Technological Advisory Council

Antenna Technology

Working Group

June 21, 2019

Antenna Technology Working Group

- **Chairs:**
  - Greg Lapin, ARRL
  - Marty Cooper, DynaLLC
- **FCC Liaisons:**
  - Martin Doczkat, OET
  - Michael Ha, OET
  - Bahman Badipour, OET
  - Kamran Etemad, WTB
- **Participants / Contributors:**
  - Mark Bayliss, VisualLink
  - Nomi Bergman, Advance Newhouse
  - Lynn Claudy, NAB
  - Brian Daly, ATT
  - Adam Drobot, OpenTechWorks
  - Danilo Erricolo, Univ Illinois Chicago
  - Jeff Foerster, Intel
  - Bo Göransson, Ericsson
  - Dale Hatfield, Univ of Colorado
  - Stephen Hayes, Ericsson
  - Farooq Khan, PHAZR Inc
  - Steven Lanning, Viasat
  - Kevin Leddy, Charter Comm
  - Michael Marcus, Marcus Spectrum
  - Hamidreza Memarzadeh, Samsung
  - Bob Miller, incNetworks
  - Umesh Navsariwala, PCTel
  - Sven Petersson, Ericsson
  - Brennan Price, Echostar
  - Sudhir Ramakrishna, PHAZR Inc
  - Ted Rappaport, NYU
  - Dennis Roberson, RAA
  - Scott Robohn, Juniper Networks
  - Jesse Russell, incNetworks
  - Harry Skinner, Intel
  - Charlie Zhang, Samsung

Antenna Technology Developments

This year the Antenna Technology Working Group is continuing with two topics that were studied in 2018.

The Working Group made recommendations for action from the FCC on each of these topics:

1. Incentivize the use of new improved antenna technologies.
2. Facilitate a multi-stakeholder group to create guidelines or industry best-practices to improve the aesthetics of 5g/small cell deployments.

Antenna Technology Developments

- The working group recommended that the FCC institute policies that incentivize the use of new improved antenna systems. The Commission seeks information on the technical characteristics of new system, particularly, but not exclusively, in the millimeter wave bands, such as:
  - Characterizing and analyzing potential interference.
    - For example, for phased array and MIMO antennas, what assumptions are necessary unique to these antenna systems relative to the gain between in-band and out-of-band emissions?
    - How should antenna patterns and especially dynamic antenna patterns be taken into account in performing such analyses?
    - To what extent can the antenna patterns and gain be used to mitigate interference risks?
  - Trade-offs between performance improvements and interference risks with the increased flexibility of improved antenna systems.
  - Proposed changes in FCC rules that affect improved antenna systems.

Antenna System Technology Developments

- Massive MIMO, Distributed MIMO, Spatial Division Multiple Access (SDMA) and other technologies promise improved performance.
- Trade-offs associated with the higher frequencies that result in smaller sizes and more complex antenna designs
- The large number of frequency bands presents challenges for cell site and phone designers.
- Use of disguised antennas to facilitate acceptance of dense deployments of small cell antennas
- Special challenges related to access to poles and street lights in municipalities.

Antenna System Technology Developments

- Dynamic antenna systems:
  - can precisely direct radiated energy to, and receive signals from, specific users. Co-channel sharing is thus possible
  - may reduce co-channel interference through use of highly directional beams, limited dwell times at any single location, low antenna heights, and significant down tilt
  - Sharing is enabled through the use of narrow or shaped dynamic antenna patterns. This may allow enhanced interference management between different services such as Fixed Service, Mobile Service and Satellite Service, and between federal and non-federal systems.

Dynamic Antenna Systems

- What remains to be seen:
  - How tightly will the mm-wave beams be focused?
  - Sidelobes still exist in all focused beams; how much they can be attenuated?

Technical Characteristics of New Antenna Systems

- IEEE Communications Society
  - Future Networks Initiative
  - Roadmap
- MIMO Tutorial
  - Digital vs Analog
  - Beam Patterns
  - Interference Suppression
  - mmWave Propagation Characteristics

Antenna Technology Developments

- The work group recommended the Commission facilitate a multi-stakeholder group to create guidelines/industry standards to improve the aesthetics of 5G/small cell deployments to improve public acceptance.
  - The FCC should work with private sector stakeholders to realize this important initiative.

Small Cell Appearance

- An industry best practice for installing small cells may help to decrease local resistance to their installation.
- The basis of this best practice document will come from:
  - A Multi-Stakeholder group with expertise in all aspects of small cell placement.
  - Public opinions about the topic that will be requested via a TAC public notice, published in concert with the 5G/IOT Working Group.
- Examples of objectionable installations are self-evident.

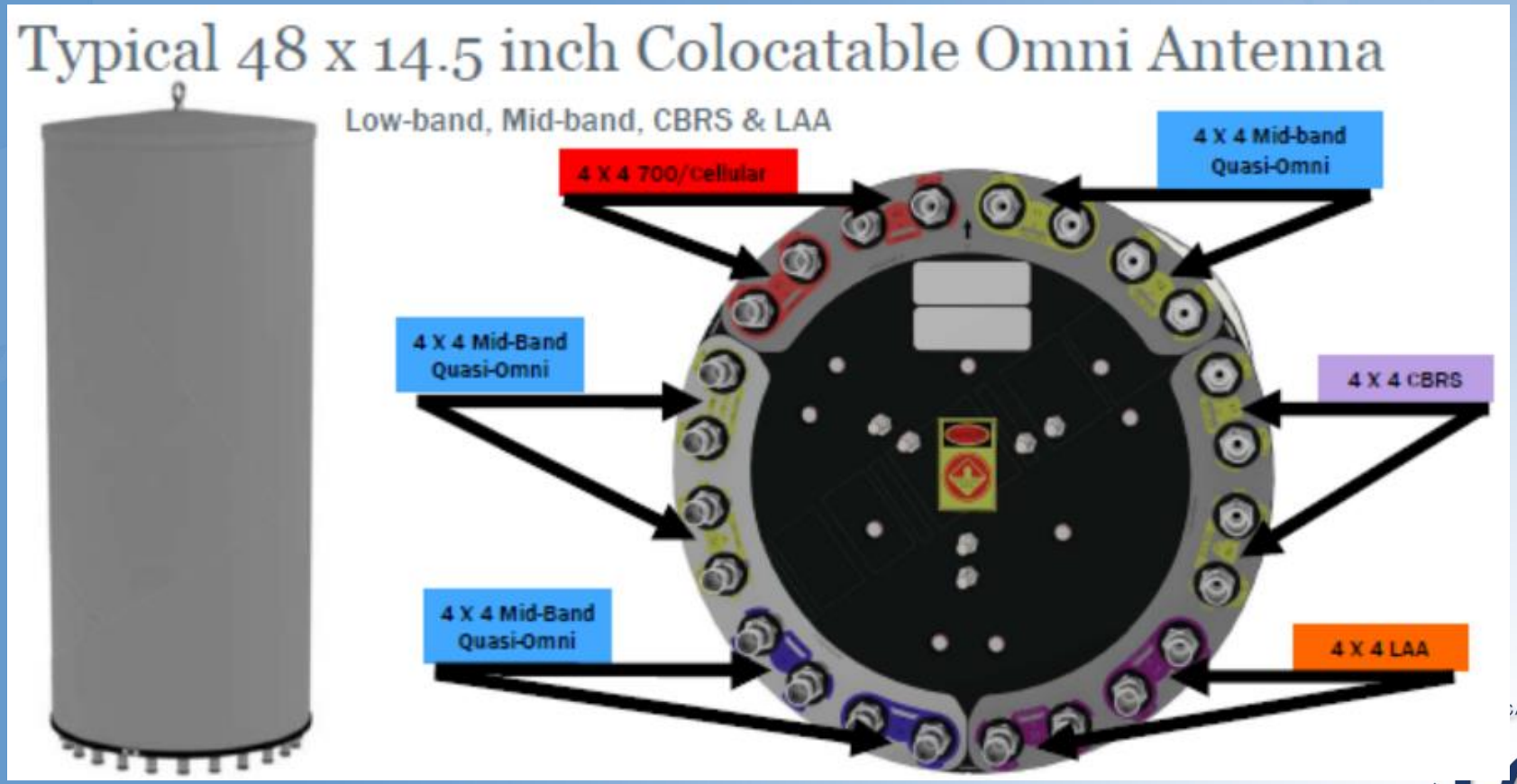
Small Cell Appearance – What to Avoid

Small Cell Appearance – Acceptable Solutions

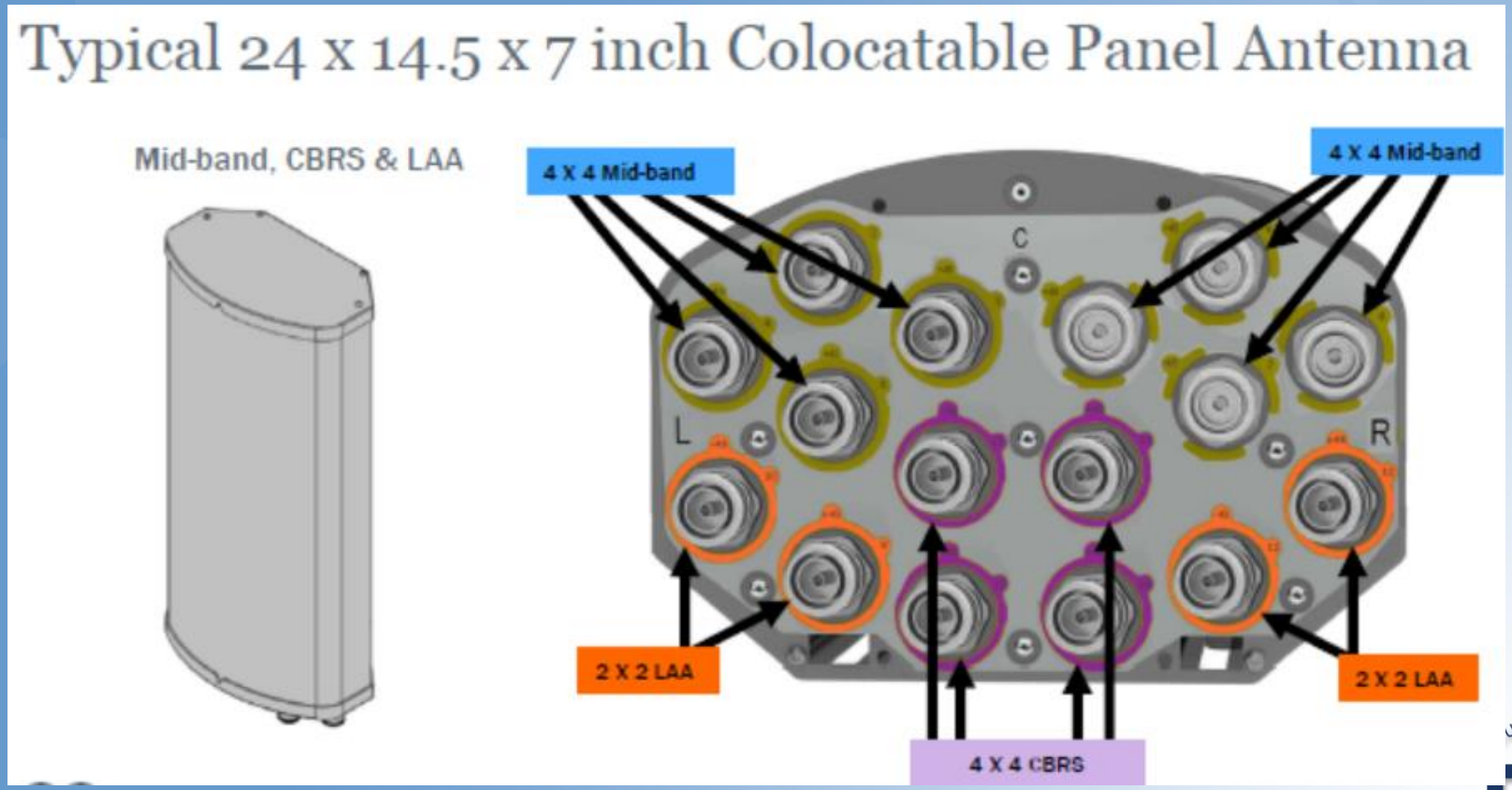
Small Cell Appearance

- Trepidation exists about the advent of 5G because communities have expressed fear that their landscape will appear like a forest of small cells.
- Sharing of small cells by multiple vendor can help to reduce the number of small cells that need to be built.
- Antenna canisters that support multiple antennas and frequencies will aid in sharing.

Compound Antennas Improve Cell Appearance



Compound Antennas Improve Cell Appearance



Advantage of Multi-Stakeholder Group

- Regulatory solutions are only partially effective.
  - For example, the “shot clock” regulation can be circumvented by requiring small changes to each re-application, resetting the shot-clock each time.
  - Some municipalities have ignored regulation without repercussion.
- If a group containing municipal representation agrees to a set of guidelines, individual municipalities may be more likely to accept them with minimum modification or delay.
- Technical representation in the group will help assure that guidelines are practical, buildable and affordable.

Cellular Base Station Appearance

- Representation of a multi-stakeholder group
  - Cellular Industry representative(s)
  - Local zoning representative(s)
  - State level zoning representative(s)
  - Technical & Aesthetic Design Community
  - Cost & Value representative(s)
  - Tower provider(s)

Cellular Base Station Appearance

- Multi-stakeholder – Potential Representatives
  - National League of Cities
  - Cell Site Providers (e.g. Crown Castle, American Tower, SBA)
  - CTIA, PCIA or Individual Providers
  - American Institute of Architects

THANK YOU

5G/IoT Working Group

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

John Barnhill, Alianza –SWG's

Date: June 21, 2019

2019 Working Group Team Members

- Brandon Abley, NENA
- Ahmad Armand, T-Mobile
- Kumar Balachandran, Ericsson
- John Barnhill*, Alianza
- Mark Bayliss, Visualink
- Marty Cooper, Dyna
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- Dale Hatfield, Univ of Colorado
- Steve Lanning, Viasat
- Greg Lapin, ARRL
- Kevin Leddy, Charter
- Brian Markwalter, CTA
- Lynn Merrill, NTCA
- Robert Miller, inc Networks
- Paul Misener, Amazon
- Jack Nasielski, Qualcomm
- Mike Nawrocki, ATIS
- Arthur Nichols, Windstream
- Madeleine Noland, ATSC
- Dennis Roberson, entigenlogic
- Hamid Reza, Samsung
- Scott Robohn, Juniper
- Kevin Sparks, Nokia Bell Labs
- Marvin Sirbu, Spec. Gov. Emp.
- Tom Sawanobori, CTIA
- David Young, Verizon

FCC Liaisons: Michael Ha, Padma Krishnaswamy, Nicholas Oros

5G and the Internet of Things WG: 2019 Charter

5G is a topic that is critically important to the communications industry, our economy and U.S. international competitiveness.

For 2019, the work group is tasked to provide insight on the development of this technology and make recommendations as it evolves.

The group will focus on technical insights and recommendations.

5G and the Internet of Things WG: 2019 Charter Questions

- How are low, mid, and high frequency bands being used in deployments, both in the U.S. and internationally?
- What is the status of deployment of vertical support & services, i.e. energy, transportation, health care, etc.
- What technical steps are being taken to ensure deployment of 5G services to rural areas, especially those related to low latency dependent applications?
- How are 5G capacity, speed and latency projections playing out in general and by application and by geography?

- Considering that a long roll-out is likely, what is the 5G evolutionary path and where will this lead us in terms of new functionality to meet the needs and desires of the citizens of the U.S.?
- To what extent is 5G making a difference for IoT deployments. How will this evolve?
- What is the status of satellite offerings of 5G service?
- What new developments have arisen that the Commission should be aware of and/or address?

5G/IOT: 2ND QTR 2019 ACTIVITIES

5G/IoT WG Activities and Presentation Agenda

- A number of SME speakers: CBRS, Rural, manuf., Spectrum
- Standards activities & tracking
- WW deployments investigation
- 5G/IoT Vertical impacts
- SWG: Spectrum: licensed, unlicensed, dedicated, WW activities
- SWG: 5G Rural/underserved opportunities and issues
- Antenna/NR – follow up on 2018 Public Notice

- 5G Spoofing/jamming investigation and review
- 5G drivers related to IPv6
- Satellite services related to 5G
- New 5G related developments

Speaker	Representing	Key Learnings
Lowell Feldman	EVOLVE CELLULAR	• Need rural specific antenna dev • Hi-power on front and back a plus • Unlicensed lacks investment traction
Neeti Tandon	AT&T	• Create a Cat C in CBRS w/hi-power • Achieve > distance/coverage (up to 3.4mi) • Fewer number of Cat C CBSD
Dave Wright	ALLIANCE cbrs	• Optimized use of an existing spectrum • PAL begins in 2020 • SAS and ESC build out on time
Sankar Ray	5G americas	• IoT requires comprehensive security approach • Threat surface: device, transport, node, apps/service • Other threats: RAN, UE, core, slicing, NfV/SDN, network
Richard Candell	NIST	• Factory wireless has strict QoS/Latency • No 'one-size fits all' solution (Wi-Fi, 5G) • Several use case classes w/ varying reqs.
Ahmad Armand	T-Mobile	• 600MHz & mid-band for rural - merger dependent • Mobile BB DS ≥10Mbps to 74% rural residents • Fixed BB ≥25/3 Mbps to 84% of rural residents

5G/IOT DEPLOYMENT UPDATE

5G Deployments and Subscription Forecasts

- **10 million 5G subscriptions** are projected worldwide by the end of 2019
- By the end of 2024:
  - **1.9 billion 5G subscriptions** for enhanced mobile broadband
  - Over **20 percent of all mobile subscriptions** will be 5G
  - 5G networks will carry **35 percent of mobile data traffic** globally
- 5G coverage of up to 65% of the world's population in 2024
  - Radio deployments in new bands in the sub-6GHz range
  - Deployments in mmWave frequency bands

  } Reach 45% of pop. 2024

  - Deployments in existing LTE bands

  } Reach additional 20% of pop. 2024

Faster than expected: enthusiasm for 5G has led Ericsson to forecast an extra 400 million enhanced mobile broadband subs. globally by the end of 2024

US 5G 2019 Rollouts

- **Verizon**: Verizon: FWA 5G operating in **4 cities**. Mobile 5G operating in **2 cities**. Plans to have service in **30 cities** by end of year 2019
- **AT&T**: mobile 5G coverage in **22 cities 2019, Nationwide coverage 2020**
- **T-Mobile**: Commercial 5G launch in second half of 2019 launching in **30 cities**; nationwide coverage expected in 2020
- **Sprint**: Deploying 5G in **9 cities** in first half of 2019
- **U.S. Cellular**: 5G services coming in second half of 2019
- **C Spire**: Fixed 5G services in Mississippi **(1)**
- **Charter**: Testing 5G, but no published rollout plans
- **Starry**: Fixed 5G currently in **(5) cities**

Total: 95 City Deployments*

https://www.lifewire.com/5g-availability-us-4155914

Global 5G Deployments: Investment by 224 Operators in 88 Countries

- 5G mobile or 5G fixed wireless broadband networks, tests, trials
- As of April 2019, **39 operators** have announced either non-3GPP-compliant or 3GPP-compliant 5G technology deployments
  - 15 deployments are 5G mobile or FWA services
  - 13 deployments are 3GPP-compliant
- EE launched commercial 5G in **six UK cities** on May 30

- **South Korea**: SK Telecom, KT, and LG U+ **launched 5G FWA in** Dec 2018 3420-3700 MHz
  - **First** country WW to launch full 5G commercial services
  - As of June the number of **subscribers are approx. 900,000**

https://www.gizmochina.com/2019/06/10/5g-subscribers-south-korea-to-top-1-million/

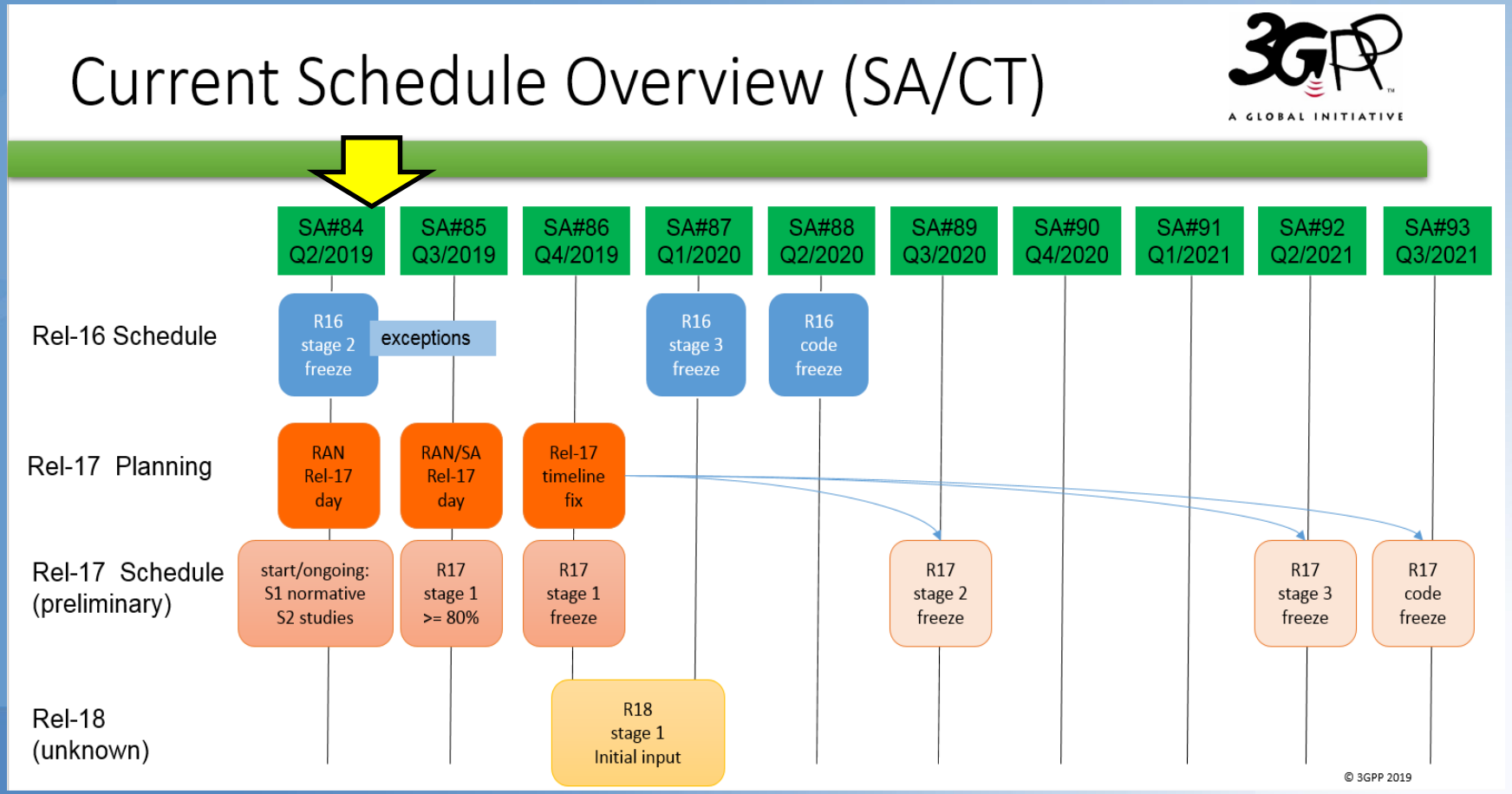
5G/IOT STANDARDS UPDATE

Standards

- **3GPP**
  - Rel 15 late drop completed March 2019 (ASN.1 in June 2019)
  - Rel 16 status (in progress)
    - Complete March 2020 (ASN.1 in June)
    - eMBB enhancements; Slicing, URLLC; V2X; Positioning; 5G Satellite; Study of Enablers for Network Automation for 5G
    - Use of multiple access technologies for simultaneously services active on a UE
  - Rel 17
    - Final agreement on timeline December Plenary
    - Stage 1 targeted to be complete in December
    - Potential areas: Verticals (healthcare, UAS); NR evolution; Integrated Access Backhaul (IAB); Enhancements (relays, edge, proximity services); support for mmWave above 52.6 GHz
- **ITU**
  - 3GPP submission update & self evaluation targeted for October, final in July 2020

ATIS 5G Related Activities

5G Projected Industry Standards Timelines



5G/IOT VERTICALS

5G/IoT Verticals of Focus – TAC Investigating

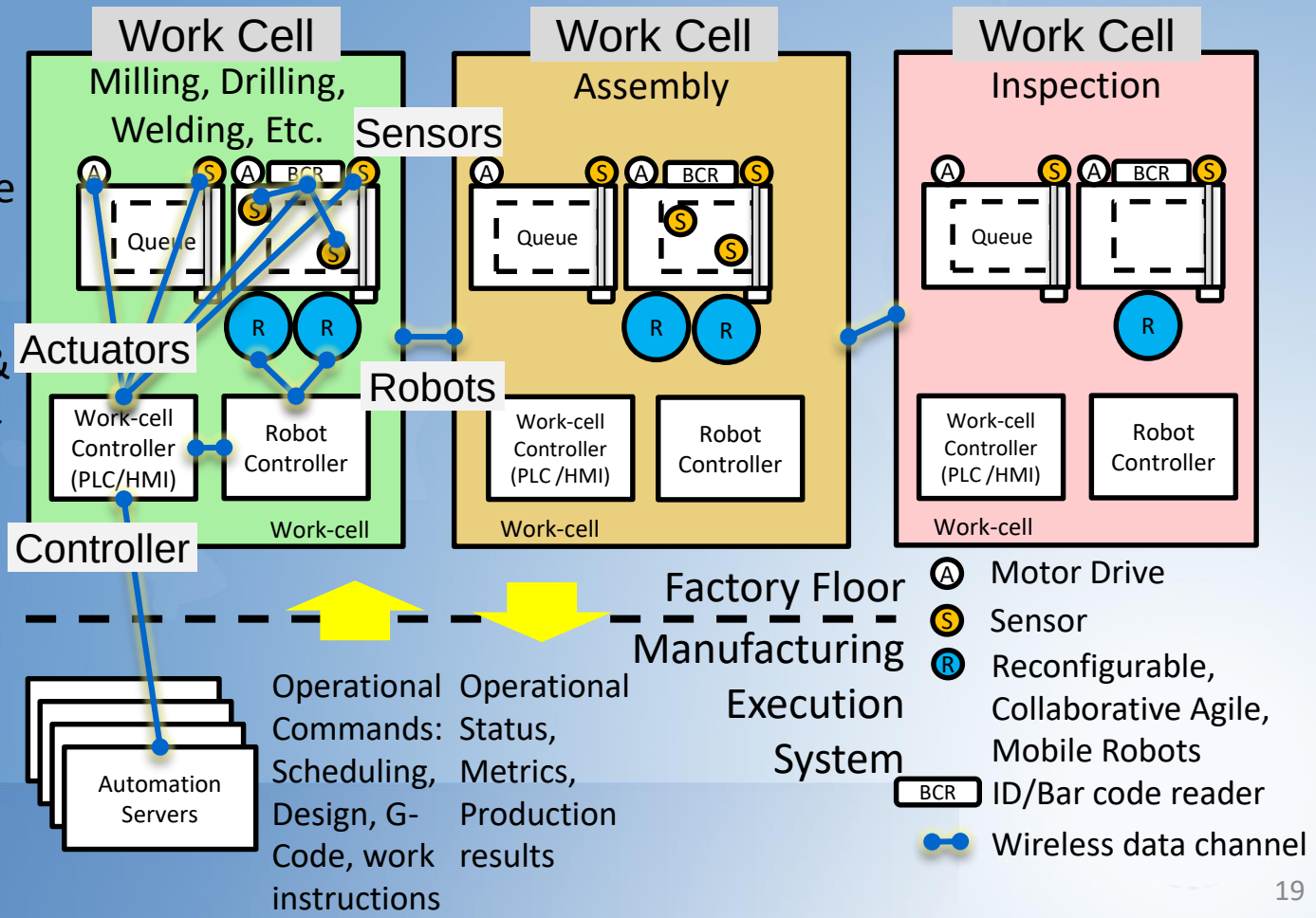
- **Industrial (IIoT)-** WiP
  - URLLC, TSN-like service support
  - Industrial automation and control
- **Enterprise** – Q3
  - Fixed wireless, collaboration
- **Transportation** – Q3
  - Connected transportation
  - Maintenance, Entertainment
- **Healthcare** – Q3
  - Massive data sets, real-time needs
- **Energy** – Q3
  - Sensification, Smart Grid, meters, homes, industrial

IoT: 5G will have significant impact on x-vertical device connectivity

IIoT: Vision of Wireless in the Factory *Special Thanks To Richard Candell, NIST*

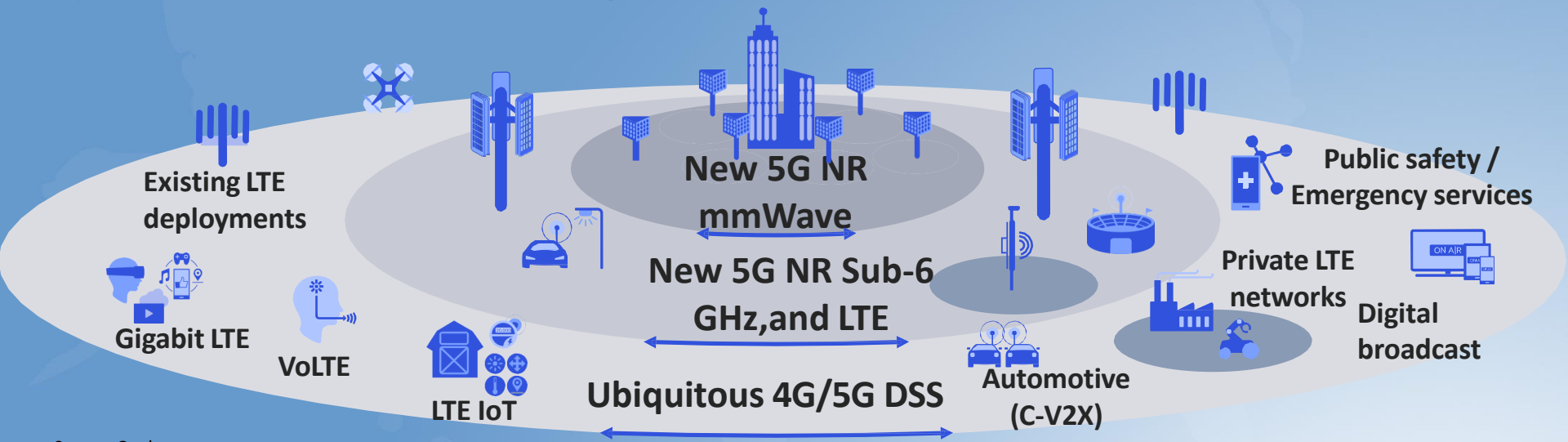
Technical drivers and key requirements:

- Multiple reconfigurable and collaborative mobile robots
- Real-time movement & tool coordination (*sub-millisecond latencies*)
- Ultra-reliable communications with simultaneous redundant channels



5G/IOT SPECTRUM [SWG]

Spectrum: Low, Mid, and High-Band (mmWave) Needed for 5G



Source: Qualcomm

	Low Band	Mid Band	High Band
Coverage	High	Medium	Low
Capacity	Low	Medium/High	High

Global Snapshot of 5G Spectrum Bands Allocated or Targeted

WW Spectrum: Europe

Focus on mid-band (3.4–3.8 GHz) and 26 GHz (24.25-27.5 GHz) for 2018+

EC RSC, CEPT, key European Members are driving activities to accelerate 5G rollout in EU
Intense regulatory activity for 3.4-3.8 GHz and 26 GHz. Auctions expected in 2018-2019.

UK	•5G strategy published in March 2017 – DCMS and HM Treasury •Ofcom auctioned 150 MHz in 3.4–3.6 GHz in 2018, more spectrum (120MHz) in 3.6–3.8 GHz in 2019 •Likelihood of a multiband auction in 2019 including (700MHz, 3.4–3.8GHz, and possibly 26GHz) •Initiated mmWave program on 26 GHz band for early 5G deployment
Germany	•BenetzA planning to award 3.4-3.7 GHz in Q1 2019 •3.7 – 3.8 GHz for verticals in 2019 •Published award procedure for 24.25 – 27.5 GHz in Sep. 2018
France	•ARCEP to award 340 MHz (3.46–3.8GHz) of spectrum in 2019; ARCEP working on making 26 GHz available by 2020
Belgium, Austria, Switzerland planning to release spectrum in 2019	

WW Spectrum Europe - Continued

Italy 	•Auction completed in 2018:700MHz, 3.6–3.8GHz, 26.5–27.5GHz •Major 5G trials gov't program on 100 MHz of spectrum in 3.7–3.8 GHz; •Government working on re-farming 3.4–3.6 GHz (MoD, MiSE, AGCOM
Ireland 	•Ireland successful auction of 350 MHz of spectrum for 5G •26GHz auction in 2018
Spain 	•In Spain, the 3.6-3.8 GHz band was auctioned in Q3 2018 •Organizing trials on 26 GHz band – at least 1.4 GHz available for release from 2019 depending on market demand
Finland 	•Auction completed in Sept. 2018: 3410-3800 MHz •Ficora is looking at "large-scale 5G tests" in 26 GHz, decided to make available up to 1 GHz for it in 2017—commercial in 2020
Sweden 	•PTS is looking at "large-scale 5G tests" in 26 GHz, decided to make available up to 1 GHz for it in 2017 •Commitment to make available pioneering bands starting in 2019

WW Spectrum: China, South Korea, and Japan

China 	•MIIT allocated 3.3-3.6 GHz & 4.8-5.0 GHz as official 5G bands; in addition, CMCC received a 5G trial license for 2.6 GHz (Band n41). •mmWave in longer term. Chinese gov't solicited input on 24.75-27.5 GHz & 37-42.5 GHz bands. Approved small-scale trial usage. •In June 2019 China allocated the following low and mid band spectrum • China Mobile- 2515MHz-2675MHz & 4800MHz-4900MHz, China Telecom- 100MHz from 3400MHz to 3500MHz, China Unicom - 100MHz from 3500MHz to 3600MHz
South Korea 	•Auctioned 5G spectrum for sub-6 and mmWave, 3.42–3.7 GHz & 26.5–28.9 GHz. 5G service launched in March 2019
Japan 	•5G rules for 3.6 - 4.2 GHz, 4.4 - 4.9 GHz and 27 - 29.5 GHz specified •Maximum 500 MHz in Sub-6 and 2 GHz for mmWave plans unchanged •Awarded spectrum blocks to NTT DOCOMO, KDDI, Softbank, Rakuten • Five 100 MHz blocks of C band (3.7-4.2 GHz), One 100 MHz block in 4.5 GHz, Four 400 MHz blocks of 28 GHz

WW Spectrum: South East Asia and Australia

Singapore 	•Regulator issued a public consultation on 5G spectrum, including bands below 1 GHz, between 1 and 6 GHz, and above 6 GHz. •Considering 3.5 GHz, 4.8 GHz, 26 GHz, 28 GHz, 38 GHz as candidates and will finalize 5G spectrum and regulatory frameworks in 2019
Hong Kong 	•Regulator allocated mid-band (3.3–3.4 GHz, 3.4-3.7 GHz, 4.8–4.99 GHz) & mmWave (24.25-28.35 GHz) bands to mobile and will assign in 2019
Indonesia 	•Telkomsel showcased 28 GHz during Asian Games 2018 •Government announced 2019 consult on 5G policy in 2019 with 3.5 GHz and 26 GHz as candidates, finalizing policy in 2020
Australia 	•5G auctioned 125 MHz in 3.6 GHz band 10-2018 (total 3.4-3.7 GHz) •Regulator consulting on 26 GHz spectrum and plans to auction in 2020 •Regulator has announced it will consult on 28 GHz spectrum
Other governments in the region initiating 5G stakeholder consultations this year	

WW Spectrum: Latin America

Chili 	• Public consultation released to 3.7-3.8 GHz & 28 GHz bands as 5G • In 2018, SUBTEL revoked all 3.5 GHz band licenses as underutilized.
Mexico 	• The mobile industry is positioning the 28 GHz band with Mexico's IFT.
Peru 	• MTC published a resolution to re-farm 2.3 GHz and 3.5 GHz bands
Brazil 	• ANATEL released public consultations on using the 2.3 & 3.5 GHz bands for telecom services, identifying both for short term 5G deployments. • In 2018, conducted compatibility studies & tests with satellite receivers
Columbia 	• As part of a plan to release spectrum for IMT, ANE has stated that it will clear the 3.4-3.5 GHz band in 2018, the 3.5-3.6 GHz band in 2019, and the 3.3-3.4 GHz & 3.6-3.7 GHz bands in 2020.

5G Global Frequency Summary

Spectrum Block										
2.3GHz										
2.6GHz										
3.3-3.4GHz										
3.4.3.8GHz		3.4-3.7			3.5	3.6-3.8			3.3-3.6	3.4-3.7
3.8-4.2GHz										
4.4-4.8										
4.8-5.0										
24-27.5	26		26	26.5-27.5	26	26	26	26		
27.5-29										27-28.9
37-42.5										
Spectrum Block										
2.3GHz										
2.6GHz										
3.3-3.4GHz										
3.4.3.8GHz	3.6-3.8		3.4.3.7		3.4-3.7	3.7-3.8		3.5	3.5	3.4-3.7
3.8-4.2GHz	3.8-4.2									
4.4-4.8										
4.8-5.0	4.9-4.9		4.8-4.9							
24-27.5			24.5-27.5		26					
27.5-29			27.528.35	28	28	28	28			
37-42.5										

WW Spectrum Summary

- EU focus mid-band (3.4–3.8 GHz) and 26 GHz (24.25–27.5 GHz)
- China focus is completely mid-band, 3.3–3.6 GHz & 4.8–5.0 GHz
- South Korea: 3.42–3.7 GHz and 26.5–28.9 GHz
- Japan: 3.6–4.2 GHz, 4.4–4.9 GHz and 27–29.5 GHz
- SE Asia: Mostly low and mid-band, with 26GHz and 29GHz in two countries
- LATAM: 2.3GHz, 3.5–3.8GHz, and Mexico 28GHz
- USA - 3.45–3.55GHz (NTIA study), CBRS (3.55–3.7GHz), 3.7–4.2 (Active Proceeding) + mmWave

Summary: mid-band dominates, mmWave part of first wave in most countries

UNITED STATES FREQUENCY ALLOCATIONS

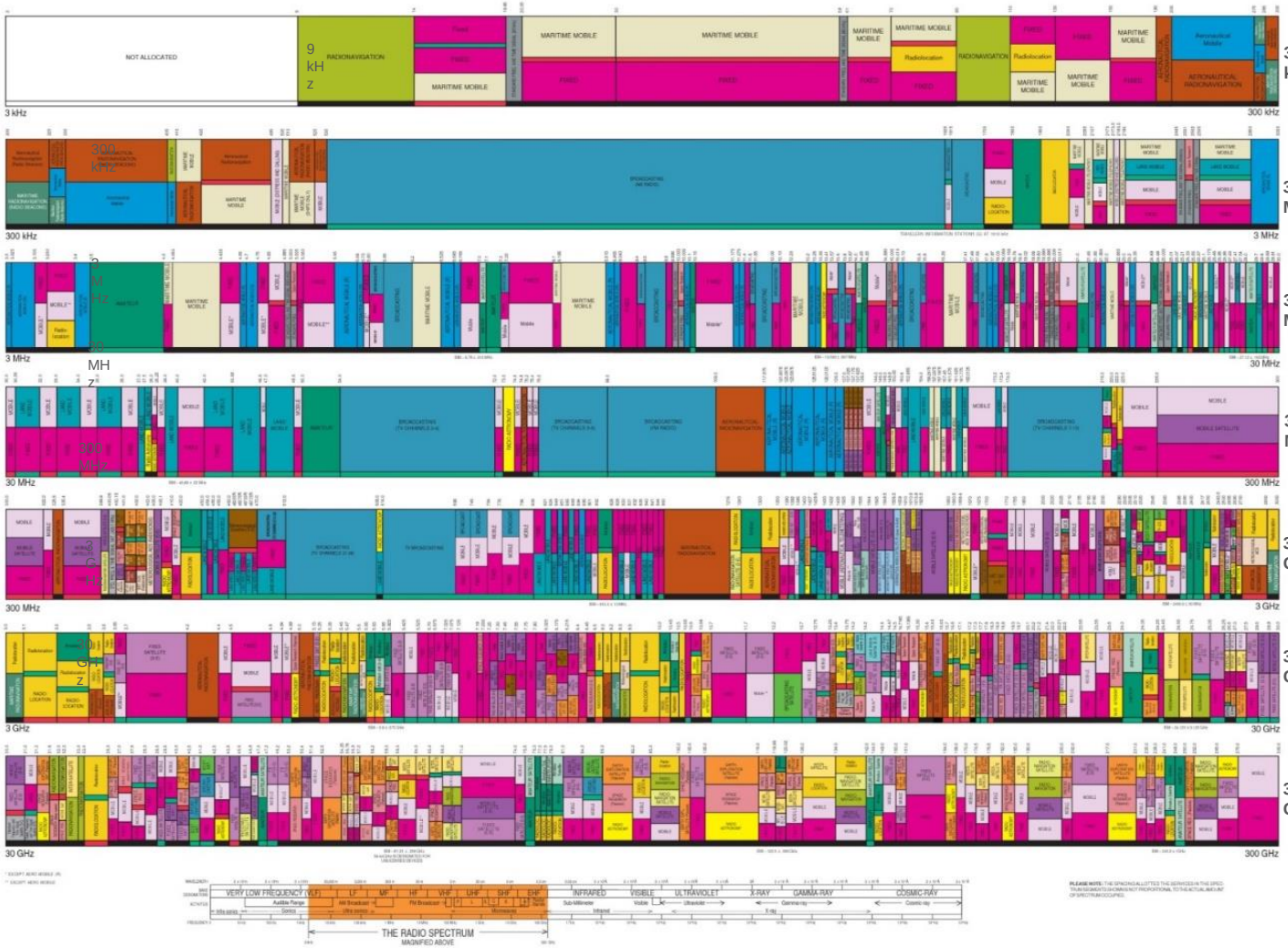
THE RADIO SPECTRUM

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and NTIA. Due to its size and complexity, it cannot fully reflect all aspects, i.e., footnotes and recent changes made to the Table of Frequency Allocations. Therefore, for complete information, users should consult the Table to determine the current status of U.S. allocations.

U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
October 2003



Spectrum Policy Options

1. **Licensed Spectrum** Strictly regulated approach. Clear separation of deployments, in space, time or frequency. Typically how national operators acquire access to spectrum

2. **Unlicensed Spectrum** all devices can access the spectrum. No control of the number of devices in a specific space, time or frequency domain. Typically how WiFi networks operate. Current US allocations of unlicensed spectrum are more than 500 MHz in low bands, 14 GHz in millimeter wave frequencies, and up to 1.2 GHz if the 6 GHz allocation becomes policy

3. **Locally Licensed/Shared Access (includes "Dedicated")** a regulatory framework that allow for several users in same band. Quality pending the national regulatory framework. E.g.: 3.55 – 3.7 GHz in US, 3.7-3.8 GHz in Sweden and Germany, 3.8 – 4.2 GHz in UK

Licensed Spectrum

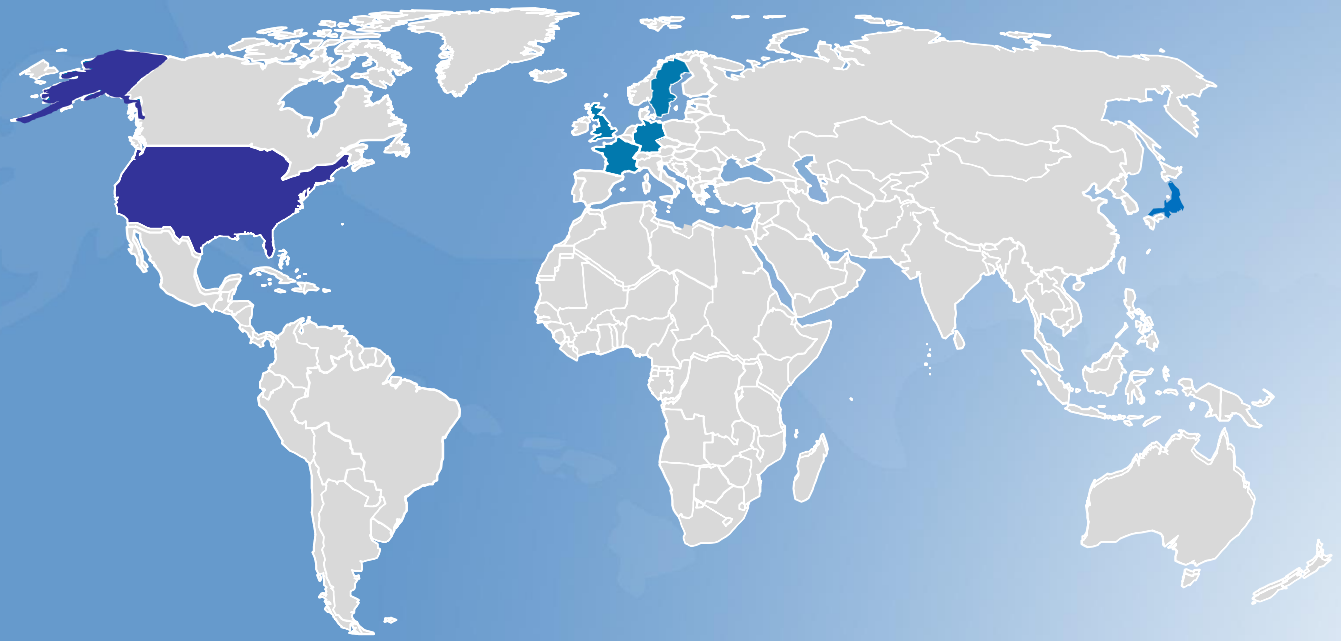
- Responsible for creating the mobile telephone revolution with vertical service model for voice/SMS/circuit data
- Packet services created an information revolution by bringing the Internet to the palm of your hand
  - Further expansion promised by cellular IoT
- Provides a channel delivery mechanism for information service delivery including media, broadcast, interactive services
- Significant realization of immediate value by forcing investment into infrastructure: RAN, Core, Transport (requires ROI by purchasing operator)
- 5G will harness technological solutions to bringing support more vertical
  - Approach is to create a horizontal platform to host verticals; *Public services, transportation, smart utilities, industrial wireless for monitoring and critical communication*

5G Spectrum Debate: *more licensed/more unlicensed*

- The licensed model only carries so far with all use cases
  - Service providers motivated on ROI and create products that maximize the revenue potential for spectrum
  - What is the role of network slicing in being able to dedicate resources to critical societal needs?
- How many use cases are there that need their own spectrum and can fill that allocation with traffic?
  - Will this dedicated or shared licensing lead to more innovation?
- Public safety and QoS sensitive applications; transportation, industrial automation , rural broadband are areas where adequate support is lacking
  - Can some of these be done over-the-top?
  - Is Spectrum sharing the proper approach?
  - Or, is the solution providing dedicated spectrum for certain verticals?

The Conundrum: with limited spectrum how to meet all these needs

Dedicated/Shared Spectrum: Top IIoT Manufacturing Markets



Discussions on dedicated spectrum for Industries ongoing

3.7-3.8 GHz in Sweden, Germany
2.3 GHz, 3.8-4.2 GHz, 1800 MHz in UK
2.6 GHz in France
26 GHz in Germany
37 GHz in US
4.6-4.8 GHz in Japan
28.2-29.1 GHz in Japan

Alternative methods of spectrum allocation: leasing and shared

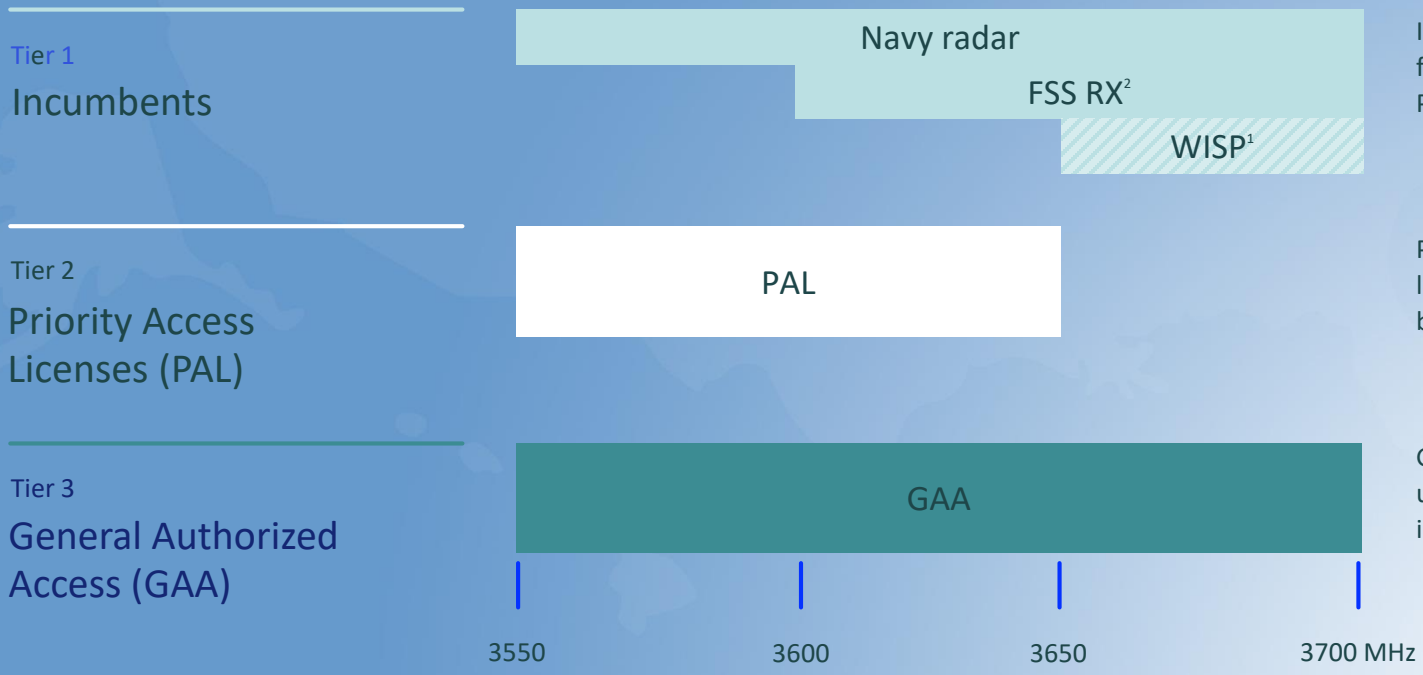
3.55-3.7 CBRS
37-37.6 GHz
3.5 GHz in the UK

* China, US, Japan, Germany, Sweden, South Korea, UK, France, Italy, Netherlands

Dedicated Debate: How to drive innovation, economic development and meet needs of key industry verticals vs use of non-dedicated spectrum

Mid-band: CBRS introduces a 3-tiered shared spectrum

Good opportunity for shared spectrum uses



1 Wireless ISP transitioning from incumbent to PAL/GAA after 5 years; 2 Fixed satellite service – receiving only; 3) Citizen Broadband Radio Service (CBRS)

Implementation: CBRS will most likely not be used for critical services

Spectrum Observations

- China and other countries focused completely on sub 6GHz spectrum for 5G
  - Sub 6GHz provides greater transmission distance, reduced interference, as a result, fewer antennas
- The balance of licensed, unlicensed and dedicated or shared is complex; the key is meeting citizen, business needs while stimulating investment and innovation
- Spectrum re-use and shared are potential ways to optimize usage
  - *CBRS has the potential to provide spectrum to address private use and industry specific needs*
  - *CBRS lacks capability to fit verticals/uses that demand determinism (industrial, critical services)*
- USA spectrum management is very proactive and encompasses low, mid and mmWave. Additional focus needed on mid-band, including C-Band.
- mmWave is not a good fit for rural deployments; densities and distances challenge this spectrums characteristics
- Optimizing spectrum utilization should be a top priority- *how do we measure success?*

The TAC will further investigate these areas (in Q3/Q4) for potential opportunities and recommendations

5G/IOT RURAL-UNDERSERVED UPDATE

Comparing Deployment Requirements

Is 5G the answer?

Density
Coverage
Speed
Reliability

Density
Coverage
Speed
Reliability

Speed
Reliability

5G Doesn't Solve:

- Coverage
- Spectrum Needs
- Backhaul Costs
- Interconnect Costs
- Antenna Costs

URBAN SUBURBAN RURAL

Solving the Rural Divide – More Questions than Answers

Solution will include 5G combined with other networks for Education Proposal, Satellite, LTE & WiFi; Spectrum Policy; Antenna Design; Backhaul; & Rural Funding

- Low population density
- Long distances/geographic coverage
- Economics: business model
- X-Haul: availability and cost
- Spectrum challenges
  - Lower has longer propagation
  - Higher is challenged

- Spectrum BW required in low bands to efficiently provide rural service
  - Unlicensed does NOT encourage investment
- Study how antenna design affects spectrum efficiency for low bands
- Identify any barriers in the use of new antenna designs to benefit rural areas
- Adjustment in power or interference rules to better serve rural areas
- Can 5G serve as supplement drop deployment for FTTH
- What barriers exist for backhaul for 5G in rural areas
- Slicing impact on rural markets

A Proposal: Education 2.0

Solving the Digital Divide

Premise: Broadband is an “equalizer’, an “enabler”, every student needs wireless access

The Need:

- Broadband access is an essential requirement for the future of education
- Millions of students are unserved or can’t afford Broadband Access

Solving the Digital Divide should be a national priority!

A Proposal to Solve the Digital Divide for Education: Education 2.0

- Stimulate creation of a network dedicated to education in rural & urban areas
- Hardware and related SW optimized for broad coverage and low cost
- ATSC 3.0 or other nets through 3GPP TS 22.261 for simultaneous operation W/ 5G
- Subsidize network with “no-cost” spectrum and free geographic sites
  - Unused lower frequencies reverse-auctioned on the basis of low price
  - Sites at schools, libraries, or donated
- Curated content (possibly by DoEd): i.e., dedicated search engine, special content

5G/IOT SECURITY CONCERNS

Spectrum Jamming, Spoofing and Sniffing Concerns

- Premise: Society depends ever more critically on wireless services
- Wireless services (like all others) are vulnerable to failure due *malicious action*, human error, or acts of nature
  - Vulnerabilities include jamming, spoofing, sniffing, cyberattacks, misconfiguration, and unintentional interference both human and natural
  - Solutions and mitigations include laws and regulations, system and component design including SDN/programming, operating best practices including behavioral aspects and analyses, and market incentives

Spectrum Spoofing Details

- Since radio receivers are inherently open to impinging signals in order to operate, they have unique vulnerabilities (e.g., spectrum denial attacks)
- Since wireless services are increasingly digital, they are also exposed to cybersecurity vulnerabilities
- Disagreement on the importance of spectrum denial attacks relative to cybersecurity attacks “up the protocol stack”
- Impact: range from simple data collection/monitoring to safety of life affecting services (e.g., insulin pumps in the healthcare vertical market)
- These are local attacks that have the potential to cause detrimental impacts particularly in a 5G environment that enables millions/billions of device connectivity, and NR cell density

Potentially detrimental impacts to millions of connected devices due to (NR) new radio density

5G Features for Privacy Protection

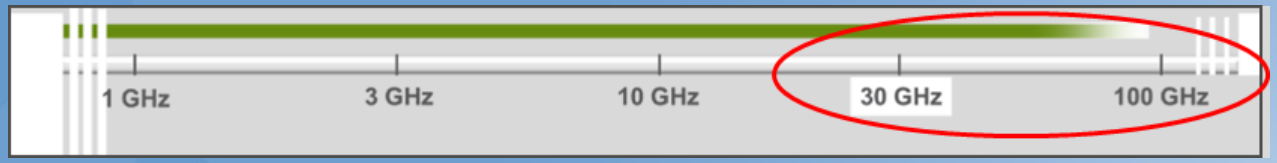
- Protection against IMSI catchers
  - Privacy protections on the Uplink through a concealed long-term Subscription Concealed Identifier (SUCI)
  - Paging timing determined using a temporary identifier as opposed to the IMSI
    - In 4G there was an option to use the IMSI as a paging identifier
    - Radio Network temporary Identifier (I-RNTI) is refreshed frequently
- Further investigation ongoing on other aspects of resilience to spectrum vulnerabilities

Spectrum Spoofing Next Steps

- Proposed TAC work
  - Survey the relative risks posed by various vulnerabilities, and available mitigations
  - Describe the state of the art
  - Identify areas where additional work is needed
  - Recommend actions to the Commission
- Activities/Method
  - Invited presentations
  - Technical research by WG members
  - Group analysis and discussion

5G/IOT ANTENNA – NR

NR Densification Characteristics



Carrier frq (GHz)	10	28	38	73
Number of Antenna Elements	4	32	64	256
BW (MHz)	500	500	500	600
Cell radius (m)	250 (R_{ref})	250	250	100
Coverage - No. of cells $(R_{ref}/R)^2$	1	1	1	6.25

mmMagic – Strand 1: Coverage KPI

>24gHZ Requires much greater density of NR's to support, though provides greater spectrum re-use

>24gHZ substantial increase in deployment cost for SPs

- KPI requirement is a cell edge data rate of 100 Mb/s
- Bandwidths of the order of 500-600 MHz per channel

Ref: mmMagic, "Millimetre-Wave Based Mobile Radio Access Network for Fifth Generation Integrated Communications (mmMAGIC): Use case characterization, KPIs and preferred suitable frequency ranges for future 5G systems between 6 GHz and 100 GHz," FP4-ICT-671650-mmMAGIC/D1.1

5G Densification – Potential Barriers to Deployment

- **Small cell densification**/mmWave deployment- up to 2-year cycle
  - For every cell, *an MNO needs to gain site & equipment approvals; negotiate fees with site owner; deploy, provision & maintain the base station; ensure it has appropriate backhaul & power; and conform to the city's aesthetic and environmental regulations.*

TAC Public Notice NR/Antenna Design & Aesthetics

- Intent is to reduce barriers to NR acceptance
- Address design & Install aesthetics
  - Densification for 5G mmWave will require greater number of antennas compared to traditional spectrum
  - Need guidelines for technologists for antenna design and placement
  - Need to meet varied zoning requirements of municipalities and enterprises
  - Address both brownfield and greenfield deployments
  - Note: power related issues will *not be* part of PN
  - Promote shared RAN deployment to reduce antenna clutter and/or cost

Action: Partner with TAC Antenna WG to issue PN

Source: Ericsson

5G/IOT: IPV6 – A CALL TO ACTION

IPv6 & 5G

- The need to support over 20 billion + IoT devices in a few years will out strip IPv4 capacity. Using Ipv4 to support 20 billion devices will require the use of NAT's adding additional network latency.
- By deploying 5G with native IPv6 as the primary protocol and IPv4 support through IPv6 tunnels there is the ability to continue to support IPv4 and have all the advantages of IPv6
- IPv6 5G USA adoption will put the USA in the leadership role for both IPv6 and 5G deployment and set a standard for the world to follow
- WW action/adoption: May 7, 2019, CHINA Ministry of Industry and Information Technology (MIIT)
- 3GPP supports IPv6: this is a deployment issue, not a technology issue
- IPv6 could be leveraged to integrate the user-plane into a layer used for forwarding packets to various data-paths

IPv6 Support 2015-2017: Top Consumer Devices

IPv6 Supported Consumer Devices -- US Market

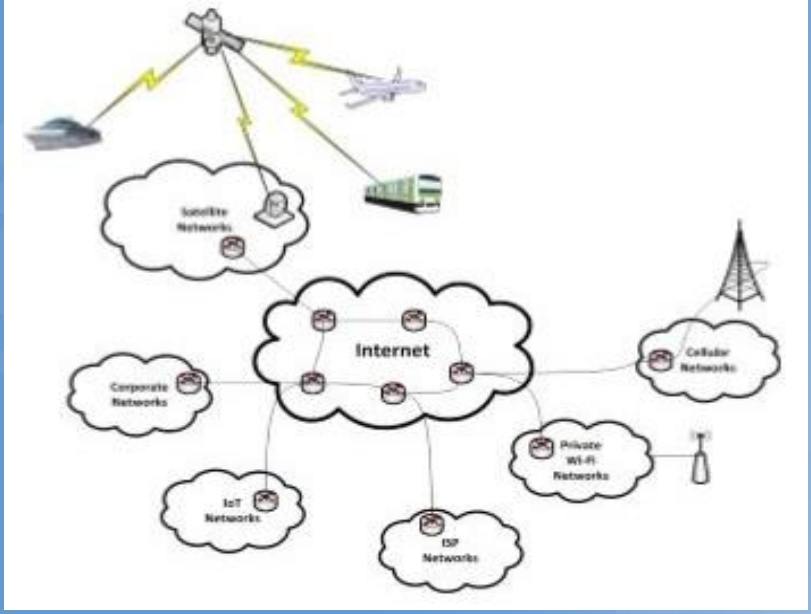
Category	2015 MarketMetric Estimate	2015 IPv6 Support (Percentage)	2016 MarketMetric Projection	2016 IPv6 Support (Percentage)	2017 MarketMetric Estimate	2017 IPv6 Support (Percentage)
Smartphone Units	174,641	100.00%	183,373	100.00%	167,947	100.00%
Tablets	66,315	100.00%	60,300	100.00%	51,688	100.00%
Mobile Computers	26,980	100.00%	27,654	100.00%	48,778	100.00%
Smart TV	23,886	14.00%	26,992	60.00%	33,797	100.00%
Game Consoles	18,378	38.23%	18,664	44.35%	16,206	60.00%
Printers	16,729	74.10%	17,062	87.91%	13,820	100.00%
Streaming Media Players	15,080	69.90%	15,834	69.90%	16,920	57.70%
Smart Watches	10,598	55.74%	13,565	58.45%	12,120	58.45%
Desktop Computers	8,061	100.00%	7,217	100.00%	16,745	100.00%
e-readers	7,534	53.90%	7,166	53.90%	5,923	80.00%
Top 10 Categories Aggregate	368,202	319272.2096	377,827	340875.0707	383,944	364083.98
		86.71%		90.22%		94.83%

- **Computing platforms were at 100% (smart phones, tablets, desktop & mobile PCs)**
- **Smart TVs significantly improved y-o-y, 14% → 60% → 100% *(%-units-shipped-with-IPv6)***
- **Consumer printers improved y-o-y, 74% → 88% → 100%**
- **Growth or decay in categories does impact the "Aggregate" number**

RE: CTA, April 2018

5G/IOT: SATELLITE RELATIONSHIP

Satellite will Continue to be an Integral Component of the Internet

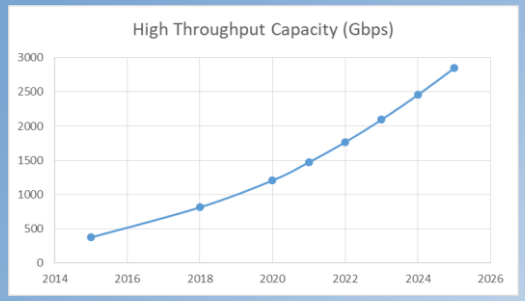


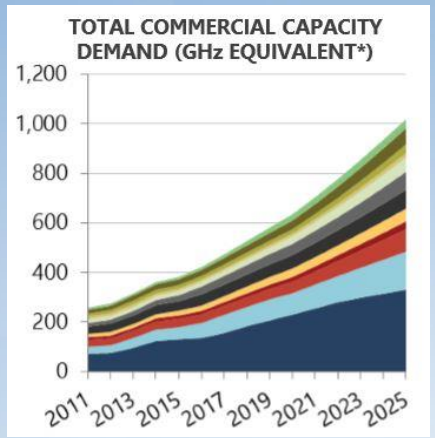
5G should be put in the context of balanced roadmap to future wireless technologies that include satellite, microwave, mm-wave, cellular and Wi-Fi networks that will collectively compete for the broadening demand for new applications. Each of these networks provides its unique value in user management, security and capabilities, each providing connection to the global Internet.

Cisco VNI report predicts that 5G cellular devices in 2021 will represent only 0.2% of all connected devices in the world and will account for only 1.5% of network traffic. In addition, the total of all IP Internet traffic will exceed 84 exabytes of data, *50% will be Wi-Fi, 30% will be fixed and only 20% will be mobile data.*

The Satellite Industry launches capacity to meet demand

New GEO launches will add 1 Tbps capacity/launch with one scheduled over the US and two more to cover rest of the world – more will be added to meet demand





REFERENCE STATUS AND INFORMATION ON LEO AND MEO CONSTELLATIONS

	O3b Networks	OneWeb	LEOSAT	Telesat	SPACEX
Full Constellation Size	20 satellites	648 satellites (900 including spares)	78-108 satellites	2 distinct prototype satellites ordered in April 2016 as part of a test and validation phase for its constellation	4,000 satellites
Total Capacity	210 Gbps	~5 Tbps (7.5 Gpbs/satellite)	1.2 to 2.0 Tbps		8-10 Tbps
Frequency	Ka-band	Ku-band	Ka-band	Ka-band	Ku-band
Orbit	MEO (8,062 km)	LEO (1,200 km)	LEO (1,400 km)	LEO (1,000 km)	LEO (1,100 km)
Cost per Satellite	$80 million, after initial eight satellites	<$500,000	$30-45 million	-	$2.5 million
Mass	~700 kg	<150 kg/satellite	-	-	-
Satellite Life	12 years	~7 years	10 years	-	-
Latency	<150 ms	<50 ms	<50 ms	<50 ms	<50 ms
Vertical Markets	Backhaul/Trunking, Energy, Maritime, Government	Backhaul, Government, Mobility, Broadband	Enterprise, Maritime, Backhaul/Trunking, Energy	Government, Mobility, Rural Connectivity	Broadband

These projections represent rough dated estimates based on trends. As satellite is a fast innovating telecom sector, past trends do not define future capacity

Euroconsult, Satellite Communications and Broadcasting Market Survey 2016

5G/IOT: NEW DEVELOPMENTS

5G: what's new

- WW 5G split: sub 6GHz vs mmWave deployments, equipment
- Dedicated spectrum initiatives: DE, SE, FR, UK, JP (IIoT)
- Market projections are up (per Ericsson)
- GPS spoofing: Timing and location impacts
- Open RAN (ORAN) potential to disrupt RAN services market
- Augmented and VR apps and devices in dev
- Hype alert: however, we are still in the early days of 5G

SUMMARY & WHAT'S NEXT

Summary

$$fcc(x) = Spectrum + \sum_{n=1}^{\infty}(5G_n)$$

- 5G is still in early days, however deployments are strong
- Spectrum management is critical path to success
  - Needs in low, mid and mmWave ranges to fit various needs
  - A number of opportunities related to shared spectrum
- Standards are on track and 3GPP R17 has many strong proposals
- Rapid development/innovation in multiple 5G/IoT verticals to take advantage of the new 5G service capabilities
- Digital divide should be a priority- may require new models
- New security threats also emerging related to spectrum
- Opportunities to drive industry collaboration related to RAN

5G/IoT WG: What's Next Q3 and Q4

- Monitor Standards, Rel 17 updates
- IoT: vertical impacts, roadblocks, opportunities
- Spectrum- deep dive on C-Band, dedicated spectrum
- Antenna Issue a TAC PN
- Greater investigation on spoofing, jamming, sniffing issues
- Rural- several key points: Antenna design, shared NR resources, study drivers - education, 5G service alternatives, review spectrum and backhaul options specific for rural
- Verticals and relevance
- Input from TAC and FCC Staff

Proposed Speakers 2019 – Q3 & Q4

- ATIS
- GSMA- slicing federation
- 5G ACIA- TSN/URLLC, industrial
- IIoT- A deployer
- 5GAA, SAE- Automotive/transportation
- Digital Globe-
- Spectrum- Qualcomm
- DOD Paper: Milo Medin (TAC)
- Emergency Services: *FCC, ATT, NINA, APCO*
- IEEE: WiFi- impact and effect of 5G, TSN
- 5G Security
- Snooping, jamming, sniffing
- NR tuning range
- Verticals:
  - Transportation/Vehicular – DoT?, Auto OEM
  - Industrial (IIoT) a deployer
  - Enterprise: ex. Major retailer
  - Smart cities: CISO
- Open-ness
  - Open RAN
- Rural Topics:
  - Rural 5G- FCC economics SME
  - Rural models – University based
  - Rural communications company
  - Rural Stakeholder: Grain processors, other
  - Connect America fund

THANK YOU!

FCC TAC AI-WG
Artificial Intelligence

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

FCC Liaisons: Michael Ha, Mark Bykowsky, Bahman Badipour, Eric Burger

Date: June 21, 2019

2019 Work Group Team Members

- Shahid Ahmed, Independent
- Nomi Bergman, Advance Newhouse
- Brian Daly, ATT
- Adam Drobot, OpenTechWorks
- Jeffrey Foerster, Intel
- Dale Hatfield, Univ of Colorado
- Lisa Guess, Cradlepoint
- Russ Gyurek, Cisco
- Stephen Hayes, Ericsson
- Mark Hess, Comcast
- Nageen Himayat, Intel
- Steve Lanning, ViaSat
- Kevin Leddy, Charter
- Brian Markwalter, CTA
- Lynn Merrill, NTCA
- Michael Nawrocki, ATIS
- Dennis Roberson, entigenlogic
- Marvin Sirbu, SGE
- Kevin Sparks, Nokia Bell Labs
- David Tennenhouse, VMware

Artificial Intelligence – 2019 Charter

- The Artificial Intelligence (AI) work group is a continuation of the 2018 Computational Power Stress on the Network WG with a focus on artificial intelligence.
- The work group is tasked with providing information on AI and the variety of roles it might play in communications networks and services.
  - Where is AI being deployed in networks today and how will it develop?
  - What benefits and risks does it provide in the broad communications space?
  - Are there Commission rules or policies that are barriers to the introduction of AI?
  - Where might the FCC introduce AI in its own systems and processes to enhance the efficiency and effectiveness of FCC missions?
- Artificial intelligence is a relatively new field and yet has very broad implications in the communications space. Therefore, the group has flexibility to determine what might be of most interest and importance and where actionable recommendations might be most valuable to the Commission.

Context to Help Guide Areas of Focus:

- Telecommunications Act of 1996

- **Title I, "Telecommunications Service":**
  - Helps to outline the general duties of the telecommunication carriers as well as the obligations of all local exchange carriers (LECs) and the additional obligations of incumbent local exchange carriers (ILECs).
- **Title II, "Broadcast Services":**
  - Outlines the granting and licensing of broadcast spectrum by the government, including a provision to issue licenses to current television stations to commence digital television broadcasting, the use of the revenues generated by such licensing, the terms of broadcast licenses
- **Title III, "Cable Services":**
  - Outlines the Cable Act reform, cable services provided by telephone companies, the preemption of franchising authority regulation of telecommunication services, VHS home video programming accessibility, and competitive availability of navigation devices.
- **Title IV, "Regulatory Reform":**
  - Outlines regulatory forbearance, a biennial review of regulations, regulatory relief, and the elimination of unnecessary Commission regulations and functions.
- **Title V, "Obscenity and Violence":**
  - Outlines regulations regarding obscene programming on cable television, the scrambling of cable channels for nonsubscribers, the scrambling of sexually explicit adult video service programming
- **Title VI, "Effect on Other Laws" :**
  - Outlines the applicability of consent decrees and other laws and the preemption of local taxation with respect to direct-to-home sales.
- **Title VII, "Miscellaneous Provisions" :**
  - Outlines provisions relating to the prevention of unfair billing practices for information or services provided over toll-free telephone calls, privacy of consumer information, pole attachments, facilities siting, radio frequency emission standards, mobile services direct access to long distance carriers, advanced telecommunications incentives, the telecommunications development fund, the National Education Technology Funding Corporation, a report on the use of advance telecommunications services for medical purposes, and outlines the authorization of appropriations.

Examples of how the Act might guide the AI-WG

- Does AI play a role in any of the titles and how would they would be applied?
  - Can AI assist in enforcing the titles?
  - Can technology help to monitor patterns and behaviors?
  - Do our selected focus areas further the mission?
- Examples:
  - Sec 706 - Advanced telecommunications incentives - can corporations leverage AI to fully execute on this initiative?
  - Insecure devices, stolen devices - Devices with default passwords can be used to attack the network. How can the FCC more efficiently attack this problem through intelligence
  - Robocalling prevention
  - Can a web crawler inspect broad information on the internet and see what threats might be emerging or better understand complaints and service offering gaps?
  - Prevention of illegal devices such as jamming devices

Strategy for the Artificial Intelligence Work Group

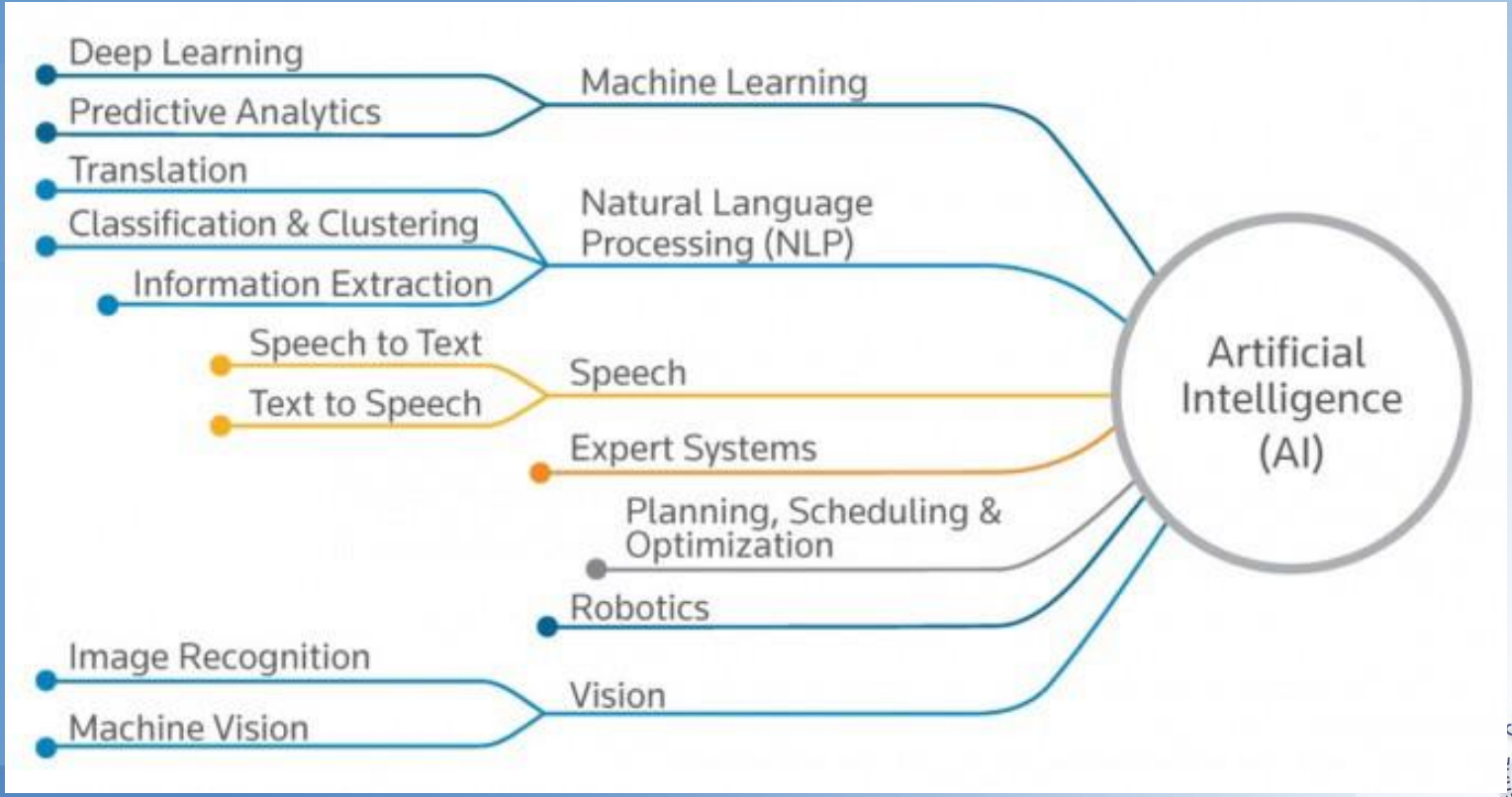
- The WG will focus on three areas

- Impact on the network itself
  - Automated management for traffic characteristics (growth/spare capacity)
  - Network orchestration and slicing (including 5G context)
  - Real-time fault detection, repair, and security response
- High impact industries and institutions
  - Industry examples: Financial, Healthcare, Agriculture, Education, Legal, Industrial control
  - In servicing these industries, what is the impact on the Network?
    - Nature of the architecture
    - Load on the network
    - Economic and Societal impact
- Internal use for the FCC
  - Legal viewpoint combined with economic impact view
  - Ease of access for the public regarding regulatory topics
  - Mechanize the enforcement of regulations

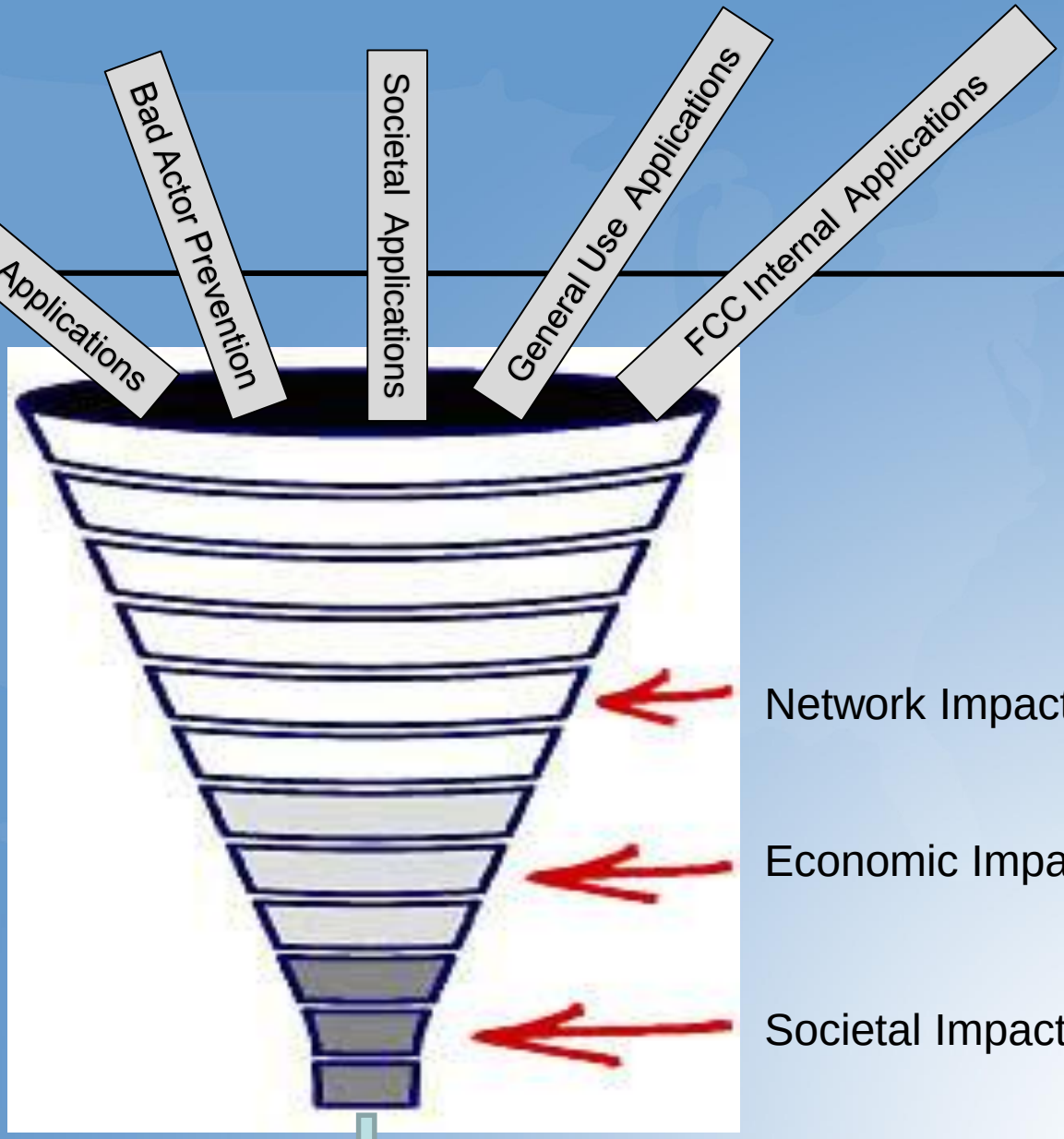
Execution Plan for Artificial Intelligence -WG

- Identify High impact applications for AI relative to FCC mission
- Learn from the experts
  - General Artificial Intelligence (AI)
    - Invite experts to describe an relevant overall view of AI
  - Industry
    - Recruit speakers from industries and institutions with large scale AI strategies
  - Network Automation and Architecture
    - Include a deeper dive including Cloud DC, remote workers and the network impact
  - FCC Application
    - Understand how the FCC can optimize workflow and execution
- Desired Outcomes
  - Provide education
    - Understand the impact of AI on fundamental network structure and the FCC mission
  - Define continuance of mission for WG into 2020
  - Develop Actionable Recommendations (examples below)
    - How to use AI within the process of the FCC to make regulations more accessible
    - Identify where the current regulatory structure is called into question because of AI

Artificial Intelligence and the Various Components



Chethan Kumar GN
Data Scientist @Iqreate Infotech Pvt Ltd



High Impact Areas of Study

Application of AI - For the Network

- Customer Experience
  - QoS/QoE – using algorithms to predict network demand
  - Machine driven policy management
- Improved Efficiency of the Operator's network
  - Predicting propagation and modelling
- Wireless design
  - Leveraging In house intelligence to maximize wi-fi coverage and performance
  - Intelligence for other forms of wireless
- Understanding Impact of AI on network architecture (including compute)
  - What is the load AI can impose or reduce on the network
- Targeted Advertising

Application of AI – Internal use for FCC

- Spectrum – efficiencies and enforcement
  - Spectrum management and use
  - CBRS
    - Dynamic capabilities, use/re-use, multiple licenses
    - Considerations toward resolving interference using AI
  - Exclusive versus non-exclusive use. Can AI facilitate the more efficient sharing of spectrum designate for commercial use? Can AI enhance a market mechanism's ability to facilitate sharing?
- Policy issues
  - Machine learning for enforcement of rules and regulations
  - Efficient comparison of how new rules affect old rules
- FCC website – improve search capabilities

Application for AI – Preventing nefarious activity

- Spoofing
  - Robocalling
  - Spectrum Spoofing
  - GPS spoofing and prevention
- Security
  - Spoofing identification and mitigation
  - Attacks within encrypted data
- Privacy protection

Application for AI - General

- Industrialized AI – examples: smart factories, chip development, smart farming
  - Safety enhancement
  - Predictive maintenance
  - Improved ROI
  - Faster time to market
- Emerging SW technologies
  - Anomaly detection
  - Use of AI to identify problems
- Computation
  - Load balancing
  - Running distributed systems
  - Optimization

Application for AI – Societal

- Accurately Mapping Broadband Availability
  - Use of AI for broadband mapping system. Optimization of federal funding for rural environments
  - Leveraging new digital resources, databases and crowdsourcing platforms, combined with existing provider service address information, can improve understanding of unserved/served areas
- Emergency Services
- Avoidance of biased results based on data and providing enhanced transparency
  - Prevent gaming of the system
  - Identify discrimination in search results and decision criteria
- Source of provenance of data
- Cell Phone theft

THANK YOU

Communication Strategies for Unmanned Aircraft Systems (UAS)

Chair: John Chapin, Roberson & Associates

FCC Liaisons: Robert Pavlak, Office of Engineering and Technology
Brian Butler, Office of Engineering and Technology
Tim Maguire, Wireless Telecommunications Bureau

Date: June 21, 2019

Working Group Members - 2019

Subgroup Chairs

- TBD for 2019

Membership

- Reza Arefi, Intel
- John Barnhill, Alianza
- Brian Daly, AT&T
- Stephen Hayes, Ericsson
- Steve Lanning, Viasat
- Steven Nordlund, Boeing
- Ted Rappaport, NYU
- Dennis Roberson, Roberson & Assoc.

Subject Matter Experts

- Sean Cassidy, Amazon Prime Air
- Jackie McCarthy, CTIA
- Jennifer Richter, Akin Gump
- Raj Sengupta, CTIA

Stakeholder Priority Topics

- Study the spectrum issues for UAS
  - Including C2, payload, identification, monitoring, collision avoidance
- Address the following specific questions:
  - What frequency bands are available today, and are they sufficient?
    - Consider payload needs as part of this
  - Which UAS activities can be carried out using existing systems or services (CMRS, Land-mobile, Satellite, Aviation, GNSS, etc.)?
  - What are the trade-offs for the various alternative frequency bands?
  - To what extent has loss of communications been a major contributor to loss of UAV?
  - What are the issues of harmful interference to systems on the ground?
  - What new requirements and roles for radar arise from UAS?

Stakeholder Priority Topics (continued)

- Specific questions (continued):
  - What is an appropriate FCC requirement for station ID in UAS transmissions?
  - What is an appropriate FCC requirement for radio certification?
  - What testing facilities are available to evaluate these concepts?
- Make recommendations including:
  - What taxonomy should the FCC use in its regulatory approach?
  - What should the FCC study or do to meet the various spectrum needs for UAS?
    - Considering the need to make efficient use of the spectrum

2018 UAS-WG Focus

- The working group had limited time to study the broad set of systems and bands relevant for UAS operation.
- The group focused its 2018 recommendations on terrestrial mobile bands and systems.
- Recommendations related to other systems (satellite, unlicensed) and bands were deferred to 2019 work items.

UAS-WG 2018 Recommendation 1

1. The FCC should consider UAV access to terrestrial mobile bands, along with corresponding service rules and associated technical parameters, taking into account FAA regulations governing their use by UAVs.

In doing this the FCC should:

a) Consider issues of potential in-band and out-of-band interference to terrestrial or aeronautical incumbent services, enforcement challenges, and what harm claim thresholds to apply.

b) Collect data from studies done by industry, FAA sponsored projects, other government agencies, academia and foreign entities.

c) Reassess any service rules that prevent integration of UAV communications functions, for example command/control and payload functions, into shared data links.

UAS-WG 2018 Recommendation 2

2. With respect to 3GPP technologies specifically, the TAC has found that 3GPP technology satisfies the expected communications requirements for low altitude UAVs. Based on this, the FCC should:

a) Consult with involved federal agencies including the FAA as necessary regarding the use of terrestrial mobile bands for UAV communications.

b) Re-assess the technical basis for prohibiting use of certain terrestrial mobile bands above ground level.

UAS-WG 2019 Work Plan

- RF analysis tools and methods
  - Sub Working Group 1
- Spectrum requirements
  - Sub Working Group 2
- Aeronautical restrictions on terrestrial mobile licenses
  - Joint between 2 Sub Working Groups
- Informational topics
  - Market Updates
  - 3GPP Work Updates

RF analysis tools and methods

- Appropriate analytic tools need to be identified or created for effective policy making regarding UAS spectrum capacity and requirements
  - Consider both aviation and non aviation bands (including terrestrial mobile and unlicensed)
  - Consider both air to ground and ground to air links

- Key topics for investigation include the following.
  - Link, coverage, capacity, in-band and out-of-band interference analysis
  - Predictability for reliable C2
  - Impact of filters and antennas including beamforming - considering both technology and market developments
  - Impact of operation at different altitudes

Spectrum Requirements

- Continue the 2018 spectrum requirements study
  - Evaluate WiFi and other systems operating in Unlicensed bands
  - Assess impact of autonomy and evolving use cases on spectrum requirements
  - Other components of the study as time permits
- Provide input to assist FCC response to ongoing multi agency UAS spectrum study (under FAA reauthorization Section 374)
  - UAS-WG expects to consider the 960-1164 MHz and 5030-5091 MHz bands as part of this

Aeronautical restrictions on terrestrial mobile licenses

- Assess issues associated with determining whether aeronautical restrictions on terrestrial mobile licenses can safely be relaxed for low altitude UAS operations
  - Incorporate RF analytic perspective (sub group 1)
  - Incorporate UAS operations and spectrum requirements perspective (sub group 2)

- Goal: assist potential FCC action in response to 2018 WG recommendations
  - Re-assess the technical basis for prohibiting use of certain terrestrial mobile bands above ground level.
  - Consider issues of potential in-band and out-of-band interference to terrestrial or aeronautical incumbent services, enforcement challenges, and what harm claim thresholds to apply.

Informational Topics

- Market updates
  - Organize best available information on UAS market size and characteristics
- 3GPP updates
  - Identify, organize, and assess relevance to FCC interests of work going on in 3GPP
  - Include terrestrial, high altitude, and satellite relayed architectures as appropriate

Communication Strategies for Unmanned Aircraft Systems (UAS)

Questions?