Federal Communications Commission Technological Advisory Council Meeting

September 15, 2022

FCC Technological Advisory Council Agenda – September 15, 2022

10am – 10:30am	Introduction and Opening Remarks •Welcome Message (TAC Chair) •Opening Remarks by OET Chief •DFO/Deputy DFO Remarks •Member Introduction/Roll Call
10:30am ~ 11:15am	Advanced Spectrum Sharing WG Presentation
11:15am-12:00pm	6G WG Presentation
12:00pm – 1pm	Lunch Break
1pm – 1:45pm	AI/ML WG Presentation
1:45pm-2:30pm	Emerging Technologies WG Presentation
2:30pm-2:45pm	Closing Remarks
2:45pm	Adjourned

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FCC TAC Advanced Spectrum Sharing Working Group

Co-Chairs: Andrew Clegg, Wireless Innovation Forum
Monisha Ghosh, Wireless Institute, University of Notre Dame

FCC Liaisons: Michael Ha, Martin Doczkat, Nicholas Oros, Bahman Badipour, Robert Pavlak, Navid Golshahi

Date: September 15, 2022

2022 Spectrum Sharing Work Group Participants

Ames, Robert	VMware
Arefi, Reza	Intel
Badipour, Bahman	FCC
Balachandran, Kumar	Ericsson
Brake, Doug	NTIA
Brenner, Dean	Consultant
Chandra, Ranveer	Microsoft
Claudy, Lynn	NAB
Clegg, Andrew	Wireless Innovation Forum
Daly, Brian K.	AT&T
Doczkat, Martin	FCC
Drobot, Adam	Open Techworks
Etemad, Kamran	FCC

Ghosh, Monisha	Notre Dame
Golshahi, Navid	FCC
Guess, Lisa	Cradlepoint
Gurney, Dave	Motorola Solutions
Gyurek, Russ	Cisco
Ha, Michael	FCC
Hatfield , Dale N.	University of Colorado
Jindal, Manish	Charter
Lanning, Steve	Viasat
Lapin, Greg	ARRL
Mahdi, Kaniz	Deutsche Telekom
Manner, Jennifer	Echostar
Mansergh, Dan	Apple
Marcus, Michael	Northeastern U

Markwalter, Brian	CTA
Merrill, Lynn	NTCA
Mukhopadhyay, Amit	Nokia
Nasielski, Jack	Qualcomm
Noland, Madeleine	ATSC
Oros, Nick	FCC
Pavlak, Bob	FCC
Peha, Jon	CMU Metro21
Russell, Jesse	incNetworks
Sawanobori, Tom	CTIA
Schulzrinne, Henning	Columbia U
Scott, Andy	NCTA
Welsh, Patrick	Verizon

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Agenda

- Charter
- Topic area updates
  - Discussion on Topic Area 1 (Potential New Bands For Sharing) and Topic Area 2 (Best practices for spectrum sharing)
- Speakers
- Work products
  - Whitepaper on lessons learnt from sharing in AWS-3, TVWS, CBRS and 6 GHz
  - Whitepaper on Spectrum Inventory
- Summary and discussion

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Advanced Spectrum Sharing WG - 2022 Charter

- Several sharing mechanisms (static/dynamic or centralized/decentralized) have been deployed to enable sharing between Federal and non-Federal users, licensed and unlicensed users or among licensed users. What are the long-term goals of these approaches? How can AI/ML and sensing-based cognitive radio techniques enhance the effectiveness of the sharing mechanisms and optimize network performance?
- What steps can be taken to better facilitate spectrum repurposing efforts? How can potential intra-band and inter-band issues be identified and addressed early in the process? How can incumbent services be better informed about the nature of adjacent or nearby spectrum environments and how can users be encouraged to take steps needed to accommodate new spectrum uses in those environments? What steps and processes should be used regarding adjacent band spectrum users' wide receiver bandwidths (i.e., the passband extends into adjacent bands)?
- What state of the art filter technologies can be utilized to mitigate potential harmful interference? How can advanced antenna systems help reduce both inter-system and intra-system interference and enhance intra-system performance? What are the cost benefit tradeoffs on utilizing the current filter technologies or advanced antenna systems?
- What are the candidate bands or services that can co-exist with low-power, indoor-only operation such as factory automation? What are the sharing mechanisms to consider?
- What are the sharing mechanisms to consider among various services above 95 GHz, including passive services?

Areas of Mutual Interest with Other Working Groups (Verbatim from Charter)

- "How can AI/ML and sensing-based cognitive radio techniques enhance the effectiveness of the sharing mechanisms and optimize network performance?" (AI/ML WG)
- "What state of the art filter technologies can be utilized to mitigate potential harmful interference? How can advanced antenna systems help reduce both inter-system and intra-system interference and enhance intra-system performance? What are the cost benefit tradeoffs on utilizing the current filter technologies or advanced antenna systems?" (Emerging Technologies WG) (May include any other technology related to sharing)
- "What are the sharing mechanisms to consider among various services above 95 GHz, including passive services? (May also consider lower bands)" (6G WG)

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Topic 1: Potential new bands for sharing

- Deep dive into 7-24 GHz bands (excluding 12.2-12.7 GHz) (“the rest of midband”)
  - Which sub-bands are appropriate for sharing/clearing/etc.
  - Can we extend existing sharing techniques from sub-6 GHz to these higher bands, or are new techniques needed?
  - Are specific types of secondary uses most compatible with a given sub-band? For example, what are the characteristics of secondary users, such as channelization, etc.?
  - Include global aspect of these sub-bands
  - How/whether to consider adjacent band (even adjacent channel) compatibility issues?
  - How to consider future evolution (or flexibility) of incumbencies, adjacent bands, etc.?
- What are the primary incumbent services in these bands?
- What should be the coexistence mechanism(s): lightly licensed (i.e., CBRS GAA), licensed (i.e., 3.45 GHz; AWS); local area licensing (e.g. UK & Europe); and/or unlicensed (i.e., 6 GHz)?
- How to share in some passive bands above 95 GHz?
  - Could enable large contiguous bandwidths

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Topic 1 update

- Previous update
  - Presentation by Mark Gibson, Comsearch on investigations into the 7 - 8 GHz band.
    - Vast majority of the federal allocations in 7125-8500 MHz are either Fixed or Satellite with number of fixed assignments declining. Approximately 20% of Fixed use is DoD
    - Fixed Satellite use in 7250-7750 (500 MHz, Downlink) / 7900-8400 (500 MHz Uplink) includes Defense Satellite Communications Systems (DSCS) and the Wideband Gapfiller Satellite (WGS)
    - Spectrum occupancy measurements for three cities indicate generally low usage: feasibility of sharing looks promising, but more study is needed to characterize current use
    - Waiting on NTIA's usage assessments and update to compendium: continue to study for relocation/coexistence
  - Presentation by Tingfang Ji, Qualcomm on experiments in 12.75 - 13.25 GHz
    - Qualcomm is designing a 6G terrestrial mobile system to operate in upper mid-band spectrum (i.e., 7 - 15 GHz) that uses wide channels (e.g., 100 MHz to 1 GHz) to provide Gbps throughput while providing improved coverage.
    - Focus of new wide area 6G R&D is on 7 – 15 GHz range
    - Incumbents include federal operations (e.g., point-to-point links, radar systems, satellite and radio astronomy) and commercial users (e.g., satellite S2E in 10.7-12.7 GHz and E2S above 12.7 GHz)

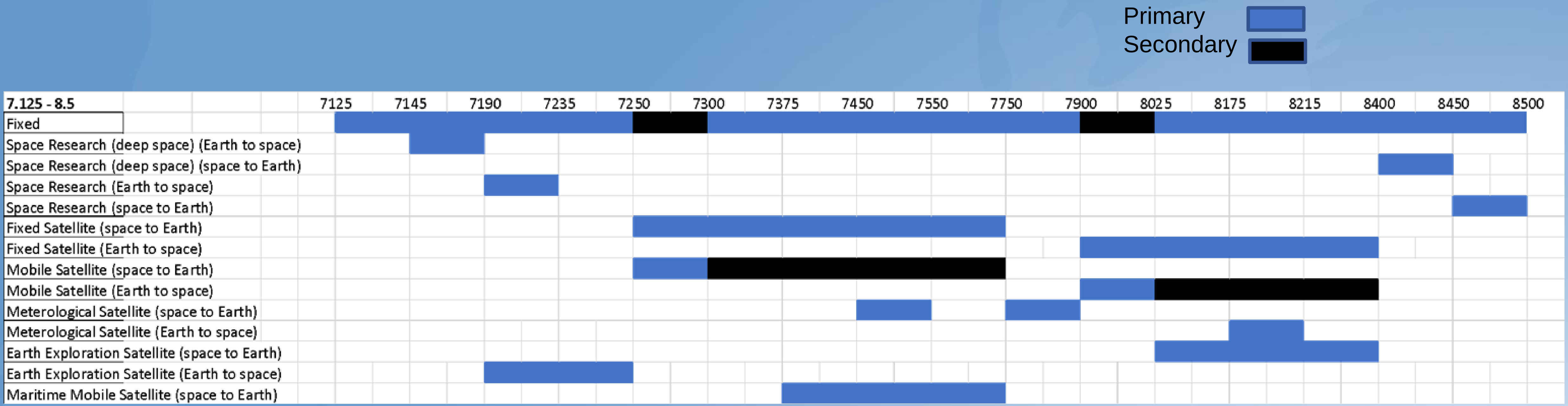
Topic 1 update continued

- Presentation by Phil Erickson, MIT Haystack Observatory on passive uses of spectrum
  - Passive radio frequency observations provide unique scientific information, generally in bands dictated by mother nature – they cannot be moved, or traded.
  - The signals being measured are very small, and thus particularly susceptible to interference.
  - Some areas of concern for the passive community:
    - Out of band and spurious emission into passive-only bands
    - In-band emission into shared bands (e.g., when previously ground-based transmissions are allowed to become airborne)
    - Increased utilization of mobile transmissions (interference from fixed sources is generally far easier to ameliorate)

- Current update
  - Created a catalog of federal and commercial allocations in 7 – 24 GHz.
    - Preliminary list of potential bands for new allocations, taking into consideration existing allocations and performance constraints.
  - Summarized current uses (and uncertainties) of spectrum above 95 GHz

7.125 – 8.5 GHz Federal allocation

Notes: (1) This type of chart shows service allocations, which may not be indicative of actual use in time/geography/bandwidth. (2) Footnotes can add additional details and caveats that are not yet captured in these plots.



- Fixed, Fixed Satellite and Mobile Satellite are the largest current allocations and will be the biggest challenge for shared used with high-power, terrestrial/mobile networks.
- Approximately 20% of Fixed use is by DoD, and satellite allocations also includes DoD operations (Source CommScope)
- Other allocations may not significantly constrain sharing because they may not be "ubiquitous" (i.e., not geographically distributed): need more information on these from NTIA.
- Some applications may need protection from 6G or other high-power terrestrial/mobile deployments

8.55 – 13.75 GHz Federal allocation

Notes: (1) This type of chart shows service allocations, which may not be indicative of actual use in time/geography/bandwidth. (2) Footnotes can add additional details and caveats that are not yet captured in these plots.

- Radiolocation is the single largest allocation in this part of the spectrum.
- ~2500 MHz in 10.7 – 13.25 GHz is allocated for Non-Federal use.
- There is relatively low usage around 13 GHz and many experimental licenses have been granted in this band.

13.75-17.1 GHz Federal Allocation

Notes: (1) This type of chart shows service allocations, which may not be indicative of actual use in time/geography/bandwidth. (2) Footnotes can add additional details and caveats that are not yet captured in these plots.

- Radiolocation, Space Research, Fixed and Mobile are the largest allocations in this part of the spectrum.
- 200 MHz in 14.2 – 14.4 GHz is not allocated for Federal usage.
- 200 MHz in 14.0 - 14.2 GHz is allocated for space research, earth to space, with mostly narrowband systems. (https://space.oscar.wmo.int/satellitefrequencies)

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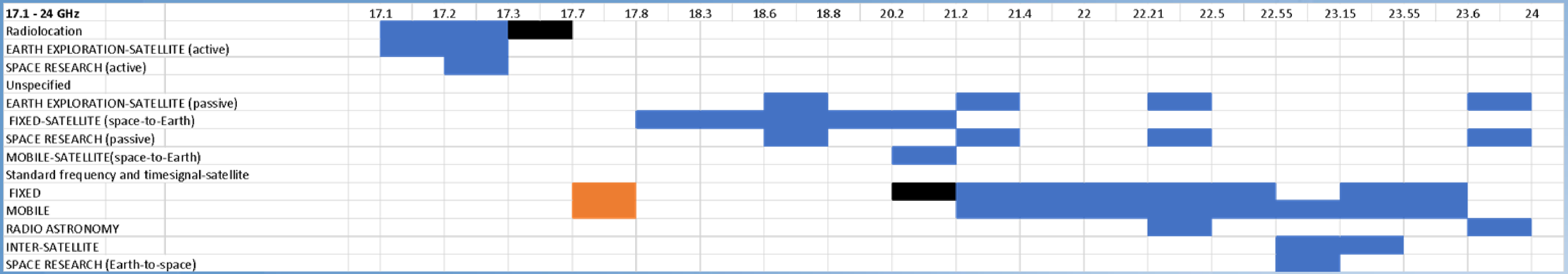
17.1 – 24 GHz Federal Allocation

Notes: (1) This type of chart shows service allocations, which may not be indicative of actual use in time/geography/bandwidth. (2) Footnotes can add additional details and caveats that are not yet captured in these plots.

Federal - Primary
Federal - Secondary
Non-Federal - Primary



- 100 MHz spectrum in 17.7 – 17.8 is not allocated for federal
- 2,200 MHz of spectrum in 17.8 – 18.6 and 18.8 – 20.2 may be practical for coexistence if used for earth stations rather than user devices

Preliminary observations on 7 - 24 GHz

- 7250 – 8400 MHz is “NATO band” commonly used in Europe; unlikely to get support for global harmonization
- 2,500 MHz of bandwidth allocated to non-Federal in 10.7 – 13.25, including 1,050 MHz mobile allocation in 12.2 – 13.25
- 200 MHz of bandwidth in 14.2 – 14.4 GHz is also for non-Federal use
- 2,200 MHz of bandwidth in 17.8 – 18.6 and 18.8 – 20.2 GHz may not be used widely

❖ **Potential bands for sharing to be investigated further:**
- **10.7 – 13.25 GHz for sharing with non-federal satellite**
- **14.0 - 14.2 GHz for sharing with space research**
- **17.8 – 18.6 GHz and 18.8 – 20.2 for sharing with federal satellite**

Note: Additional considerations need to be taken into account (for example, activity in ITU-R)

100+ GHz sharing issues

- Unlike lower bands, spectrum in 100-275 GHz has a very high density of passive bands strictly protected by Radio Regulation 5.340 (100-102, 109.5-111.8, 114.25-116, 148.5-151.5, 164-167, 182-185, 190-191.8, 200-209, 226-231.5, 250-252 GHz)
- Database of passive use:
  - While both Radio Astronomy Service/RAS and Earth Explorations-Satellite (passive)/EESS(passive) are protected by 5.340, RAS >100 GHz is very rare in populated areas due to propagation issues so major issue is only EESS(p) (Tucson AZ is major counterexample).
  - Listing of passive use is not up-to-date and does not include ephemeris data.
- Available information sources, not fully complete:
  - Recommendation ITU-R RS.1861-1 (12/2021)
  - WMO OSCAR: https://oscar.wmo.int/surface/#/search/station
- Sharing options:
  - Minimizing high elevation angle sidelobe levels.
  - Use MIMO-like antennas to produce a null on (Az, El) of NGSOs as they pass over
  - Dynamic routing: only links with acceptable impact on EESS9p) NGSOs as they pass over

Topic 2: Best practices for spectrum sharing

- Develop standardized/best practices for centralized spectrum sharing
  - We seem to be looking at each sharing framework anew each time. Can we identify commonalities for future shared spectrum systems, based on learning from TVWS and CBRS?
  - How band-specific should these sharing mechanisms be?
- Can sharing mechanisms like low-power indoor devices without AFC be extended into new bands?
  - Are there robust methods of identifying if devices are “indoors”?
    - E.g.: should devices near windows be more appropriately classified as outdoors?
- What are some of the considerations related to aggregate interference (its estimation and its actual impact)?
- Challenges related to incumbent sensing
- Improved propagation models for spectrum sharing
- How do we react to reported cases of interference, how do we record & measure it, and how do we effect enforcement when necessary?
  - Can centralized spectrum management systems be “deputized” to enforce FCC rules?
- How can we move to more dynamic operations (compared, for example, to CBRS)?

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Topic 2 update

- Presentation by Mark Gibson, Comsearch summarizing past spectrum sharing methodologies in FAST, TV White Spaces, CBRS and 6 GHz AFC.
    - Test and certification requirements, processes, timelines and costs must be clearly understood and roles must be clearly defined
    - The roles of the FCC, dynamic sharing system providers and spectrum users regarding Enforcement are unclear and should be discussed
    - Multi-stakeholder groups serve a critical purpose but still require FCC involvement

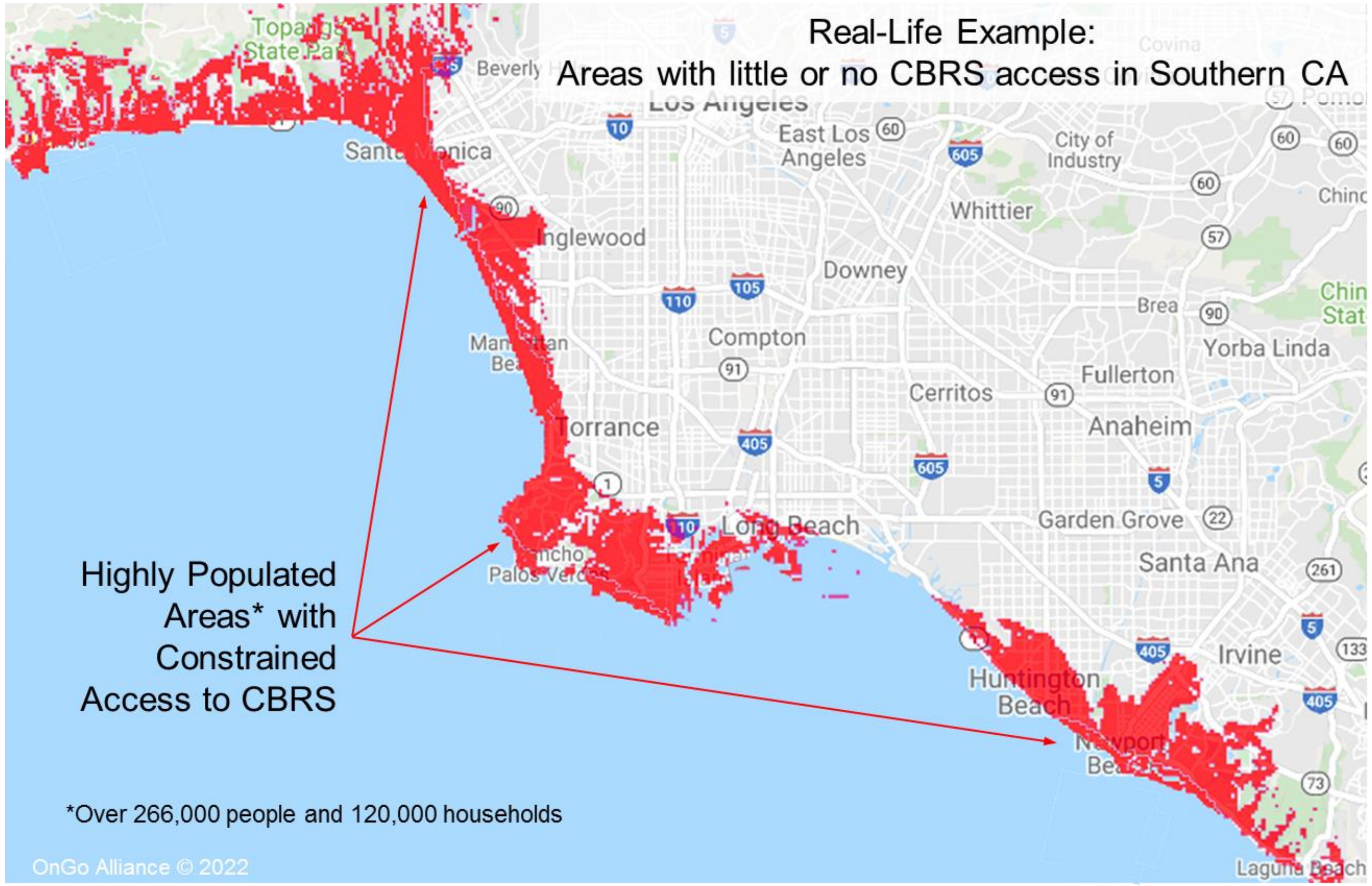
- Presentation by WG co-chair Andrew Clegg on five key lessons learned from CBRS
    - Centralized spectrum sharing is working
    - Propagation models need updating/refinement
    - Aggregate interference adds complexity
    - Incumbent sensing is problematic and should be replaced by incumbent informing
    - Efficient methods to evolve the framework should be implemented

- Presentation by Mark Gibson, Comsearch summarizing lessons learned from 6 GHz AFC
    - Lack of data-sharing among AFCs may complicate enforcement
        - Interference identification, mitigation and enforcement still need to be addressed, particularly in the context of centralized, dynamic spectrum management systems
    - Issues with ULS require substantial work to deal with
    - Difficult to achieve consensus on application of propagation parameters such as building entry loss and ITM confidence and reliability
    - Indoor device self-geolocation is harder than it seems

What Manhattan looks like

What ITM thinks Manhattan looks like (Flatland!)

Example Whisper Zone Impact (SoCal)



Topic 2 update

- The group is drafting a white paper on a collection of lessons learned across TVWS, CBRS, and 6 GHz, and other examples, and how they can be applied to future shared spectrum opportunities
  - Document draws on presentations and experiences of WG members
  - Will also draw on CBRS lessons learned document being developed by WInnForum that contains ~30 topic areas
    - WInnForum document is in drafting stage and is hoped to be balloted by late September/early October but schedule is dictated by member feedback and internal WInnForum processes
  - The TAC white paper may evolve into a slide deck, whichever the group thinks is the most efficient delivery mechanism
  - The group's goal is to have the document in place for approval by the TAC this year, although the timing is tight

Topic 3: Receiver standards and technology advances

- What degree of interference is acceptable to an incumbent in a particular band, and should the responsibility of mitigation fall on the new entrant rather than the incumbent, even if the new entrant is adjacent channel?
- Should we define a level of interference that the incumbent must be able to accept, i.e. define “harm thresholds”?
  - If yes, how do we account for legacy devices?
- Smart antenna technologies are primarily being deployed to improve performance (throughput, coverage, density): how may they be better leveraged for spectrum sharing (i.e., directionality, including directionality of nulling)?
- Do advanced filters play a role? Are there operational limitations to filters and their impact on the ability to share spectrum? What are the costs/benefits?
- Is there an interplay between spectrum sharing and increased risk for security and resiliency, both for the incumbent and the secondary user?

Topic 3 update

- Previous update
  - Presentation by Dale Harfield, Silicon Flatirons summarizing all the responses to the receiver NOI.

  - Presentation by JP De Vries, Silicon Flatirons, on Harm Claim thresholds (HCT)
    - Harm claim thresholds are in-band & out-of-band field strength profile not to be exceeded at more than some (small) % of locations at some statistical confidence level before a system can claim harmful interference.
    - Enable regulators to specify the interference environment in which a wireless system is expected to operate
    - Incorporate reception in rights definitions without reference to receiver performance
    - An engineering prior for addressing legal question of harmful interference
    - Simple to include in rules and measure in the field

  - Presentation by Preston Marshall, Google, on Receiver Standards
    - Significant benefit in establishing baseline "*Receiver Assumptions*" that can be used for assessing engineering impact of other uses of the spectrum
      - Not mandatory, but advisory to buyers
      - Could be modified over time as new technology emerges
      - Based only on "Linear" changes in spectrum uses
    - Making these assumptions mandatory would have to be carefully crafted to not distort the market and available technology
      - Short usage that would not be likely to be impacted by any new uses
      - Low cost equipment that would not need to be highly reliable, but would not be viable at higher cost/energy/mass points (like a smart-watch)
      - How to address future changes in usage that impact compliant equipment
- Current update
  - Extensive discussion on comments submitted to the receiver NOI.
  - No recommendations yet drafted

Topic 4: Modeling of interference

- It is clear from recent spectrum disputes that there is a need for better modeling of potential sources of interference. Example:
  - Spatial interference rejection potential of Massive MIMO arrays.
  - Radar altimeter models, end-to-end, not just RF levels of interference.
  - Propagation models focused on interference modeling rather than coverage
    - Validation of long-distance propagation models such as troposcatter
  - How to avoid multiple “worst-case” assumptions (i.e., application of joint statistics)?
  - In a broader sense, how should we deal with statistics of interference, rather than static/deterministic interference calculations? “Risk-informed analysis”
  - How to adapt interference modeling based on real-world measurements and sharing experience?

- How can potential interference scenarios be tested at-scale prior to rulemaking?
  - Testbeds, in academia (e.g. PAWR), industry and government labs like ITS.
  - Industry-accepted interference models for accurate simulations.
  - Lab testing
  - Timely testing with all stakeholders engaged can avoid last-minute delays caused by interference concerns.

Topic 4 update

- Previous
  - Interference modeling to be incorporated into recommendations on potential shared spectrum bands
- Current
  - No specific recommendations yet made, although interference modeling is taken into consideration in the lessons learned recommendations and in the recommendations of potential shared spectrum bands
  - As time allows, we may produce a separate set of key recommendations on interference modeling

Topic 5: Economic Incentives of Shared Spectrum

- Impacts to legacy systems
  - Is it more economically efficient to pay for legacy systems to upgrade? Is this a viable option in all cases? Most cases? Few cases?
  - What are the components of legacy systems that need to be addressed? (Front-end filter, pre-amps, IF filters, etc.)
- Impacts to incumbents
  - Changes in conops
- Impacts to the new entrants

Topic 5 update

- Previous
  - Dedicated discussion at May 24 WG meeting
  - Economic incentives to be incorporated into recommendations on potential shared spectrum bands
  - Presentation by Thomas Hazlett, Clemson University, Economics of Spectrum Sharing
- Current
  - No significant new activity during this quarter

Speakers

- March 22, 2022: Mark Gibson, Comsearch, Overview of Shared Spectrum, 7/8 GHz
  - Topic 1, Topic 2
- March 29, 2022: Preston Marshall, Google, Receiver Expectations
  - Topic 3
- April 05, 2022: Tingfang Ji, Qualcomm, 6G in 12.75 GHz
  - Topic 1
- April 26, 2022: Pierre de Vries, Silicon Flatirons, Harm Claim Thresholds
  - Topic 3, Topic 5
- May 10, 2022: Phil Erickson, MIT Haystack Observatory, Passive Sharing
  - Topic 1
- July 12, 2022: Bob Baxley, Zylinium, Dynamic Spectrum sharing
  - Topic 2
- Aug 02, 2022: Thomas Hazlett, Clemson University, Economics of Spectrum Sharing
  - Topic 5
- Aug 30, 2022: Mark Gibson, Comsearch, Lessons learnt from 6 GHZ AFC
  - Topic 2

Work Product

- Based on deep-dive examination of bands from Topic 1
- For bands identified as potential “low-hanging fruit” for sharing, examine the bands in terms of the key topic areas:
  - Interference modeling
  - Economic incentives
  - Receiver standards
  - Technology enablers

Thank You

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FCC TAC 6G Working Group

Co-Chairs: Brian Daly, AT&T

Abhimanyu (Manu) Gosain, Institute for Wireless Internet of Things, Northeastern University

FCC Liaisons: Michael Ha, Martin Doczkat, Kamran Etemad, Nicholas Oros, Sean Yun

Date: September 15, 2022

34

Outline for FCC TAC Formal Readout September 15 2022

- WG participants
- Charter
- Invited SMEs overview
- 6G Standards, Roadmap and Advisements
- 6G Technology Ecosystem Observations
- Draft Recommendations/Advisements Summary
- 2023 6G Working Group (proposed) Focus Areas

2022 6G Working Group Team Members

Bayliss,Mark	Visual Link Internet		**Simsek, Meryem**	VMWare
Brenner, Dean	Consultant		**Bali, Ramneek**	Charter
Chandra, Ranveer	Microsoft		**Welsh, Patrick**	Verizon
Clegg, Andrew	Wireless Innovation Forum		**Tooley, Matt**	NCTA
Cooper, Alissa	Cisco		**Khayrallah,Ali**	Ericsson
Cooper,Martin	Dyna,LLC		**Damnjanovic,Aleksandar**	Qualcomm
Drobot, Adam	Open Techworks			
Forester,Jeffrey	Intel			
Gammel, Peter	GlobalFoundries			
Ghosh, Monisha	Notre Dame			
Guess, Lisa	Cradlepoint			
Kuoppamaki,Karri	T-Mobile			
Lapin, Greg	ARRL			
Manner, Jennifer	Echostar			
Markwalter, Brian	CTA			
Mansergh, Dan	Apple			
Merrill,Lynn	NTCA			
Mukhopadhyay, Amit	Nokia			
Nawrocki, Michael	ATIS			
Nichols, Roger	Keysight			
Peha, Jon	CMU			
Schulzrinne, Henning	Columbia U			
Thakker, Rikin	WIA			

6G WG - 2022 Charter

- Provide information on the **development and deployment of 6G technology**, make recommendations and provide technology insights on new developments that need our attention, from the need for more **spectrum to the vulnerabilities of supply chain to the changing dynamics of global standards development**.
- How does **Open RAN/vRAN** continue to benefit 6G technology development and the ecosystem?
- What are the efforts to ensure an **adequate level of security is provided in Open RAN/vRAN architecture** and what are the cost/benefit tradeoffs to consider?
- What are the opportunities for using **mmW/terahertz bands for fronthaul/backhaul** in support of dense deployment of 6G systems given the capacity capabilities and corresponding bandwidth demands anticipated for 6G systems?
- How is 6G technology envisioned to enhance or be utilized in **autonomous driving, edge computing, emergency alerting, and smart city technology** deployments?
- How can **6G help bridge the digital divide** by bringing down the costs of delivering broadband particularly to rural and urban underserved areas?

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BLUF - Draft Recommendations/Advisements

- **6G Development Timeline**
  - 5G Advanced Evolution to continue for future 3GPP Releases (17,18,19)
  - 6G Fundamental research is underway with Federal and Industry Investments
  - ITU defined IMT-2030 and twinning with WRC will set 6G radio performance requirements

- **O-RAN and Open RAN Security**
  - Disaggregated O-RAN Networks need to demonstrate Multi-Vendor Interoperability.
  - Federal incentives need to align with subsystem integration and demonstrate performance parity with legacy networks
  - Securing the Open Fronthaul interface real time system from targeted attacks

- **mmWave and Sub-Thz**
  - Opportunity: joint comms and sensing, large transmission bandwidth, indoor and personal area network deployment
  - Challenge: High mid-band value for deployment scenarios, very high path loss
  - Focus on high directionality systems

- **Spectrum Needs**
  - Mid Band: 500MHz opportunity in 7-24 GHz, existing sharing mechanisms
  - Sub Thz: 100-1000GHz for highly demanding use cases: Immersive comms,,cobots
    - Policy is nascent
  - Heterogeneity of access: Space,Aerial,Terrestrial Integrated Networks requires coordination

- **6G Use Cases and Application Verticals**
  - Focus on application centric view with Multi-sensory and Immersive Communication use cases are quickly emerging
  - Emergence of Key Value Metrics (KVI) beyond traditional metrics for 5G
  - Focus on zero energy, sustainability, inclusion and deployment economics

Working Group SME Presenters

SME Speakers

Organization	Topic	Speaker	Summary
AT&T	ITU-R process for IMT	Marc Grant (ATT)	• Described IMT terrestrial component radio interface development process • Shared Draft timeline "IMT towards 2030 and beyond" • ITU WRC and ITU-R Study process are interrelated and collaborate to be globally harmonized
NEXT G ALLIANCE An ATIS Initiative	6G Roadmap Overview	Mike Nawrocki Amitava Ghosh Douglas Castor (NextGAlliance)	• Described Initiative to advance North American mobile technology leadership over the next decade through private sector-led efforts. • 6G Technology Roadmap focused AI-native distributed cloud and communication systems to meet application requirements with key focus on resiliency, energy efficiency, and sustainability.
N	Wireless Networks Operating in the THz Band	Dr. Josep Jornet (NEU)	• Described opportunities at Thz bands for joint communication and sensing using extremely large bandwidth • Described technical challenges and advances to use plasmonics based Massive MIMO systems, wavefront engineering and modulation schemes to mitigate.
O-RAN ALLIANCE	6G proposed capabilities	Scott Poretsky Paul Smith Arda Akman (O-RAN Alliance)	• Described O-RAN Alliance charter, membership and structure including updates to specification development, release of open source software and plugfests to test vendor interoperability and promote deployment of Open Radio Access networks using the Option 7.2x Functional Split • Described approach to standardization harmonization with ETSI • Shared technical challenges on security of O-RAN networks with larger attack surface, threat vectors and shared work of O-RAN Security Focus Group (SFG)

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SME Speakers

Organization	Topic	Speaker	Summary
	German 6G Research Initiatives / 6G Platform	Falko Dressler (TU-Berlin)	• Shared vision of German 6G Program and development of research hubs with 160 research groups at 21 universities and 15 research institutes. • Research Focus on New NTN topologies, information theoretical concepts, open architectures, quantum, security, resiliency and privacy driven approach.
	6G system for ubiquitous computing	Clara Li Geng Wu (Intel)	• Shared vision for wide area cloud with ubiquitous computing across devices, network nodes and data centers. • Shift from radio paradigm to services and systems focus.
	Silicon Technologies for 6G sub-THz	Ned Cahoon (Global Foundries)	• Explained component and silicon advances for high frequency 6G RF circuits (PA,LNA) and phased array systems • Shared comparative analysis of SiGe,GaN,InP across technology,packing,spacing and thermal benchmarks for 6G.
	ITU-R:Future Technology Trends Report	Marc Grant (ATT)	• Shared a report produced by ITU WP 5D providing a broad view of future technical aspects of terrestrial IMT systems considering the time frame up to 2030 and beyond • Key drivers include requirements for:Energy Efficiency/Data Rate/Latency/Jitter/Sensing resolution and Accuracy/Coverage and Spectrum utilization
	O-RAN Alliance Next G Research Group (nGRG)	Dr. Chih-Lin I (O-RAN Alliance)	• Described new forum to facilitate O-RAN ALLIANCE related 6G research efforts and to publish research findings • Vision to unify the 6G technology path/timeline to avoid incompatibility b/w O-RAN ALLIANCE and other SDOs • Leverage public private partnership model with academia and industry.

SME Speakers

Organization	Topic	Speaker	Summary
USD R&E	B5G Network Customization for DoD Enterprise: R&D Enablers	Dr Sumit Roy (OUSD DoD R&E)	• Shared DoD perspective on 5G-FutureG program to foster US leadership by investing in Beyond 5G, via partnerships with industry (both commercial and defense industrial base); influence international spectrum access and communications standards via technology leadership. • Focus on identifying dual-use standards feature alignments with industry. • Innovative solutions for shared spectrum access that will lay the foundation for more efficient access to the electromagnetic spectrum.
Greater Arizona Educational Leadership AZBSN Arizona Broadband Stakeholder Network Arizona Telecommunications and Information Council COVID-19 DIGITAL ACCESS TASK FORCE	Arizona Broadband Policy Past, Present, and Future	Mark Goldstein Jeff Sobotka Sandip B. (Arizona Commerce Authority)	• Social and physical distancing is becoming the new normal requiring unprecedented demand for digital access, including affordable Internet access and other digital inclusion and digital equity resources. • The pandemic has illuminated the long-standing deficiencies in affordable broadband Internet access in Arizona, particularly in tribal, rural and other underserved communities and low-income neighborhoods in Arizona. • As a result, the homework gap is a major issue for many of our students. • Broadband is essential to connect schools, universities, community colleges, homes, libraries, health care facilities, businesses and communities to support education, health care, community services and economic development.
ERICSSON	An Innovation Journey Into A 6G Future	Mischa Dohler (Ericsson)	• Described fundamentals of a 6G network platform across vectors of limitless connectivity, trustworthiness, native AI, and ubiquitous compute. • Suggested KPI(s) for data rate, spectral efficiency, latency and energy efficiency. • Framed challenges on developing a Cyber-physical continuum, self synthesizing networks and zero energy devices to meet human societal needs with 6G.

SME Speakers

Organization	Topic	Speaker	Summary
INTELSAT	7GHz-24GHz Usage and Future from Satellite Industry Perspective	Hazem Moakkit: VP of Spectrum Strategy Salim Yaghmour:	•Satellite use-models are expanding. GEO, MEO, LEO all being applied more to existing and new use cases. •7-24GHz band is central to Satellite industry especially given •Interference to/from Earth stations is an increasing issue with expanding capabilities of Tx (directional) and Rx (sensitivity) on satellites. •7-24 GHz band has significant incumbency with multiple shared users, international regulation, and critical applications (e.g. Earth Exploration Services) •Satellite industry becoming more integrated with mobile communications industry •WRC-23: Three significant agenda topics related to 7-24GHz range

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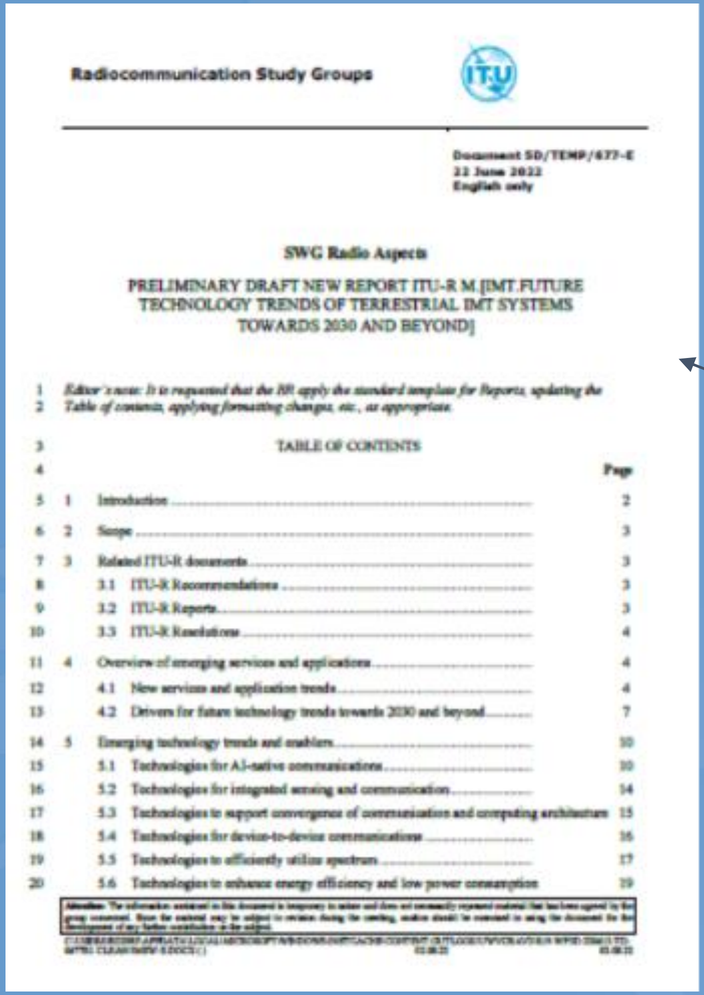
5G, 5G Advanced, & 6G Standards, Consortia Roadmap

ITU-R IMT towards 2030 and beyond



Radiocommunication Study Groups

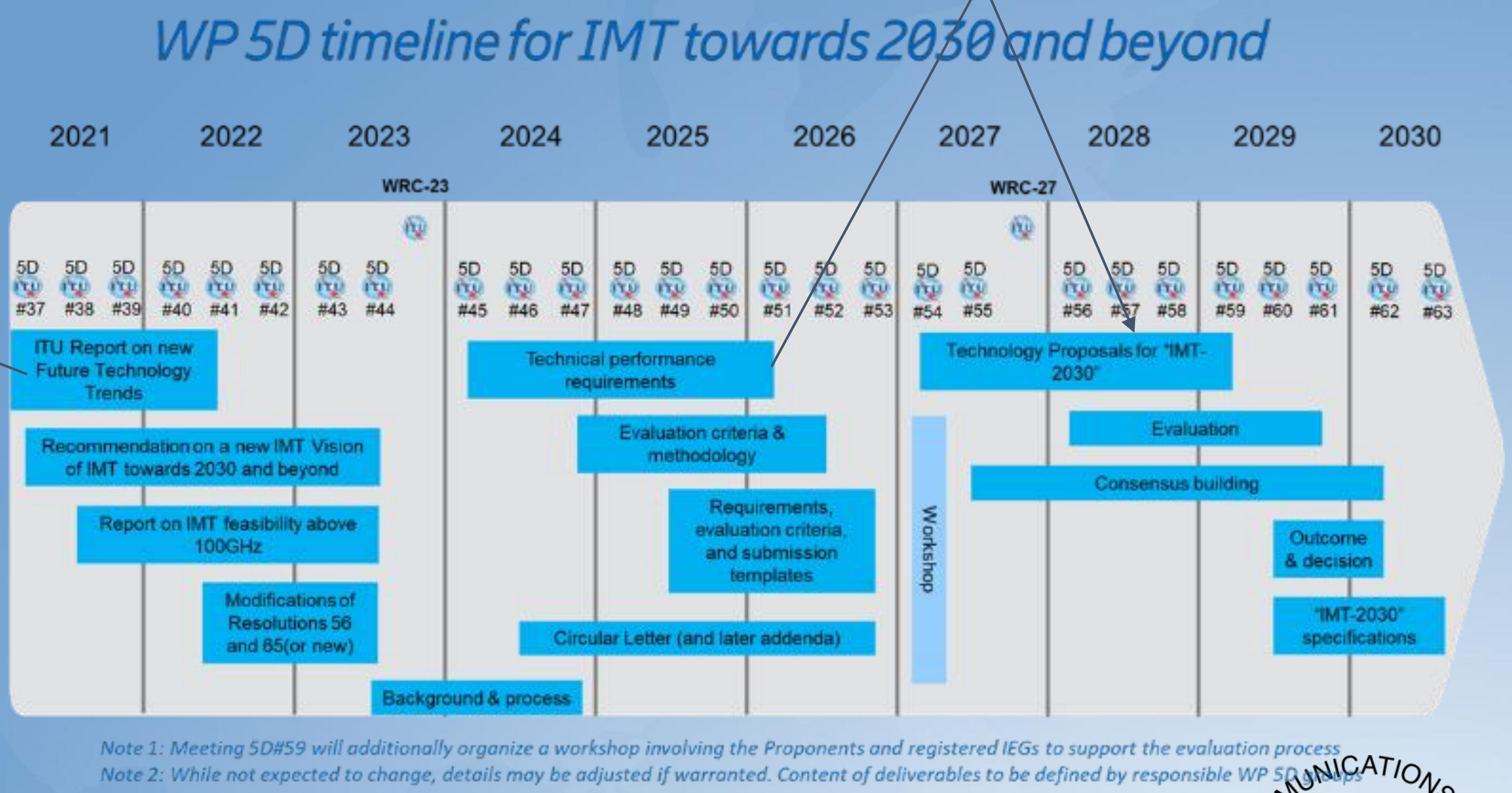
Document 5D/TEMP/677-E
22 June 2022
English only

SWG Radio Aspects

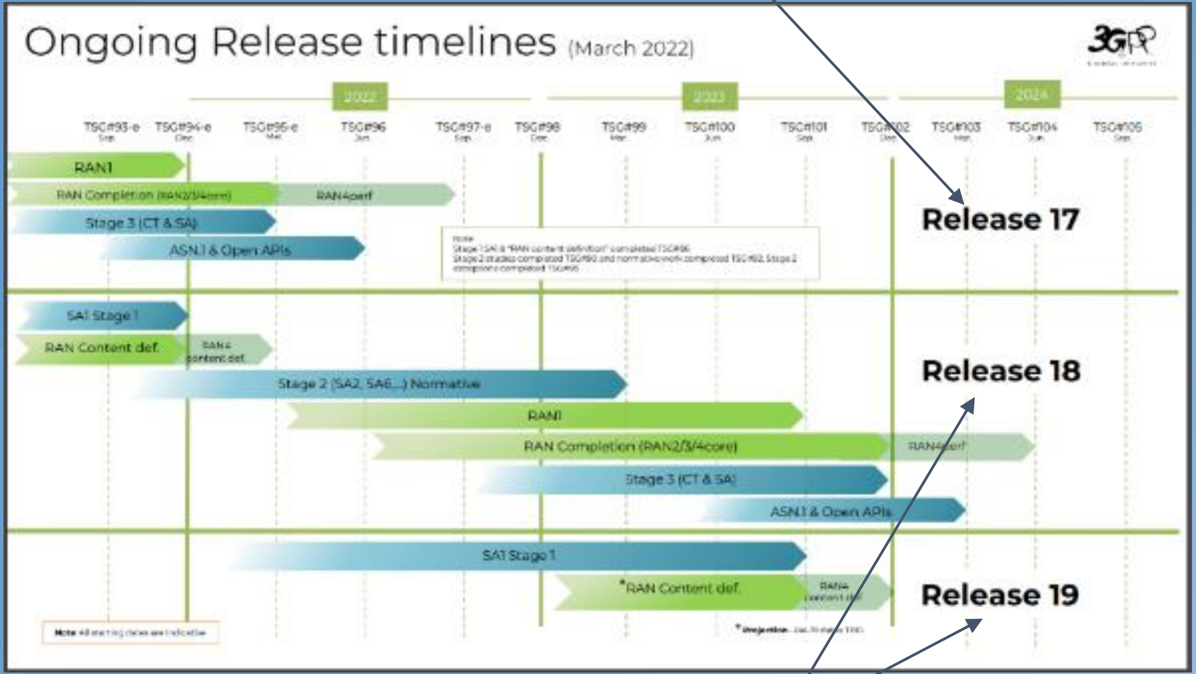
PRELIMINARY DRAFT NEW REPORT ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS OF TERRESTRIAL IMT SYSTEMS TOWARDS 2030 AND BEYOND]

Editor's note: It is requested that the BR apply the standard template for Reports, updating the Table of contents, applying formatting changes, etc., as appropriate.

TABLE OF CONTENTS



3GPP - 5G to 6G Path



Today

- Release 17 completed June 2022 (with exceptions completing in September)
- Primary aim of Rel-17 is to improve 5GS performance, support new use cases and verticals, and provide ubiquitous connectivity in different deployment conditions and scenarios
- 3GPP release 18 represents a major evolution of the 5G System and due to this the 3GPP has decided to brand it as the first release of 5G Advanced.
- Rel-18 will include major enhancements in the areas of artificial intelligence (AI) and extended reality that will enable highly intelligent network solutions that can support a wider variety of use cases
- Rel-19 is starting to look at advanced services such as Integrated Sensing & Communications, localized mobile metaverse services, service robots, and ambient powered IoT

Today's Deployments are based on R15 & 16
Deployments are typically ~24 months after a 3GPP release completion

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3GPP Release 17 - Now "complete"

Sampling of Topics

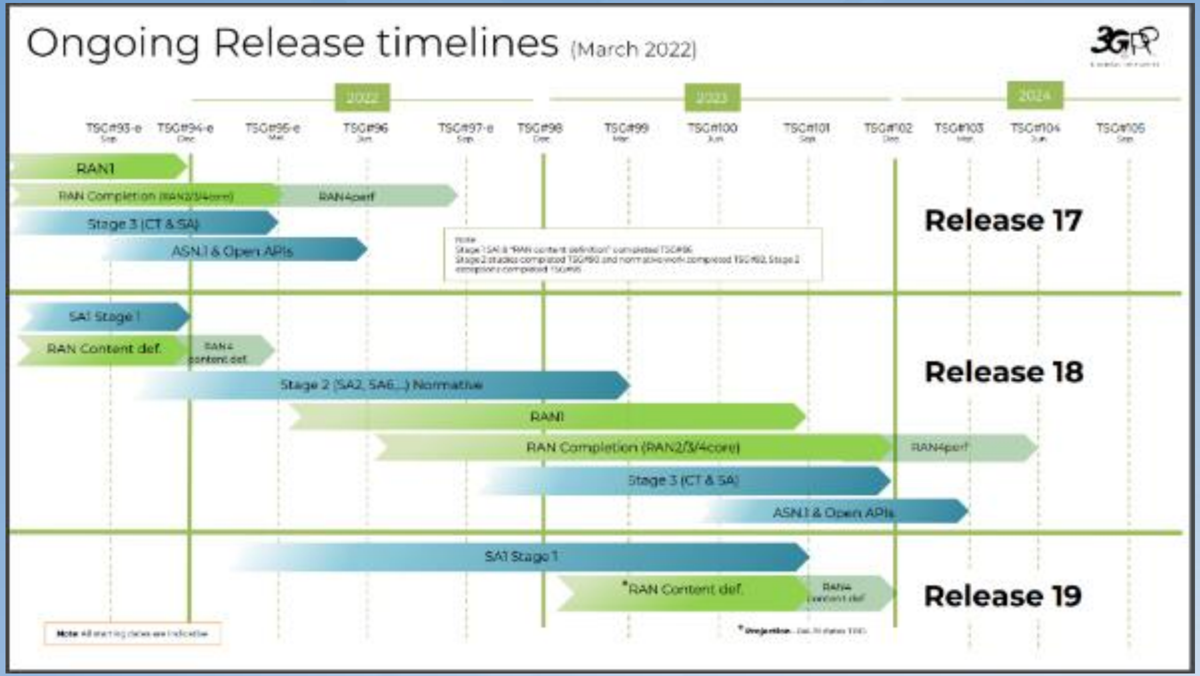
eMBB: NR MIMO, NR support to 71 GHz, Dynamic Spectrum Sharing, Non-Terrestrial Networks, Coverage enhancements

eMBB and URLLC: Positioning evolution, enhancements for XR, mobility enhancements

Massive MTC: Industrial IoT, V2X services

Public safety: NR sidelink enhancements, multicast/broadcast, UAS

Cross domain: AI/ML RAN enhancements, XR, IAB, RAN Slicing/Network Slicing, Network Automation, Edge computing, 5G Wireless-Wireline convergence



3GPP Release 18

Sampling of Topics

eMBB: Dynamic spectrum sharing, network energy savings, duplex operation evolution, NR sidelink evolution, UL coverage enhancements, smart repeater, CA enhancements, NTN evolution

eMBB and URLLC: Positioning evolution, enhancements for XR, mobility enhancements

Massive MTC: RedCap evolution, low power WUS, small data

Public safety: UAS/UAV/UAM, NR sidelink evolution, multicast/broadcast

Cross domain: AI/ML RAN enhancements, resiliency of gNB-CU-CP

Mobile IAB

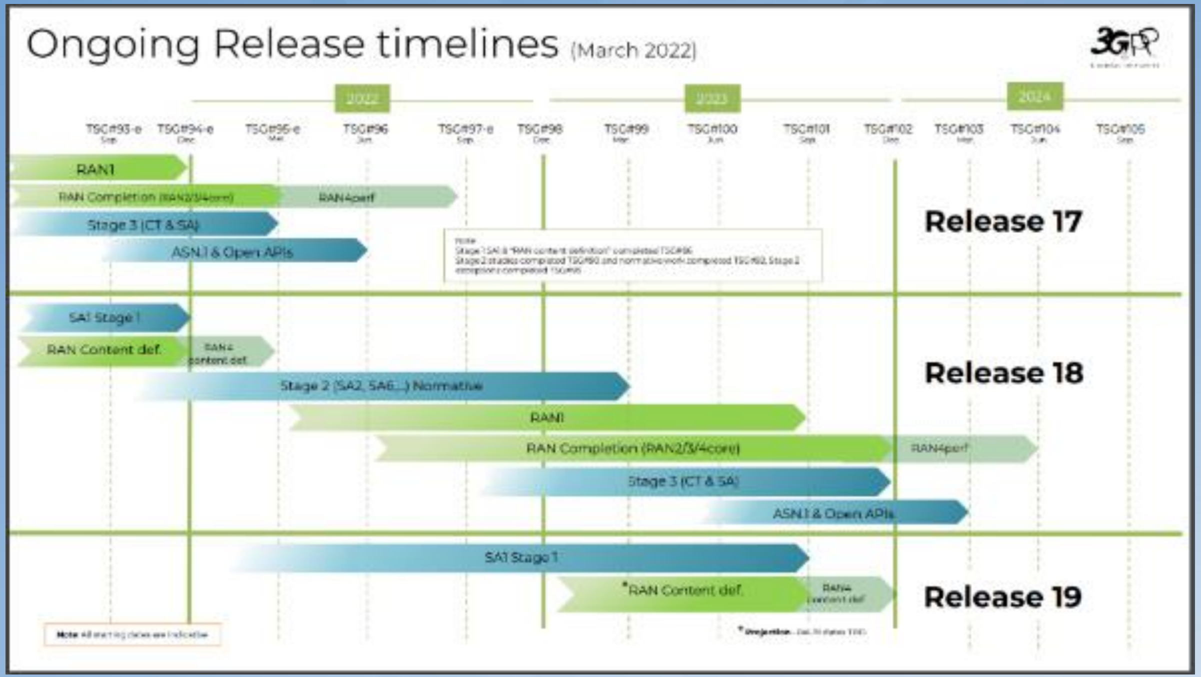
MIMO Evolution for Downlink and Uplink

Network Slicing Phase 3

Edge Computing Phase 2

Non-Terrestrial Networks

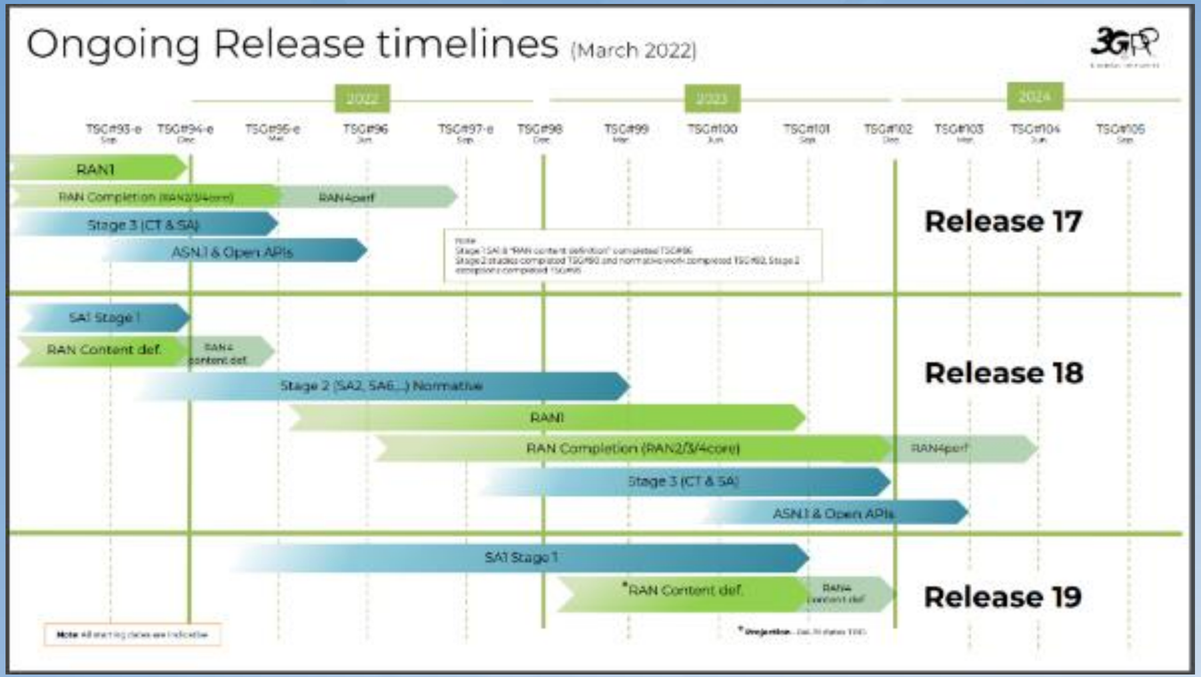
System Support for AI/ML-based Services



3GPP Release 19

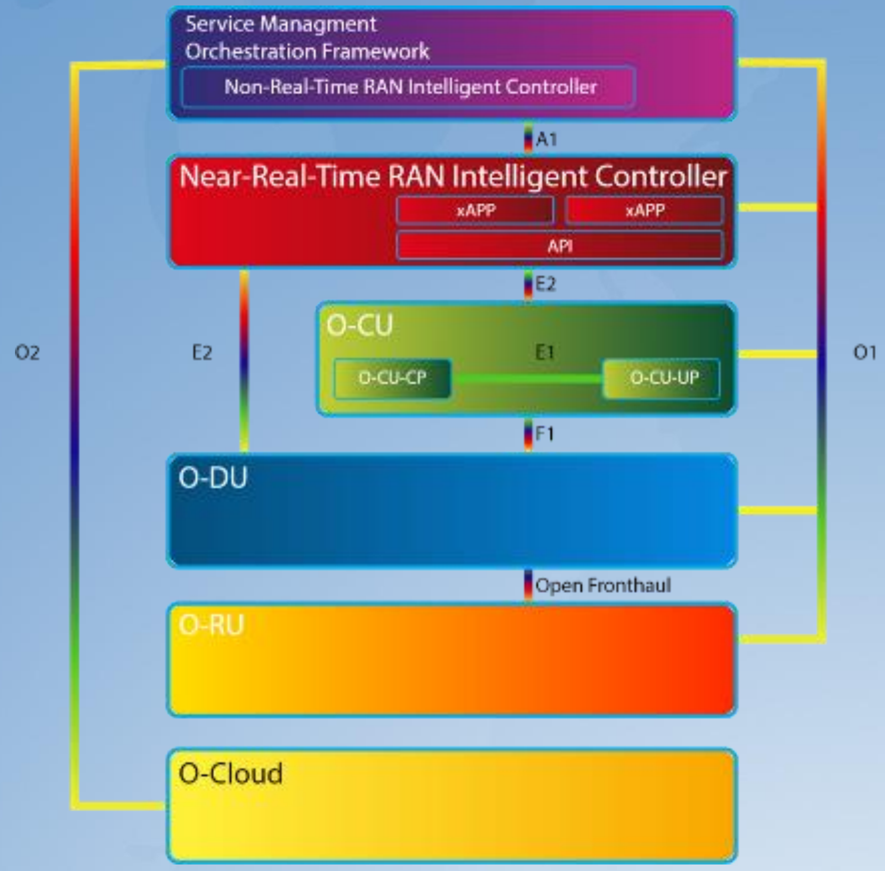
Sampling of Study Topics

- Integrated Sensing and Communications
- Network Sharing Aspects
- Localized Mobile Metaverse Services
- Satellite access - Phase 3
- Network of Service Robots with Ambient Intelligence
- FRMCS (Future Railway Mobile Communication System) Evolution – Phase 3
- Study of AI/ML Model Transfer – Phase 2
- Roaming Value Added Services
- Upper Layer Traffic Steering, Switching and Split over dual 3GPP Access
- Energy Efficiency as Service Criterion
- UAV Phase 3
- Ambient power-enabled Internet of Things



O-RAN ALLIANCE 2022 Updates

- 52 O-RAN ALLIANCE Specifications published since March 2022
- 6th Release of open software for the RAN - “F” - delivered by the O-RAN software community
- 1st certificates awarded in the O-RAN Certification & Badging program by Asian OTICS
  - O-RAN certificates state that an equipment or function is conformant to O-RAN specifications
  - O-RAN badges confirm interoperability or end-to-end functionality of an O-RAN solution.
- WG11: Security Working Group: Security experts from the O-RAN ecosystem have been applying systematic threat analysis on different components of the O-RAN Architecture.
- Security is becoming an integral part of individual interface or function specifications and there is a security testing specification for proper verification.
- O-RAN fronthaul control, user and synchronization plane specification, which was submitted earlier this year for adoption by the ETSI Technical Committee Mobile Standards Group through the ETSI PAS (Publicly Available Specifications) process
- O-RAN ALLIANCE has formed its next Generations Research Group (nGRG).



O-RAN ALLIANCE nGRG Candidate Research Streams

nGRG Candidate Research Streams

O-RAN ALLIANCE

RS01: Requirements

6G use cases and standard gap analysis
- What 6G use cases and requirements must be considered?
- What are 5G standard gaps towards these requirements?
- What are current O-RAN limitations?
- What 6G O-RAN concepts can be promoted to 3GPP standards?
- What functional services does 6G O-RAN need to provide?

RS02: Architecture

Architecture towards 6G O-RAN
- What are key architecture principles?
- Why does O-RAN benefit from SBA approach?

Extreme disaggregated RAN
- How does disaggregation play role in future RAN?

RIC evolution
- What are gaps in RIC to meet 6G use cases?
- How does AI/ML look like in 6G RIC?
- Will intent-based control play a role in RIC?

RAN-core-edge harmonization
- What is the trend for RAN-CN NF and edge AF integration, and why is it important ?

Architecture support for new features in air interface
- What enhancements are needed to support JCS, CF-MIMO, RIS...?

RS05: Management

Zero touch management and orchestration
- How should O-RAN evolve on network management?
- What are gaps regarding OAM/SMO orchestration and automation?

RS04: Security

Native security, privacy and trust
- What is native security design in O-RAN?
- What are key areas regarding security, privacy and trust in new O-RAN design?

RS03: AI/ML

Native and cross-domain AI
- What is native AI design in 6G O-RAN?
- Why is native AI important for O-RAN?
- How to integrate AI cross-domain when other domains have native AI design?

RS06: Cross domain

Softwarization and cloudification
- What are key problems in O-RAN cloudification?

New sharing paradigms
- How does 6G O-RAN deal with spectrum sharing and infrastructure sharing?

Network exposure and cross-domain integration
- What are trends for cross-domain integration with verticals?

Network migration
- How to migrate from 5G/5Gadv, WiFi to 6G O-RAN?

RS07: Sustainability

Carbon-neutral O-RAN
- Energy efficiency aspects in 6G O-RAN

RS08: nG Research Platforms

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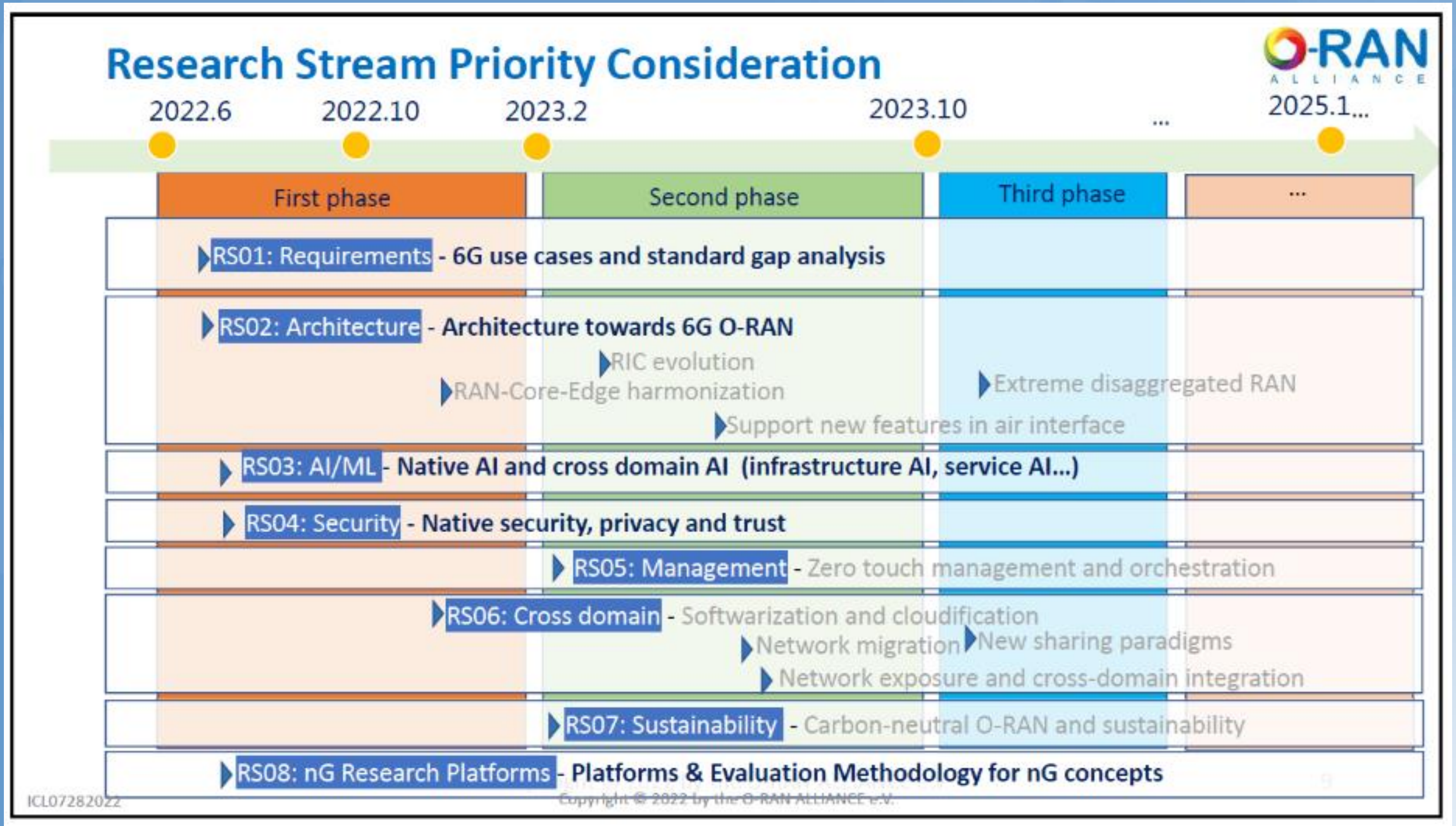
O-RAN ALLIANCE Research Stream Priority/Timeline



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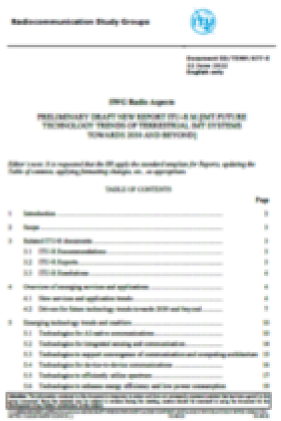
WG Observations

1. Development and Deployment of 6G Technology

6G Planning & Global Research is in Progress

ITU-R WP5D

- IMT towards 2030 and beyond



ATIS Next G Alliance

atis

- 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

AT&T, Bell, Charter, ciena, ERICSSON, FACEBOOK, intel, interdigital, JMA, Microsoft, NOKIA, Qualcomm, 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.

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Next G Alliance Audacious Goals

- Top priorities for North America's contribution and leadership
- Selected by Next G Alliance membership
- Address multiple stakeholder interests

Next G Alliance Desired Outcomes

NORTH AMERICAN LEADERSHIP

- Powerful work collaboration across industry, government and academia

- Robust marketplace using innovative applications and technologies that connects society in a new digital world

- Increased ownership of technology advancements that enable the 6G vision

DISTINCTIVE ADVANCEMENTS

(a few examples)

Multi-dimensional, multi-party and multi-sensory experiences

AI-Native, trusted and ethical AI

Higher Frequency (THz/Sub-THz) and multi-use spectrum

Design for Sustainability, reduced energy, zero-energy devices

Transform quality of life and work across healthcare, public safety, and education

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6G Planning & US Research Investments are Underway

New NSF Spectrum Innovation Center

ComSenTer:
140/220/300 GHz MIMO Testbed to Demonstrate the next generation "6G" Hydra basestation

JUMP 2.0
Exploratory research on an 8- to 12-year time horizon that is anticipated to lead to defense and commercial opportunities in the 2030–2035 timeframe

International 6G R&D and Innovation Consortium (RDIC)

New NSF directorate: Technology Innovations and Partnerships

CHIPS & Science Act

- ➢ On August 22, the President signed into law CHIPS and Science Act.
- ➢ Includes ~$52.7B to increase domestic semiconductor capacity and another $1.5B for a grant program promoting and deploying wireless technologies that use open and interoperable radio access networks
- ➢ Will establish a technology, innovation, and partnerships directorate at the National Science Foundation (NSF) to focus on fields like semiconductors and advanced computing, **advanced communications technology**, advanced energy technologies, quantum information technologies, and biotechnology
- ➢ NTIA tasked with developing the open RAN grant program

Needs of the telecom industry should be addressed as the funding is allocated

Semiconductor Research

Innovation pipeline

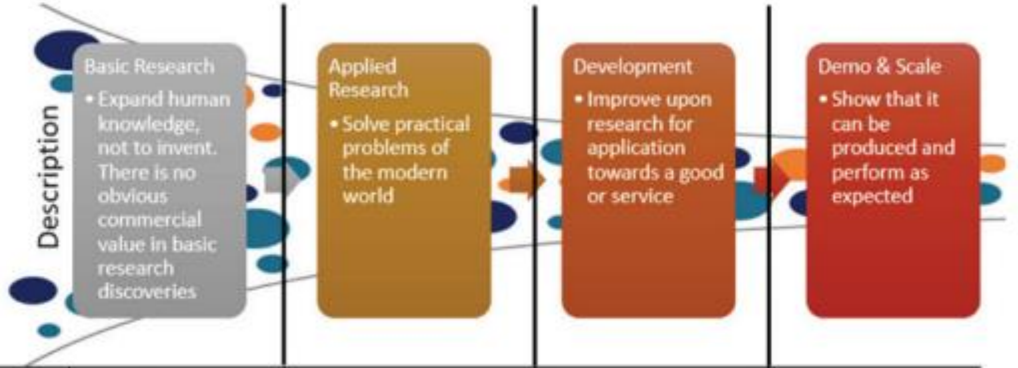
- Create new technology, mature that technology, and manufacture it to strengthen the US economy, strengthen national security, and improve society

Key new programs in the pipeline

- National Semiconductor Technology Centers (NSTC)
- National Advanced Packaging Manufacturing Program (NAPMP)

Telecom industry interest

- Engage with these programs to ensure that innovations in technology and manufacturing benefiting the telecom industry are pursued



Lead performer	Nat labs, NIST, Academia	Academia, Industry	Industry, Academia	Industry
Annual: $3B+ Cost-share	$1,250M low	$250M 1:1		$1- 2B TBD
Gov. Program (commercial)	NSF, NIST, DOE	Microelectronics Manufacturing USA Institute		NSTC, NAPMP
Projects	Basic research User facility projects	Programs/ projects Research centers	10X bigger/ 10X fewer, start-up	10X bigger demo, pilot
IP Model	Open IP	NERF IP	Exclusive IP	Exclusive IP, Revenue %

Figure 7. The U.S. innovation pipeline divided into four segments and their corresponding characteristics.

Source: SRC response to RFI by DoC and NIST:
Incentives, Infrastructure, and Research and Development
Needs to Support a Strong Domestic Semiconductor Industry.

2. Open RAN

DRAFT Areas for Advisements: O-RAN

Multi-vendor Interoperability

Open RAN architecture introduces more complexity due to the increased number of vendors and disaggregation of traditional network functions.

- Focus on Multi-Vendor testing and produce performance benchmarks
- DoD/NTIA 5G Challenge is a federal initiative incentivizing vendor diversity

Security

O-RAN Open Fronthaul interfaces form a real-time communication system.Key security objectives need to provide:

- Confidentiality and integrity of mobile subscriber data
- Availability to transport 5G control,user and synchronization messages
- Authentication for Open Fronthaul network elements

DRAFT Advisement and Recommendation: Open RAN Strategy

Why does O-RAN matter to policymakers?

- US government and its allies views concentration of vendors and dominance of a small set of suppliers as a national, economic, and network security threat
- See Open RAN as a vehicle to diversify the supplier chain to include trusted vendors, offer alternatives to existing supply chain and increase American participation in the supply chain.
- Policymakers also recognize the benefits of increased competition, innovation, and potentially lower prices.

Policy Recommendations

- Signal government support for open and interoperable networks
- Drive adoption of Open RAN based solutions to both achieve scale and as a counter to traditional suppliers
- Support Open RAN development through R&D investments, government procurement and financial support for global development of open and interoperable wireless technologies (i.e., CHIPS Act)
- Avoid mandating particular technologies through heavy-handed or prescriptive solutions.

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3. mmWave and THz

mmWave and Sub-THz Opportunities and Challenges:

Opportunities

- Terabit wireless backhaul
- Inter-satellite and Space Networks
- Terabit Wireless Personal Area Network(WPAN) /WLAN
- Joint Communication and Sensing

Huge Transmission Bandwidth <-> Very High Pathloss

Technology and Deployment Gap

- Need for Ultradirectional Antenna Systems,Ultrabroadband Analog Front ends, Ultra High speed Digital back ends
- *"Majority of value is still in the mid-band for operators"*- Mischa Dohler,Ericsson

Recommendation:

Super Directional dynamic beamforming

RIS (Reflective Intelligent Surface) : Reflect Arrays and Metasurfaces

4. Spectrum Needs

6G Spectrum Needs Analysis

Spectrum Needs Study: Vertical outlook from devices, sub-systems to architecture for sub-THz and THz + low/mid-band needs outside of current NPRM proceedings

6G Spectrum Needs SWG Strategic Priorities

- Anticipate/Optimize Mobile Wireless needs given growing use & other demands
- Set stage for development & innovation in new/existing bands
- Closing the Digital Divide

Problems We Are Trying To Solve	• Which are the most appropriate additional bands for consideration? • Which use-cases will demand additional spectrum? • What are the technical ramifications and required innovations to address these new bands? • What are the most acute co-existence and interference issues that can arise? • How can we make the best use of spectrum for all users—especially under-served locations & demographics?
Nature of Our Recommendations	• Practical technical considerations for bands new to 6G • Use-Case considerations for bands new to 6G • Geographic Area-based licensing considerations for bands new to 6G • Considerations given the expanding use of Unlicensed and Lightly-Licensed Bands • Considerations to motivate the operators and their vendors to increase efficiency of existing spectrum use • Considerations to address unused spectrum allocations • “Public” vs. “Private” networks: How do these impact spectrum needs

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6G Spectrum Needs: Areas of Recommendations to Be Clarified

Focus Areas	Identified Issues to Be Clarified Dec '22
Which new **use-cases** will have most impact on 6G Spectrum Needs and what new Spectrum (or new approaches) will be required?	Most Demanding Use Cases: • Enhanced Human Communications (e.g. Immersive & Holographic Telepresence) • Enhanced Machine Communications (e.g. cooperative robotics) • Enabling Services (e.g. accurate positioning/mapping, digital healthcare, recognition, etc.) Provide recommendations on how to assess demands and consider licensing/sharing schemes.
What facets of Spectrum Technology must be addressed to progress resolving the **digital divide**?	Most important: A Modern Education is not feasible without full-time (e.g. Mobile) internet access • Coverage and cost are prohibitive • Urban and Rural Scenarios require different approaches • Technical solutions interwoven with social and political issues • Resolving spectrum issues is necessary but not sufficient Provide recommendations on technical opportunities related to spectrum
What are the technical considerations for adding 6G spectrum between **7GHz and 24GHz**?	An opportunity for more contiguous bandwidth with less challenge than FR2 and above. 7GHz-24GHz is a large range: • State-of-the-art and physics "dividing lines" lie therein. Policy constraints exist. Sharing technologies are immature • New technologies (e.g. MIMO and AAS) may require rethink of EMF exposure evaluation methods Provide recommendations on sub-bands to consider, sharing issues, and EMF evaluation methods
What are the technical considerations for adding 6G spectrum between **100GHz and 1000GHz**?	An opportunity for very large contiguous bandwidth for extreme use-cases. • "100-1000GHz" is a large range: State-of-the-art and physics "dividing lines" lie therein. • Significant technical demands on radio systems (RF to digital processing) • Policy is spotty and nascent. Sharing technologies are immature • May require rethink of EMF exposure evaluation methods. Provide recommendations on sub-bands to consider, sharing issues, and EMF evaluation methods

5. 6G Services and Application Vertical(s)

6G Use case perspectives from around the globe, across the industry

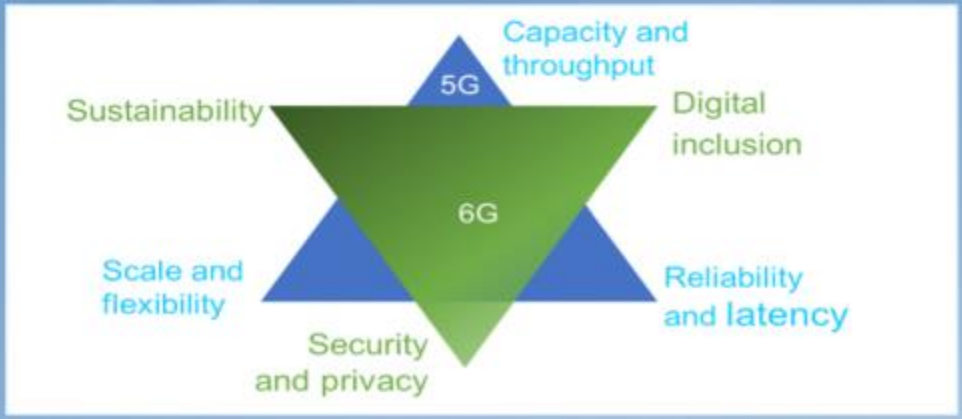
6G Use Case	Description	6G Network KPI Perspective (Preliminary)
Holographic/Immersive communications	Dynamic interaction among people, things, and environments through lifelike 3D rendering -Personalized education, training	-Throughput per stream: multi-Gbps -Number of streams: 100's -Latency and jitter: <20 ms
Multi-sensory communications	Experiencing touch (including the feelings of temperature, pressure, texture) as well as smell and taste in a more distant future -Remote work, Virtual meetings	-Throughput per stream: multi-Gbps -Number of streams: 100's to 1000's -Latency and jitter: <20 ms -Synchronization across streams: <10ms
Mapping, positioning, sensing, twinning	Sense, detect, locate, identify, and image targets during remote operation, thus improving situational awareness, and enabling better allocation of for physical resources including preventive maintenance -Manufacturing -Smart cities	-Throughput per stream (Bidirectional): Multi-Gbps -Number of streams: 1000's -Latency and jitter: < 10 ms
Robots and Cobots	Humans working collaboratively with robots to achieve outcomes that are challenging to be done by robots alone -Industry 5.0 applications	-Throughput: Multi-Gbps -Latency: <10 ms -Number of streams: 100's -Reliability: 7 9's -Positioning accuracy: < 1 cm -Sensing accuracy: >99%

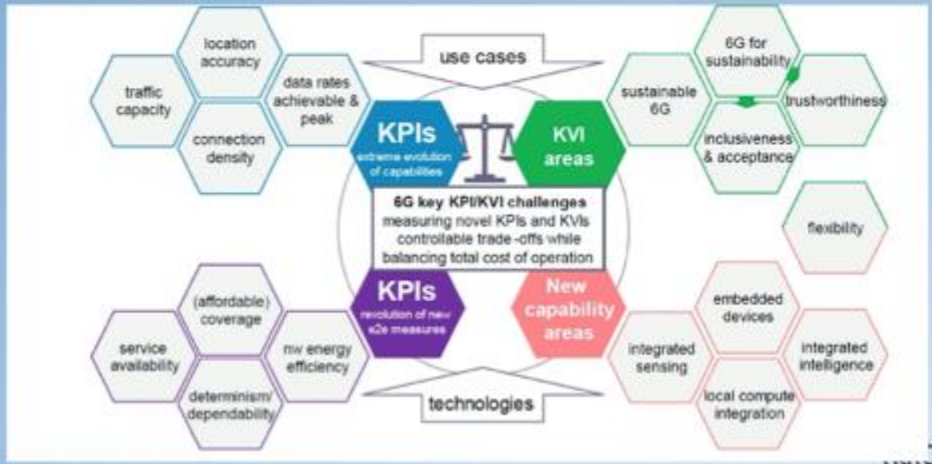
Expectations of 6G and setting the directions on the foundation of 5G

- 6G Key Performance Indicators (KPIs) are built upon 5G KPIs and further extended
- 6G Key Value Indicators (KVIs) are introduced to cater to the United Nations Sustainability Development Goals (UN SDGs) and are NOT always easy to measure directly

Example new KPIs :
- Area traffic capacity
- Control plane latency
- Connection reliability
- Positioning accuracy
- Sensing accuracy
- …

Example new KVIs:
- Energy efficiency
- EMF radiation
- Carbon footprint
- Trustworthiness
- Inclusiveness
- …





Source: https://hexa-x.eu/

Next G Alliance Applications & Use Cases

Four Foundational areas:

1. **Living**: How to improve the quality of everyday living
2. **Experience**: How to improve the quality of experience in areas such as entertainment, learning and healthcare
3. **Critical**: How to improve the quality of critical roles in sectors such as healthcare, manufacturing, agriculture, transportation, public safety
4. **Societal Goals**: How to attain and improve on high-level societal goals

Four categories of use cases:

1. Network-Enabled Robotics and Autonomous Systems,
2. Multi-sensory Extended Reality,
3. Distributed Sensing and Communications, and
4. Personalized User Experiences.

6. Bridging the Digital Divide

6G & the Digital Divide

Social and physical distancing is becoming the new normal requiring unprecedented demand for digital access, including affordable Internet access and other digital inclusion and digital equity resources.

Students, parents, teachers, seniors, library patrons and the general public do not have affordable and equitable access to the Internet.

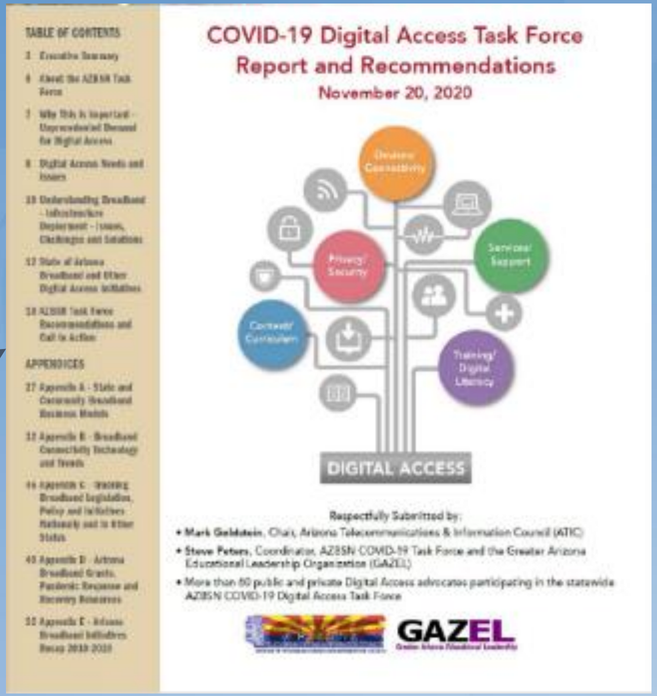
- As a result, the homework gap is a major issue for many of our students.
- Broadband is essential to connect schools, universities, community colleges, homes, libraries, health care facilities, businesses and communities to support education, health care, community services and economic development.

In many places, rural and remote areas lack proper connectivity which has led to an increasing digital divide.

- These areas may have low population density, low incomes, difficult terrain, and non-existent infrastructure, lacking a power grid, for example

6G could be the first mobile radio generation that truly aims to close the digital divide.

- However, to do so, **special requirements and challenges must be considered from the beginning of the design process.**



Digital Equity and 6G

Digital equity means all individuals and communities have access to a reliable broadband connection, thereby playing an important role in achieving several U.N. Sustainable Development Goals.

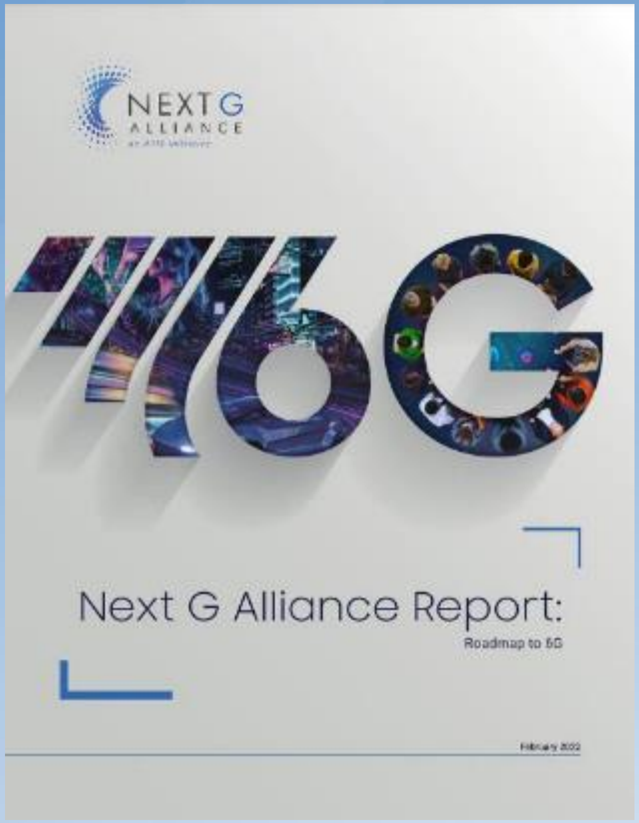
- ➢ Internet access supports greater access to education, employment, and economic growth.
- ➢ The result is a society that is inclusive and allows participation from all components of society, increasing innovation and spurring sustainable industrialization.

Digital equity should be understood as a requirement to achieve three conditions for each user:

- ➢ **Affordability**: Affordability is an enabler of Digital Equity and Accessibility, subject to policy and market forces.
  - 6G user equipment and the 6G network architecture must be cost effective and with improved operational efficiency, thereby reducing overall cost of access to individuals.
- ➢ **Accessibility**: 6G technologies, providing multiple modal forms of access/communications, must be accessible to all members of the population.
- ➢ **Geographic availability**: 6G network services must be available to the entire population of potential users.

6G-enabled services will be important to improving the quality of life in North America and its local communities.

- ➢ They apply to areas such as public services, health care, education, safety and security, and the environment.



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Draft: Recommendations & Advisements

Draft Recommendations/Advisements

- **6G Development Timeline**
  - 5G Advanced Evolution to continue for future 3GPP Releases (17,18,19)
  - 6G Fundamental research is underway with Federal and Industry Investments
  - ITU defined IMT-2030 and twinning with WRC will set 6G radio performance requirements

- **O-RAN and Open RAN Security**
  - Disaggregated O-RAN Networks need to demonstrate Multi-Vendor Interoperability.
  - Federal incentives need to align with subsystem integration and demonstrate performance parity with legacy networks
  - Securing the Open Fronthaul interface real time system from targeted attacks

- **mmWave and Sub-Thz**
  - Opportunity: joint comms and sensing, large transmission bandwidth, indoor and personal area network deployment
  - Challenge: High mid-band value for deployment scenarios, very high path loss
  - Focus on high directionality systems

- **Spectrum Needs**
  - Mid Band: 500MHz opportunity in 7-24 GHz, existing sharing mechanisms
  - Sub Thz: 100-1000GHz for highly demanding use cases: Immersive comms,,cobots
    - Policy is nascent
  - Heterogeneity of access: Space,Aerial,Terrestrial Integrated Networks requires coordination

- **6G Use Cases and Application Verticals**
  - Focus on application centric view with Multi-sensory and Immersive Communication use cases are quickly emerging
  - Emergence of Key Value Metrics (KVI) beyond traditional metrics for 5G
  - Focus on zero energy, sustainability, inclusion and deployment economics

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Draft: Proposed 6G WG Items to address in 2023

2023 6G Working Group (proposed) Focus Areas

Since 6G is early in the development cycle, there are study Items that the TAC should carry over into 2023:

- 5G Advanced Evolution Towards 6G
- 6G Research & Standards Progress
- Spectrum related - WRC ‘23
- Use Cases & Applications – How is 6G technology envisioned to enhance or be utilized in **autonomous driving, edge computing, emergency alerting, and smart city technology** deployments
- ….

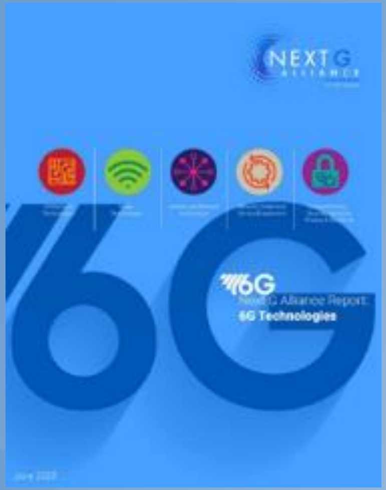
More to come!

References

References 1/2

Next G Alliance 6G Library

(https://www.nextgalliance.org/6g-library/)



References 2/2

ITU-T (Jan 2020)
- International telecommunication industry

Next G Alliance (Feb 2022)
- Americas telecom industry and academia

5G Americas (Dec 2020)
- Americas telecom service providers and equipment vendors

Hexa-X (April 2021)
- Telecom industry and academia in Europe

IMT-2030 Promotion Group (June 2021)
- Telecom industry and academia in China

NGMN (Feb 2022)
- Leading global mobile network operators

Thank You

FCC Technological Advisory Council Agenda – September 15, 2022

10am – 10:30am	Introduction and Opening Remarks •Welcome Message (TAC Chair) •Opening Remarks by OET Chief •DFO/Deputy DFO Remarks •Member Introduction/Roll Call
10:30am ~ 11:15am	Advanced Spectrum Sharing WG Presentation
11:15am-12:00pm	6G WG Presentation
12:00pm – 1pm	Lunch Break
1pm – 1:45pm	AI/ML WG Presentation
1:45pm-2:30pm	Emerging Technologies WG Presentation
2:30pm-2:45pm	Closing Remarks
2:45pm	Adjourned

Federal Communications Commission Technological Advisory Council Meeting

(Lunch Break)

September 15, 2022

FCC Technological Advisory Council Agenda – September 15, 2022

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2:45pm	Adjourned

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FCC TAC
Artificial Intelligence and Machine Learning Working Group

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

FCC Liaisons: Chrysanthos Chrysanthou, Kambiz Rahnavardy, Patrick Sun,
Sean Yun, Michael Ha, Martin Doczkat

Date: September 15, 2022

AIWG Members

Name	Organization	Name	Organization
Mark Bayliss	Visual Link	Nageen Himayat	Intel
Nomi Bergman	Advance/Newhouse	Greg Lapin	ARRL
Dean Brenner	TAC Chair	Jose Mejia	RapidSoS
William Check	NCTA	Amit Mukhopadhyay	Nokia Bell Labs
Krishna Chintalapudi	Microsoft	Jack Nasielski	Qualcomm
Martin Cooper	Dyna LLC	Mike Nawrocki	ATIS
Andrew Clegg	WInnForum	Jon Peha	CMU Metro21
Adam Drobot	OpenTechWorks	Balaji Raghothaman	Keysight
Brian Daly	AT&T	Meryem Simsek	VMware
Monisha Ghosh	Notre Dame	Paul Steinberg	Motorola Solutions
Lisa Guess	Ericsson (Cradlepoint)	Michelle Thompson	ORI
Mark Hess	Comcast Corporation	Tom Van Meter	Juniper
		James Goel	Qualcomm

Agenda

- Charter
- AI/ML and Computing
- Impacts of AI/ML and Computing on Telecommunications
  - 2020 Pilot Project Recommendation
- Notional Recommendations

Appendix – SME Speakers

Artificial Intelligence, Machine Learning and Computing Working Group - AIWG

Charter

Charter

Artificial Intelligence and Machine Learning WG 2022

1. Expand pilot project proposal(s) from the 2020 TAC session to provide details and associated quality metrics that will allow the Commission to explore, extract the value, and gauge the success of implementing AI/ML techniques.

2. Explore 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.

Charter

Artificial Intelligence and Machine Learning WG 2022 - continued

3. Evaluate the use of AI/ML methods and techniques applied to assuring the safety, security, and performance of network equipment, network control, and network operations in a network environment that increasingly relies on automation, is seeing a rapid growth of new network connections, and is increasingly digitized and software-ized.

4. Consider the implications of AI/ML adoption by content providers and the impact on consumers, focusing on understanding causes of and approaches to dealing with addictive behaviors.

Charter

Artificial Intelligence and Machine Learning WG 2022 - continued

5. Formulate a better 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.

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Charter

Topic Areas for the Working Group

1. Definition, Description, and Plan of an “AI/ML and Computing” Pilot Project for the FCC (Charter 1.)
2. “Safe Uses of AI/ML and Computing” including impacts on the Network (Charter 3.) and impacts on consumers and end-users (Charter 4. and 5.)
3. “AI/ML and Computing” to improve the utilization of Spectrum, addressing the basic components of wireless/cellular networks. Concentration on issues of propagation and interference (Charter 2.)
4. “AI/ML and Computing” for the Network – Performance and Properties. Concentration on issues of strategic value for the FCC. (Charter 3.)

Artificial Intelligence, Machine Learning and Computing Working Group - AIWG

AI/ML and Computing

AI/ML and Computing

Areas of AI/ML

1. Machine Learning
   - Supervised
   - Unsupervised
   - Reinforced
   - Federated
2. Neural Networks
3. Expert Systems
   - Knowledge Graphs
4. Fuzzy Logic
5. Natural Language Processing
6. Machine Vision
7. Robotics
8. **General Artificial Intelligence**

Areas of Computing

1. General Purpose
   - HPC
   - Cloud (Multi-tenant, Virtualized,…)
   - Fog/Edge
   - Facilities Based
2. Information Technology
3. Simulation
4. Emulation
5. Distributed
6. Realtime
7. Embedded
8. AI/ML
9. ……..

AI/ML and Computing

- AI and the AI world consist of of many different methods and techniques that work best when combined with the methods, techniques, and algorithms from the world of Computing. It is not just about Machine Learning (ML).

- The overarching consideration is Digital Transformation where data and information in Digital form combined with the power of computing allows us to solve complex and challenging problems that were previously intractable.

- The major factors that have enabled the advances in AI/ML are:
  - The exponential increases in available computing power
  - The access to large volumes of Digital Data
  - Key algorithmic advances in ML techniques
  - Significant investments in AI/ML across many vertical sectors

- Other branches of AI, relevant to Telecommunications, have also seen significant advances (e.g., Natural Language Processing, Knowledge Graphs, ,……)

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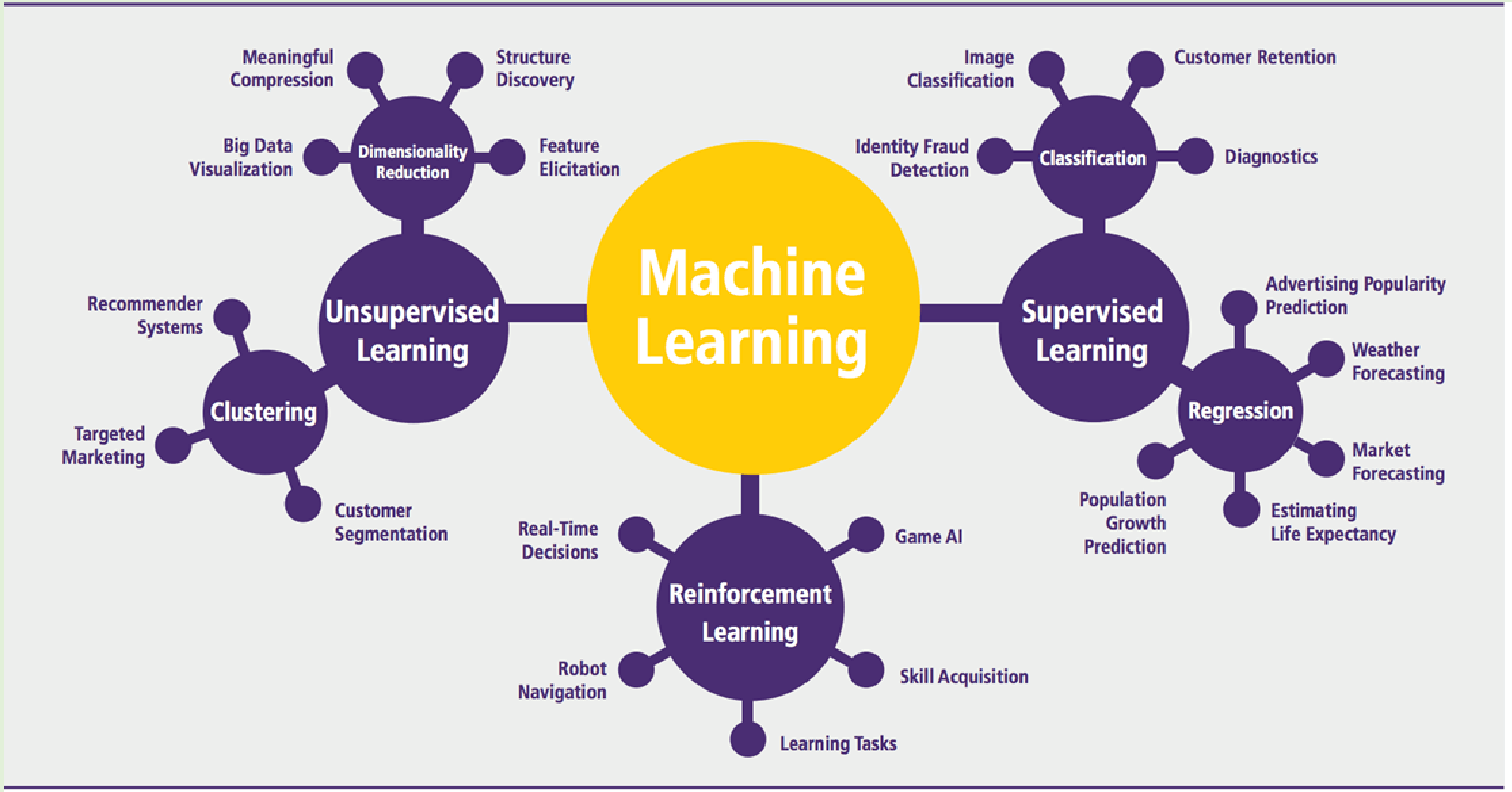
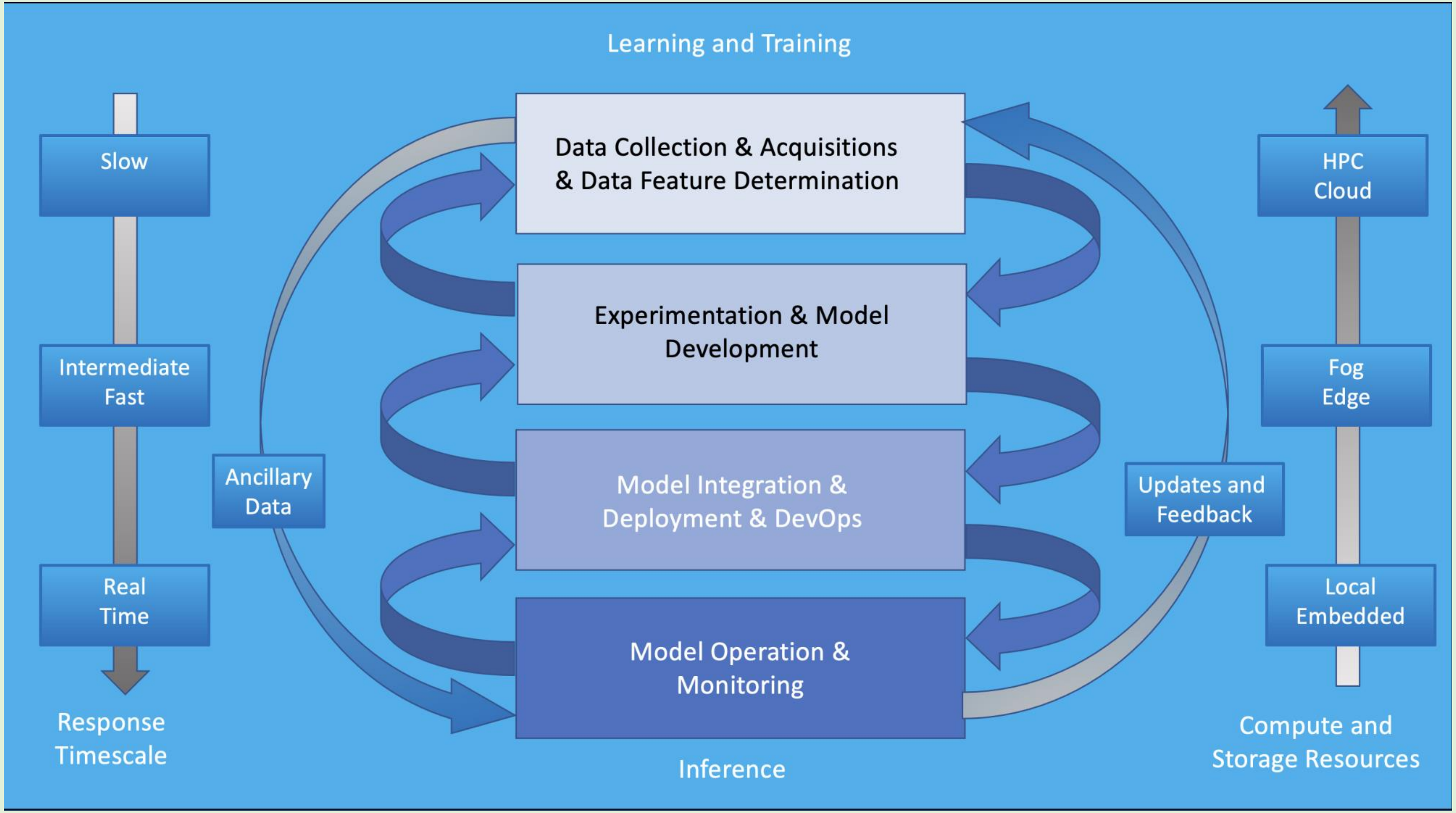
AI/ML and Computing



AI/ML and Computing

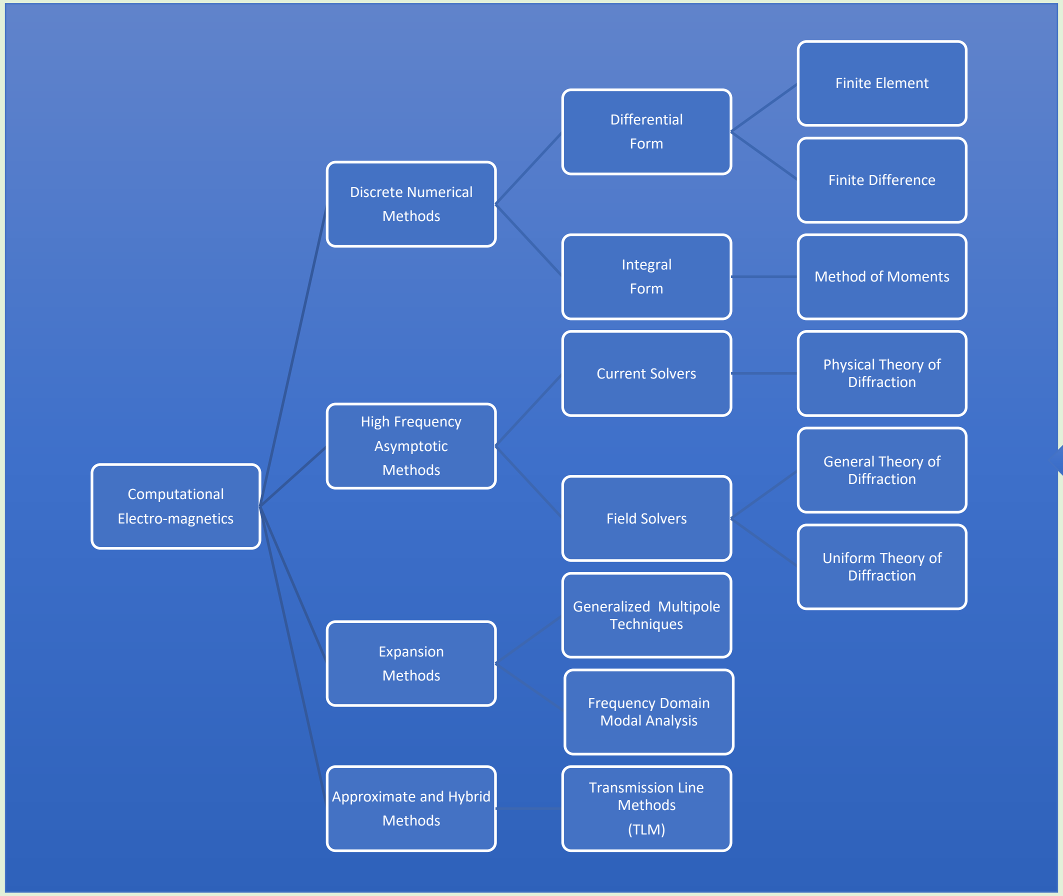
- In a typical ML implementation, the starting point is:
  - The creation of a model
  - The identification of key model features,
  - The collection and curation of data to feed the model (including labeling)
  - A cycle of epochs to determine the “weights” in the model’s inference engine
  - A cycle of updates to the model and to the data based on model’s performance
  - Extensive model testing – to understand validity and boundaries of applicability
  - Pilot exercises for deployment
  - Full Scale Integration of ML Model into an Application/System
  - Deployment
  - Operation (Feedback, Data collection, Retuning, …..)
  - Maintenance and Updates
- The ML inference engine is usually just part of a solution as a component of a larger system or system-of-systems.

AI/ML and Computing

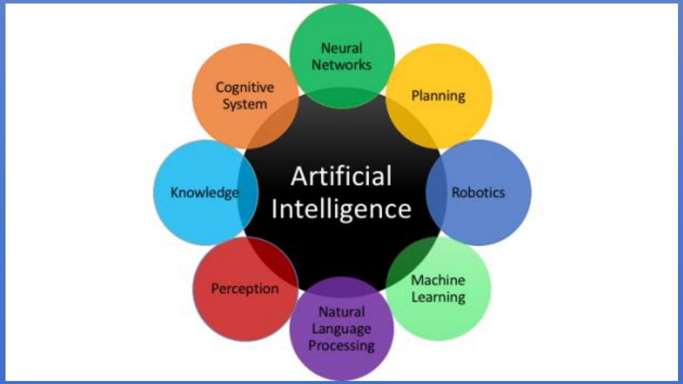


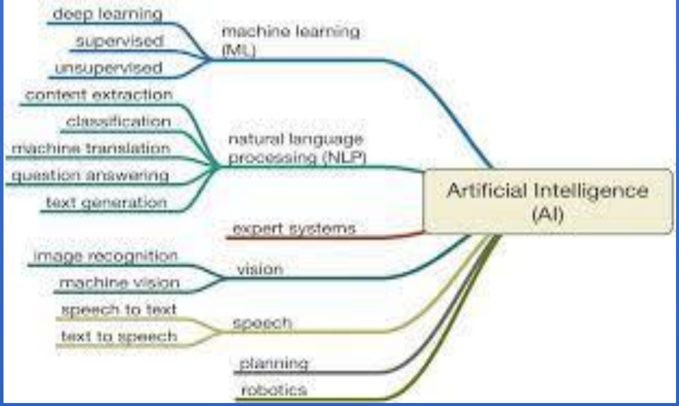
AI/ML and Computing

Simulation and Analytics for Electromagnetics

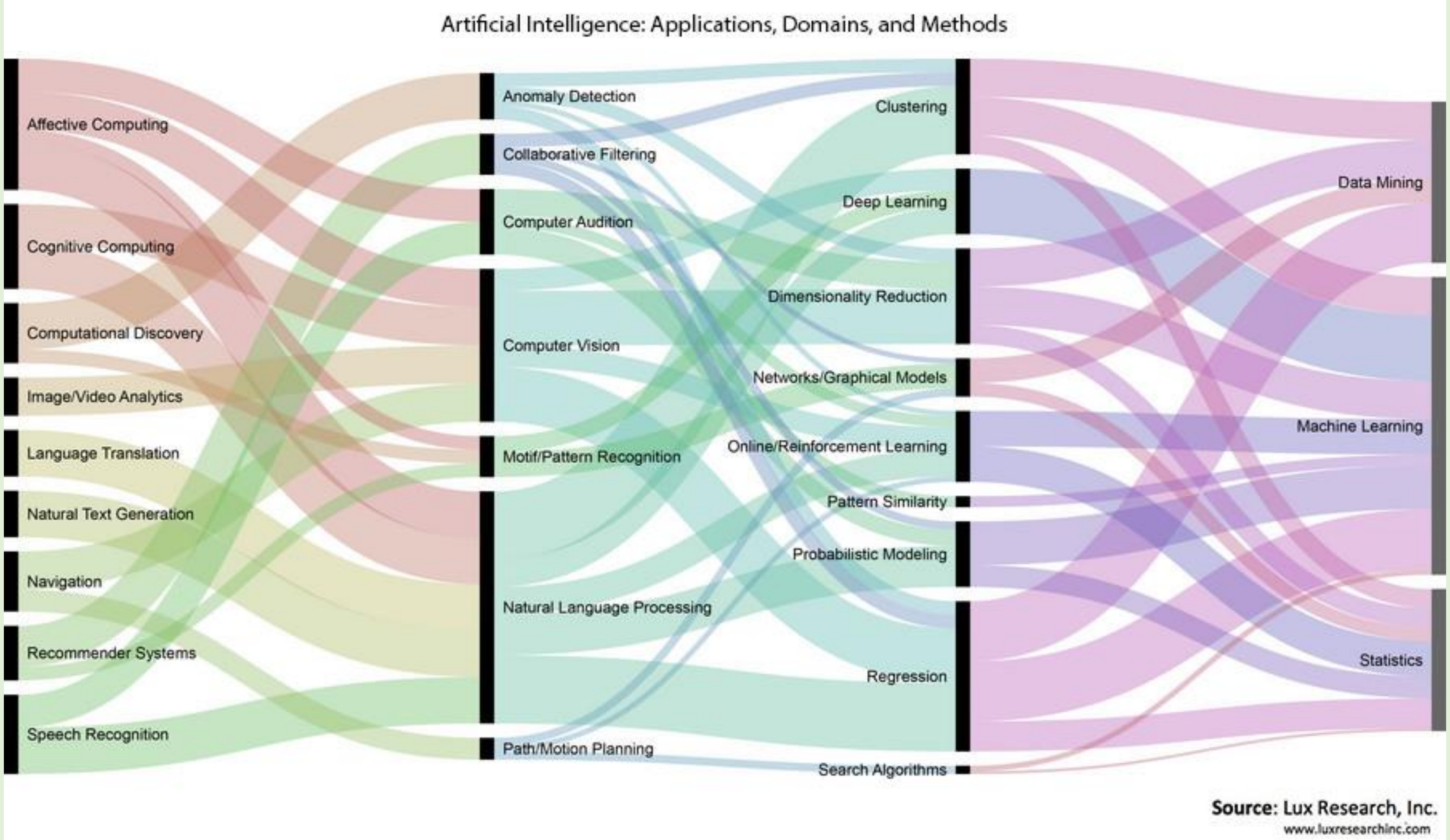


Artificial Intelligence and Machine Learning





AI/ML and Computing



Artificial Intelligence, Machine Learning and Computing Working Group - AIWG

Impacts of AI/ML and Computing on Telecommunications

Telecommunications: Impacts of AI/ML and Computing

- Digital Transformation is having a profound impact on the Telecommunication Industry affecting both business models and much of the underlying technology:
  - Softwarization
  - Virtualization
  - Higher levels of efficiency, optimization, and automation in operator processes
  - Software, Infrastructure, Business to Business, Business to Customer - as a Service Business Models
- The trends are affecting patterns of traffic on the Network as well as the design of the Network itself.
- Computing Networks, Data Storage Networks, and Data Networks should be considered as an essential bundle with Telecommunication Networks. The embedded AI/ML and Computing Software is an essential ingredient of each Network.

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Telecommunications: Impacts of AI/ML and Computing

- Successful Digital Transformation is not without challenges. Polls and analysis conducted by McKinsey & Company, Gartner, and other analysts have found that somewhere between 70-85% of all Digital Transformation Initiatives Fail.

  https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/why-digital-strategies-fail

  https://www.forbes.com/sites/unit4/2021/10/11/why-transformations-fail-and-how-they-can-succeed-with-people-power/?sh=7f5245272f89

  https://www.buildingbettersoftware.com/blog/70-of-digital-transformations-fail%E2%80%8A-%E2%80%8Adont-be-one-of-them/

- One of the main causes is the unwillingness of management to fully commit to digital technologies, provide the appropriate resources, and to staff and partner appropriately.

Telecommunications: Impacts of AI/ML and Computing

- AI/ML and Computing are deeply embedded in Telecommunications Networks, Network Operations, and in Services and Applications that run over the Network

For the Network this includes the complete lifecycle

- Design of the Network and its components
- Development (including planning)
- Deployment
- Operations
- Maintenance, Repair, and Upgrades
- Retirement

It also includes important Network attributes such as

- Security and Assurance
- Reliability and Availability

Recommendations – Extracting Value from Artificial Intelligence for the FCC through Pilot Projects from 2020

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.

- **2020 Recommendation**. 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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Potential Impacts of AI on the FCC – Pilot Projects from 2020

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)

Potential Impacts of AI on the FCC – Pilot Projects from 2020

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
…………………	

Recommendations – Extracting Value from Artificial Intelligence for the FCC through Pilot Projects from 2020

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

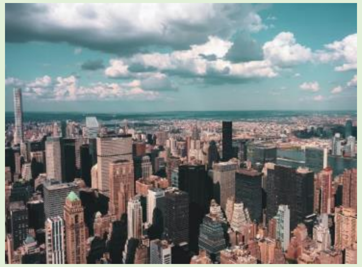
Artificial Intelligence, Machine Learning and Computing Working Group - AIWG

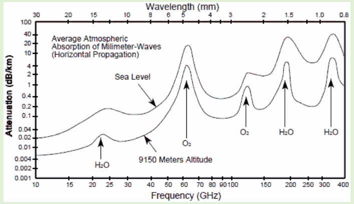
Notional Recommendations

Topic 1 and Topic 3: Notional Areas of Recommendation

- Pilot Project developed around a Systems Model for Automated Network Management & Control. Applicable to Cellular Networks and to Spectrum Sharing

Environment

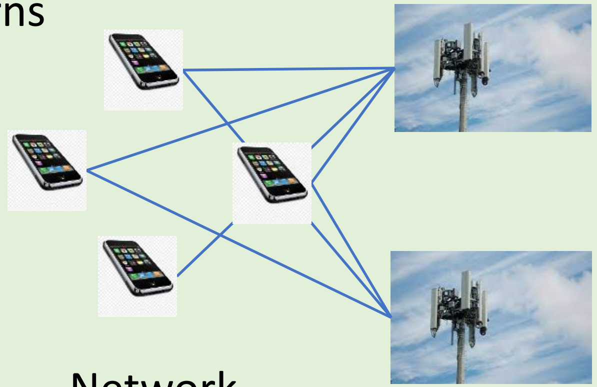




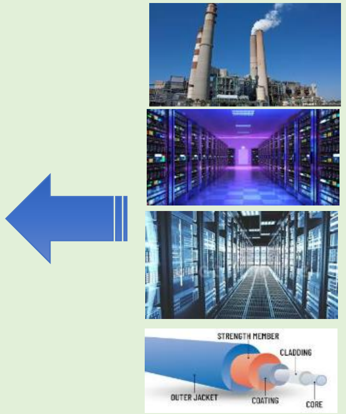
Phenomenology

Use Patterns

Components



Network

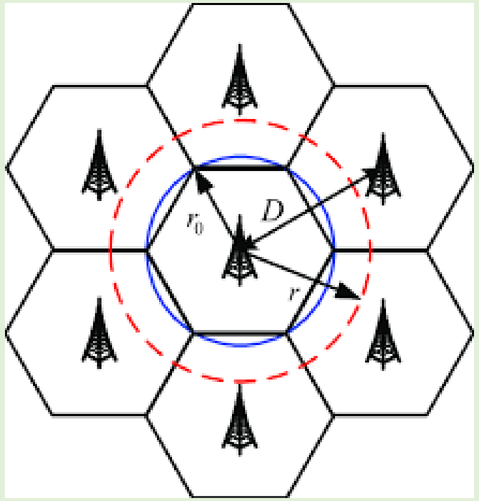


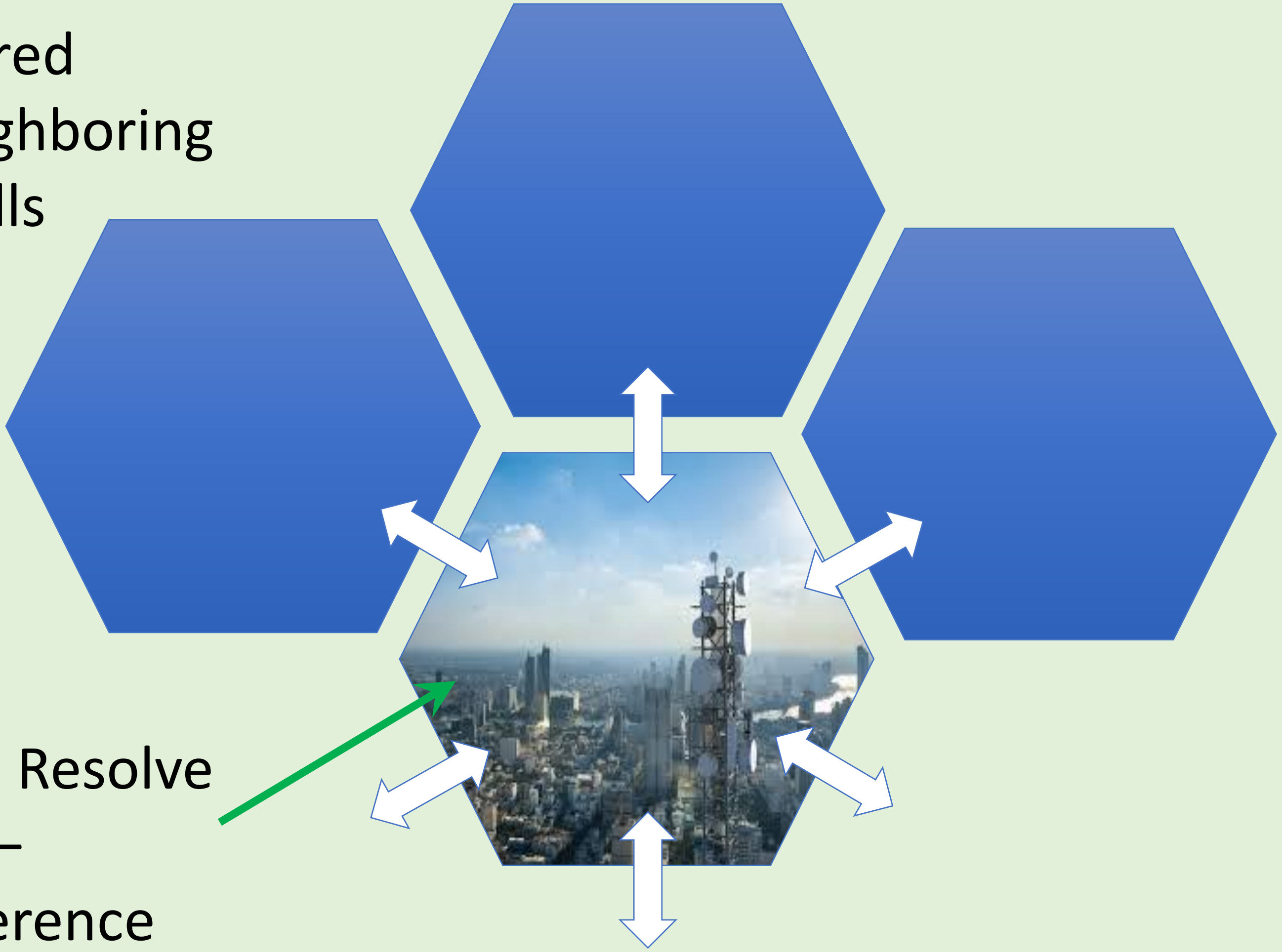
Infrastructure

Performance – Propagation - Interference

Topic 1: Notional Areas of Recommendation

Reduced Data
Shared
With Neighboring
Cells





AI/ML and Analytics To Resolve
Local EM Environment –
Propagation and Interference

Topic 2: Notional Areas of Recommendation

- Develop an FCC publication that quantifies the concerns and risks as well as expected behaviors of the FCC relative to AI (effectively a 'code of conduct'). This might be analogous to the memorandum published by the deputy secretary of defense on the topic '[Implementing Responsible Artificial Intelligence in the Department of Defense].'

- Convene an industry working forum of practitioners/experts (technology providers, service providers, AI/ML experts) to analyze the current regulatory framework requirements and metrics (security, reliability, interference, economic) relative to use of AI/ML and develop (voluntary) industry actions to compensate. Consider including a risk-based framework that includes aspects of how the AI is applied (level of autonomy, statically pre-trained vs. operational learning, etc.)

- Engage with NIST on their AI RMF and consider using that lifecycle-oriented structure to develop industry profiles and playbooks that impart guidance and best practices on safe use of AI.

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Topic 2: Notional Areas of Recommendation

- Engage with other government agencies who have similar concerns and are undertaking proactive actions on the safe use of AI in their field (e.g., US NRC) and collaborate on knowledge and best practices.
- Monitor activities internationally (e.g., focus on the EU initiatives around AI regulation) and consider adoption of best practices (e.g., proposed bans on the use of AI to influence perception or behavior of individuals).
- Assess the need changes (altered or extended regulation) where AI/ML has the potential to substantially magnify undesirable behaviors and outcomes. For examples: a) consider wiretapping laws and how AI (Natural Language Understanding) would be interpreted in that framework. b) consider current rules and regulations on robocalling and assess the implications of AI (natural language understanding) and operational ML (adaptive conversations).

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Topic 4: Notional Areas of Recommendation

- Built around "AI/ML and Computing" Operations and the Future-scape exercise conducted by the AIWG. Examining the full lifecycle of the Network and its Components.

- Algorithms, Hardware, Infrastructure, and Workforce. How to effectively optimize the efficient use of resources in an operational context. [If you can't operate it, it is useless]

- Evidence and fact-based analysis for achieving and operating high performance reliable Networks for Telecommunications. Factors for success? The truth is in the McKinsey article on Digital Transformation.

Artificial Intelligence, Machine Learning and Computing Working Group - AIWG

Summary and Close

- Supporting the FCC’s high-level goals – Leadership in Telecommunications is a goal of the strategic plan
- We interpret that AI/ML and computing in general as part of the underlying fabric in telecommunications. Making it digital as much as possible, With a high degree of automation - which is also digital.
- FCC has to be on top of the stack of how you do a digital transformation not just for a single company, but for the sector. How do you make sure the operators are in a position for success?
- The reason we call for the convergence of key infrastructures (Computing, Communications, Storage, and Data) is because you need them to succeed.

- 5G is a disaggregated distributed system that functions because it has the algorithmic stuff under the hood that makes it all work. 6G is likely to be even more complex and the challenge is to make it work and to do so efficiently. AI/ML and Computing play a fundamental role in making that possible – its' not just about a new radio and more spectrum, its about efficient use of resources and optimization.

- Operational world. Have to worry about how you actually deploy stuff, who is in charge, how people have to be trained, how you make decisions, solution world and people world come together. How do you move the industry if you want the US to be a leader, to be on the top of the pile.

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Thank You!

Appendices

FCC TAC AIWG Presentation: April 20th, 2022

Talk Title: **"AI Operations for the Future of Networking"**

Bob Friday
Chief AI Officer
Juniper

- **Biography:** Bob is the CTO and co-founder of Mist Systems, a Juniper Company. He is currently Junipers' Chief AI Officer.

  Bob started his career in wireless at Metricom (Ricochet wireless network) developing and deploying wireless mesh networks across the country to connect the first generation of Internet browsers. After Metricom, Bob co-founded Airespace, a start-up focused on helping enterprises manage the flood of employees bringing unlicensed Wi-Fi technology into their businesses. Following Cisco's acquisition of Airespace in 2005, Bob became the VP/CTO of Cisco enterprise mobility and drove mobility strategy and investments in the wireless business (e.g., Navini, Cognio, ThinkSmart, Phunware, Wilocity, Meraki). He also drove industry standards such as Hot Spot 2.0 and market efforts such as Cisco's Connected Mobile Experience. He holds more than 15 patents.

FCC TAC AIWG Presentation: April 27th, 2022

Ayodele Damola
Director
AI/ML Strategy at Ericsson
Plano TX

Talk Title: **"Leveraging AI/ML in Radio Access Networks (RAN)"**

Biography: Ayodele Damola is the Director of AI/ML Strategy at Ericsson

Ayodele has 17+ years of experience in the telecommunications industry. He works in the MANA CTO Office focusing on driving the AI/ML strategy for North America looking into key market and technology trends in AI/ML and identifying business opportunities and threats.

Previously Ayodele worked in Ericsson Research in Kista, Sweden. He is an inventor with 18 granted US patents.

He holds a Master of Science degree in Computer Networks from the Royal Institute of Technology (KTH) Sweden and has completed professional development programs at Harvard and McGill universities.

linkedin.com/in/ayodele-damola-bba27b4

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FCC TAC AIWG Presentation: May 12th, 2022

Guido Lobrano
Senior VP and Director General for Europe at ITI - The Information Technology Industry Council

Talk Title: **“The European Union’s Artificial Intelligence (AI) Act”**

Biography: Guido Lobrano is the Senior Vice President of Policy, Director General for Europe at ITI

Guido Lobrano is ITI’s Senior Vice President of Policy and Director General for Europe, leading ITI’s work on the European Union’s activities impacting technology and innovation. Guido is based in Brussels, Belgium, where he opened ITI’s first office in Europe. He coordinates ITI’s work on EU initiatives in areas such as privacy, cybersecurity, artificial intelligence and data, competition policy and platform issues, and supports the work on digital trade and taxation.

Before joining ITI in October 2017, Guido was deputy director for legal affairs, internal market and digital economy at BusinessEurope, the confederation of European industry. He was in charge of digital and tech policy, as well antitrust and state aid legislation. He also coordinated the team responsible for single market policy.

He led the association’s advocacy on Europe’s i2010 Strategy and the Digital Agenda for Europe (2012), as well as the 2015 Digital Single Market (DSM) and Digitizing European Industry strategies. He was in charge of privacy and data issues, e-commerce, sharing economy and platforms among others. He covered key legal and policy debates from a cross-sectoral industry perspective, including the 2008-2009 EU Telecoms Review, collective redress (EU-level class action schemes), the process leading to the General Data Protection Regulation (GDPR), the transition from the EU-US Safe Harbor to Privacy Shield.

Guido began his professional career working in law firms in the United States, France, Italy and Belgium, on international and EU law. He is a frequent speaker on a variety of topics, particularly technology and competition policies. He received his law degree in Italy at the University of Sassari and an Erasmus diploma from the University of Vienna.

https://www.linkedin.com/in/guidolobrano/

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FCC TAC AIWG Presentation: May 12th, 2022

Marco Leto Barone
Policy Manager – Europe at ITI - The Information Technology Industry Council

Talk Title: **“The European Union’s Artificial Intelligence (AI) Act”**

Biography: Marco Leto Barone, Policy Manager – Europe at ITI

Marco joined ITI as a Policy Fellow in March 2019 and now works as a Manager of Policy on ITI’s Brussels team. Before joining ITI, Marco worked on tech policy as a Blue book trainee at the European Commission’s DG CNECT in Luxembourg. Prior to that, he interned at the Brussels office of the consultancy firm Brunswick Group, where he focused on EU public affairs, technology, consumer issues and financial services. Marco has a background in EU Affairs, and he studied at the University of Groningen in the Netherlands, at the University of Deusto in Spain and at the University of Bologna in Italy.

https://www.linkedin.com/in/marco-leto-barone/

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FCC TAC AIWG Presentation: May 25th, 2022

Professor Randall Davis, CSAIL (Computer Science and Artificial Intelligence Laboratory, MIT

Talk Title: **“Artificial Intelligence: What it Can and Can’t Do (Yet)”**

Biography: Prof. Randall Davis, CSAIL, MIT

Randall Davis received his undergraduate degree from Dartmouth, graduating summa cum laude, Phi Beta Kappa in 1970, and received a PhD from Stanford in artificial intelligence in 1976. He joined the faculty of the Electrical Engineering and Computer Science Department at MIT in 1978 where he held an Esther and Harold Edgerton Endowed Chair (1979-1981).

He has been a Full Professor in the Department since 1989. He has served as Associate Director of MIT's Artificial Intelligence Laboratory (1993-1998), as a Research Director of CSAIL from 2003-2007, and as Associate Director of CSAIL from 2012-2014.

Dr. Davis has been a seminal contributor to the fields of knowledge-based systems and human-computer interaction, publishing some more than 100 articles and playing a central role in the development of several systems. He and his research group are developing advanced tools that permit natural multi-modal interaction with computers by creating software that understands users as they sketch, gesture, and talk.

He is the co-author of *Knowledge-Based Systems in AI*. In 1990 he was named a Founding Fellow of the Association for the Advancement of AI and in 1995 was elected to a two-year term as its President. From 1995-1998 he served on the Scientific Advisory Board of the U. S. Air Force, earning the USAF Decoration for Exceptional Civilian Service.

Dr. Davis has also been active in the area of intellectual property and software. In 1990 he served as expert to the Court in Computer Associates v. Altai, a case that produced the abstraction, filtration, comparison test now widely used in software copyright cases.

From 1998 to 2000 he served as the chairman of the U.S. National Academy of Sciences study on intellectual property rights and the information infrastructure entitled The Digital Dilemma: Intellectual Property in the Information Age, published by the National Academy Press in February 2000.

https://www.csail.mit.edu/person/randall-davis

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FCC TAC AIWG Presentation: June 8th , 2022

Professor Stuart Russell, Electrical Engineering and Computer Sciences, UC Berkeley

Talk Title: **"Artificial Intelligence and Machine Learning"**

Biography: Prof. Stuart Russell, EECS, UC Berkeley

Stuart Russell received his B.A. with first-class honors in physics from Oxford University in 1982 and his Ph.D. in computer science from Stanford in 1986. He then joined the faculty of the University of California at Berkeley, where he is Professor (and formerly Chair) of Electrical Engineering and Computer Sciences and holder of the Smith-Zadeh Chair in Engineering. He is also an Adjunct Professor of Neurological Surgery at UC San Francisco and Vice-Chair of the World Economic Forum's Council on AI and Robotics.

Russell is a recipient of the Presidential Young Investigator Award of the National Science Foundation, the IJCAI Computers and Thought Award, the World Technology Award (Policy category), the Mitchell Prize of the American Statistical Association and the International Society for Bayesian Analysis, the ACM Karlstrom Outstanding Educator Award, and the AAAI/EAAI Outstanding Educator Award. In 1998, he gave the Forsythe Memorial Lectures at Stanford University and from 2012 to 2014 he held the Chaire Blaise Pascal in Paris. He is a Fellow of the American Association for Artificial Intelligence, the Association for Computing Machinery, and the American Association for the Advancement of Science.

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, global seismic monitoring, and philosophical foundations. His books include "The Use of Knowledge in Analogy and Induction", "Do the Right Thing: Studies in Limited Rationality" (with Eric Wefald), and "Artificial Intelligence: A Modern Approach" (with Peter Norvig). 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

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FCC TAC AIWG Presentation: June 15th , 2022

Charles Clancy, Senior Vice President, General Manager, MITRE Labs, Chief Futurist

Talk Title: **“TBD”**

Biography: Charles Clancy, General Manager, MITRE Labs

Charles Clancy is senior vice president, general manager of MITRE Labs, and chief futurist. He is responsible for sparking innovative disruption, accelerating risk-taking and discovery, and delivering real-time technology capabilities and execution through the company’s laboratories, solution platforms, and MITRE Fellows program. He leads technical innovation to anticipate and meet the future demands of government sponsors and industry and academic partners.

Clancy is an internationally recognized expert on topics at the intersection of wireless, cybersecurity, and artificial intelligence.

Before joining MITRE in 2019 as vice president for intelligence programs, Clancy served as the Bradley Distinguished Professor in Cybersecurity at Virginia Tech and executive director at the Hume Center for National Security and Technology. There, he led Virginia Tech’s research and experiential learning programs in defense and intelligence.

He started his career at the National Security Agency, filling a variety of research, engineering, and operations roles, with a focus on wireless communications. He has co-authored more than 250 patents and academic publications, as well as six books. He co-founded several venture-backed security startup companies that apply commercial innovation to national security challenges.

Clancy is an IEEE Fellow and sits on the AFCEA International Board of Directors’ Executive Committee, the AFCEA Intelligence Committee, the Intelligence and National Security Alliance Advisory Committee, the Systems Engineering Research Center Advisory Board, the Alliance for Telecommunications Industry Solutions Next G Alliance, and the Center for New American Security Task Force on Artificial Intelligence and National Security. He also serves on advisory boards at Howard University, Norfolk State University, North Carolina A&T State University, and Virginia Tech. In 2021, *WashingtonExec* magazine named Clancy one of the nation’s Top Climate Executives to Watch.

Clancy holds a bachelor’s degree in computer engineering from the Rose-Hulman Institute of Technology, a master’s degree in electrical engineering from the University of Illinois at Urbana-Champaign, and a doctorate in computer science from the University of Maryland, College Park.

https://www.linkedin.com/in/clancytc/

https://www.mitre.org/about/leadership/executive/charles-clancy

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FCC TAC AIWG Presentation: July 6th , 2022

JP Vasseur, Vice-President, Head of Engineering, Predictive Networks, and Cisco Fellow

Talk Title: **“Use cases for AI/ML in Telecommunications and Lessons Learned on developing AI/ML technologies at Scale.”**

Biography: JP Vasseur, Cisco Fellow (VP), Head of Engineering, Predictive Networks

JP Vasseur, PhD is a Cisco Fellow and lead of an engineering team developing products where he has been working on several networking technologies such as IP/MPLS, Quality of Service, Traffic Engineering, network recovery, PCE, “Internet of Things” (as the Chief Architect), Security, Wireless Networks since he joined Cisco in 1998. From 1992 to 1998, he worked for Service Providers in large multi-protocol environments, with a key focus on bringing cutting-edge innovation in shipping products.

JP has been an active member of the Internet Engineering Task Force (co-author of more than 35 IETF RFCs, funders and co-chair of several Working Groups such as the PCE and ROLL WG), and in several SDOs.

Since 2010, JP has been leading world class engineering teams of advanced networking and Analytics/Machine Learning (Self Learning Networks, Cloud-based Machine Learning) with key applications such as Security, network cognitive and predictive analytics for Enterprise Networks (wireless, LAN, WAN). JP is a regular speaker at various international conferences, he is involved in various research projects and the member of a few Technical Program Committees. JP Vasseur is also Associate Professor at Telecom Paris.

He is the (co)inventor of more than 500 patents in the area of IP/MPLS, Security, The Internet of Things and Machines Learning / Analytics (#1 inventor at Cisco), with large impact in Internet Technologies.

He is the coauthor of “Network Recovery” (Morgan Kaufmann, July 2004), “Definitive MPLS Network Designs” (Cisco Press, March 2005) and "Interconnecting Smart Object with IP: The Next Internet (Morgan Kaufmann, July 2010 - http://www.thenextinternet.org/).

JP received a PhD in Networking (Mines-Telecom Paris – France, a Master of Science in Computer Science (Steven - USA) and an engineering degree in computer Science (France).

https://www.linkedin.com/in/jp-vasseur-phd/?originalSubdomain=fr

https://www.youtube.com/watch?v=Jb8U1BrJlXo&ab_channel=TechFieldDay

https://newsroom.cisco.com/c/r/newsroom/en/us/a/y2019/m08/meet-cisco-s-top-inventor-jp-vasseur.html

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FCC TAC AIWG Presentation: July 13th, 2022

Tommaso Melodia
Director, Institute for the Wireless Internet of Things, and William Lincoln Smith Professor at Northeastern University

Talk Title: **"AI/ML-based Control and Orchestration in the Open RAN: Architectures, Algorithms, and Testbeds"**

Biography: Tommaso Melodia,

- 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.

https://www.linkedin.com/in/tommasomelodia/

https://ece.northeastern.edu/wineslab/tmelodia.php

FCC TAC AIWG Presentation: July 20th, 2022

Yoav Miche, Head of Network Security Research at Nokia Bell Labs, Finland

Talk Title: **“AI/ML-based Control and Orchestration in the Open RAN: Architectures, Algorithms, and Testbeds”**

Biography: Yoav Miche PhD, Head of Network Security Research at Nokia Bell Labs

Yoan is currently the head of the Network Security research team in Nokia Bell Labs. He received a double M.Sc. degree in Telecoms and Signal/Image processing from the ENSIMAG and Gipsa Lab, France. He received a double degree Ph.D. in Applied Machine Learning (for watermarking and steganography) from Aalto University, Finland (then Helsinki University of Technology) and the INP Grenoble, France. He was a postdoctoral researcher on industry collaboration projects during 4 years at Aalto University, mainly focusing on applications of machine learning to (cyber)security problems. He joined Nokia Research (now Bell Labs) Finland in 2014 as a cybersecurity researcher and took the lead of the cybersecurity research team in 2018. His topics of predilection include neural networks, anomaly detection, data mining, network security, and he is still fascinated by watermarking and steganography technologies. He was Associate Editor for Elsevier's Neurocomputing from 2012 to 2021, and now serves as a member of the Advisory Board for the journal. He is also on the editorial board (and one of the co-founders) of the Machine Learning and Knowledge Extraction (MAKE) journal. He has been on the Advisory and Stakeholder Boards of several EU projects, recently including the SHERPA project (on the Ethics of AI/ML) and the SAPPAN project (on the sharing and automation of security knowledge).

https://www.linkedin.com/in/yoan-miche-5842533b/?originalSubdomain=fi

https://www.bell-labs.com/about/researcher-profiles/yoanmiche/#gref

FCC TAC AIWG Presentation: July 20th, 2022

Henning Sanneck, Manager, Network Automation Research, NOKIA Standards, Munich, Germany

Talk Title: **“AI/ML-based Control and Orchestration in the Open RAN: Architectures, Algorithms, and Testbeds”**

Biography: Dr. Henning Sanneck, Manager, Network Automation Research

Henning Sanneck is Manager, Network Automation Research in the Standards unit of Nokia Strategy & Technology, Munich, Germany. He received his Dr.-Ing. (PhD) degree in Electrical Engineering from the Technical University of Berlin with a thesis on Voice over IP QoS in 2000. Then, Henning joined Siemens - Mobile Networks as a Senior Research Engineer, becoming an Innovation Project Manager in Radio Network Management in 2003. In 2007, at the formation of Nokia Siemens Networks, he started to lead a line team driving Self Organizing Networks (SON) concepts, IPR and demos for LTE using policy-based management technologies. Since 2009, Henning and his team have been working on applying and adapting analytics and machine learning technologies to Radio Network Management (in particular for anomaly detection and diagnosis) using network data- and simulation-based approaches. In 2014/15, as "Head of Cognitive Network Management" for Nokia Networks Research, he has also acted as the coordinator of the research & standardization work in that technical area which included the strategy development and technology transfer supervision. Henning’s team has been continuously involved in nationally (BMBF) and internationally (EU) funded research projects.

His current research interests are in (Beyond) 5G Network Management and Orchestration, in particular configuration, healing and the operation of Cognitive Functions in virtualized, sliced radio access networks (across public and private deployment scenarios). Henning has published 80 papers and has 30 patents granted or published. He has been co-editor and -author of the book "LTE Self-Organizing Networks" (2011) and co-author of the book "Towards Cognitive Autonomous Networks" (2020).

https://www.linkedin.com/in/henning-sanneck-62529819/ and https://sanneck.net/

FCC TAC AIWG Presentation: July 21st, 2022

Kathy Baxter
Principal Architect
Ethical AI Practice at Salesforce

Talk Title: **“Salesforce Ethical AI Maturity Model”**

Biography: Kathy Baxter, Principal Architect, Ethical AI Practice at Salesforce.

- As a Principal Architect of Ethical AI Practice at Salesforce, Kathy Baxter develops research-informed best practice to educate Salesforce employees, customers, and the industry on the development of responsible AI. She collaborates and partners with external AI and ethics experts to continuously evolve Salesforce policies, practices, and products. She is also a member of Singapore’s Advisory Council on the Ethical Use of AI and Data.

  Prior to Salesforce, she worked at Google, eBay, and Oracle in User Experience Research. She received her MS in Engineering Psychology and BS in Applied Psychology from the Georgia Institute of Technology. She is the co-author of "Understanding Your Users: A Practical Guide to User Research Methodologies." You can read about the Ethics AI Practice Team's current research at salesforceairesearch.com/trusted-ai and follow her on Twitter at @baxterkb.

https://www.linkedin.com/in/kathykbaxter/

https://www.salesforce.com/in/blog/authors/kathy-baxter

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FCC TAC AIWG Presentation: September 21st, 2022

Daron Acemoğlu, Institute Professor, Department of Economics and the Sloan School, MIT

Talk Title: **“TBD”**

Biography: Prof. **Daron Acemoğlu** , Department of Economics and Sloan School, MIT

Daron Acemoglu is Elizabeth and James Killian Professor of Economics in the Department of Economics at the Massachusetts Institute of Technology. He has received a BA in economics at the University of York, 1989, M.Sc. in mathematical economics and econometrics at the London School of Economics, 1990, and Ph.D. in economics at the London School of Economics in 1992.

He is an elected fellow of the National Academy of Sciences (United States), the Science Academy (Turkey), the American Academy of Arts and Sciences, the Econometric Society, the European Economic Association, and the Society of Labor Economists. He has received numerous awards and fellowships, including the inaugural T. W. Shultz Prize from the University of Chicago in 2004, and the inaugural Sherwin Rosen Award for outstanding contribution to labor economics in 2004, Distinguished Science Award from the Turkish Sciences Association in 2006, the John von Neumann Award, Rajk College, Budapest in 2007.

He was the recipient of the John Bates Clark Medal in 2005, awarded every two years to the best economist in the United States under the age of 40 by the American Economic Association, and the Erwin Plein Nemmers prize awarded every two years for work of lasting significance in economics. He holds Honorary Doctorates from the University of Utrecht, Bosporus University, and the University of Athens.

Daron Acemoglu’s areas of research include political economy, economic development and growth, human capital theory, growth theory, innovation, search theory, network economics and learning. His recent research focuses on the political, economic and social causes of differences in economic development across societies; the factors affecting the institutional and political evolution of nations; and how technology impacts growth and distribution of resources and is itself determined by economic and social incentives. In addition to scholarly articles, Daron Acemoglu has published four books: *Economic Origins of Dictatorship and Democracy* (joint with James A. Robinson), which was awarded the Woodrow Wilson and the William Riker prizes, *Introduction to Modern Economic Growth*, *Why Nations Fail: The Origins of Power, Prosperity, and Poverty* (joint with James A. Robinson), which was a New York Times bestseller in 2012; and *Principles of Economics* (joint with David Laibson and John List).

http://economics.mit.edu/faculty/acemoglu/index.htm

https://mitsloan.mit.edu/faculty/directory/daron-acemoglu

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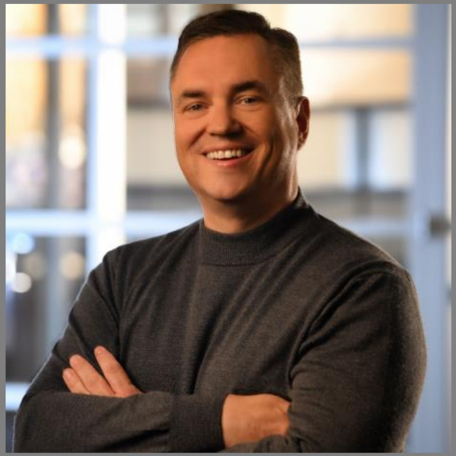
FCC TAC AIWG Presentation: July 27th , 2022



Frank Schirrmeister, Senior Group Director, Solutions & Ecosystems, Cadence

Talk Title: **“Enabling AI/ML semiconductor and system design and the role of Ai/ML in increasing development productivity”**

Biography: Frank Schirrmeister, Senior Group Director, Solutions & Ecosystem, Cadence

Frank Schirrmeister is senior group director, solutions & ecosystem at Cadence, where he leads a team translating customer challenges in the hyperscale, communications, consumer, automotive, aerospace/defense, industrial, and healthcare vertical domains into specific requirements and solutions. His team focuses on cross-product technical solutions such as 5G, artificial intelligence, machine learning, safety, security, and digital twins, as well as partner collaborations.

Frank holds a Dipl.-Ing. in electrical engineering from the Technical University of Berlin, Germany. Prior to joining Cadence, Frank held senior engineering and product management positions in embedded software, semiconductor, and system development, both in Europe and the United States.

https://resources.pcb.cadence.com/authors/frank-schirrmeister

https://semiengineering.com/author/frank-schirrmeiste/

https://www.linkedin.com/in/frankschirrmeister/

FCC Technological Advisory Council Agenda – September 15, 2022

10am – 10:30am	Introduction and Opening Remarks •Welcome Message (TAC Chair) •Opening Remarks by OET Chief •DFO/Deputy DFO Remarks •Member Introduction/Roll Call
10:30am ~ 11:15am	Advanced Spectrum Sharing WG Presentation
11:15am-12:00pm	6G WG Presentation
12:00pm – 1pm	Lunch Break
1pm – 1:45pm	AI/ML WG Presentation
1:45pm-2:30pm	Emerging Technologies WG Presentation
2:30pm-2:45pm	Closing Remarks
2:45pm	Adjourned

FCC TAC
Emerging Technologies Working Group

Chairs: Brian Markwalter, CTA
Henning Schulzrinne, SGE (Columbia University)

FCC Liaisons: Martin Doczkat, Bahman Badipour, Kamran Etemad, Padma Krishnaswamy

Date: September 15, 2022

Working Group Roster

Mark Bayliss	Visual Link	Steve Lanning	Viasat
Nomi Bergman	Advance	Greg Lapin	ARRL
Ranveer Chandra	Microsoft	Kaniz Mahdi	Deutsche Telekom
Bill Check	NCTA	Jennifer Manner	Hughes
Lynn Claudy	NAB	Lynn Merrill	NTCA
Andrew Clegg	WInnForum	Michael Nawrocki	ATIS
Mischa Dohler	Ericsson	Madeleine Noland	ATSC
Jeff Foerster	Intel	Jesse Russell	Inc Networks
Peter Gammel	Global Foundries	Lewis Shepard	VMWare
Dale Hatfield	UC Boulder	Marvin Sirbu	SGE
Mark Hess	Comcast	Ted Solomon	NRTC
Karri Kuoppamaki	T-Mobile		

Summary Status

- *Emerging Technologies* working group charter covers a wide range of technologies
  - from PHY to systems and resilience
  - from smart antennas to SOCs
  - from last-mile access networks to broadcast and satellite communications
  - from keyless access and positioning and IoT to “traditional” broadband
- So far, limited needs for FCC action identified
- Need to identify possible opportunities for addressing long-term concerns, such as
  - efficient use of spectrum
  - universal broadband deployment
  - network resilience and reliability
  - new IoT applications and availability
  - accessibility
  - emergency calling (positioning)

Charter/Questions Posed

- Provide information on emerging technologies, including the **IoT ecosystem** and the spectrum access needs for potential high-bandwidth devices, that are under development or in use that will improve the US consumer experience on applications related to communications. This should include advances in **semiconductor technologies for RF front ends, antennas and digital basebands**.
- What are the **new features or additional chipsets** that are expected to be embedded into wireless devices, including **UWB and other sensors**, and how would they promote additional services and applications?

Charter/Questions Posed

- What are the new tools to **restore internet access during shutdowns** and other disruptions?
- What are latest enhancements and capabilities of **cable and broadcasting standards** that may benefit the consumers?
- How is **indoor/outdoor location service** envisioned to improve and what are the technologies that are under consideration?
- What is the status of **small satellite development**, what frequency bands are under consideration for use, and what services are envisioned?

Charter/Questions Posed

- What **optical/laser** technologies are being utilized for space or terrestrial communications, what is the performance of these technologies in supporting communications, and what steps should be taken to ensure proper use of these technologies?
- What are the network-driven emerging technologies such as **quantum computing** and **blockchain**, and how would they improve user experience in communications services?

Speakers to Date (Q1-Q2)

Topic	Speaker	Organization
Ultra Wideband (UWB)	Karthik Srinivasa Gopalan	Samsung for FiRa Consortium
UWB in phones	Nihar Jindal	Google
Broadcast TV (ATSC 3.0)	Madeleine Noland	ATSC
Blockchain and networking	Deborah Simpier	Althea
Location services via Wi-Fi	Ganesh Venkatesan, Carlos Cordeiro	Intel
Electric utility resilience and security	Emma Stewart	NRECA
Free space optical communications	John Cooper	Project Taara
Current 5G chipsets	Sunil Patil	Qualcomm
Next generation passive optical networks	Ed Harstead	Nokia

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Speakers Since June TAC Meeting

Topic	Speaker	Organization
Satellite links for smartphones	Rob Reis	Higher Ground
IC evolution to 6G	Mingxi Fan	MediaTek
Steerable flat panel satellite antennas	Lilac Muller, Ryan Stevenson	Kymeta
LEO satellite systems throughput	Nils Pachler de la Osa	MIT
Array antennas and beamforming	Gabriel Rebeiz	UCSD
UWB technology and applications	Tim Harrington	UWB Alliance
Cable technology overview	Jeff Chen, Mark Walker	CableLabs
Satellite technology update	Jennifer Manner	Echostar
Advancements in RF front ends	Harish Krishnaswamy	Columbia University

Satellite Links for Smartphones

- *Rob Reis, Higher Ground*
- SatPaq – satellite radio and antenna that clips to smartphone
- GEO satellite connectivity for texting
- Military & first responder applications
- Patch antenna (44 degrees coverage) and spread spectrum modulation to reduce Adjacent Satellite Interference (ASI)
- Operates by waiver to Part 25.218
- The Commission has procedures for considering Higher Ground's desired rule changes independent of this working group or advisory committee

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IC Evolution to 6G

- *Dr. Mingxi Fan, MediaTek*
- Optimization at all layers
- Antennas, packaging, semiconductor technology
- RFFE integration, PA efficiency
- Lean protocol stacks, dynamic QoS, awareness between app and radio
- AI assisted radio access
- Takeaway: increasing level of technology integration continues in smartphones

	5G	6G Projection
Data Rate	100Mbps –10Gbps	1Gbps–1Tbps
Device MIMO	2Tx / 4+Rx	4Tx / 8+Rx
Spectrum	+3.5-7GHz +mmW (28-60GHz) ~3+ GHz more	+7-14GHz +Sub-THz ~50+GHzmore?
Network Densification	+ massive MIMO	Infrastructure and device cooperation

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Steerable (holographic) Flat Panel Antennas

- *Lilac Muller & Ryan Stevenson, Kymeta*
- Always on, go anywhere comms
- Military, first responders, maritime
- GEO and LEO compatible
- Holographic beamforming: a type of analog beamforming with phased arrays
- Manufacturing similar to LCD flat panel technology
- Looking to LEO integration and 5G NTN

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LEO Satellite System Throughput

- *Nils Pachler de la Osa, MIT*
- Simulation of LEO Systems

Initial Constellation

	Telesat	OneWeb	SpaceX	Amazon	
ISL (Gbps)	20	0	0	0	20*
# of sat.	298	716	1,584	578	
Max. Throughput (Tbps)	7.52	1.44	10.3	8.97	12.5
Avg. data-rate per sat. (Gbps)	25.2	2.01	6.50	15.5	19.6
Max. data-rate per sat. (Gbps)	34.4	9.97	19.7	50.8	
Satellite utilization (%)	73.4	20.2	33.0	30.5	38.5

Final Constellation

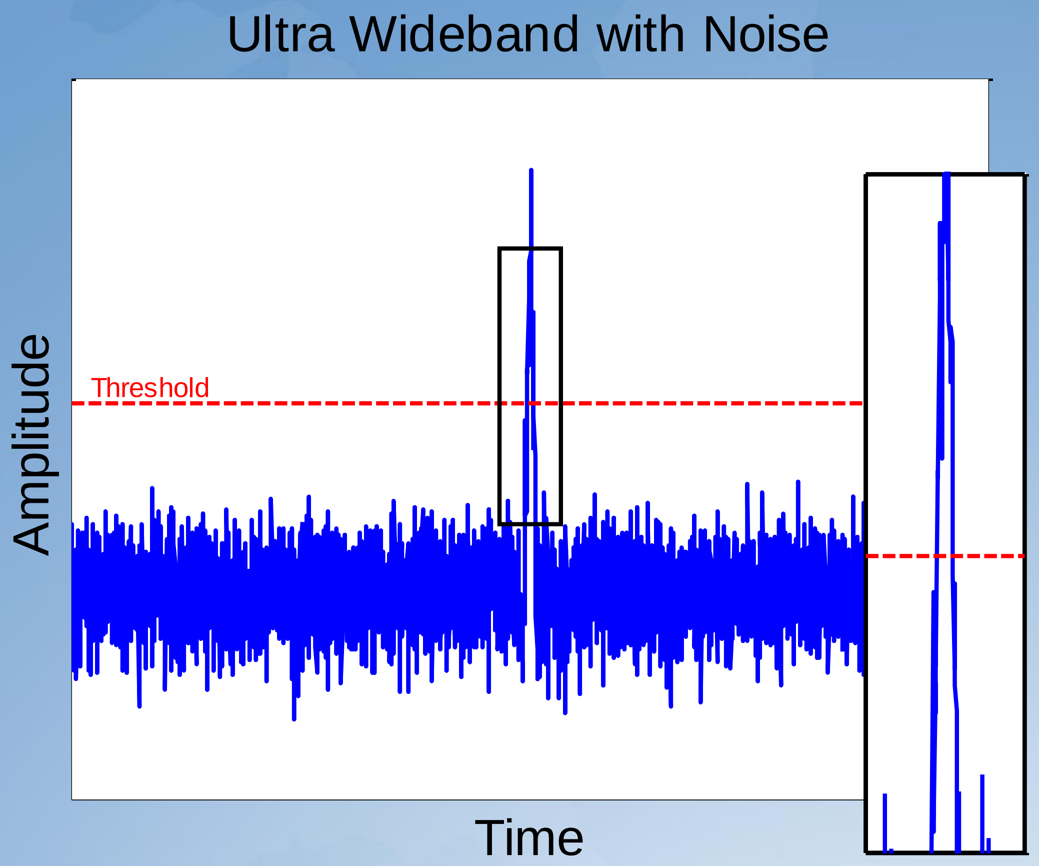
	Telesat	OneWeb		SpaceX	Amazon	
ISL (Gbps)	20	0	20*	20	0	20*
# of sat.	1,671	6.372		4,408	3,236	
Max. Throughput (Tbps)	25.4	26.9	30.3	27.2	41.4	53.4
Avg. data-rate per sat. (Gbps)	15.2	4.22	4.76	6.16	12.8	16.5
Max. data-rate per sat. (Gbps)	34.4	19.7		19.7	50.8	
Satellite utilization (%)	44.3	21.4	24.2	31.3	25.2	32.5

Phased Array Antennas

- *Dr. Gabriel Rebeiz, UCSD*
- Phased array antennas now ubiquitous
  - Hundreds of thousands of base stations
  - Millions of smartphones
- DARPA funded underlying research on mixed signal systems, GaN, SiGe and mm-Wave array technology
- Analog beamforming well established
  - But are the system issues resolved?
  - Is it underutilized in 5G?
- Current research on digital beamforming at the antenna element

UWB Technology and Applications

- *Tim Harrington, UWB Alliance*
- Impulse-based waveforms, wideband but spaced in time
- 2003 UWB approved in USA: 3.1- 10.6 GHz
- Limited applications until IEEE 802.15.4z and SOC improvements
- 2019 breakthrough to smartphones, tags
  - keyless entry, secure payment, AR/VR ranging
- Possible regulatory changes in EU, waivers in US for certain applications



Cable Technology Overview

- *Jeff Chen, Mark Walker, CableLabs*
- From HFC to "Fiber Deep" with distributed access architecture under the 10G rubric
- Enables fast upgrades (from 4% of homes @ 1 Gbps to 80% in 2 years)
- DOCSIS 4.0, 10 Gbps down, 6 Gbps up
- Wi-Fi is critical to customer experience
  - 57% of global internet traffic
  - Billions of devices
  - Wi-Fi 6E and Wi-Fi 7
  - Seeking additional power for 6 GHz LPI (Low Power Indoor)
- Mobile
  - Active in CBRS and National Spectrum Consortium PATHSS Task Group
  - Accelerating ORAN

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Satellite Communications, Now and into the Future

- *Jennifer Manner, Echostar*
- Satellites are critical for commercial, military and disaster recovery
- Rapid changes
  - Lower satellite and launch costs
  - Part of the 5G ecosystem with NTN
- Challenges
  - Spectrum and orbit shortage
  - Space debris and traffic
  - Capital intensity and risk
  - Regulatory regimes (technology neutrality)
- Key to extending 5G coverage for anyone anywhere

Next Steps

- Intersperse SME talks with group discussion
- Possible gaps in SME topics
  - Regulations and developments “above RF”
  - Quantum communications, atom-based radios and other breakthroughs
  - Usability and accessibility
  - Spectrum crowding and noise floor (better fit for Spectrum Sharing WG?)
- Deepen some topics
  - e.g., outage recovery
  - emerging IoT standards (DECT 2020, Wi-Fi HaLow, …)
- Group and discuss issues raised by speakers. Do any rise to level of actionable recommendation?

Thank You

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