and MS) from the University of Rome - La Sapienza and his Ph.D. in Electrical and Computer Engineering from the Georgia Institute of Technology in 2007. He is an IEEE Fellow and recipient of the National Science Foundation CAREER award. He was named a College of Engineering Faculty Fellow in 2017 and received the Søren Buus Outstanding Research Award in 2018 - the highest research award in the College of Engineering at Northeastern University. Prof. Melodia has served as Associate Editor fo IEEE Transactions on Wireless Communications, IEEE Transactions on Mobile Computing, Elsevier Computer Networks, among others. He has served as Technical Program Committee Chair for IEEE Infocom 2018, General Chair for IEEE SECON 2019, ACM Nanocom 2019, and ACM WUWnet 2014. Prof. Melodia is the Director of Research for the Platforms for Advanced Wireless Research (PAWR) Project Office, a $100M public-private partnership to establish 4 city-scale platforms for wireless research to advance the US wireless ecosystem in years to come. The PAWR Project Office is co-lead by Northeastern University and US Ignite and is overseeing the overall deployment and operation of the PAWR Program. Prof. Melodia's research on modeling, optimization, and experimental evaluation of Internet-of-Things and wireless networked systems has been funded by the National Science Foundation, the Air Force Research Laboratory the Office of Naval Research, DARPA, and the Army Research Laboratory.

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Abhimanyu Gosain

Northeastern University

Technical Program Director PAWR, Northeastern University

"AI In the Open RAN: Toward Wireless Networks with a Brain?"

Abhimanyu (Manu) Gosain is a Technical Program Director for PAWR and Director of Industry Engagement for Institute of Wireless Internet of Things at Northeastern University. In this role, he is in charge of setting strategic goals and the research agenda for a $100 million public-private partnership for the NSF Platforms for Advanced Wireless Research (PAWR) program and $25M DARPA Colosseum program. His numerous professional publications and experience exemplify use-inspired basic research in the field of networking technologies such as LTE, 5G, dispersed computing, edge computing and Internet of Things. He is an IEEE Senior Member. He received his M.S. degree from Tufts University and M.B.A. from Boston University with High Honors .

Sridhar Kowdley
Stephen Dennis

Homeland Security
Science and Technology

Program Manager, DHS Science & Technology Directorate

"Artificial Intelligence and Machine Learning"

Sridhar Kowdley is a Program Manager at the U.S. Department of Homeland Security (DHS) Science and Technology Directorate, Office for Interoperability and Compatibility. He leads several initiatives including the Project 25 Compliance Assessment Program (P25 CAP), the DHS Counter-Jamming Initiative to assess illegal jamming threats to responder communications, and the NGFR - Harris County OpEx.

Stephen Dennis Data Analytics Engine Director, HSARPA, Science & Technology Directorate, DHS. Stephen Dennis provides leadership and guidance to information analysis and critical infrastructure protection programs within the Homeland Security Advanced Research Projects Agency (HSARPA) of the Science & Technology (S&T) Directorate of the Department of Homeland Security (DHS).

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Thyagarajan Nandagopal

Deputy Division Director, CISE Directorate at the National Science Foundation

"NSF PAWR and MLWINS Programs and the role of AI"

Dr. Thyaga Nandagopal serves in the Directorate of Computer & Information Science and Engineering (CISE) of the National Science Foundation. He is the Deputy Division Director (DDD) for the Division of Computing and Communication Foundations (CCF). Prior to his DDD position he managed wireless networking and mobile computing research within the Networking Technologies and Systems (NeTS) program at NSF. He has been with the Foundation since February 2012. He has managed networking and mobile computing research within the NeTS program, and contributed to several other crosscutting programs, including Spectrum Efficiency, Energy Efficiency, and Security (SpecEES) and Industry/University Collaborative Research Centers (IUCRC). He has built coalitions in support of new research directions, including leading the establishment of the Platforms for Advanced Wireless Research (PAWR) program, which has garnered $50 million in cash and in-kind contributions from an industry consortium of about 30 wireless networking companies and technology associations. He serves as co-chair of the Wireless Spectrum Research and Development (WSRD) Interagency Working Group.

Before joining NSF, Dr. Nandagopal spent 10 years as a Member of the Technical Staff at Bell Labs/Alcatel-Lucent Bell Labs. His research interests dealt with networking in the cloud, green networking, and software-defined networks. In this role, he helped pioneer the development of the first commercial carrier-grade software-defined network platform (ALU 9980 AINP) between 2006 and 2008, with industry-leading features such as service-chaining and network function virtualization. He also worked extensively on wireless ad hoc/mesh networks and sensors/RFID systems, with specific focus on algorithms for enabling efficient operations of these systems.

Dr. Nandagopal holds 38 US patents awarded and several patents pending and has published numerous papers in highly regarded conferences and journals in the field. He has also served as program chair or co-chair for many technical program committees, and Associate Editor for *IEEE Transactions on Mobile Computing*. Dr. Nandagopal is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE).Dr. Nandagopal holds a Ph.D. in electrical engineering from the University of Illinois at Urbana-Champaign (UIUC); M.S. degrees in applied mathematics and computer engineering from UIUC; and a B.Eng. in electronics and communication engineering from Anna University (Chennai, India).

Preston Marshall

Google

Engineering Director and Principal Wireless Architect for Google Wireless

"Propagation Modeling - Now Enabled by Machine Learning, Geo-Data and Crowdsourcing"

Dr. Preston F. Marshall is an Engineering Director, and Principle Wireless Architect for Google Wireless, responsible for spectrum access technology, with a focus on the creation of a vibrant ecosystem of equipment, users, and standards in the newly shared 3.5 GHz Citizens Broadband Radio Service (CBRS) band. He is chair of the Wireless Innovation Forum Spectrum Sharing Subcommittee, developing the standards base for 3.5 GHz spectrum sharing, and vice chair of the Board of the CBRS Alliance, developing coexistence and neutral host technology for the 3.5 GHz band. He has a new book on this subject, "*Three Tier Shared Spectrum, Shared Infrastructure, and a Path to 5G*", recently released by Cambridge University Press, as well as two prior books on Cognitive Radio.

He has been heavily involved in wireless technology and policy, including: Deputy Director of the Information Sciences Institute (ISI) at the University of Southern California, a Research Professor at USC's Electrical Engineering Department, a contributor to the President's Council of Advisors on Science and Technology (PCAST) spectrum study that led to the creation of the CBRS band, and Program Manager with the Defense Advanced Research Projects Agency (DARPA), directing multiple wireless and sensing technology programs.

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FCC Technological Advisory Council Agenda – December 1, 2020

10am – 10:15am	Introduction and Opening Remarks
10:15am – 10:30am	Announcements and Roll Call
10:30am – 11am	FCC Chairman's Remarks WG Recommendations (5 minutes for each WG)
11am – 11:45am	Artificial Intelligence WG
11:45am – 12:30pm	Future of Unlicensed Operations WG
12:30pm – 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

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FCC TAC
Future of Unlicensed Operations
Q4 2020 Report

Chairs: Kevin Leddy, Charter & Brian Markwalter, CTA

FCC Liaisons: Monisha Ghosh, Michael Ha, Nick Oros, Bahman Badipour, Mark Bykowski, Chrys Chrysanthou, Martin Doczkat

Date: December 1, 2020

2020 Working Group Team Members

FCC Liaisons

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

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
Mark Bayliss, Visual Link Internet
Jack Nasielski, Qualcomm
Russ Gyurek, Cisco
Chris Orem, Charter (SME)

Future of Unlicensed Operations Agenda

- Working Group Charter
- Summary and Overview
- Spectrum Sharing
- 60 GHz Personal Radar
- Conclusion

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**?

Summary and Overview

Topical Groupings and Outcomes

- Protocols, Standards and Technologies
  - Wi-Fi 6, 6e and 7
  - 5G NR-U
  - Access protocols
  - Regulatory approach

- 60 GHz personal radar
  - 60 GHz communications
  - 60 GHz personal radar technology

- Spectrum Sharing
  - WISPs
  - Infrastructure/services for commercial venues
  - SAS providers

- Future Approaches
  - AFC
  - Potential to Expand Low Power Indoor (not addressed in 2020)

Topical Groupings and Outcomes

- Protocols, Standards and Technologies
  - Wi-Fi 6, 6e and 7
  - 5G NR-U
  - Access protocols
  - Regulatory approach

Stay The Course

- 60 GHz personal radar
  - 60 GHz communications
  - 60 GHz personal radar technology

Rulemaking Needed

- Spectrum Sharing
  - WISPs
  - Infrastructure/services for commercial venues
  - SAS providers
- Future Approaches
  - AFC
  - Potential to Expand Low Power Indoor (not addressed in 2020)

Future TAC Work

On Cooperation, Competitiveness and Approaches

- Vibrant technology development and standardization exists within the co-dependent licensed and unlicensed ecosystems
- Balanced addition of spectrum for both unlicensed and licensed across low, mid and high bands helps both ecosystems
- Detailed planning and assessment of use cases, including crowded venues or short-range high data rate is driving technology and standards development
- Light touch regulatory approach works best

- **Recommendation**: Do not change current FCC approach of tailored operational and emissions limits; continue to allow industry to establish technical parameters and innovate with minimal regulatory constraints

60 GHz Radar Recommendation

- 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."
- Continued development of 60 GHz personal radar technology, e.g., Google Soli
- Associated waiver requests
- Industry has formed a 60 GHz Coexistence Study Group for Communications and Radar

- **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

Spectrum Sharing Recommendation

- Growth and advancement in sharing technologies will increase access to spectrum
- More study is needed to understand the demand and technology differences, similarities, and points of intersection between unlicensed and shared spectrum

- **Recommendation:** Create a TAC Working Group for 2021 to explore Spectrum Sharing
  - Examine sharing approaches used by the FCC (consolidate reviews from 2020 TAC)
  - Examine sharing technologies in the marketplace, history, lessons learned, and suggest opportunities to improve based on real-world application
  - Identify new methods for spectrum sharing
  - Evaluate potential metrics and KPIs to help measure the efficacy of shared spectrum
  - Categorize incumbents and map sharing technologies to ideal use cases / incumbents, including low power indoor operation
  - Identify upcoming and future spectrum opportunities suitable for spectrum sharing

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Spectrum Sharing Review and Recommendation

Fourth Quarter Presentation Summaries

Organization	Topic	Speaker	Summary
WISPA ERICSSON	Advancing CBRS in the Fixed Wireless Community and CBRS Field Experience	Richard Bernhardt, WISPA Virgil Cimpu, Ericsson	• WISPs are transitioning from Part 90 to Part 96. Inability to convert older equipment to support Part 96 have resulted in costly upgrades for small WISPs • Users on the east coast have experienced EIRP limitations due to DPA (wide range of protected area) and ESC sensor protection. Additionally, a large number of channels are protected within DPAs on an ongoing basis, further limiting use • GAA coexistence by SAS operators is lacking support. If a user experiences interference issues, manual intervention is required to resolve. Differences in SAS implementations have led to challenges for device manufacturers. For example, the heart beat interval for devices varies among SAS operators, which requires configurability with the equipment
comsearch A CommScope Company	Centralized Dynamic Spectrum Management Systems	Mark Gibson	• TVWS showed promise but was hindered due to regulatory uncertainty, inefficient FCC database certification processes, and lack of Enforcement guidance • Comsearch was in the first SAS phase and is also one of the four ESCs. Testing and certification took nearly two years • ITS was selected as the SAS testing lab to appease DoD concerns. The SAS operators were required to cover the costs of the lab yet were negatively impacted by government delays. Would have been beneficial to have SAS operators part of the testing lab selection process • Enforcement in CBRS is still unclear and is a known issue. Comsearch is relying on the FCC's Enforcement bureau to engage and lead the enforcement discussion • Multi stakeholder groups (MSG) are leveraged for defining 6 GHz rules. As standards are needing to be created, the requirements are kicked down to the appropriate standards bodies (WInnForum, Wi-Fi Alliance). Challenges observed in standing up the MSG due to lack of more defined structure / hierarchy

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Fourth Quarter Presentation Summaries

Organization	Topic	Speaker	Summary
intel Hewlett Packard Enterprise	6 GHz Automated Frequency Control	Hassan Yaghoobi, Intel Chuck Lukaszewski, Hewlett Packard Enterprise	• Low Power Indoor Devices are the only approved Part 15 device class in 6 GHz: APs are required to be fixed to prevent outdoor transmission and are restricted to lower energy than standard power. • Standard Power specification is under review by the Multi Stakeholder Group and will require AFC and have pointing angle restrictions. There is an open rulemaking for Very Lower Power APs. • Client devices have three variants: mobile (must transmit 6 dB lower than the device class they are connected to), Subordinate Indoor (same rules as Lower Power Indoor + no direct internet connection), and Fixed Outdoor (same rules as Standard Power+ attached to structure) • AFC managed APs must be able to determine their geolocation and request a list of available channels every 24 hours. Channel availability request must include AP geolocation, FCCID, and AP serial number • There is no reporting requirement for devices to inform the AFC what channel was selected
amazon	Amazon Sidewalk	Manolo Arana	• Sidewalk is an opt-in community based network (using network sharing) for IoT. Utilizes Amazon products as bridges to provide IoT devices with internet connectivity. Shares Wi-Fi with neighbors / community members • Still in proof-of concept / pilot stages, but have seen promising customer adoption • Bandwidth requirements are low (~80 kbps requirement for video, 2 kbps for long range needs). Purpose is to assist connectivity gaps between homes and devices, provide connections during an outage (assuming range isn't an issue), and allow remote support to troubleshoot device issues • Security has been an early design priority. Developing three layers of encryption: application, over-the-air, and gateway to server. Uses hashes and key rotation, ID rotation, and does not store routing data • Sidewalk uses 900 MHz for connecting remote IoT devices, primarily due to the propagation and ranges (up to 2 km in LoS), primarily using LoRa. Uses FSK @ 900 MHz and 2.4 GHz BLE for shorter ranges

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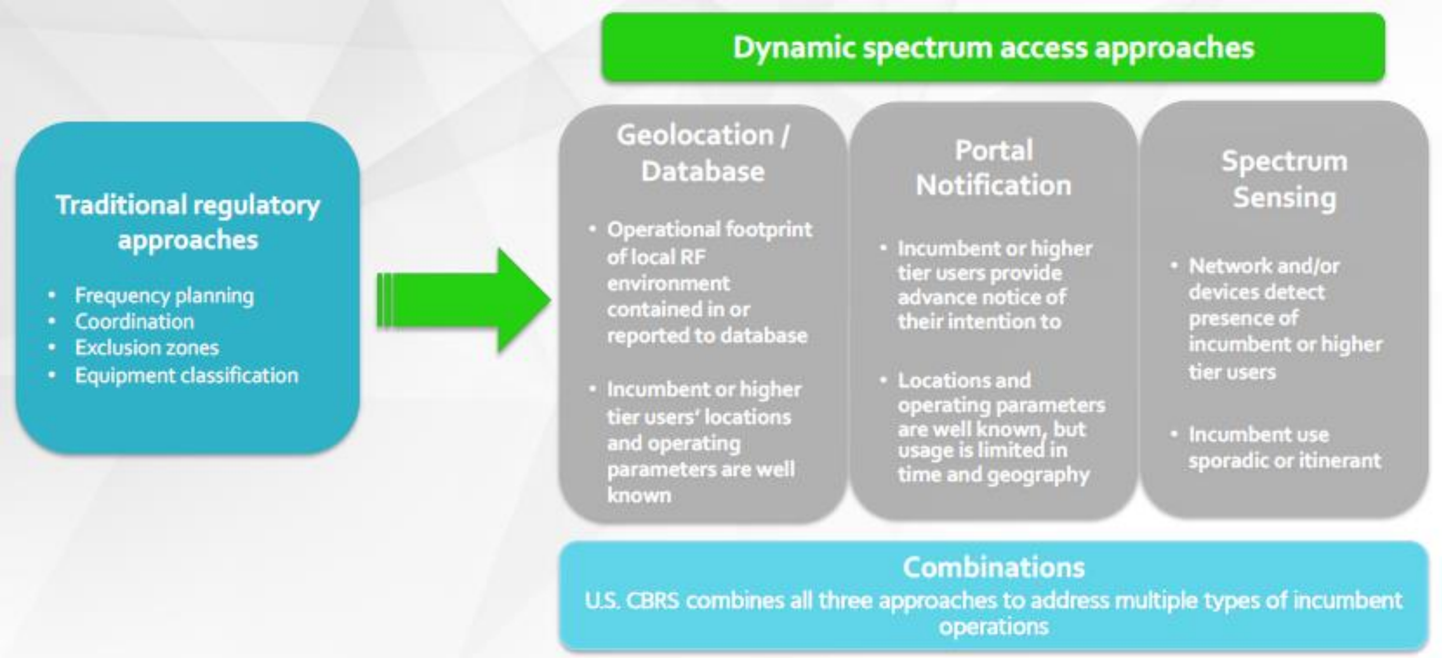
As use of shared bands grows, so will the need for Dynamic Spectrum Access

- Dynamic Spectrum Access is a software-based approach for allocating spectrum rights on a dynamic basis
- There are several approaches for implementing DSA, which can vary based on requirements, outcomes, incumbents, etc.
- Benefits include:
  - Increase in spectral efficiency by allowing commercial users to existing bands
  - Increase competition and secondary marketplace
  - Maintain and protect incumbents
- As DSA continues to evolve and improve, so will sharing opportunities



Source: Federated Wireless

Nature of Incumbents Determines Sharing Potential

	Examples	Characteristics	Sharing Potential
Fixed Operations	Satellite operators, PTP/PMP/WISP, Fixed Wireless, fixed TV broadcast	**Geographic Considerations:** Stationary and predictable **Timing Considerations:** Potential for synchronization. Avoidance is an option **Interference Tolerance:** Higher tolerance due to common use of industry standards	High – new entrants can avoid incumbents unless overcrowded
"Mobile" Operations	MNOs, auxiliary broadcast services, regional and smaller carriers	**Geographic Considerations**: Unpredictable location **Timing Considerations:** Potential for synchronization. Avoidance is likely not an option **Interference Tolerance:** Higher tolerance due to common use of industry standards	Medium – new entrants may require stricter rules or coordination w/ incumbents
Radar Operations	Aeronautical, weather, military	**Geographic Considerations**: Unpredictable - can be fixed or mobile **Timing Considerations:** Erratic transmission timing and patterns. Avoidance is likely not an option **Interference Tolerance:** Highly sensitive to interference	Low – very difficult to coexist with incumbents. Avoidance is a key method but is not always possible

Federal vs commercial incumbents are an additional consideration when determining viability and approach for sharing

5 GHz Dynamic Frequency Selection

Early Challenges Hindered Adoption, But Interest Persists

Band, Frequency Range	5 GHz U-NII-2A, U-NII-2C
Use Case	• Wi-Fi, LTE-LAA
Primary Incumbents	• **Radar Operations:** Weather Radar
Spectrum Sharing Model	• **Sensing:** APs are required to sense the presence of incumbent transmission, and relocate unlicensed users to a new channel if incumbents are detected
Timeline	• Standardized in 2003
Feedback and Learnings	• Misalignment between sharing technology and incumbent / use cases • DFS certification adds product cost which some vendors cannot justify • Mobile weather radar creates a less predictable footprint and limits use cases. DFS logic will usually block DFS channels from future use after a couple positive DFS triggers • Some early procedural and user configurability problems. Higher bar for certification can be a limiting factor • Certification process stability and higher value use cases result in continued interest

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TVWS Database

A Valuable (albeit difficult) First Step in Spectrum Sharing Database Technology

Band, Frequency Range	Inactive space between UHF/VHF channels (470-690 MHz)
Use Case	• Rural fixed wireless broadband
Primary Incumbents	• **Fixed Operations:** Over-the-air TV receivers – broadcasters have longstanding licenses to TV channels • **Mobile Operations:** Wireless microphones – wireless microphones use TVWS spectrum to communicate
Spectrum Sharing Model	• **Database:** incumbent data obtained from FCC databases. All TVWS devices must register with a TVWS database administrator
Timeline	• Established by FCC in 2007
Feedback and Learnings	• First large scale commercially managed dynamic spectrum database solution • Suffered from regulatory uncertainty due to the TV station repack • TVWS database certification was performed in serial, leading to commercial delays • Enforcement was not fully clarified

CBRS Spectrum Access System and Environmental Sensing Capability

Largest Commercial Scale Database Sharing Initiative, Need Experience Before Evaluating

Band, Frequency Range	3.55 – 3.70 GHz (3.55-3.65 for PAL and GAA, 3.65-3.70 for GAA)
Use Case	• Mobile, Fixed Wireless / PTP
Primary Incumbents	• **Radar Operations:** Primarily Navy radar systems • **Fixed Operations:** WISP Point-to-Point Operators, typically rural wireless ISPs
Timeline	• Established by FCC in 2015

Feedback and Learnings	• Industry consensus that CBRS will provide broad access to highly valuable mid-band spectrum
	• SAS platform certification processes were initially time consuming and lacked SAS operator input
	• Enforcement role not clarified between FCC and SAS operators. SAS coordination and coexistence requirements need to be better defined for all user tiers – but still in early phases of SAS implementation
	• Technology complexity is challenging for smaller scale / less sophisticated users to adopt without additional support
	• Protection Areas and incumbent sensing makes CBRS difficult to be commercially viable in certain areas
	• Incumbent informed processes, which are being considered as an updated approach for CBRS, has both risks and benefits
	    • May result in lost investment by ESC operators
	    • Adds usability concerns to CBRS operators in active incumbent areas

Automated Frequency Coordination in 6 GHz

Less Complex than SAS, Still Under Development

Active Proceeding

Band, Frequency Range	6 GHz / U-NII-5 and U-NII-7 standard power outdoor
Use Case	• Outdoor Wi-Fi, Fixed Wireless / PTP

Current Use / Incumbent	• **Fixed Operations:**
	  • Fixed point-to-point wireless operations
	  • Earth-to-space fixed satellite operators – heavily used by broadcasters to transmit content and data (remote live broadcast, sporting events, etc)
	• **Mobile Operations:** Public safety land mobile radio services

Spectrum Sharing Model	• **Database:** incumbent data obtained from FCC's Universal Licensing System database
Timeline	• Established by FCC in 2020
Feedback and Learnings	• Received feedback on several AFC topics, including: channel selection and optimization reporting, multi-stakeholder group challenges, incumbent concerns. We are withholding specifics about feedback and recommendations due to the open proceeding

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Other Sharing Mechanisms

- Beyond database and sensing, spectrum sharing (in broad terms) also includes:
  - Incumbent Informed Processes
  - Protection Areas
  - Power Limits and Interference Thresholds
  - Frame Synchronization
  - Listen-Before-Talk
  - Adaptive Duty Cycle

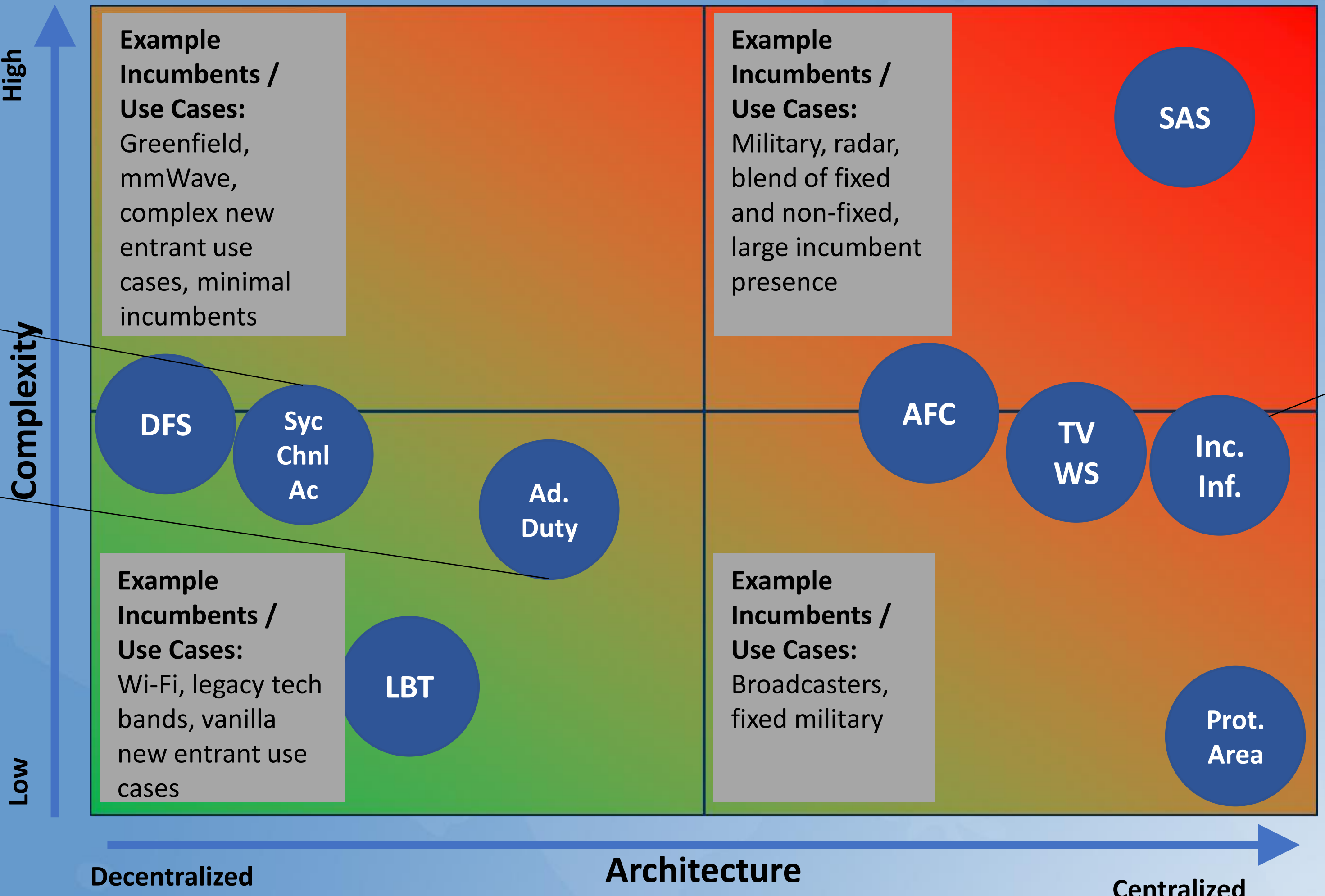
Heat Map of Spectrum Sharing Technologies

Incumbents: Dynamic, low risk, flexible
New Entrants: Wide range of technologies, low concern for legacy technologies

Synchronous Channel Access

Adaptive Duty Cycle

Incumbents: Low risk, inflexible
New Entrants: Wide range of technologies, concerns for legacy technologies



Incumbents: Dynamic, well-defined, inflexible
New Entrants: Multiple user tiers, wide range of technologies, low concern for legacy technologies

Incumbent Informed

Incumbents: Static, well-defined, inflexible
New Entrants: Simplistic rules and requirements (points and radius is sufficient), low concern for legacy and competing technologies

Spectrum Sharing Recommendation

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60 GHz Radar and Recommendation

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
  - Radar and sensing from room scale to gesture control

- Communications
  - IEEE 802.11ad IEEE 802.11ay
  - 5G NR-U
- Sensing/Radar
  - IEEE 802.11ad/ay
  - WLAN Sensing
  - FMCW

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

Regulatory Background and Google Request

- 60 GHz band (57-71 GHz) regulated as unlicensed intentional radiator through 47 CFR 15.255
  - For <u>personal radar</u>, *FCC 15.255(c)(3)*: "short-range devices for interactive motion sensing, the peak transmitter ***<u>conducted output power shall not exceed –10 dBm and the peak EIRP level shall not exceed 10 dBm</u>***<u>."</u>
  - 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
- 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 ***<u>+13 dBm EIRP, +10 dBm</u>*** 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

60 GHz Radar 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

- Potential areas of consideration:
  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?

Closing Thoughts

- Facts and Figures for 2020 Unlicensed Working Group
  - Performed historical analysis of unlicensed spectrum policy and technology in the US
  - Reviewed prior unlicensed work by the TAC
  - Met with a wide range of industry leaders:
    - Industry groups, researchers, and advisors: Wi-Fi Alliance, WISPA, CTA, CableLabs, University of Chicago, Marcus Spectrum Solutions
    - Major radio and hardware manufacturers: Ericsson, Cambium, Cisco, Intel, Qualcomm, Broadcom
    - SAS and White Space Operators: Google, Federated Wireless, Commsearch, Microsoft
    - End User Product/Services: Facebook, Amazon, Google, Boingo
- Summary of Recommendations

1. The FCC should avoid further codifying standards in regulation, and allow industry to define technical specifications
2. FCC should open a rulemaking on personal radars in 60 GHz spectrum where the FCC has been receiving waivers to use the spectrum for personal radar
3. The FCC should dedicate a TAC working group to focus on spectrum sharing in 2021

Appendix

History of Unlicensed Spectrum

Encouraging Progress from 2015 Unlicensed TAC Recommendations

Key Finding	Unlicensed Spectrum use has grown enormously, especially with the rise of smart phones and tablets				
Recommendations	Revisions to Part 15 rules are unnecessary at this time, but the Commission should continue to monitor	More unlicensed spectrum should be made available: - Between 6 - 57 GHz - >64 GHz	Promote more spectrum sharing	Consider rules to improve spectral efficiency as part of the rulemakings on additional unlicensed spectrum	Continue to rely on industry standards bodies to promote efficiency and co-existence
Progress	✓ Minimal revision to Part 15 for unlicensed. Light touch approach has been huge benefit	✓ Addressed thus far by CBRS GAA, 5.9 GHz, 6 GHz, and expansion of 60 GHz	✓ FCC is demonstrating via CBRS, 3.45-3.55, 2.5, and 6 GHz	✓ Light touch regulation combined with SAS and AFC increase efficiency. Standards bodies are taking the lead on efficiency methods	✓ 6 GHz and CBRS will be testing grounds as both will likely have large scale 3GPP-IEEE hybrid operations

FCC has accelerated unlicensed spectrum allocations in recent years

1990 | 2000 | 2010 | 2020

1985

900 MHz
FCC authorizes ISM use between 902-928

2.4 GHz
FCC authorizes ISM use between 2400-2483.5

5 GHz
FCC authorizes ISM use between 5725- 5850

1989

Part 15
Part 15 is modified to allow conforming unlicensed use for any application

1997

5 GHz
FCC sets unlicensed rules for 5.15-5.25 (U1), 5.25-5.35 (U2A), and 5.725-5.825 (U3)

2001

60 GHz
FCC authorizes 57 – 64 GHz for unlicensed use

2003

5 GHz
FCC authorizes 5.47-5.725 (U2C) for unlicensed use

2016

60 GHz
FCC authorizes 64-71 GHz for unlicensed use

2018

CBRS
FCC finalizes rules for shared use of CBRS

2019

5.9 GHz
FCC issues NPRM to authorize 45 MHz for unlicensed

2020

6 GHz
FCC finalizing rules for unlicensed 6 GHz operation

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Unlicensed Portfolio is Growing to Keep Pace with Demand

Spectrum availability needs to stay 5-10 years ahead of demand

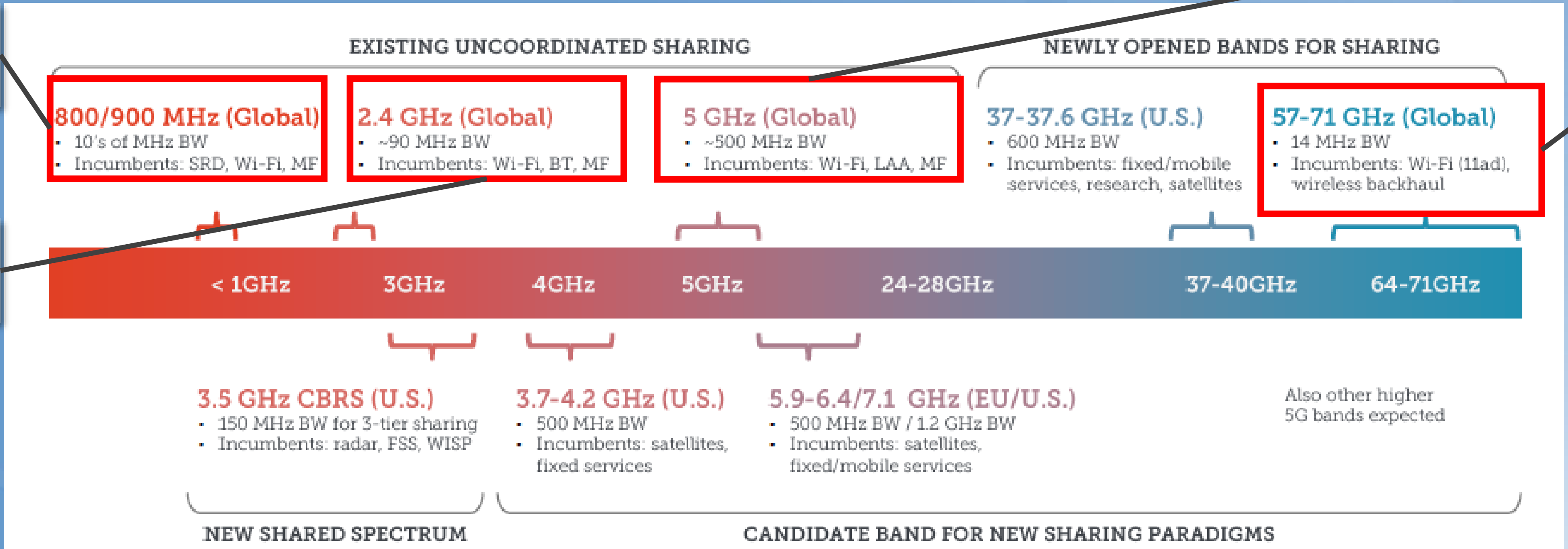
Fast, suffers from DFS, becoming congested

WiGig in the US

Fast, large channel BW, propagates poorly (requires LoS)

Slow, congested, propagates well

Better speeds, highly congested



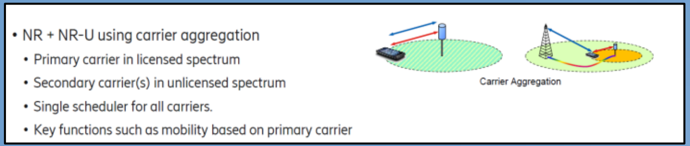
Source: Boingo

***Additional bands include TVWS and the modified 5.9 GHz DSRC*

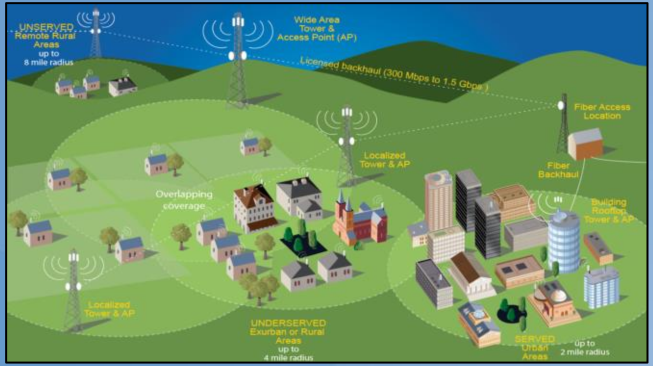
How Unlicensed Complements and Competes With Licensed Spectrum

Unlicensed Spectrum Can Augment and Complement Licensed Operations

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



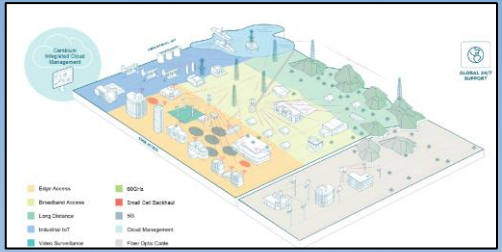
Source: Ericsson



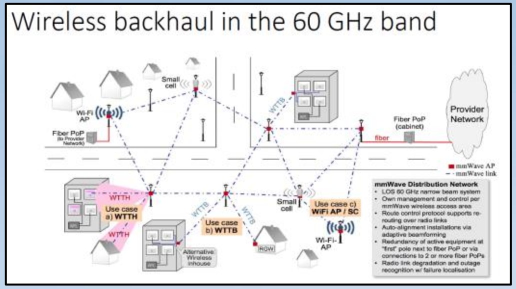
Source: WISPA

Unlicensed Spectrum Creates Competitive Opportunities

- WISPs and FWA providers use 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



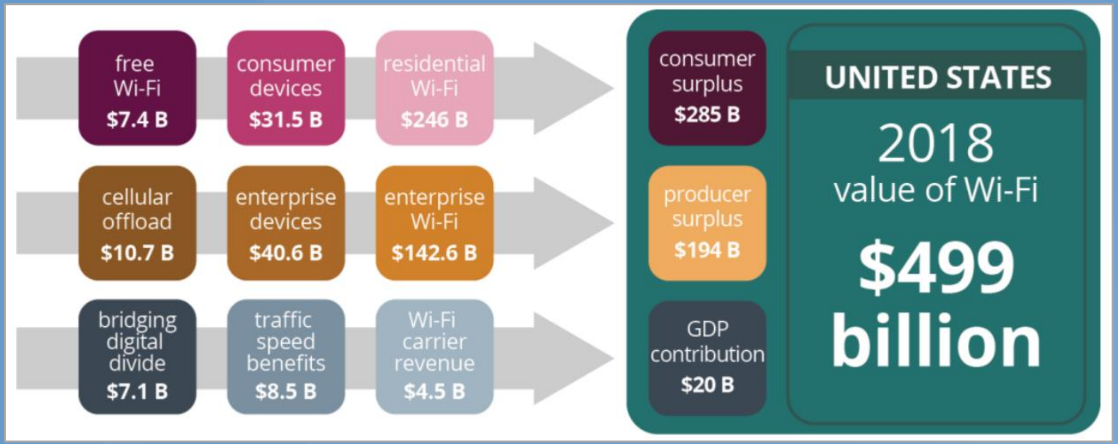
Source: Cambium



Source: Intel

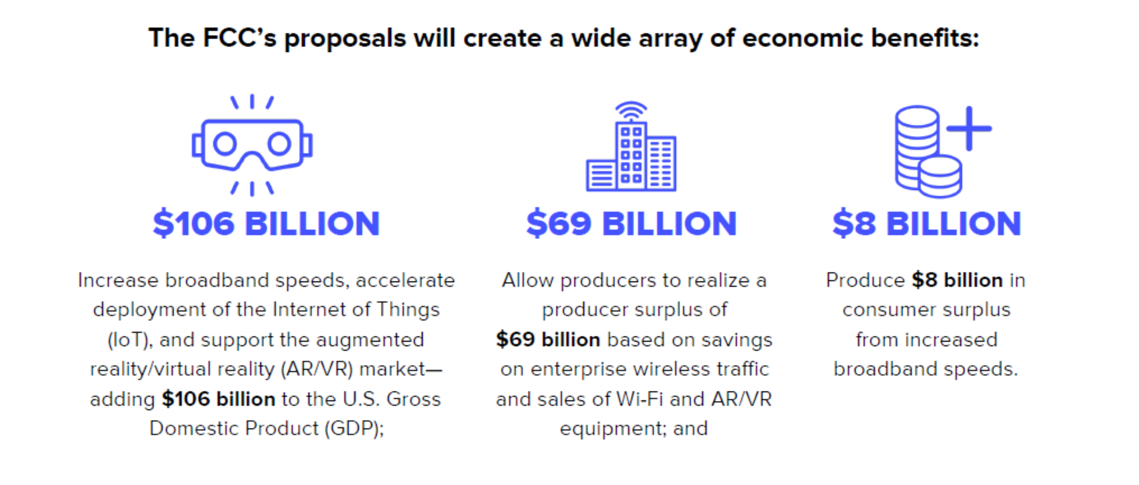
Unlicensed Spectrum has Significant Economical Value to the US Economy

Unlicensed use spans all sectors of the marketplace, and is both a productivity tool and business model enabler



Source: Wi-Fi Alliance

According to the Wi-Fi Alliance, the value of Wi-Fi was **$499 billion in 2018,** and is expected to reach **$993 billion by 2023**



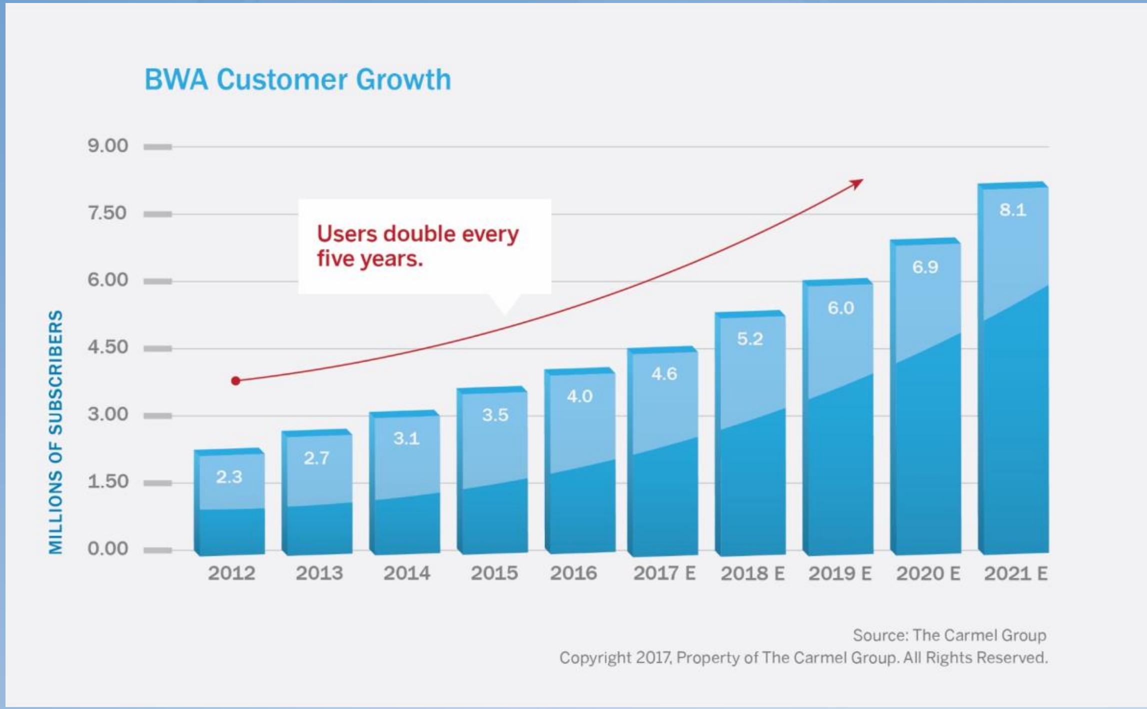
Source: Wi-Fi Forward

Wi-Fi Forward estimates that 5.9 GHz and 6 GHz will add an additional **$183 billion** to the US economy **by 2025**

Comparisons of unlicensed and licensed economic value are challenging. They complement each other in many applications while underlying competition remains.

Examples of Business Models Built on Unlicensed: WISPs

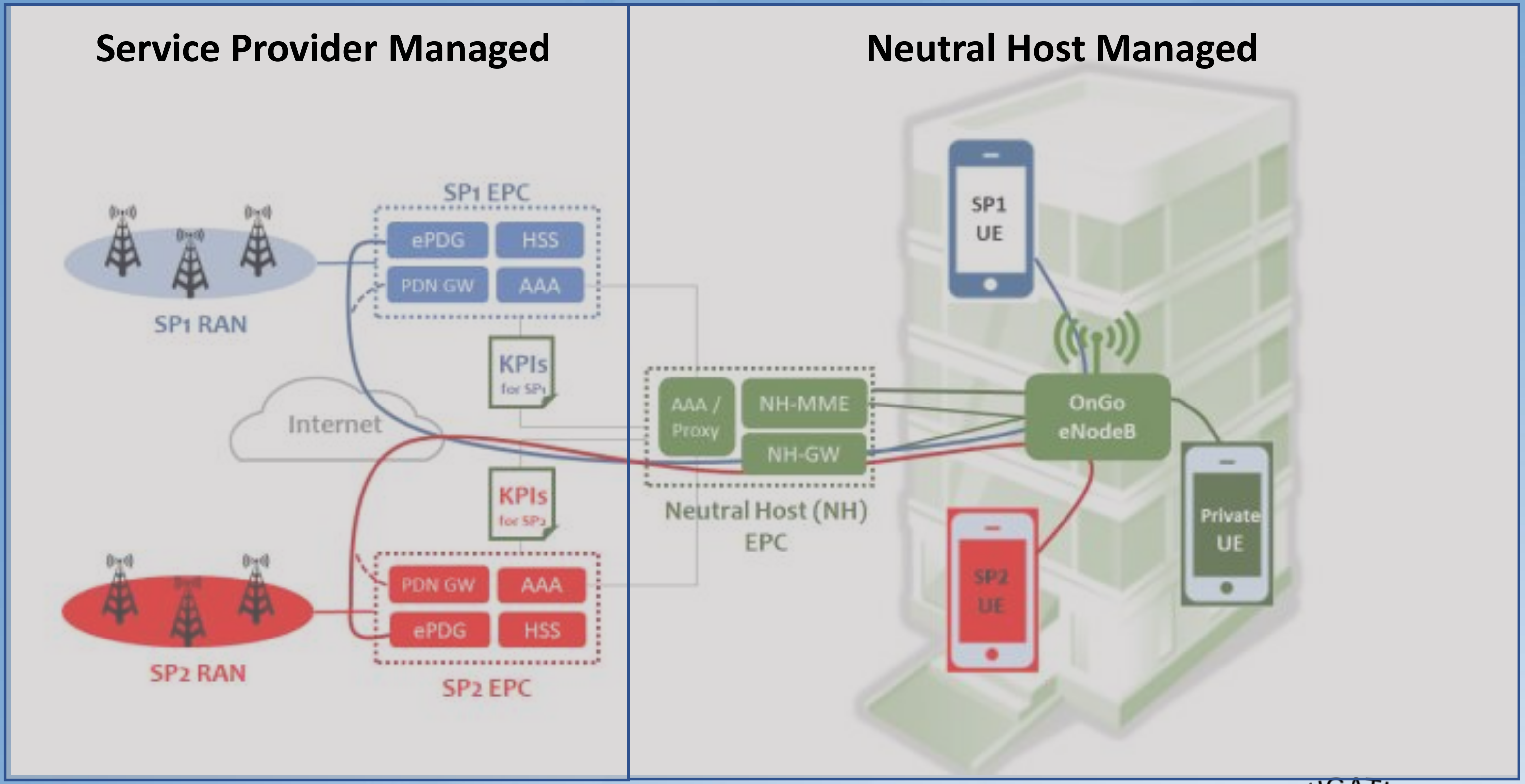
- WISPs often employ multiple wireless technologies and a tailored architecture for service delivery
- WISPs leverage a variety of bands including 900, 2.4, 2.5, 3.5, 5 GHz, and traditional licensed bands where available / affordable
- Planning to use 6 GHz
- WISP operators are often small business owners operating in rural US
- WISPs are estimated to serve 8.1 million customers by 2021
- There are two main challenges faced by WISPs:
    - **Capital:** WISPs often seek unlicensed spectrum due to costs/complexity of acquiring licenses
    - **Spectrum:** face limited unlicensed options and often suffer from interference issues from competing devices



Examples of Business Models Built on Unlicensed: Neutral Host / DAS Provider

Neutral Hosting may emerge as an economical opportunity with new bands and technologies

- Neutral Hosting allows infrastructure owners to operate services and ISPs on common infrastructure
- Boingo via DAS has operated as a neutral host for venues and businesses for over a decade
  - Solves network management & ops needs for venue owners
- Neutral Hosting may have potential in rural, but the business model faces challenges:
  - Up-front CAPEX
  - Agreements with ISPs / MNOs
  - Questionable financial model
  - Lack of spectrum options



Source: CBRS Alliance

Current Wireless Standards and Rulemaking Processes

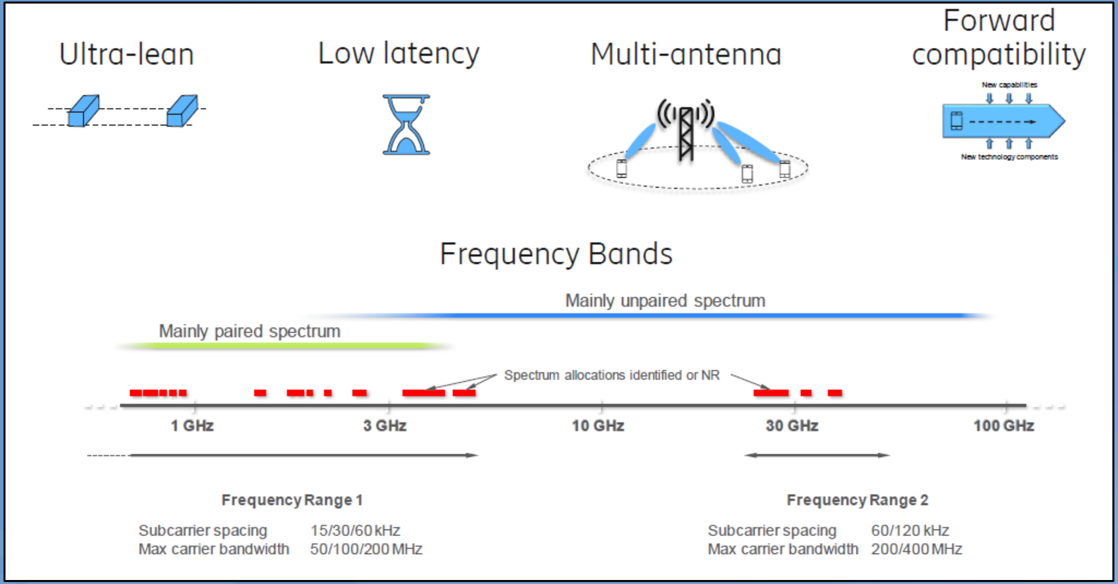
Wi-Fi 6 / 6e Use Cases and Benefits

- 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

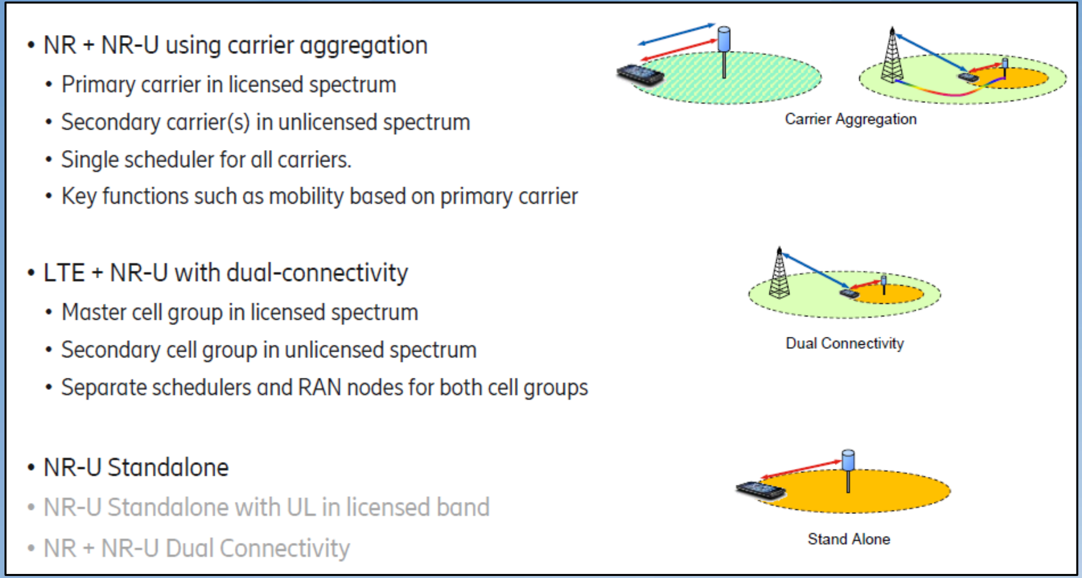
Wi-Fi CERTIFIED 6 feature	Benefit
Uplink and downlink Orthogonal Frequency Division Multiple Access (OFDMA)	Increases network efficiency by allowing simultaneous access for multiple devices Lowers latency. More deterministic. Ideal for low bandwidth applications
Multi-User Multiple Input Multiple Output (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

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:
  - Multi-Gigabit @ low latency and low power communication
    - Wireless AR/VR, wireless backhaul
  - 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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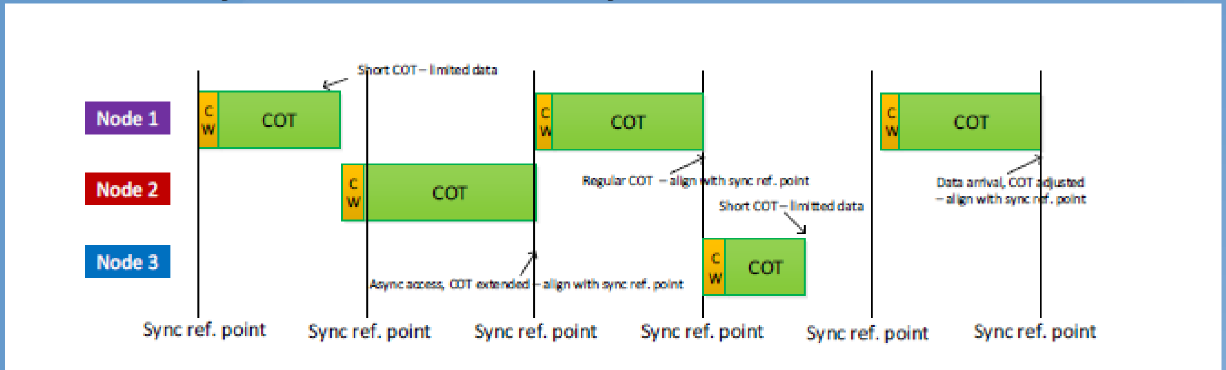
Current Database Sharing Technology Side-by-Side Technical Overview

	6 GHz U-NII Automated Frequency Coordination (AFC)	TV White Space Database (WSDB)	Citizens Broadband Radio Service Spectrum Access System (SAS)	So What?
Protected incumbents	• Fixed microwave links • Fixed-satellite earth stations • Mobile ENG & public safety • Radio astronomy	• Over-the-air TV receivers • Wireless microphones • WMTS and radio astronomy (in channel 37), public safety, others	• Federal users • Fixed-satellite earth stations • Grandfathered Part 90 devices	• Complex incumbent environment will likely require more complex sharing solutions
Key technical challenge(s)	Protect known fixed receivers & very small number of mobile receivers in U-NII-6 & U-NII-8 two sub-bands	Protect several fixed & mobile receivers	Protect mobile federal naval radars & limit aggregate interference to protected users	
Aggregate interference management	No (stateless); the entering node does not change the rights of future nodes	No (stateless); the entering node does not change the rights of future nodes	Yes (stateful); the entering node influences the rights of future nodes	• Stateless models are more simplistic but reduce control and ability to optimize
Peer Database synchronization	No *(incumbent content obtained from ULS and AFC Registrar)*	Yes *(incumbent content only; no RF state)*	Yes	• Peer database synchronization improves coordination, but adds complexity
Principal protection criteria	I/N[1] (dB)	Angular distance (KM @ ϑ) or I/N (dB)	Interference (dBm)	• No universal agreement on which interference method is best and will largely rely on incumbent variables
Admission control	Access Points only	Access points & clients	All BTS-CBSDs and CPE-CBSD with >23 dBm power	• Agreement on AP requirement, but not client devices • Control should be placed at the highest level possible
Master Geolocation accuracy requirement	Flexible based on geolocation uncertainty with a confidence level of 95% of the device capability	Flexible based on 95th %ile device capabilities	±50 meters horizontal and ±3 meters elevation	• Should be governed by risk to incumbents • May increase opportunity for efficiency, but adds costs and complexity
Network discovery by clients	client device will be required to send the probe request on the same frequency as the access point's transmission	Pre-association admission control (e.g., "enablement") required	Under continuous control of authorized CBSD	• Will be driven by incumbent requirements, whether multiple tiers of users will exist, and targeted use case
Max Power	36 dBm EIRP (Standard Power Aps under AFC control) 30 dBm EIRP (Low power indoor with no AFC reqmts)	Max EIRP is 36dBm (40dBm in isolated areas)	Max EIRP 30 dBm (indoor) Max EIRP 47 dBm (outdoor)	

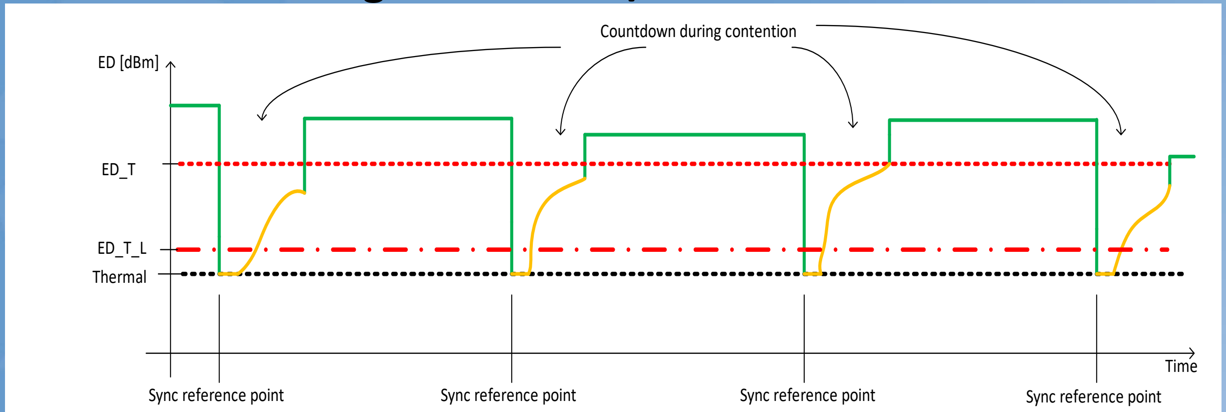
Advances in coexistence offers complementary and alternative sharing capabilities

Synchronized and Asynchronous Contention



Source: Qualcomm

Sensing of Licensed / Prioritized Users



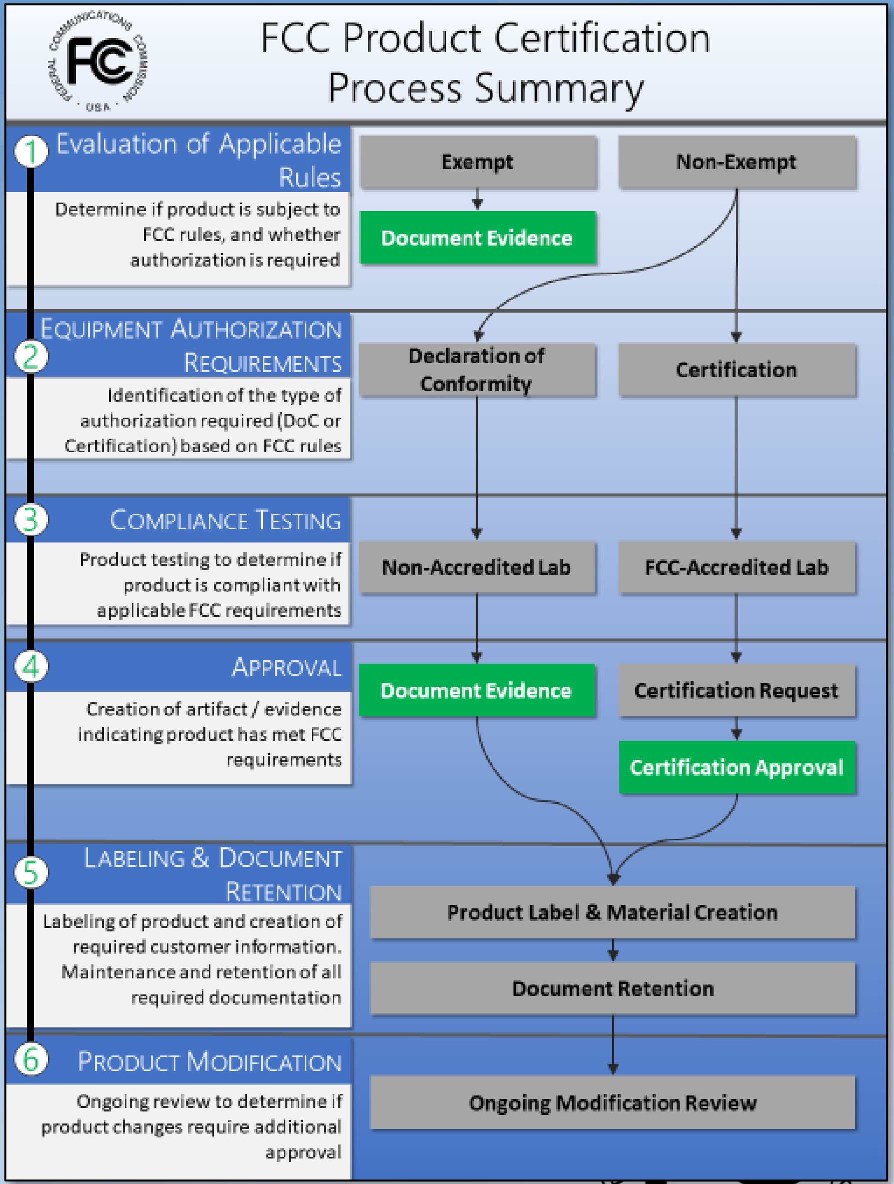
Source: Qualcomm

- As 3GPP and IEEE coexistence will continue to be needed, opportunities exist to improve performance in hybrid deployments
  - Boingo provided real world feedback about challenges deploying 3GPP radios on the same channels as Wi-Fi
- According to Qualcomm, time-based synchronization may improve detection of licensed operation in co-deployment scenarios
- While the technology may hold promise, the FCC is hesitant to adopt or mandate Qualcomm’s approach given the early development stage

FCC Rulemaking & Product Certification

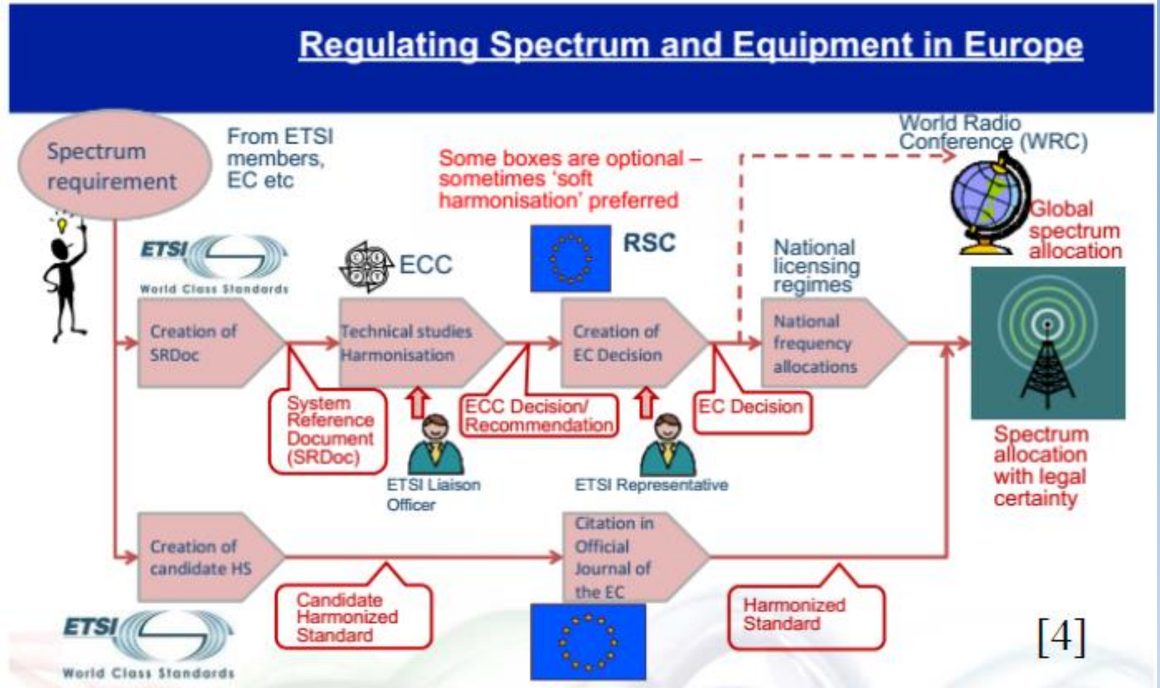
Centralized and predictable process

- In the US, the FCC has generally taken a "lighter touch" approach for rulemaking
  - Results in simpler technical rules
  - Allows for flexibility of use
  - Simplifies the modification process
  - Leans on industry and standards bodies for defining technical specifications
- RF-generating product certification follows a prescriptive process managed by the FCC as the central authority
  - Most products using unlicensed frequencies must be certified by the FCC



EU Rulemaking & Product Certification
Broader Rulemaking Scope, De-Centralized Certification

- In the EU, spectrum rules and product certifications are handled differently
- Generally, regulatory bodies allows manufacturers to self-attest as conforming to harmonized standards
- To accomplish this, **greater specificity is defined in regulations**



So What? So far, we've heard that US-based companies have benefited and tend to **prefer the FCC's light touch rulemaking approach** over the EU's use of harmonized standards.
However, shared bands may require a slightly higher degree of specification by regulators

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

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Speaker Notes – Full Year

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Presentation Summaries

Organization	Topic	Speaker	Summary
Qualcomm	Overview of Unlicensed Synchronization	Aleks Damnjanovic	• Synchronous contention in unlicensed bands can reduce access latency and improve fairness and spectral efficiency in multi-technology deployments • It is not necessary for all devices to conform to synchronous contention, but the more device do, the performance for all devices increasingly improves
CES Consumer Technology Association	Overview of 2015 TAC Unlicensed Study	Brian Markwalter	• Most 2015 recommendations were addressed to some extent • While CBRS appears is a major highlight since 2015, 60 GHz has not delivered on expectations
cisco	Broadband Access using License-Exempt Devices	Peter Ecclesine	• Standards rely heavily on international alignment to become successful • 5 GHz became mainstream only when phone manufactures started selling 5 GHz-compatible phones • Scanning patterns of weather radar make U-NII-2 unreliable for unlicensed use
Wi Fi Alliance	Wi-Fi 6 and Global Wi-Fi Regulation	Alex Roytblat and Mark Hung	• 802.11ax seeks to achieve real world gains: average 4x increase in throughput, reduced power consumption, better targeting of use cases • Key enabling technologies include: OFMDA, Target Wake Time, BSS Coloring, MU-MIMO, and Beamforming
boingo	Business Model for Unlicensed Spectrum	Derek Peterson	• Boingo was an early adopter of DAS deployments • Challenges with Wi-Fi and LAA co-deployments – technically co-exist but do not perform well on the same channel • 160 MHz channels in public locations underperformed when compared with 80 MHz channels due to congestion and interference

Presentation Summaries

Organization	Topic	Speaker	Summary
ERICSSON	ETSI TC BRAN and Harmonized Standards	Guido Hiertz	• Harmonized standards provide the linkage between industry standards and legislative rules (in this case, the EU) • Unlicensed product certification in the US differs from the EU – FCC certifies unlicensed devices whereas companies self attest compliance to harmonized standard in the EU • Detailed regulatory standards require similarly detailed compliance testing that covers all the details in the standards (as in the case with the EU harmonized standards)
WISPA	Rural Use of Unlicensed Spectrum	Claude Aiken	• WISPs are typically independent operators. Often small business owners, farmers, etc living in rural communities where traditional ISPs may not operate • WISPs operate on a range of spectrum, but favor unlicensed due to the prohibitive costs of acquiring licenses • WISPs face two major challenges: capital and spectrum (congestion when sharing CPE receiving on unlicensed with in home routers)
federated wireless	CBRS / SAS and Spectrum Sharing	Kurt Schaubach	• Dynamic Spectrum Access is a software-based approach for allocating spectrum rights on a dynamic basis using data feeds and sensing devices • CBRS SAS, while not perfect, is a leap from previous database-managed spectrum approaches (TVWS) • Federated believes software based sharing should be opened up on existing bands wherever possible. Recommendation is to have FCC improve SAS/sharing technology review process
BROADCOM	Importance of Portable Devices	Chris Szymanski	• Semiconductor manufacturers require significant investment to produce new products. Scale is essential to chip economics – typically look to 500M units to justify costs for new products, usually requiring a global marketplace • Portable Devices are expected to be a significant growth opportunity. Use cases include: wearables, short range hotspots, AR/VR, screen mirroring, healthcare devices • As is, 5 GHz U-NII-2C is not suitable for portable requirements. U-NII-2B should be made available for low power, and U-NII-2C low power use should be exempt from DFS requirements
Marcus Spectrum Solutions	History of Unlicensed Spectrum	Michael Marcus	• Michael spent 25 years with the FCC and was instrumental in the advancement of unlicensed spectrum • Technical rules should continue to be simple – light touch regulatory approach has benefited industry and spectrum resources. CBRS and DFS have suffered from overly burdensome rules • FCC should acquire the resources/funding to improve spectrum enforcement, planning, and research • CBRS rules are overly complex. The Navy should take on greater responsibility for sensing and alerting on their traffic

Presentation Summaries

Organization	Topic	Speaker	Summary

Microsoft	TV White Space	Michael Daum	• TVWS refers to the unused TV broadcast spectrum
			• TVWS internet uses a point-to-multipoint radio design - a radio can typically support up to 10 homes
			  • TVWS spectrum is ideal for wireless broadband due to its range and ability to penetrate obstructions
			  • Economics hinder broader adoption of TVWS technology
			• The Airband Initiative is a partner program where Microsoft helps rural ISPs raise funding and find TVWS technology solutions
			• Microsoft has three requests of the FCC: leverage terrain-based propagation models, relax emissions mask requirements (potentially via a new class of devices with lower requirements), and allow for directional antennas

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
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

USA

Presentation Summaries

Organization	Topic	Speaker	Summary
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. 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
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 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 based on proprietary tech, 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

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

Thank You!

FCC Technological Advisory Council Agenda – December 1, 2020

10am – 10:15am	Introduction and Opening Remarks
10:15am – 10:30am	Announcements and Roll Call
10:30am – 11am	FCC Chairman's Remarks WG Recommendations (5 minutes for each WG)
11am – 11:45am	Artificial Intelligence WG
11:45am – 12:30pm	Future of Unlicensed Operations WG
12:30pm – 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

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Federal Communications Commission Technological Advisory Council Meeting

December 1, 2020

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3pm	Adjourned

FCC TAC
5G RAN Technology Working Group
Final 2020 Report

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

FCC Liaisons: Bahman Badipour, Reza Biazaran, Bob Pavlak, Ken Baker, Kamran Etemad, Sean Yun, Charles Mathias, Monisha Ghosh, Michael Ha

Date: December 1, 2020

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

*SME participant

5G RAN Technology WG: 2020 Charter

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

1 1. What is the roadmap of RAN architecture evolution in 5G/6G radios and how does it compare to the previous generations?

2 2. How does the potentially disruptive network virtualization proposed by O-RAN affect the development of RF front-end and fronthaul technologies?

3 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

6 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?

7 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?

8 6. How can propagation modeling tools be better utilized to predict interference between systems?

5 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?

4 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.

X = Rough order of coverage in outline

Broad Areas:

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

Outline

Performed component & system analysis of 5G evolution

UE Modem/RF | RF Components | New 5G Fronthaul | Baseband Processing & vRAN

E2E RAN system-level analysis

Narrowed focus to areas of greatest impact on spectrum management

5G Evolution – Areas of greatest change & dynamics

Focus on Advanced Antenna Systems (AAS)

Developed recommendations on top spectrum/interference management topics

- Near-term practical best practices
- Equipment authorization
- Characterizing radiated emissions
- Transmitter identification
- Active interference management

15 SME talks under-pinning WG effort end-end

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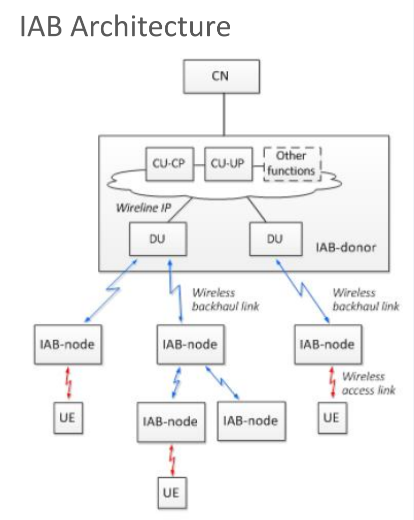
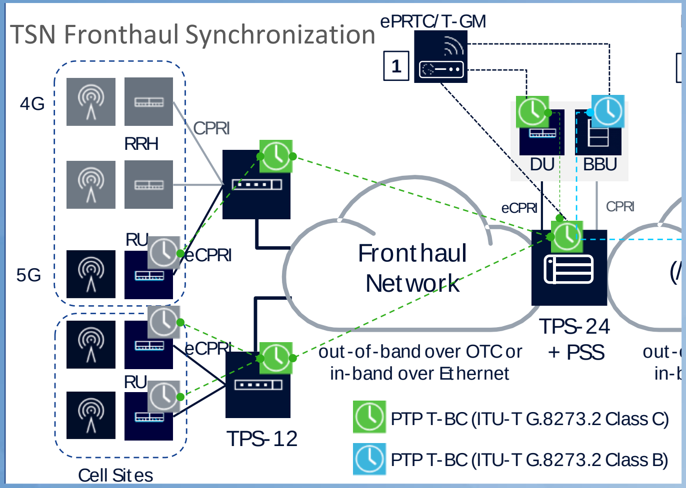
Speakers and Key Observations (Since Sept. TAC)

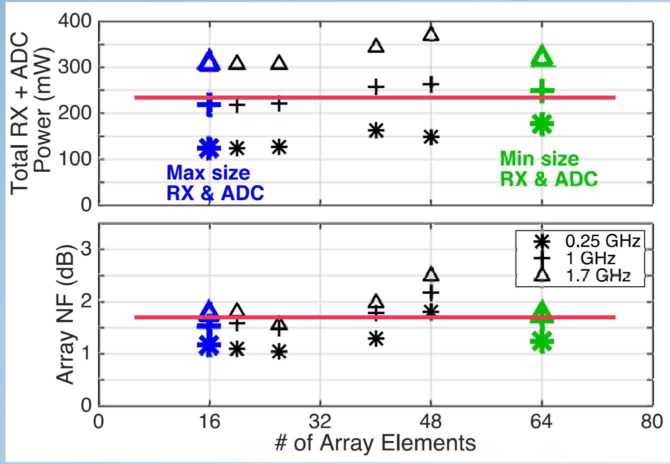
Topic	Speaker	Key Observations
5G X-Haul advances – Integrated Access & Backhaul (IAB)	Milap Majmundar	IAB (R16) for densification, range extension, and indoor coverage applications Designed to gracefully coexist w/fiber BH, existing CU/DU structure, R15 specs Dynamic L2 relaying routes around mmWave link degradations/blockages
5G X-Haul advances – TSN-Fronthaul/eCPRI	Shilpi Dave	eCPRI packet based fronthaul interface consistent with multiple RAN split pts Efficient CPRI/eCPRI switching w/TSN FH (IEEE 802.1CM) & RoE (IEEE 1914.3) IEEE 802.1Qbu Frame Preemption enables deterministic networking Very stringent synchronization required across TSN FH (ITU-T G.8273.2 Class C)
5G AAS BS power consumption	Greg Wright	Power/bit has declined over decades but array size & thruput now rising rapidly Research shows scalability (constant power across array sizes, & scaling digital functions with # of users) possible with system-level ecosystem optimization



Source: Milap Majmundar, AT&T Labs



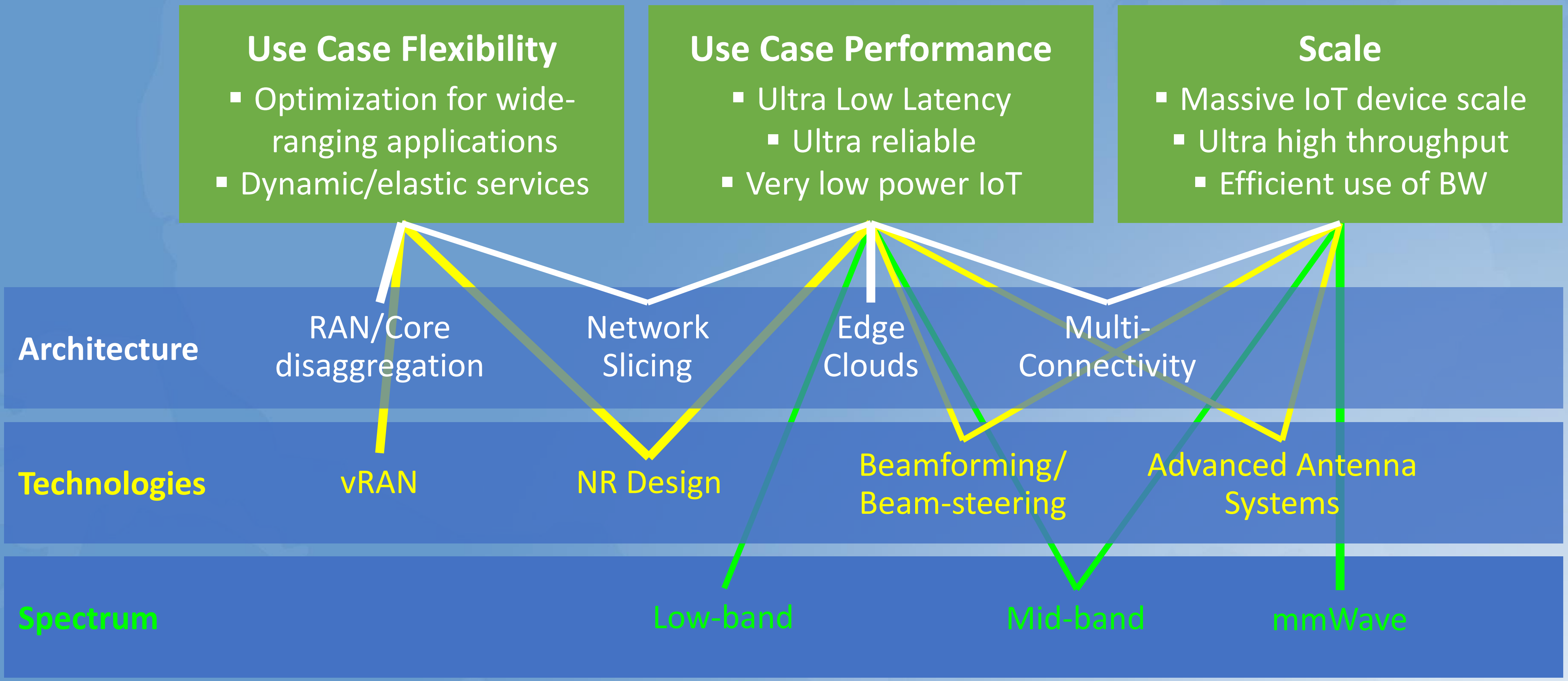
Source: Shilpi Dave, Nokia



Performance scaling of FADER IC Analog Radio

Source: Greg Wright, Nokia Bell Labs

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



End Goals

Enabling Advancements

5G RAN Evolution – Changes of Greatest Impact

- Huge advances in capacity, use case optimization, and deployment flexibility
- Enabled by a wide array of technological, architectural and spectrum innovations
- Many new degrees of freedom; only some impact spectrum management

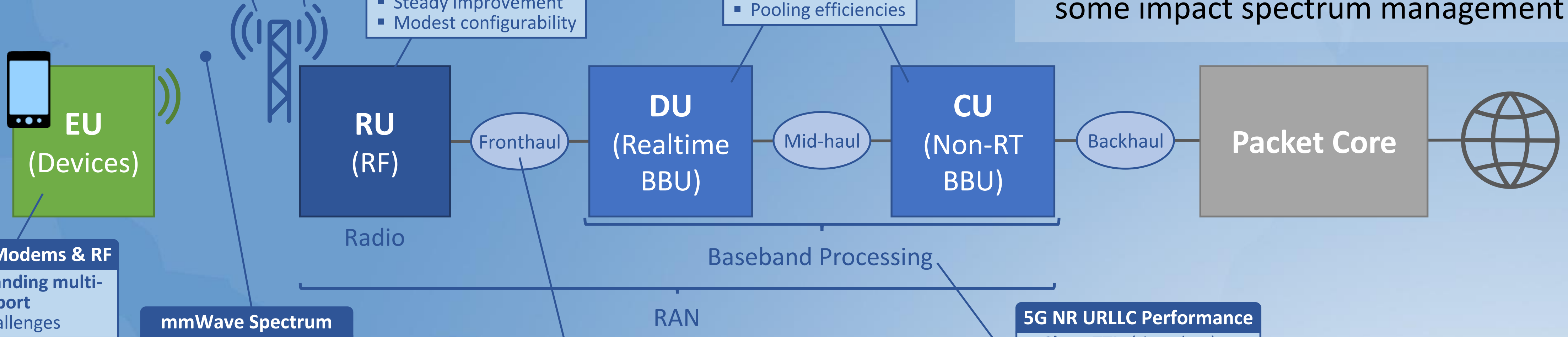
Integrated Access & Backhaul
- Wireless self-backhaul for hard-to-fiber sites
- Shifts RF environment dynamics

RAN Disaggregation
- **Centralization** efficiencies
- Facilitates slicing

Advanced Antenna Systems
- High gain **beamforming** & **beam steering**
- Key for mid/high band performance
- Introduces **dynamic RF environment**

Radio Components beyond AAS
- Steady improvement
- Modest configurability

Virtualized RAN
- **Resource flexibility**
- Facilitates slicing
- Pooling efficiencies



5G Device Modems & RF
- **Ever-expanding multi-band support**
- Power challenges

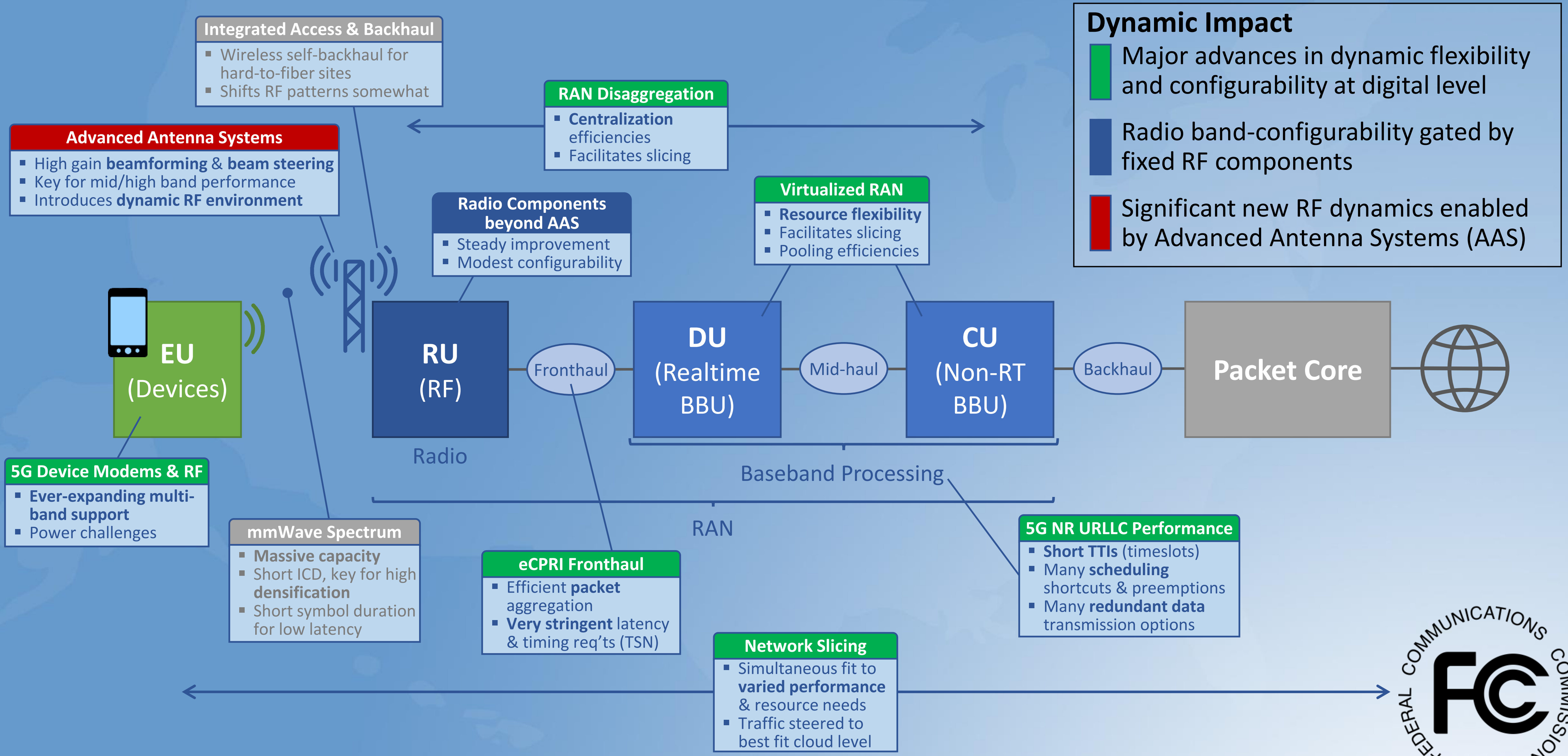
mmWave Spectrum
- **Massive capacity**
- Short ICD, key for high **densification**
- Short symbol duration for low latency

eCPRI Fronthaul
- Efficient **packet** aggregation
- **Very stringent** latency & timing req'ts (TSN)

5G NR URLLC Performance
- **Short TTIs** (timeslots)
- Many **scheduling** shortcuts & preemptions
- Many **redundant data** transmission options

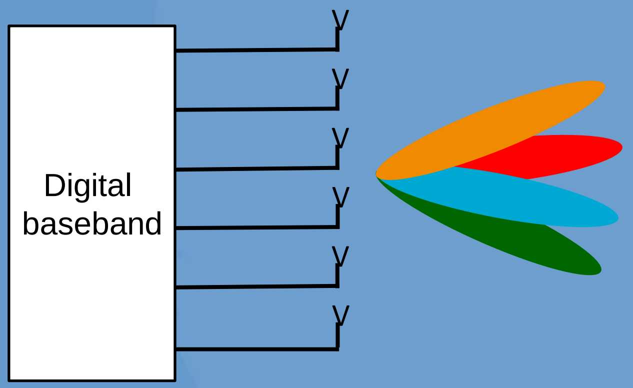
Network Slicing
- Simultaneous fit to **varied performance** & resource needs
- Traffic steered to best fit cloud level

5G RAN Evolution – Main New Areas of RAN Dynamics



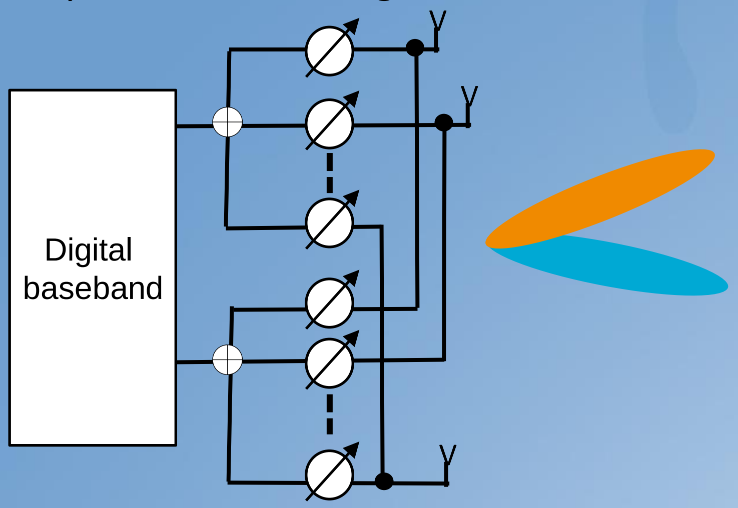
Beamforming/Beam-steering Variations

Digital beamforming



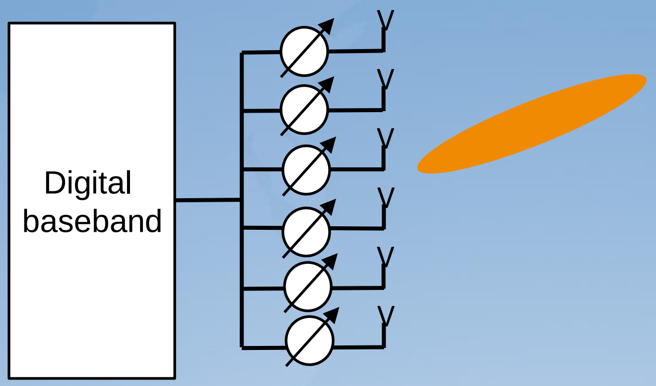
Full flexibility, multiple beams per time unit
Adaptable to multi-path and frequency-selective fading, e.g with eigen-beamforming

Hybrid beamforming



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

Analog beamforming/beam-steering



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

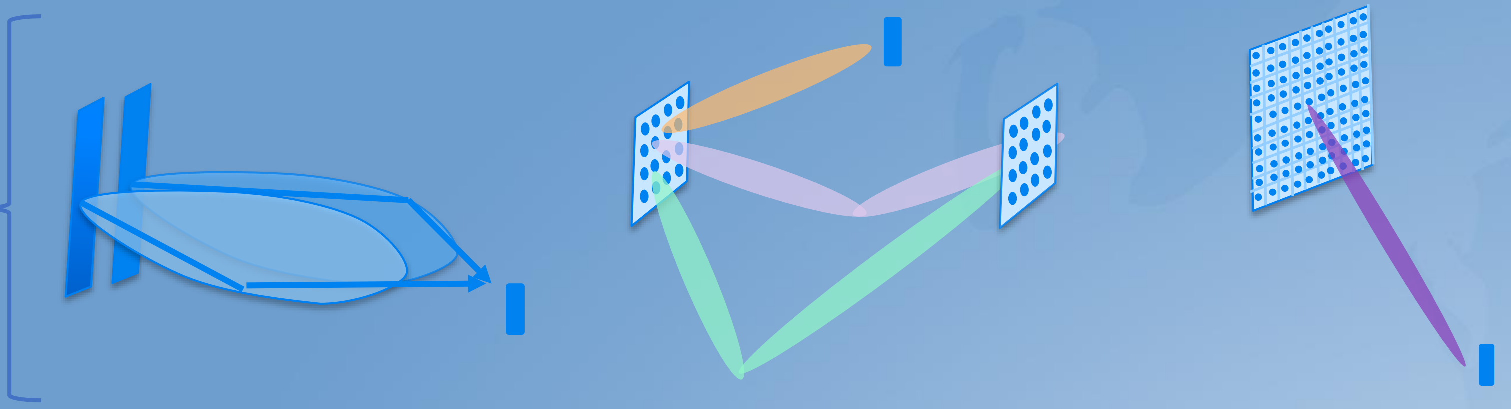
Performance/BW efficiency
Cost & Complexity

Pros & cons are very band-dependent

Simplicity & Economy
Power efficiency

MIMO/Beamforming Application to Different Bands

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



Attributes	Low bands < 2 GHz	Mid bands 2-6 GHz	High bands ≫ 6 GHz
Single antenna size/aperture	Large	Medium	Small
Channel propagation modes	Rich (esp. w/polarization)	Rich	Mainly one dominant mode
Primary applicable gain type	Diversity	Diversity & Array (trade off)	Array
Beamforming applicability	-	Digital or Hybrid	Analog

AAS focus

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 can increase base station power consumption

Main focus of the WG for recommendations, in line with strong interference management focus of charter

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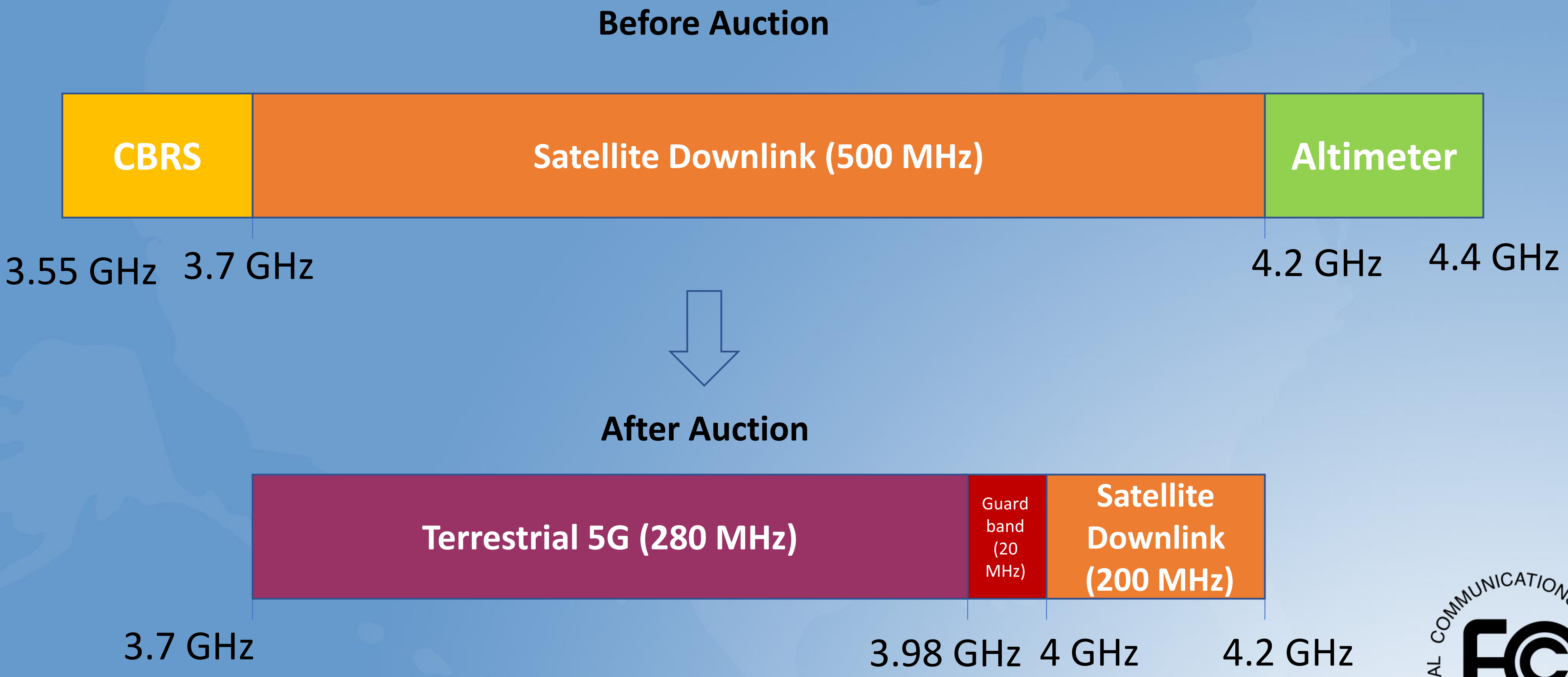
5G RAN Tech WG
Near-term interference/coexistence best practices SWG

Kumar Balachandran
Ahmad Armand
Kamran Etemad
Tom Sawanobori

C-Band multi-stakeholder group findings



C Band spectrum planning best practices

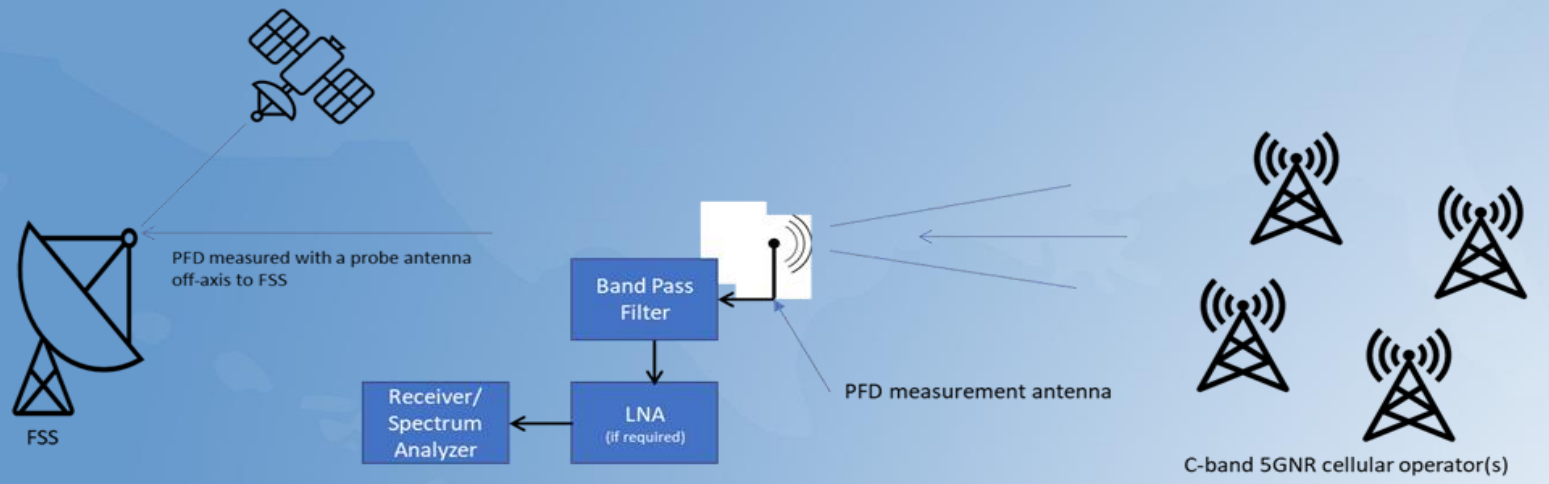
- New licensees
  - Incorporate FCC-mandated PFD limits (or equivalent calculated power spectral density thresholds) into network designs to adequately protect incumbent earth station receivers
    - Consider incumbent sites that may exceed PFD compliance for unwanted emissions with a free space propagation assumption and assuming worst case transmitter performance (e.g. -13 dBm/MHz)
      - Use realistic propagation models to predict interference impact of network deployments on incumbent locations
  - Consider using external transmitter filters to reduce OOBE and, subsequently, the allowable distance to incumbent receiver
- Incumbent operators
  - Provide best available deployment information for your typical deployment to new licensees
  - Ensure that compliant 5G-rejection filter is installed on each antenna
    - Consider 5G filters with performance better than minimally required
  - Develop and follow a process to resolve performance degradation at your sites that eliminates non-5G sources before identifying potential 5G sources of interference
    - If degradation likely to be 5G interferer(s), identify most likely sources of interference before contacting new licensee(s)

C Band spectrum interference mitigation best practices

- Potential for new licensees
  - Reducing base station power
  - Improving base station filter rejection
  - Reorienting base station antennas
  - Choice between fixed sector MIMO or 5G active antenna systems
    - Use active reconfiguration of coverage with beam nulling and other interference suppression techniques
  - Engineering with realistic path loss models incorporating terrain and clutter
- Potential for incumbent operators
  - Changing operating channel (if possible)
  - Shielding antenna
  - Improving link margin
  - Improving the 5G rejection filter
- Additional techniques for transportable sites
  - Vehicles may require specialized equipment to rapidly identify the cause/source
  - Adjusting the location of transportable sites to help reduce interference levels

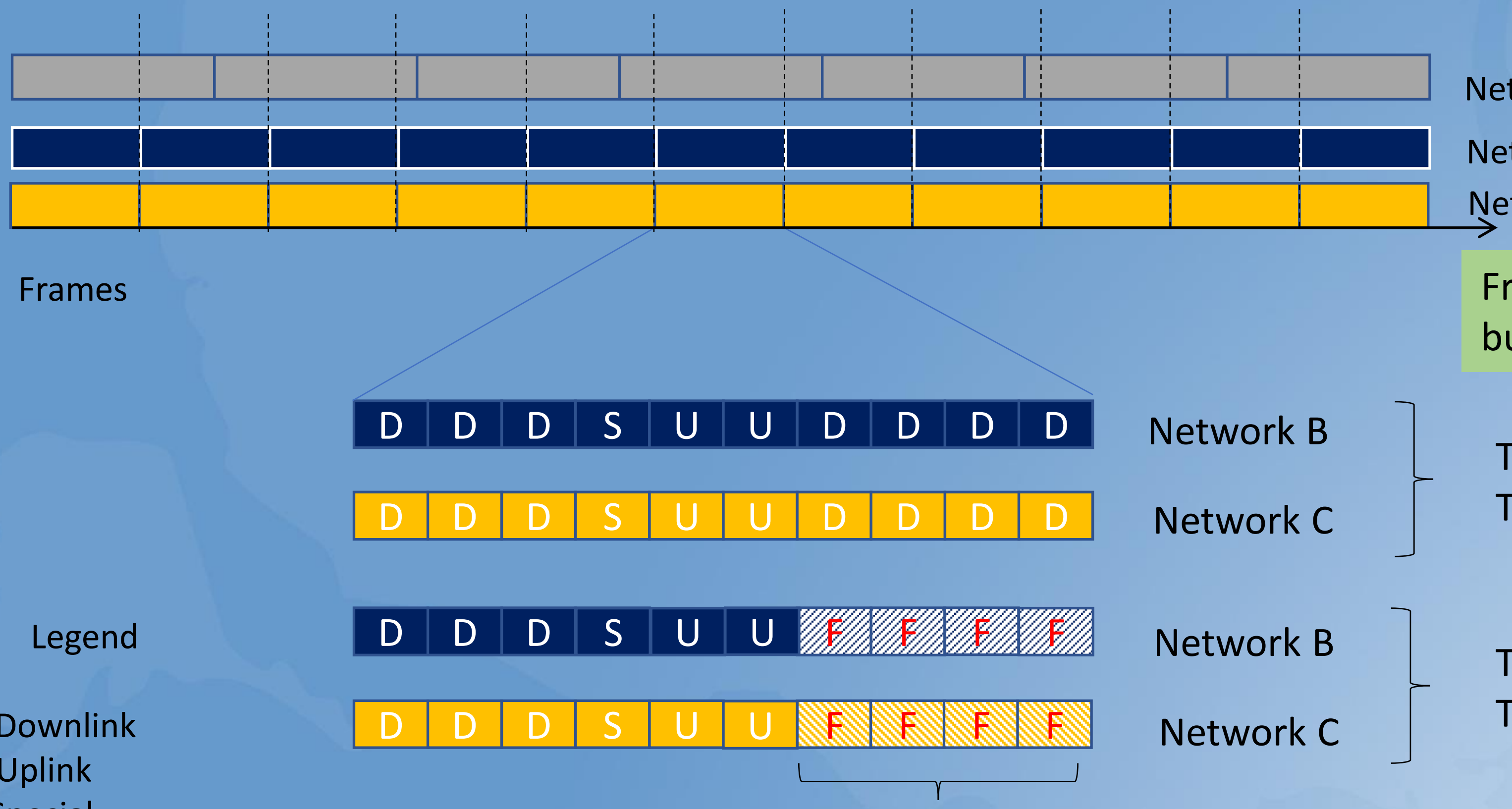
C Band spectrum interference measurement practices

- Perform Received Signal Strength Indication or "RSSI" measurement to assess impact of new licensees transmissions.
- Identify the strongest cell/beam contributors to enable licensee mitigation
  - In-band service measurements for each licensee utilizing a 5G-NR capable scanner to measure cell/beam-specific 5G-NR Synchronization Sub Block (SSB) Reference Signal Received Power ("RSRP").
  - Likely correlation between the cells with the strongest measured SSB RSRP and those with the largest contribution to the OOBE
- Assess PFD compliance
  - Estimate the aggregate, per licensee PFD through application of a transmitter signal emission mask.



Adjacent Band Coexistence using TDD synchronization

Full and Partially synchronized TDD



A and B Frame (Time and Phase) not Synchronized

B and C Frame (Time and Phase) Synchronized

Frame Time and Phase synchronization is necessary but not sufficient for Interference Mitigation.

TDD Frame Time and Phase synchronized
TDD Fully Synchronized Frame structure

TDD Frame Time and Phase synchronized
TDD Partially Synchronized Frame structure

Legend

D – Downlink
U – Uplink
S – Special
F – Flexible (D or U)

Flexible Slots:
Dynamic DL/UL Usage
More Susceptible to Interference

Example shows ~60% synchronization of subframes between Network B and C

Adjacent Band Coexistence Recommendations

- Maximize use of spectrum across adjacent bands
  - Most countries are planning spectrum allocations without guard bands
  - Without synchronization, modifying antenna orientations or planning for separation distance may be needed
- Tradeoffs

TDD synchronization	Benefits	Cons	Comments
Full synchronization	Maximizes spectral efficiency. Allows close base station placements.	Minimizes flexibility for different/evolving use cases.	Works best if adjacent operators have similar use cases (e.g. enhanced MBB)
Semi-synchronization	Partial synchronization provides some interference mitigation	Requires some geographical separation to maintain good performance.	Adjacent operators need to coordinate to mitigate interference.
Unsynchronized	Flexibility in use cases	Requires large geographical separation or outdoor/indoor separation (e.g. indoor factory).	Unlikely, but possible if one operator has unique use case (e.g. video uploads).

- Findings and draft recommendations
  - Partial TDD synchronization guidelines (for future bands beyond C Band) that consider all the tradeoffs and global comparisons, along with 4G LTE and 5G technologies, offer an opportunity for coordination. To assess its effectiveness a public comment process may be useful.

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5G RAN Tech WG
RF Measurement Challenges & Equipment Authorization Impacts SWG

Greg Lapin
Khurram Muhammad
Martin Doczkat
Robert Pavlak

Transmitter Testing Background

1) Mainly, FCC AAS regulations base system performance on EIRP (e.g. § 30.202)
2) Use of EIRP may be limited in terms of its application to more modern transmitter and antenna systems — in the past it was easier to measure conducted power and then factor in a fixed antenna gain to obtain the maximum power transmitted.
3) Maximum power transmitted is used to estimate the maximum field strength at a given distance that potentially could cause harmful interference.
4) Regulations were written to limit maximum power transmitted (EIRP) in order to provide a simple means of controlling the possibility of harmful interference.

AAS Testing Today

1) Today, many Advanced Antenna Systems have power amplifiers embedded in the antenna arrays, and thus there is no way to measure conducted power. The transmitter power limits in § 30.202 would be difficult to confirm.
2) To perform testing on AAS today, a calibrated field strength is measured and then EIRP is calculated back from there.
3) Energy emitting from an antenna in a given direction, as well as transmitter power and other RF characteristics are much more dynamic. This is particularly true of OOBE and other spurious emissions.
4) The goal of regulatory limits remains the control of the amount of signal power in space that could cause harmful interference.

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AAS Equipment Authorization Recommendations

1) FCC Regulations should be examined in regard to adding field strength limits for certification of Advanced Antenna Systems. Systems could be tested with either field strength or EIRP, however there should be equivalency for mobile and other services.
2) No changes are needed to existing FCC testing protocols. After reviewing current FCC testing documents (KDB 842590), 3GPP Testing Specifications (38.141-1,-2), ANSI Testing Standard (C63.26), and the CTIA Test Plan for Wireless Device Over-the-Air Performance, we have concluded that, based on existing FCC regulations, current FCC antenna testing protocols correctly specify testing requirements for Advanced Antenna Systems and do not require more testing than is necessary, given the FCC's light touch regulatory approach.

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AAS Testing Recommendations For Future Study

1) **Measurement of power flux densities over a probabilistic 3D pattern, across multiple frequencies, could allow for additional opportunities to improve spectrum efficiency.** This would entail more involved antenna testing procedures, which would have to be developed. The costs and benefits of this approach must be weighed. Availability of these data in a frequency sharing database could allow for more dense spacing of transmitters and feed into efforts to address active interference management (see recommendations in that later section).
2) **For user equipment, explore and evaluate the impact of power control on out-of-band emissions.** It has been shown that under the highest power settings many handsets exhibit excessive out-of-band emissions due to nonlinearities in the amplifiers. At lower power settings the out-of-band emissions are decreased much more than would be attributable to the decrease in power level. However, current evaluations are made at the worst case, highest power levels, which may overstate the out-of-band behavior of the device.

5G RAN Tech WG
Active Interference Management SWG

Kumar Balachandran
Ahmad Armand
Kamran Etemad
Kevin Sparks

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Addressing Interference Management in Dynamic RF Environments

Dynamic nature of AAS-based RAN systems (beam forming, beam steering) present key challenges:

- Measurement of AAS radiated emissions, and their impact on interference
- Identifying widely varying interference sources
- Mitigating interference without impairing the performance effectiveness of AAS systems

WG investigated the following approaches to address these challenges:

- Use of Total Radiated Power (TRP) in place of conducted power for AAS RAN systems
- Potential for new Tx identification schemes
- Leveraging new tools and technologies for active interference management

Summary Recommendations on Evaluating the Radiated Emissions

- **For Active Antenna Systems** (AAS)
  - **Integrated amplifiers** make conducted power measurements difficult
  - **Total radiated power** (TRP) is accepted as an alternative to EIRP for equipment certification
    - Suitable for AAS antennas in mid- and high-bands
    - Conducted emissions still applicable for traditional sectorized/fixed antenna systems
  - Dynamic beamforming make use EIRP based measures less applicable
  - Studies are needed on optional use for AAS of **an <u>averaged</u> radiated measurements for interference susceptibility**
    - Coverage and compatibility analysis for in-band coverage planning and spectrum sharing, and out-of-band protection

- **TAC recommends multi-stakeholder studies** on application of <u>properly averaged</u> radiated power measurements for coverage/compatibility analysis
  - Does TRP offer adequate representation of average radiated power in-band and out-of-band?
  - TRP represents a spatial average of radiated power while instantaneous power can reach the level of EIRP
    - Victim bandwidth dependencies need consideration
    - Are spatially averaged assumptions representative of the interference impact on compatibility analysis?
      - Other licensees in adjacent channels or across service boundaries
      - Other services sharing spectrum in-band or out-of-band
    - What are the effects of power amplifier non-linearities and digital-pre-distortion on average radiated out-of-channel emissions?

* Effective Isotropic Radiated Power

Transmission Identification – Summary & Recommendation

- In many sharing and coexistence scenarios identifying the type and location of interference sources can be an essential part of effective mitigation
- Two approaches to transmitter identification were considered: (1) RF fingerprinting and (2) Tx Identifiers

1) RF fingerprinting involves victim system RF monitoring/reporting with centralized AI/ML RF signature analytics to identify interfering Tx
   - Benefits include applicability to existing Tx systems, and potentially less impact to Rx systems for monitoring
   - Challenge is deterministic identification may not be reliable in some use cases.
2) A generic broadcast transmitter identifier may further facilitate the identification of type and location of interference sources
   - If used for inter-system interference, the Tx ID would need to be simply readable without full decoding of the TX signal
   - Benefits include simplicity and reliability, and challenge may be industry adoption and standardization.

- Additional study is needed to assess the feasibility and effectiveness of both and hybrid approaches

➢ **Recommendation:** Promote a feasibility study - working with industry, SDOs, academia and federal agencies as needed - on effective methods of identifying transmitters for interference mitigation purposes

Active Interference Management

- Along with new active antenna challenges, the 5G Era also brings many new advanced tools and technologies to help address those challenges
  - New 5G NR remote interference management (RIM) features
- The WG focused specifically on future forms of inter-system Active Interference Management as arguably the area of greatest unmet potential
- Our working definition of Active Interference Management (AIM) is: "*Feedback from/about an interference victim that goes back to the interferer in order to mitigate the interference*"
- WG concluded that potential AIM use cases for the foreseeable future divide primarily between:

a) short timescale closed loop mitigations adapted from existing intra-system interference mechanisms

b) Long timescale/offline accurate predictive interference avoidance

Enabling future forms of Active Interference Management

NG Tools/Technologies to Apply

Adapted closed loop mitigations

- New-in-5G remote interference management tools
- Inter-system SON
- Pervasive sensing by interferer, victim or third party (network of sensors)
- Tx unique identifiers
- Intermediating information aggregation/relay/clearinghouse functions
- Crowdsourced propagation data
- AI/ML

Predictive interference avoidance

Potential Evolution Path of Active Interference Management

<u>Short timescale</u> (near RT)

Near-Realtime Closed-Loop Interference Mitigation
- BS self-sensing
- Victim-sensing involving

Propagation data collection & aggregation

<u>Longer timescale</u> (non-RT)

Continuously Refined Data-Driven Propagation Models
- Predictive interference avoidance
- Efficient manual mitigation/remediation

Long-term potential to combine both

Closed-Loop Leveraging Fine-Grain Propagation Models
- Auto mitigation negotiation
- Advanced spectrum sharing

Mid-term → Future → Far Future

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Tools & technologies for Short Timescale Closed Loop Mitigation/Avoidance

Intra-system Technology Enablers

- Near Real-time Channel Sensing/Measurements:
  - Downlink/Uplink measurement by BSs
  - DL/UL/Side-link measurement by UE/MSs
- Near Real-time Actions:
  - By network, based on BS measurement
  - By network, based on UE measurement report
  - By UE, based on UE measurement and network guidance
  - May involve lowering power, down-tilting, changing the TDD (DL/GP/UL) resources

Closed Loop Management using Scheduling/RRM and Self Organizing Network (SON) Functions.

Mapping to Inter-system

- Intra-system supported in 3GPP std. but limited adoption in early products
  - BS meas./sensing: RIM/NR-U
  - MS meas./sensing: RRM/CLI/NR-U/V2X
- Needs expansion to Inter-System and Inter-RAT:
  - Tech neutral channel sensing and measurement. Example: RSSI, Channel Busy Ratio, Duty Cycle, etc.
  - May consider transmitter identifiers for high power nodes. May need standardization.

Inter-system closed loops have longer action time due to coordination/communication delays.

Potential Applications/Benefits

Applications:

- Maximum and more opportunistic spectrum reuse with effective interference management across different links:
  - Dynamic TDD
  - V2X
  - Unlicensed
  - Integrated Backhaul/Relay
  - Broadcast/Multicast

Benefit:

- Data Driven, Near Real Time
- Locally Relevant
- Network controlled and UE assisted

RRM: Radio Resource management
NR-U: 5G New Radio in Unlicensed Band
CLI: Cross Link Interference management
RIM: Remote Interference Management
DL/GP/UL: Downlink/Guard Period/Uplink

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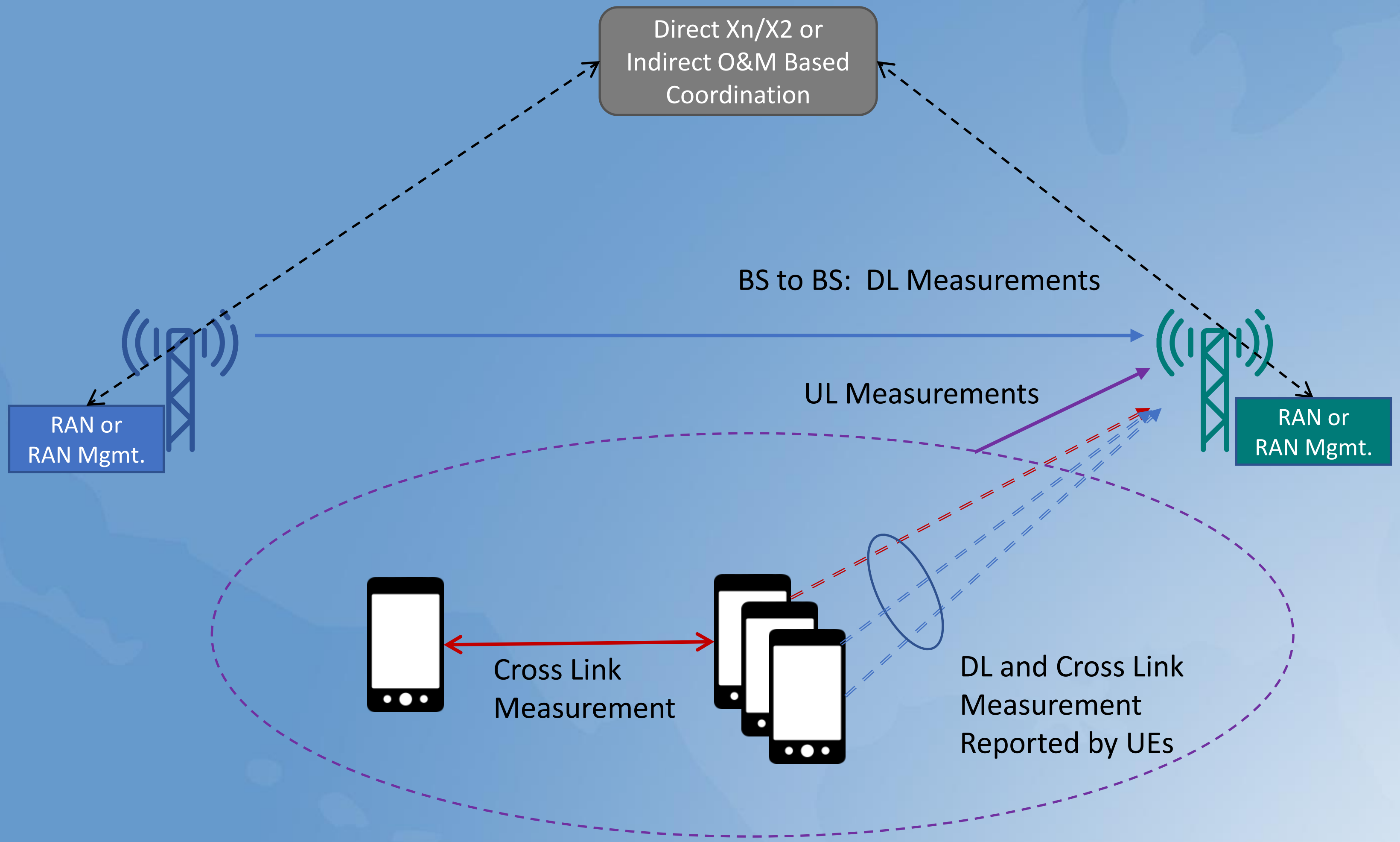
Near Real-time Channel Sensing/Measurements



Tools & technologies for Longer Timescale Predictive Interference Avoidance

Intra-system Technology Enablers

- Use of Long-term Channel Sensing and Measurement
  - Logged Measurements time and location stamped over a period of time
  - Data aggregation and Crowdsourcing
- Learning and Modelling
  - Path loss Modeling
  - Modeling Traffic/Loading Patterns
  - Modeling Environmental Effects
- Predictive Interference Avoidance

Mapping to Inter-system

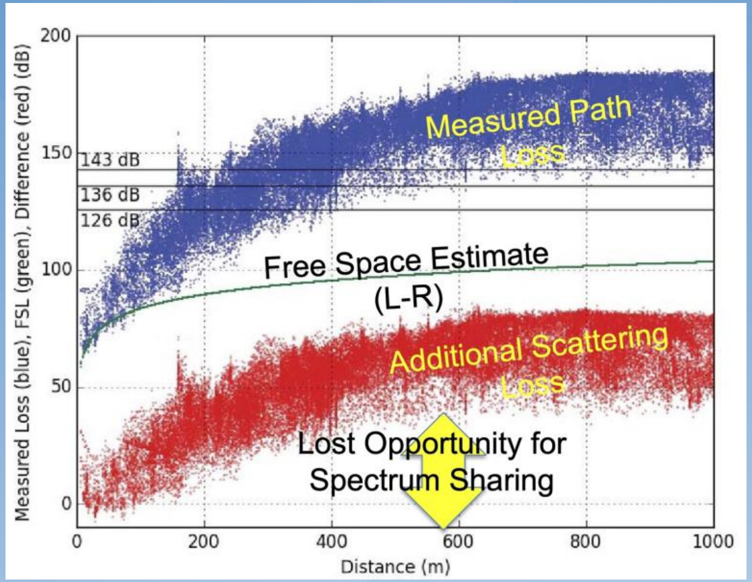
- Inter-system supported in 3GPP standard but limited adoption in early products
  - Limited use in Intra-system O&M/SON system using proprietary solution.
  - Measurements can include RSSI/RSRP, SINR, throughput and other QoS Metrics
- Needs Simple Expansion to Inter-System and Inter-RAT:
  - Tech neutral channel sensing and measurement
  - Example: RSSI, Channel Busy Ratio, Duty Cycle, etc.
- Path loss modeling can be applied to inter-system and adjacent band interference prediction and avoidance

Potential Applications/Benefits

- Path loss and Channel models may be shared and reused across different systems
  - Data sharing may happen initially with lower resolution data
- Intersystem crowdsourcing of data can enhance and enrich models for more realistic interference prediction and avoidance
- Improved models can be used to avoid overprotection:
  - Coordination/Protection Zones
  - Synchronization Zones
  - GuardBands

The Opportunity of Data-Driven Propagation Models

- Existing models rely primarily on terrain modeling
  - Do not account for environment-specific clutter, multi-path propagation, diffraction, etc.
  - Early Google path loss experiments show large deviation from free space estimates
- Propagation changes over time and atmospheric conditions
  - Tropospheric ducting and rain scatter can increase propagation distance
- Overly simple models can cause:
  - Coverage and capacity requirements: inaccurate investment projections when used to determine infrastructure
  - For spectrum sharing: Loss of spectrum opportunities



Source: Preston Marshall, Google

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

- New tools and approaches can enable data-driven propagation models
  - AI/ML analytics
  - Granular geodata
  - Crowdsourced propagation data

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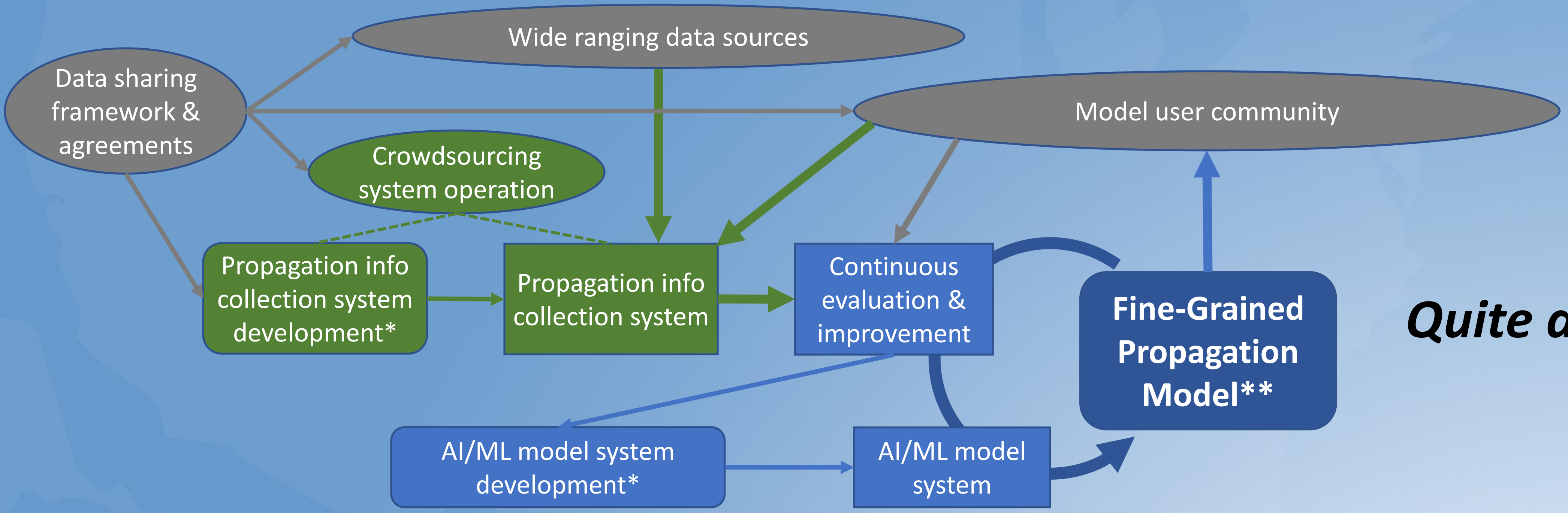
What would it take to create a Fine-Grained Propagation Model?



Quite a lot.

*Many testing and trials stages not shown explicitly
** Model localization would likely start with metro level granularity; subsequent iterations could drive toward finer granularity

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Summary Recommendations on Active Interference Management

- Many current methods of *intra-system* active interference management may be **extensible to *inter-system***
  - Measurement parameters will need to be generalized/genericized to work across different radio systems
  - Intermediate coordination functions may be needed for interference-related data exchange between un-like systems
  - Such a system could also serve as a platform for collecting and aggregating measured propagation data over time

➢ Recommendation: Form a multi-stakeholder expert technical group to study **inter-system active interference management** potential in detail

---

- A longer-term ambition would be to develop **field data-driven localized propagation models**
  - Combining crowdsourced propagation data with AI/ML analytics to better predict and avoid interference
  - Accurate location-specific models could also improve spectrum utilization by avoiding overly conservative constraints
  - Building such models would take considerable resources and organization over an extended period of time
  - If successful for predictive purposes, such models might ultimately be utilized in closed loop mitigation

➢ Recommendation: Encourage and build, via FCC fora or similar, broad industry interest and engagement in **research programs pursuing data-driven propagation modeling**
  - Including NSF (funding, leadership), NIST, NTIA/ITS, academia and industrial research

Recommendations Summary

Near-term practical best practices	▪ Partial **TDD synchronization guidelines** (for future bands beyond C Band) that consider all the tradeoffs and global comparisons, applicable to 4G LTE and 5G technologies, offer an opportunity for coordination
Equipment authorization	▪ FCC Regulations should be examined in regard to adding **field strength limits** for certification of Advanced Antenna Systems, as conventional conducted power measurements not possible with AAS ▪ Areas for future study: (1) practicality of **3D probabilistic power flux** characterization to improve sharing, and (2) evaluation of the **impact of power control on out-of-band emissions**
Characterizing radiated emissions	▪ Initiate multi-stakeholder studies on application of **properly averaged radiated power** measurements for coverage/compatibility analysis purposes, considering the dynamics of AAS RF transmissions
Transmitter identification	▪ Promote a feasibility study, working with industry and standards fora, on **effective methods of identifying transmitters** (including RF fingerprinting and explicit Tx identifiers) for interference mitigation purposes
Active interference management	▪ Form multi-stakeholder expert technical group to study in detail the potential for generalization of intra-system mechanisms to **inter-system active interference management** ▪ Encourage and build, via FCC fora or similar, industry interest and engagement in research programs pursuing more accurate **data-driven localized propagation modeling**

Thank You

FCC Technological Advisory Council Agenda – December 1, 2020

10am – 10:15am	Introduction and Opening Remarks
10:15am – 10:30am	Announcements and Roll Call
10:30am – 11am	FCC Chairman's Remarks WG Recommendations (5 minutes for each WG)
11am – 11:45am	Artificial Intelligence WG
11:45am – 12:30pm	Future of Unlicensed Operations WG
12:30pm – 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
5G/IoT/O-RAN Working Group

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

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

Date: December 1, 2020

Outline for FCC TAC Formal Readout December 1, 2020

- WG participants
- Charter
- Recommendations summary
- Topics and invited SMEs overview - 4^{th} qtr
- Standards & deployment updates
- Key observations
- Final recommendations
- 2021 topics

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

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5G/IoT/Open RAN Charter 2020

Open RAN

- Industry developments and overview
- Challenges and roadblocks
- Adoption and scalability
- Multi-vendor support in disaggregation
- Testing
- Evolution

6G

- Technology trends, planning & obstacles
- FCC engagement opportunity

IoT

- Is dedicated or shared spectrum needed to support industrial IoT applications
- IoT verticals and service requirements

Other

- Spectrum sharing- future needs, opportunities and frameworks
- 5G security, reliability and resiliency

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Recommendations/Advisements

- **O-RAN**
  - FCC to support MV interoperability, plugfests
  - Encourage acceleration of ORAN adoption

- **Security**
  - Spoofing, interference are real concerns
  - System supply chain, MV systems
  - Network reliability, resilience- area to monitor

- **6G**
  - Challenges: lack of fiber for x-haul, power reliability
  - Architecture changes: Mesh, evolved IAB*
  - Create US roadmap- partner with industry
  - Readiness of THz is uncertain- support research

- **Spectrum Sharing**
  - Hi-level framework: guidelines, rules, and goals,
  - Sharing is dependent on the spectrum band; incumbents, etc
  - Interference; need to quantify, measure & enforce
  - 2021: Formal FCC TAC WG for spectrum sharing

- **IIoT**
  - IoT and enterprise use cases are quickly emerging
  - Demands vary widely on QoS/determinism
  - Locally licensed spectrum desired to provide necessary determinism, control, and compete with worldwide options (e.g. BNetzA)
  - Both mid-band and mmWave are suitable
    - Facilitates spectrum re-use

*IAB- Integrated Access and Backhaul

Working Group SMEs 4th Qtr

5G/IoT/OpenRAN Invited Speakers 4th Quarter

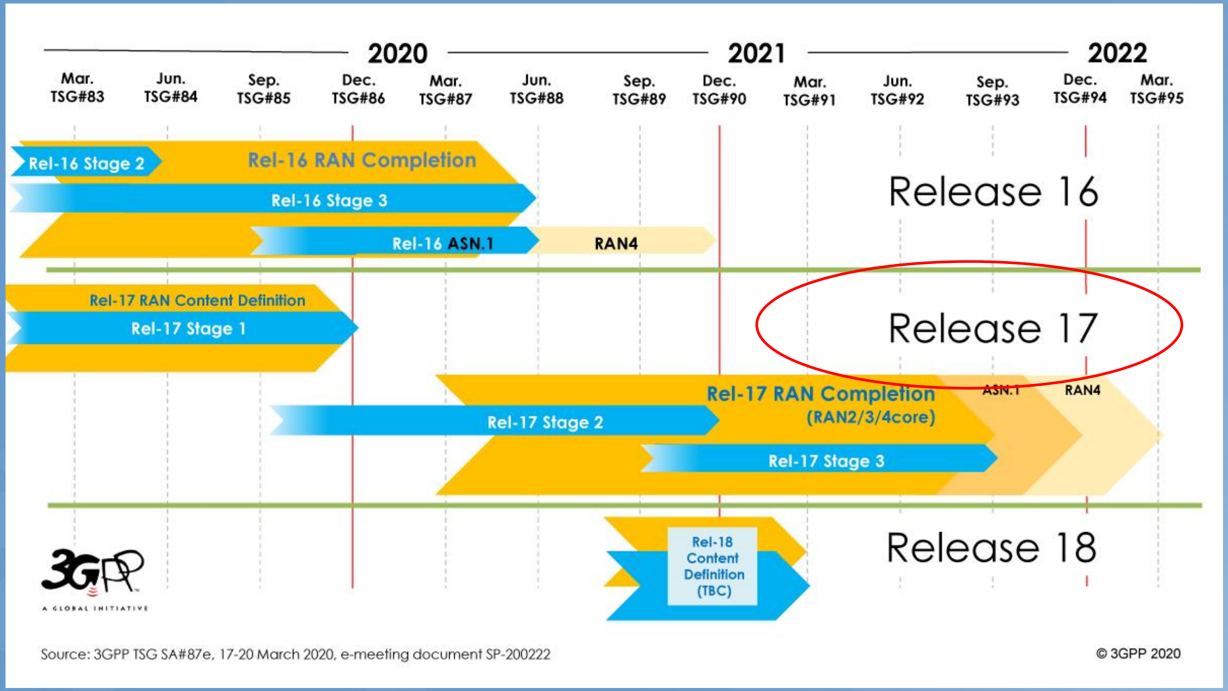
Organization	Topic	Speaker	Summary
EIRP Safety	EIRP, Harmful emissions	Greg Lapin 9/24	• Over 70 years of formal RF safety study, more than 1500 studies referenced • mmWave: IEEE and ICNIRP standards referenced over 50 mmWave studies • FCC regulations derived from scientific standards, advice from expert agencies
QUALCOMM	5G Security-CSRIC report	Dr. Farrokh Khatibi 10/8	• CSRIC VII WG2&3 published 2 reports on the security of 3GPP NSA & SA arch’s • The WGs are analyzing optional security features of 3GPP TS 23.401 (for NSA) & 3GPP TS 23.501 (SA) to ensure security & interoperability in NA 5G systems
PAWR Project Office	Open, programmable 5G architecture	Abhimanyu Gosain (NE U) 10/8	• Research proposal and development related to “white-box” radio • Open Air Interface: Focus on creating a modular end-to-end architecture • Leverage PAWR platforms, shorten design cycles and related implementation
SAMSUNG	6G proposed capabilities	Jeongho Jeon 10/15	• While 5G was defined with “massive”, 6G will push capabilities to “Extreme” • Disaggregation and virtualization will continue. SW provides focus on services • 6G planning well underway worldwide, new industry organizations forming
QUALCOMM ERICSSON	6G conference update	[Via] Brian Daly 10/22	• Longer term R&D focusing on advancing 5G Rel 18/19/20+ and 6G • Machine learning across 5G evolution and new disruptive 6G approaches to dynamically optimize wireless system performance and efficiency • Use case & Technology case scenarios enabled by the network platform • 6G Technology Journeys/Limitless connectivity Journey

5G/IoT/OpenRAN Invited Speakers 4th Quarter

Organization	Topic	Speaker	Summary
	Transportation : Autonomous vehicles	Sierhuis Maarten 10/29	• Autonomous transportation requires very high determinism, edge compute • Human safety is the strictest use case related to network needs • AI systems may require a human interface to be effective, AI gets confused
	New IP	H. Badran, B. Brungard, V. Cerf, M. Nawrocki, C. Sharp 11/5	• China is promoting its "New IP" proposal in ITU → IMT2030 • The existing Internet has scaled and evolved to meet all needs, will continue • "New IP" is more about control/leadership, vs. solving any real need
	Next G Alliance	Mike Nawrocki 11/12	• Launched 4Q20 as private sector initiative to drive North American leadership • Opportunity to engage government on 6G research priorities and actions • Collaboration across industry and academia on national 6G roadmap

Standards, Consortia Updates

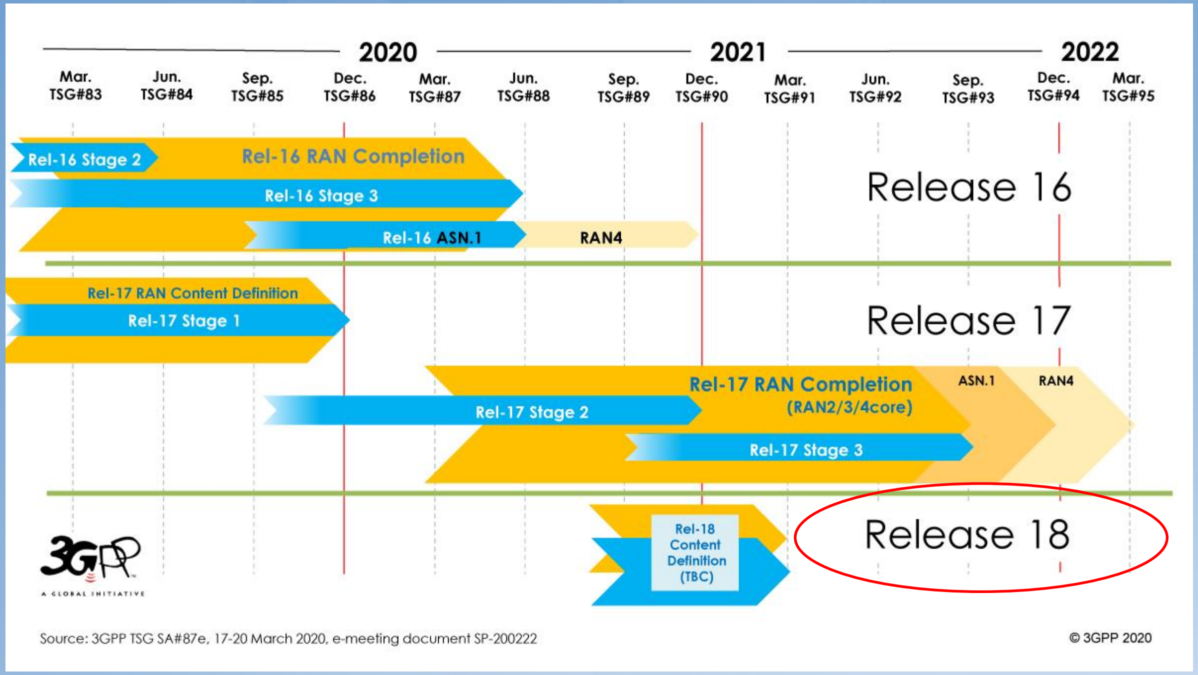
3GPP



- Firm decision on Release 17 delay in December plenary meeting
- First half of 2021 meetings will be e-Meetings
  - Hoping that the next three months will bring clarity as to whether 3GPP can start to plan for getting back to face-to-face meetings
- If e-meetings go beyond June, the delay to Release 17 could be greater than the six months currently being projected

3GPP Release 18

- With R17 timelines slipping because of CVOID 19 situation, the completion timeline for R18 stage 1 work related content remains unclear
- Work on R18 is ongoing at requirements (stage 1) level
  - So far fourteen studies have been agreed upon, e.g.:
    - Enhanced Access to and Support of Network Slice
    - 5G Timing Resiliency System
    - Study on AI/ML Model Transfer in 5GS
    - Vehicle Mounted Relays
    - 5G Smart Energy and Infrastructure
    - Enhancements for Residential 5G
    - Personal IoT Networks
    - Study on 5G Networks Providing Access to Localized Services
    - Evolution of IMS multimedia telephony service
- While stage 1 for R18 is in principle accepting new proposals, the currently ‘agreed’ list is quite full in terms of availability of time.
- Additional R18 topics will be added in 2021 when stage 2 work starts and as Radio Working Groups start discussing content

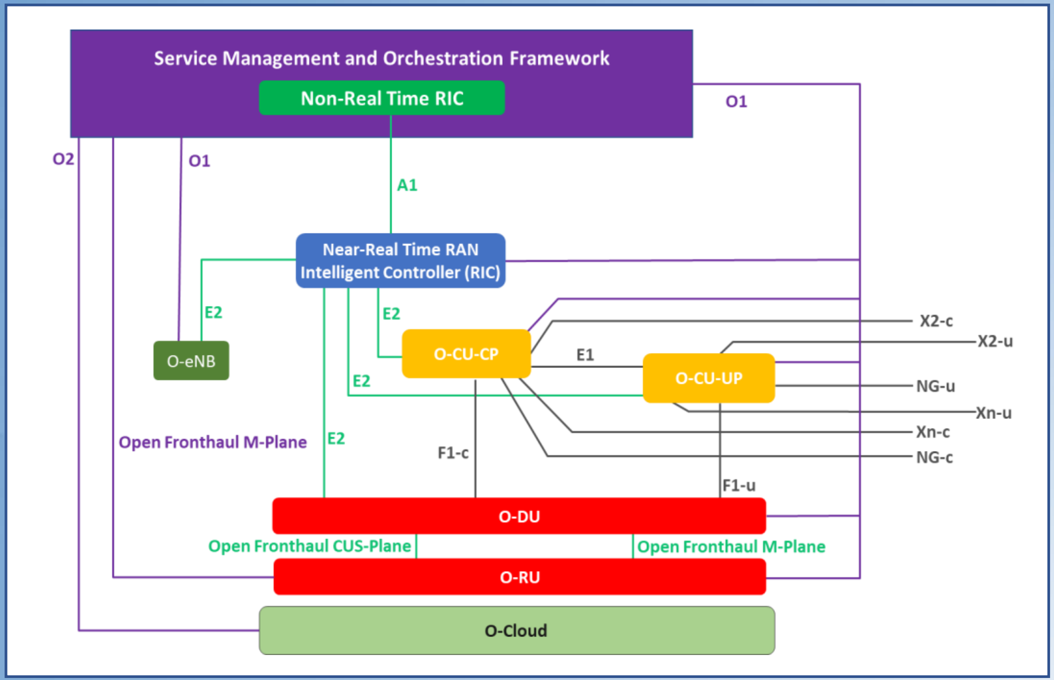


O-RAN Alliance

- 20 new O-RAN specifications since June 2020, including:
  - O2 interface – General Aspects and Principles
  - HW reference designs for indoor picocells (7-2 and 8.0 split options)
  - End-to-end system testing framework
  - Criteria and guidelines for the Open Testing and Integration Centers (OTIC)
- O-RAN ALLIANCE Security Task Group tackles security challenges on all O-RAN interfaces and components
- Second Global Plugfest with multi-vendor O-RAN functions

O-RAN Components	Security Mechanisms	Target Timeline
O1 interface	authentication-integrity-confidentiality	Available today
A1 interface	authentication-integrity-confidentiality	Available today
Related 3GPP interfaces (e.g., E1, F1)	apply 3GPP requirements	Available today
Open Fronthaul M-Plane interface	authentication-integrity-confidentiality	Available today
Open Fronthaul CUS-Plane interface	U-plane: PDCP C/S-planes: Under study	Available today 4Q20
E2 interface	3GPP requirements: Under study	1Q21
O2 interface	Under study	1Q21
x/rApps	Isolation, code signing: Under study	3Q21
OSC software	CII Badging: Under study	2Q21
Secure physical assets	Existing best practices	Operator Responsibility

PARTIAL VIEW OF THE EXISTING O-RAN SECURITY CONTROLS AND COMMUNITY'S PROGRESS



5G Deployments Update

5G Deployment Update – Nov 2020

AT&T:

- Covers >205M people in >395 markets using mmWave and sub-6 GHz.

T-Mobile:

- Covers >7,500 towns & cities and >270M people across 1.4M sq. mi primarily using sub-6 GHz.

Verizon:

- Covers >200M people in >1,800 towns & cities, 19 stadiums and six airports using sub-6 GHz and mmWave.

U.S. Cellular:

- Offers 5G in IA, ME, NC, and WI, will activate 5G in 11 more states by YE2020.

5G Smartphones

- **Samsung, Motorola, LG, Apple**
- 17 – 23 5G handset models offered per operator.

South Korea:

- SK Telecom, KT and LG Uplus launched April 2019. Regulators say >115,000 5G base stations deployed. 8.7M 5G subs as of August, ~15% of country's handset base.

China:

- China Mobile, China Telecom, China Unicom & CBN have all turned on 5G services. 300 prefecture-level cities expected to be covered by YE2020

Japan:

- NTT DOCOMO, KDDI & Softbank launched 5G service in select cities in March; Rakuten in six cities in Sept. 2020. ~330,000 5G users as of June

U.K.:

- UK MNO's EE, Three, O2 and Vodafone all offer 5G service. MVNOs BT Mobile, Tesco Mobile, Sky Mobile & VOXI have also launched 5G services.

Source: CTIA

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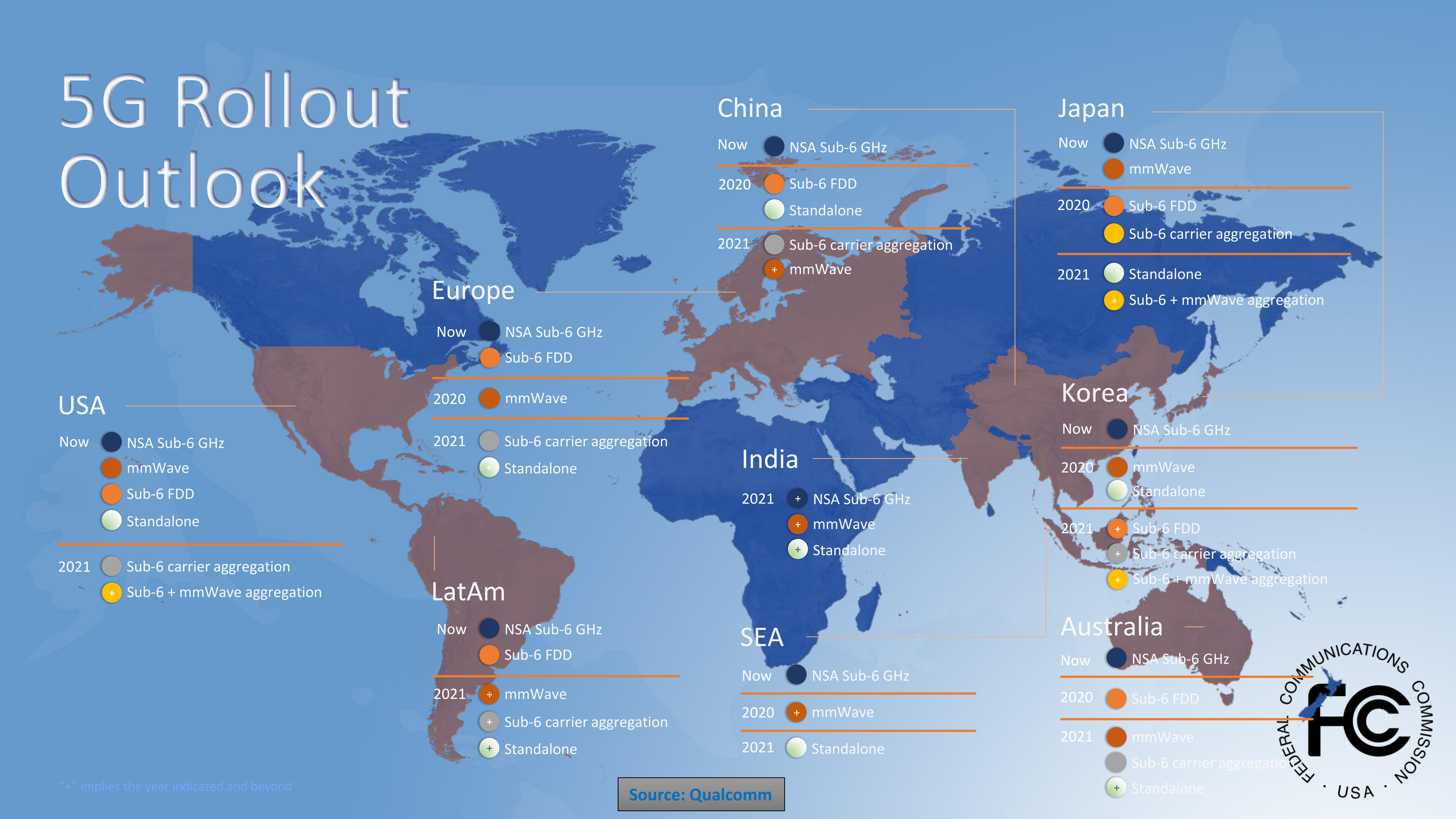
5G Rollout Outlook
China
Now NSA Sub-6 GHz
2020 Sub-6 FDD
Standalone
2021 Sub-6 carrier aggregation
+ mmWave
Japan
Now NSA Sub-6 GHz
mmWave
2020 Sub-6 FDD
Sub-6 carrier aggregation
2021 Standalone
+ Sub-6 + mmWave aggregation
Europe
Now NSA Sub-6 GHz
Sub-6 FDD
2020 mmWave
2021 Sub-6 carrier aggregation
+ Standalone
USA
Now NSA Sub-6 GHz
mmWave
Sub-6 FDD
Standalone
2021 Sub-6 carrier aggregation
+ Sub-6 + mmWave aggregation
Korea
Now NSA Sub-6 GHz
2020 mmWave
Standalone
2021 + Sub-6 FDD
+ Sub-6 carrier aggregation
+ Sub-6 + mmWave aggregation
India
2021 + NSA Sub-6 GHz
+ mmWave
+ Standalone
LatAm
Now NSA Sub-6 GHz
Sub-6 FDD
2021 + mmWave
+ Sub-6 carrier aggregation
+ Standalone
SEA
Now NSA Sub-6 GHz
2020 + mmWave
2021 Standalone
Australia
Now NSA Sub-6 GHz
2020 Sub-6 FDD
2021 mmWave
Sub-6 carrier aggregation
+ Standalone
"+" implies the year indicated and beyond
Source: Qualcomm
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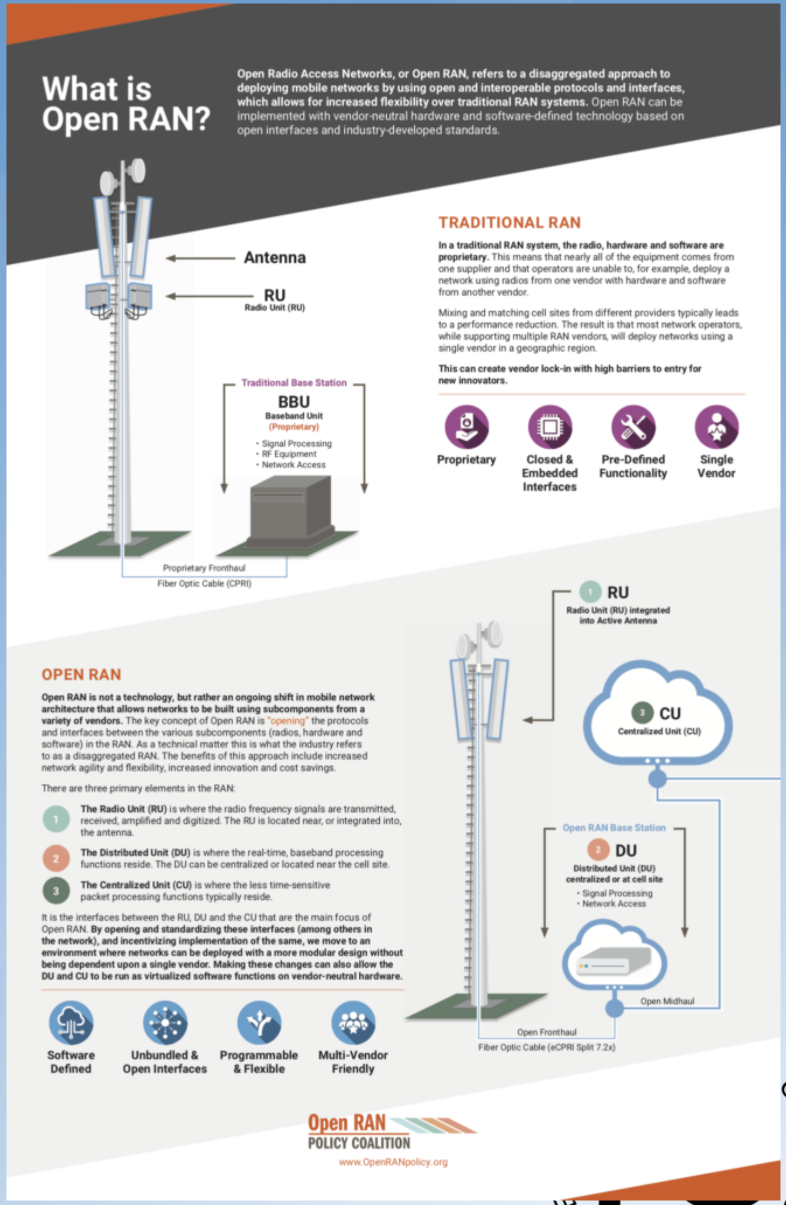
WG Observations

1. Open RAN

Potential Recommendation Areas:
FCC role in driving Open RAN

- Encourage development of Open RAN eco system by supporting the following:
  - Open RAN innovation
  - Open RAN standardization
  - Open RAN testing
  - Open RAN security and reliability
- Support "open" R&D opportunities
  - Support research on open 5G/6G technologies
  - Support interoperability through public-private events such as "plug-fests" and testing in existing 5G testbeds
- Awareness of differences between Open RAN new entrant, greenfield, and brownfield deployment timelines
  - Challenges:
    - System integration concerns by many operators
    - Legacy/existing network integration



Source: Open RAN Policy Coalition

2. Security, Resilience & Reliability

Key Areas for Advisements: Security

- 5G security
  - 5G is more secure than 4G by design. However, it creates a larger threat surface and massive IoT adds addition threats (e.g., DDoS)
  - FCC CSRIC VII working group made recommendations on 5G security and the transition to 5G (Fall 2020)
    - https://www.fcc.gov/files/csric7reportriskintroducedby3gpppdf
  - Overview of Security threats and actions
    - Industry is considering zero trust models
    - Slicing provides traffic isolation- greater security
    - Edge Compute allows threat detection closer to the source
    - Disaggregation/additional Virtualized Network Functions increases the threat surface
    - How to ensure ‘clean’ supply chain
    - Potential network sharing security issues- interconnection, neutral host
    - Jamming and spoofing issues are real and becoming more frequent
      - easy and low-cost to jam
  - Open RAN specific concerns
    - Openness of software will have positive and negative (e.g., trust chain) effects on security
    - Open RAN faces disaggregation security challenges
    - Open RAN creates additional threats because of new interfaces and integration requirements

  Note: O-RAN Coalition has created security task force to focus on threats related to Open RAN

Advisement and Recommendation: Reliability

- Power reliability, back-up for 5G architecture and service
  - Reliability of power grid is essential for communications infrastructure
    - Critical services require very high-reliability: zero down time
    - Massive deployment challenge: availability/capability vs economics
      - It is not realistic to have battery/generator back-up at every small cell site
      - Opportunity for further study, requires a system approach due to different spectrum bands
    - 9's creep: what is needed for normal operation: 4 nines, 5 nines, 6 nines?
    - Potential to over-engineer the network at increased cost and complexity for small % of service/use
  - Leverage efforts with the FCC including:
    - BDAC work and related reports on disaster recovery: https://www.fcc.gov/broadband-deployment-advisory-committee
    - Operators are focused on meeting critical needs in deployments
    - Wireless Resiliency Cooperative Framework (voluntary commitment to FCC):
      - shared roaming, mutual aid, consumer education, municipal readiness
    - Collaboration with FERC, EPRI, 911 operations
  - Industry collaboration efforts: ATIS working group on reliability
  - Recommendation: carry reliability (safety focus) work into 2021 5G/IoT/RAN working group

3. 6G, Next G

6G – Initial Views

Key expectations

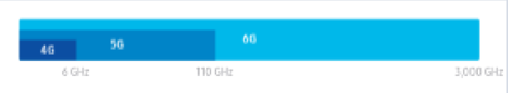
- Use case focus: *Internet of senses, connected machines, digital & programmable physical world, sustainability, Trust/secure, cognitive networking, E2E compute fabric, no-bounds connectivity, Imbedded Intelligence (AI), openness*
- 6G will continue to build on 5G, pushing "extreme" capabilities
- Focus: softwarization, openness, virtualization and further disaggregation of RAN, white-box radios, imbedded compute and AI end-to-end

Source: Ericsson, 6G Symposium

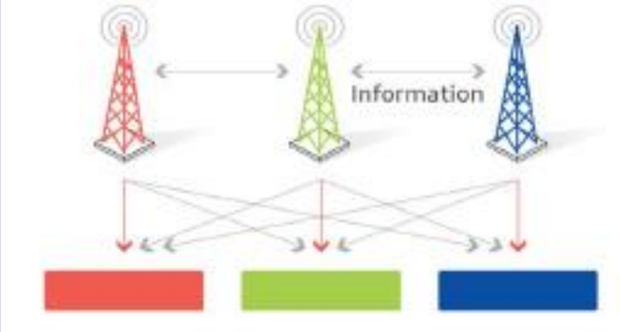
6G Technologies Focus

New Spectrum

- THz is the opportunity



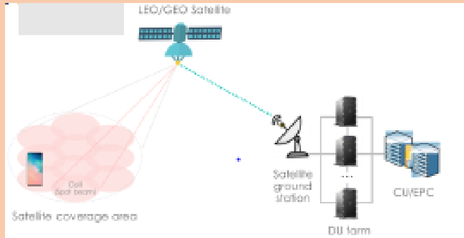
- Dynamic spectrum sharing: max utilization and efficiency



New Architecture

- IAB*, Mesh networking, flexible, mobile, on-demand BSs

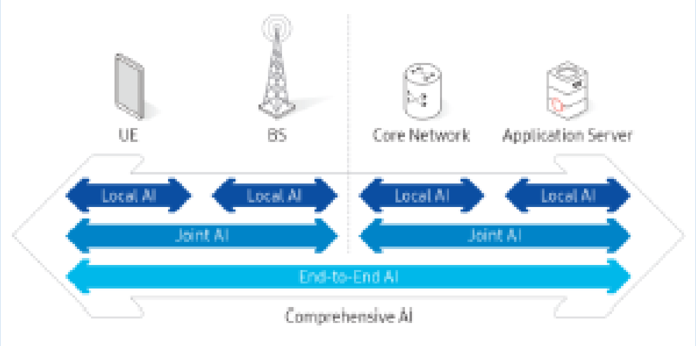
- Non-terrestrial: satellites, HAPs



- Massive MIMO

New Compute

- AI/ML to support configuration-less, optimized layer agnostic network needs



*IAB- Integrated Access and Backhaul

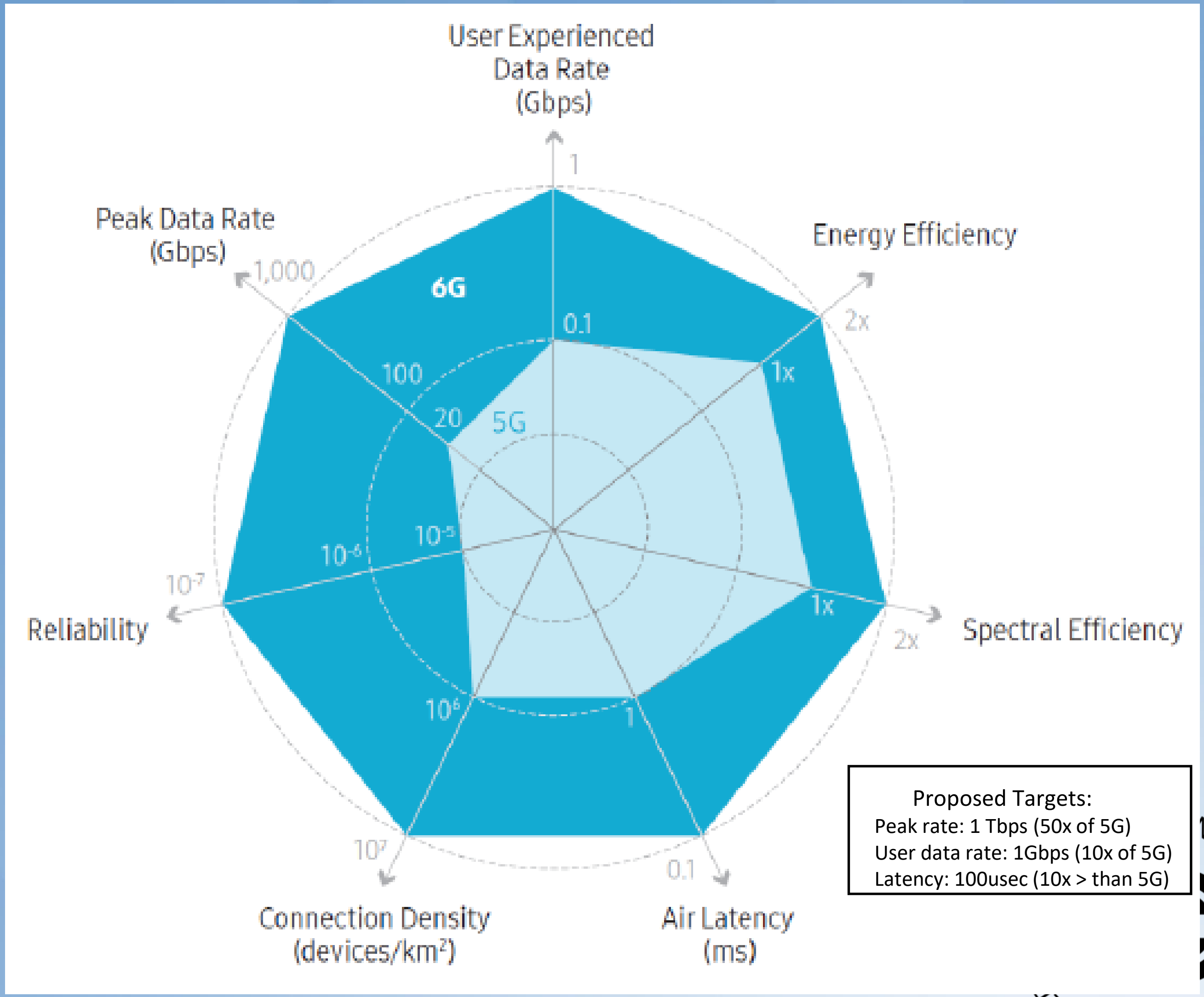
6G Performance Vision

Advanced, new services requirements:

- Substantial compute
- Higher data rates
- Determinism: Extreme low latency
- Reliability
- Density
- Location
- Low power

New services support:

- Ultra-hi resolution sensing
- More sensitive location accuracy
- Face recognition
- Anti-spoofing ability
- Gesture, motion recognition



Source: Samsung

6G Planning & Research is in Progress

ITU Network 2030

- ITU launched Focus Group to explore network technologies beyond 2030.

Chairman

HUAWEI

Vice-Chairman

verizon

KDDI Research

中国电信 CHINA TELECOM

Rostelecom

ATIS Next G Alliance

- Collaboration across U.S. government, academia, and industry to promote U.S. leadership on the path to 6G. (Just announced on Oct. 13)

Founding Members

Apple	AT&T	Bell	Charter	ciena	cisco	ERICSSON
FACEBOOK	Google	Hewlett Packard Enterprise	intel	interdigital	JMA	KEYSIGHT
LG	MAVENIR	Microsoft	MITRE	NOKIA	Qualcomm	Radisys
SAMSUNG	T Mobile	TELNYX	TELUS	uscellular	verizon	vmware

...and growing

Other Regions

- China, Japan, S. Korea, EU, Finland, and Brazil launched 6G research programs with industry and academia w/ national strategic funding.

5G/6G Challenge: x-haul Fiber Availability

- Base station requirements: for 3.5 GHz coverage to hit 70% of POP availability in the US, requires more than a million base stations (BS). At 28 Ghz, over 13 Million base-stations. For indoor locations add millions more base-stations
  [DoD report 2019: https://media.defense.gov/2019/Apr/04/2002109654/-1/-1/0/DIB_5G_STUDY_04.04.19.PDF]
- Major challenge emerging base stations require fiber backhaul to connect 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.
- Comparing the US to Japan, Korea, Singapore, China, Hong Kong etc..., utility style fiber networks have been deployed, with both broad availability and low cost. These nations have a fundamental advantage over the US in BS deployments.
- Low-cost x-haul dark fiber is necessary to enable 5G and 6G economics. Without addressing the future fiber x-haul requirements, US leadership in 5G, and more so in 6G will be nearly impossible to achieve

6G Summary and Recommendations

- FCC to promote creation of a US national roadmap
  - o Encourage industry engagement, R&D, and standards
  - o E.g. ATIS creation of Next G Alliance to coordinate US leadership
- Key 6G areas that need attention
  - o Spectrum: planning to support 6G network requirements
  - o Architecture: further densification may cause site location challenges
  - o Fiber x-haul: will be a challenge for US overall without investment and focus
    - • Mesh and IAB architecture will help
- Focus on roadmap, and plan for US to maintain technological leadership in future communications standards
  - o Encourage more US company involvement in the standards process within North America i.e. 3GPP via ATIS
- Research: FCC support:
  - o Hi-frequency mmWave and THz use
  - o Spectrum efficiency technologies

4. Spectrum Sharing

Key Areas for Recommendations: Spectrum

- 5G/6G success will need a mix of licensed, shared, unlicensed
- Additional use options need to be explored in the 3.1-3.45 GHz bands
- Consider shared spectrum where exclusive use is not a fit or practical
  - Recommendation for spectrum sharing based on a data intense/intelligence sharing model
  - For future sharing, explore smaller geographies, ex smaller than county level
  - 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:
  - 7 GHz-24Ghz
  - High mmWave
  - THz

SPECTRUM SHARING 2021- a Proposed Framework

Goals:

1. Long term goal for devices to be able to operate in most any spectrum based on need, availability and purpose

2. Move from a licensed approach to a usage approach- very dynamic and flexible

3. A "Spectrum aware" approach. Q: What is the top of Spectrum's "Maslow Hierarchy to get to self-actualization"

Specifics to solve:

- Interference:
  - Quantify: measurement
  - RAN, UE, Geo, other services
  - Other
- Radio and receiver capabilities and sensitivity
- Noise- how to manage and mitigate
- Rules, regs and enforcement
  - Bands
  - Devices
  - Radios
- Security related topics
- Content centric view?

SPECTRUM SHARING 2021- a Proposed Framework (cont'd)

Fundamental Guidelines:

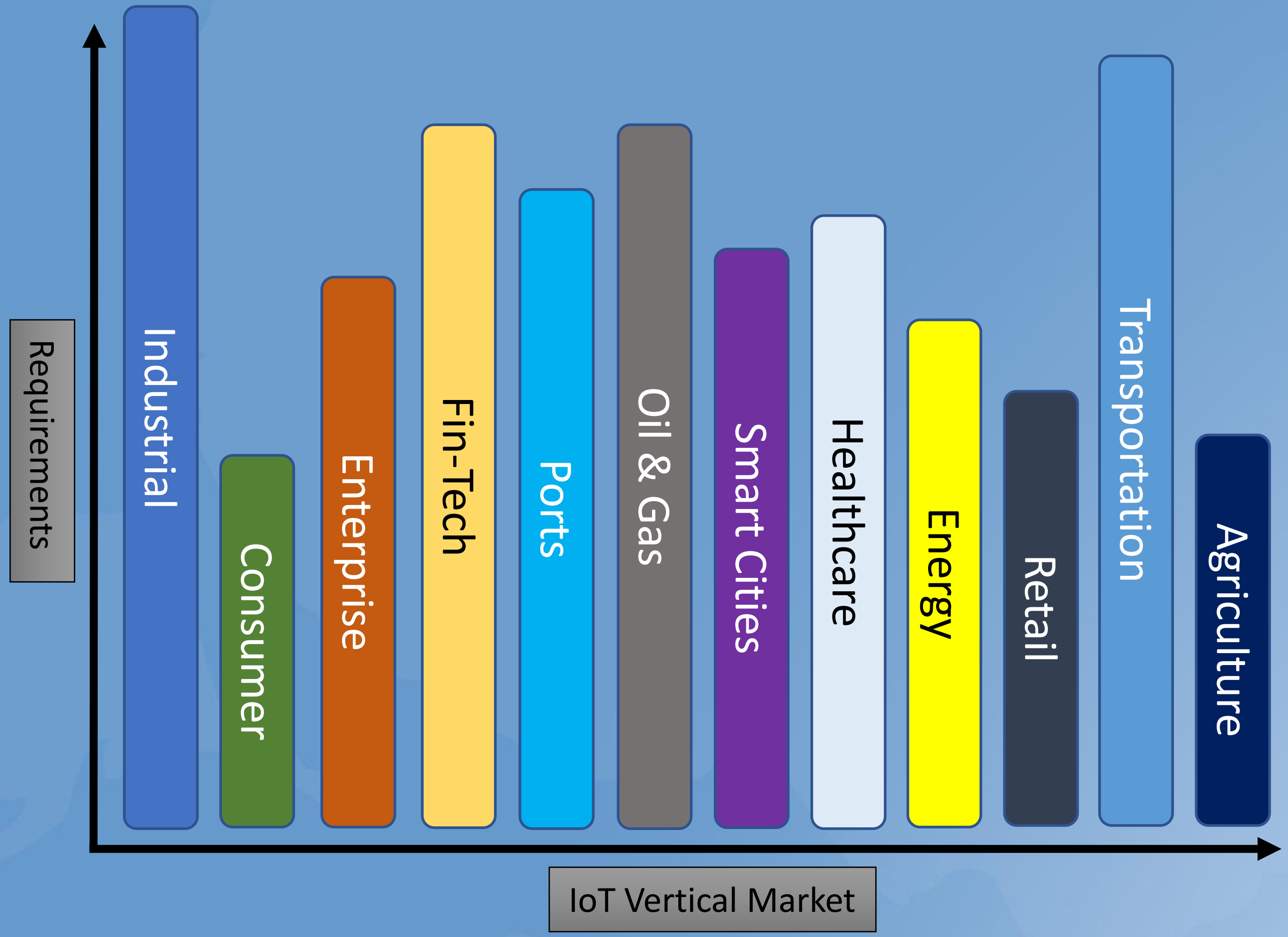
1. Protect incumbent services
2. Avoid a hi-cost, years in creation approach (e.g. KISS approach)
3. Recognition that "one size does not fit all":
   - There are multiple spectrum sharing methodologies today AFC, SAS (CBRS), TVWS
   - Create a purpose-built approach based on spectrum band, incumbent services
4. Goal: maximize the use and efficiency of services in the band
   - Measure and monitor the spectrum usage
5. Stimulate innovation
6. Focus on use by <u>all</u> services

Key elements:

- Data-driven, evidence-based approaches will be winners
- Focus on achievable data collection and transparency
- Data should be across the various elements of network, geography, UE etc
- Rely on current and future data
- Use of AI as applicable
- Cost/benefit approach

5. IoT

IoT Verticals have Specific Requirements Related to 5G Support

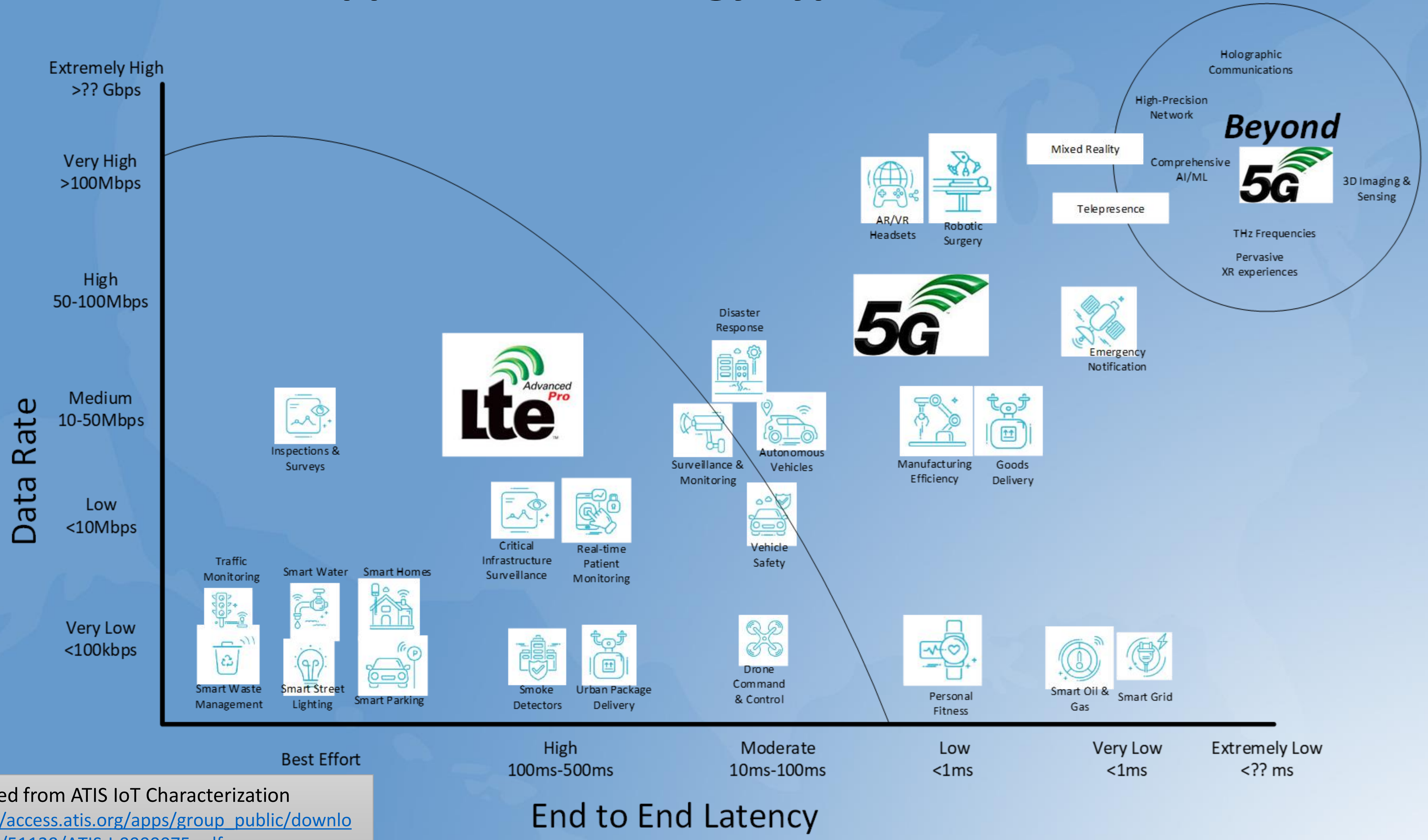


Requirements/Needs

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

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

IoT Demands Mapped to Technology Type



Adapted from ATIS IoT Characterization
https://access.atis.org/apps/group_public/download.php/51129/ATIS-I-0000075.pdf

Key Areas for Recommendations: IoT

- FCC to consider private spectrum tied to IoT/Enterprise/captured spaces
  - Focus on spectrum re-use
  - Needs are for confined geographic areas, buildings, and campuses
  - License models: lightly licensed and private licensed spectrum
  - Allows US to compete in private deployments (many other countries leading)
  - Create specific rules on power levels for private/LLS
  - Both mid-band and mmWave are applicable, see chart
  - Shielding requirements, outside-in vs inside-in
  - limit perimeter emission
  - Optimize use of the spectrum (up/down)
- Verticals 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- hi-determinism, life-safety
  - Medical: varies based on use case: Monitoring to remote/robotic surgery
- Monitor 3GPP R17 "RedCap" progress for IoT deployment impact

Spectrum comparison for local-licensed needs & use

Metric	Mid-Band	mmWave
Propagation	~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
Reflection	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

Overall Recommendations

Recommendations/Advisements

- **O-RAN**
  - FCC to support MV interoperability, plugfests
  - Encourage acceleration of ORAN adoption

- **Security**
  - Spoofing, interference are real concerns
  - System supply chain, MV systems
  - Network reliability, resilience- area to monitor

- **6G**
  - Challenges: lack of fiber for x-haul, power reliability
  - Architecture changes: Mesh, evolved IAB
  - Create US roadmap- partner with industry
  - Readiness of THz is uncertain- support research

- **Spectrum Sharing**
  - Hi-level framework: guidelines, rules, and goals,
  - Sharing is dependent on the spectrum band; incumbents, etc
  - Interference; need to quantify, measure & enforce
  - 2021: Formal FCC TAC WG for spectrum sharing

- **IIoT**
  - IoT and enterprise use cases are quickly emerging
  - Demands vary widely on QoS/determinism
  - Locally licensed spectrum desired to provide necessary determinism, control, and compete with worldwide options (e.g. BNetzA)
  - Both mid-band and mmWave are suitable
    - Facilitates spectrum re-use

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5G/IoT/RAN WG- 2021 *proposal*

2021 5G/IoT/RAN Working Group (proposed) Focus Areas

- Transition from NSA to SA
- Open-RAN & vRAN
- 6G Evolution and planning
  - X-haul needs and potential models to stimulate investment
  - 6G/edge/storage/cloud interoperability
  - Multiple Radio Access Technology (RAT) interoperability
- IoT requirements, local license details
- Impacts of "Private" networks
- Technology roadmaps (new)
- Spectrum advances in mmWave and Thz
- Small cell deployment and reliability
- Network reliability & resiliency
- Standards coordination and post Covid progress
- Security: jamming, spoofing, supply-chain

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Thank You

FCC Technological Advisory Council Agenda – December 1, 2020

10am – 10:15am	Introduction and Opening Remarks
10:15am – 10:30am	Announcements and Roll Call
10:30am – 11am	FCC Chairman's Remarks WG Recommendations (5 minutes for each WG)
11am – 11:45am	Artificial Intelligence WG
11:45am – 12:30pm	Future of Unlicensed Operations WG
12:30pm – 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

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