Federal Communications Commission Technological Advisory Council Meeting

December 19, 2024

FCC Technological Advisory Council Agenda – December 19, 2024

10:00am – 10:15am	Opening Remarks
10:15am – 11:30am	Advanced Spectrum Sharing WG Presentation
11:30am – 12:45pm	AI/ML WG Presentation
12:45pm – 2:00pm	Lunch
2:00pm – 3:15pm	6G WG Presentation
3:15pm – 3:30pm	Closing Remarks
3:30pm	Adjourned

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FCC TAC
Advanced Spectrum Sharing WG
Status Update

Chairs: Andrew Clegg (Wireless Innovation Forum)

Monisha Ghosh (Wireless Institute, Univ. of Notre Dame)

Date: December 19th, 2024

Advanced Spectrum Sharing WG Attendees

Rob	Alderfer	Charter Communications, Inc.
Kumar	Balachandran	Ericsson North America
Mark	Bayliss	Visual Link Internet
Donna	Bethea-Murphy	Viasat
Dean	Brenner	TAC Chair
Michael	Cataletto	Scientel Solutions, LLC
Ranveer	Chandra	Microsoft Corporation
Lynn	Claudy	NAB
Andrew	Clegg	Wireless Innovation Forum
Carlos	Cordeiro	Intel
Brian	Daly	AT&T
Aleksandar	Damnjanovic	Qualcomm Incorporated
Jay	Desai	Amazon
Skyler	Ditchfield	GeoLinks
Adam	Drobot	Stealth Software Technologies, Inc.
Monisha	Ghosh	Wireless Institute, Notre Dame
Iain	Gillott	Wireless Infrastructure Association
Manu	Gosain	Northeastern University
Dick	Green	Liberty Global Corporation
Lisa	Guess	Ericsson
David	Gurney	Motorola Solutions Inc.
Dale	Hatfield	University of Colorado at Boulder
Jason	Jackson	Kyndryl

David	Kaufman	Amazon (Alternate Member)
Michael	Kokkalakis	Sirius XM Radio Inc.
Humberto	La Roche	Cisco Systems, Inc.
Greg	Lapin	ARRL
Mike	Laskowsky	Rural Wireless Association
Jason	Livingood	Comcast
Dan	Mansergh	Apple Inc.
Michael	Marcus	Institute for the Wireless Internet of Things
Brian	Markwalter	Consumer Technology Association
Lynn	Merrill	NTCA - The Rural Broadband Association
Amit	Mukhopadhyay	Nokia
Jack	Nasielski	Qualcomm Incorporated
Bridget	Neville	Sirius XM Radio Inc.
Roger	Nichols	Keysight Technologies, Inc.
Timothy	O'Shea	DeepSig Inc.
Jon	Peha	Metro 21, Smart Cities Institute
Michael	Regan	Telecommunications Industry Association
Tom	Sawanobori	CTIA
Henning	Schulzrinne	SGE (Columbia University)
Ardavan	Tehrani	Samsung
Rikin	Thakker	NCTA - The Internet & Television Association
Michelle	Thompson	Open Research Institute, Inc.
David	Young	ATIS

2024 Presentations to the Advanced Spectrum Sharing WG

- Mike Marcus, Marcus Spectrum Solutions (7/2/24)
  - Title: “Coexistence and Spectrum Sharing Above 100 GHz: Opportunities, Challenges and Solutions”
  - Related charter items: [1, 4, 5, 6, 9, 10]
- David Willis & Steve Leach, Ofcom (7/16/24)
  - Title: “Cellular/Wi-Fi hybrid sharing in upper 6 GHz - UK update”
  - Related charter items: [1, 2, 3, 4, 5, 6, 8, 10]
- Dinesh Bharadia, UCSD (7/25/24)
  - Topic: Impact of network topology on energy efficiency
  - Related charter items: [9]
- Billy Kozma (ITS) and Mark Walker (Cablelabs) (8/27/24)
  - Topic: The role of clutter on propagation loss
  - Related charter items: [1, 2, 3, 6]
- Doug Hyslop, CTIA (10/15/24)
  - 3.7 GHz and radio altimeters
  - Related charter item: [4]

Note: Most of the preliminary recommendations are based upon analysis of opportunities and challenges at bands below mmW and THz. Different technical considerations may apply at these higher bands and will be explored by the SS WG in more detail in the coming months.

Advanced Spectrum Sharing Charter Item 1

- **What will advanced sharing frameworks and architectures look like in the future?**
- Lead: Amit Mukhopadhyay (Nokia)
- Current status: Preliminary recommendations to be presented today

Advanced Spectrum Sharing Charter Item 2

- **How will spectrum sharing models adapt and evolve to meet the growing demand for spectrum access among various services to support multiple purposes? How can the interplay between terrestrial and satellite services be complemented in sharing models to promote more efficient spectrum use?**
- Lead: Amit Mukhopadhyay (Nokia)
- Status: Preliminary recommendations in draft
- Related to charter items: [1, 3, 6, 10]

Advanced Spectrum Sharing Charter Item 3

- **To what extent can the FCC optimize its propagation models to reflect less conservative, more realistic assumptions and support more intensive sharing while still protecting against harmful interference? Are there specific bands where improved propagation models offer a pathway to liberalize performance capabilities beyond what the FCC permits today?**
- Lead: Dave Gurney (Motorola)
- Status: Near-final Recommendations to presented today

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Advanced Spectrum Sharing Charter Item 4

- **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)?**
- Leads: Tom Sawanobori (CTIA), Roger Nichols (Keysight)
- Status: Near-final recommendations to be presented today

Advanced Spectrum Sharing Charter Item 5

- **What is the current state of the art in receiver technology? What state of the art active antenna array and 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 (e.g., beam vs. null steering)? What are the cost benefit tradeoffs on utilizing the current filter technologies or advanced antenna systems? Are there specific bands where improved receiver technologies offer significantly improved coexistence beyond what is permitted today?**
- Leads: Monisha Ghosh (UND) & Dale Hatfield (Silicon Flatirons)
- Status: Discussions with SMEs and relevant projects like DARPA's COFFEE
- Related to charter items: [1, 4, 7, 8]

Advanced Spectrum Sharing Charter Item 6

- **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?**
- Lead: Jason Jackson (Kyndryl)
- Status: Near-final recommendations to be presented today (combined with item 8)

Advanced Spectrum Sharing Charter Item 7

- **What are the sharing mechanisms to consider among various services above 95 GHz, including passive services?**
- Lead: Jason Jackson (Kyndryl)
- Status: Deferred
- Related to charter items: N/A

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Advanced Spectrum Sharing Charter Item 8

- **What role should sensors play in informing spectrum use and in supplementing spectrum sharing databases?**
- Lead: Jason Jackson (Kyndryl)
- Status: Near-final recommendations to be presented today

Advanced Spectrum Sharing Charter Item 9

- **What are the trade-offs between efficient spectrum use and environmental considerations, including sustainability and energy efficiency?**
- Lead: Rob Alderfer (Charter)
- Status: Near-final recommendations to be presented today

Advanced Spectrum Sharing Charter Item 10

- **What methods can support the Commission in identifying spectrum bands that have the most potential and flexibility for sharing and repurposing? What are the candidate bands and which bands should be prioritized? How should those bands be combined or separated for federal and/or non-federal uses? What are the optimal coordination processes between stakeholders to better support implementation and consideration of these methods?**
- Leads: Michael Cataletto (Scientel), Andrew Clegg (WInnForum)
- Status: Document in Draft - Coordinating with the 6.1 / 6.2 team.
- Related to charter items: [1, 2, 3, 4, 6, 7, 9]

Reference:
Related Charter Items

		Future SS frameworks	Evol. of SS models; terrestrial/satellite	Prop models	Spectrum repurposing; inter/intra-band coex	Advanced technologies	Indoor	>95 GHz	Sensors	Energy efficiency	Candidate bands
Future SS frameworks	**1**		X	X		X	X	X	X		X
Evol. of SS models; terrestrial/satellite	**2**	X		X		X	X				X
Prop models	**3**	X	X			X	X				
Spectrum repurposing; inter/intra-band coex	**4**					X	X	X			X
Advanced technologies	**5**	X	X	X	X		X	X	X	X	X
Indoor	**6**	X	X	X	X	X		X			X
>95 GHz	**7**	X			X	X	X			X	X
Sensors	**8**	X				X					
Energy efficiency	**9**					X		X			X
Candidate bands	**10**	X	X		X	X	X	X		X	

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Advanced Spectrum Sharing WG – Charter Item 1

Future Advanced Spectrum Sharing Frameworks

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Introduction

Key question:

What will advanced sharing frameworks and architectures look like in the future?

Background:

As digitalization increases in society, the demand for spectrum for various wireless services keeps going up. Users of exclusively licensed, licensed-shared and unlicensed spectrum are all seeking more spectrum for their unique applications. Similarly, both terrestrial and satellite-based service providers are seeking more spectrum. However, the spectrum bands in desired frequency ranges are already occupied by various users (both federal and commercial) and many of these incumbents are also seeking additional spectrum to evolve their services. As a nation, we have reached a situation where sharing of spectrum among various users/services has become almost inevitable.

Recent advancements in technology, especially in the field of AI/ML, are expected to make spectrum sharing increasingly attractive to all interested parties.

Setting the stage

Definition - What is spectrum sharing?

Many interpretations exist today, e.g., use of unlicensed spectrum, intra-operator inter-technology or inter-operator sharing as defined in 3GPP, National Spectrum Strategy R&D Plan definition of "dynamic spectrum sharing" etc.

In this document, we use the NIST definition: "spectrum sharing as a way of optimizing the use of airwaves or wireless communications channels by enabling multiple categories of users to safely share the same frequency bands".

Scope

The discussions focus primarily on inter-system spectrum sharing and not intra-system spectrum sharing. The critical topic covered in this document is spectrum sharing among different types of users, e.g., commercial terrestrial service providers (both licensed and unlicensed), satellite or Non-Terrestrial Networks (NTNs) for communication services, federal radars, tactical networks, space research, earth exploration etc.

Furthermore, the main discussions in this document will be related to spectrum sharing in frequency range 4-24 GHz. This part of the spectrum is most desirable for many services that are the focus of policy at this time and is thus allocated to numerous services by the FCC.

Essential criteria for successful spectrum sharing

- Service assurance: A primary concern about spectrum sharing is availability of the vital resource when service is needed. The level of concern may be a bit different among different new entrants.

- Infrastructure re-use: It is important for users (federal or commercial) of spectrum to be able to reuse their existing site infrastructure , else spectrum use becomes more expensive

- Maximum use of spectrum: It is highly desirable that new entrants can use the spectrum anytime incumbents are not using it

- Joint responsibility: Just like new entrants, it is important also for incumbents to evolve their functional capabilities

Candidate frameworks for spectrum sharing

Established ones

- Contention based: Technologies used in unlicensed spectrum bands
- Enhanced coordination system based: Evolution of SAS/AFC approach with shortened timescale
- Federal-Federal, Commercial-Commercial, or Federal-Commercial sharing: Current large-scale federal-commercial and commercial-commercial frameworks, CBRS and 6 GHz AFC, are generally successfully implemented from a technical perspective, but any sharing system has to consider the long-term viability from a commercial perspective.

Future possibilities

- Inter-system signaling based: This framework would involve transmission of a well-defined signal that contains information about spectrum usage in time, frequency and spatial domain
- Indoor-outdoor based: This framework employs an indoor and outdoor spectrum sharing strategy to achieve inter-system spectrum sharing
- Interference (threshold crossing) reporting based: This framework explores the tenets of "closed-loop" systems
- Transmitter identity-based sharing: A framework where sources of interference can be identified directly or indirectly from their transmissions

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Emerging technologies for spectrum sharing

- Propagation models: Propagation models are continuing to improve, driven by the ability to better tailor them to real world propagation effects, localized conditions, and measured observations of propagation data. These are progressing from model-driven statistical techniques, to much more data-driven entities which may utilize geometric and AI/ML driven approaches.
- Digital Twins: Radio Access Network (RAN) Digital Twin (DT) is emerging as one possible avenue to model physical world properties surrounding the RAN, such as propagation, antenna properties, power control, surrounding geometry and material properties, sensing of adjacent emitters, beam steering, scheduling, frequency allocation, etc.
- Spectrum sensing capabilities: AI/ML based methods such as the use of convolutional neural networks for signal detection, classification, and localization, have improved the sensitivity, energy efficiency, and accuracy which can be achieved in RF sensing
- Spatial Processing: Improved spatial re-use via spatial processing has become much more widely used and adopted within wireless systems in the past decade.
- KPI feedback: Future spectrum sharing systems to consider arrangements which take into account fine-grained spectrum access limitations in the context of their impact to adjacent user or adjacent network KPI impact in an automated “closed loop” type system.

Near-Final Conclusions

- “Techno-economics”: The essential criteria for successful spectrum sharing have a common theme around economic impact. The sharing conditions need to be such that the users of the shared spectrum can deliver their services in a cost-effective manner. Furthermore, the sharing solutions themselves must be economically viable to build and operate, else even the most effective sharing solution may not get implemented in practice. Thus, the over-all economic impact of any sharing solution needs to be carefully evaluated.
- “Closed loop” systems: All current frameworks are essentially “open-loop” – there are no feedback mechanisms among different users (who may be considered victims or aggressors, depending upon the circumstances). This typically results in overly conservative protection criteria which ultimately means inefficient use of spectrum. A “closed-loop” framework, on the other hand, can create an environment where users exchange real-life interference information and mutually collaborate to protect each other while maximizing spectrum use.

Near-Final Recommendations

- For a specific spectrum range under study, establish a multistakeholder group comprising relevant academic, federal and commercial representatives (e.g., NSF, CSMAC, CTIA, NCTA etc.) for reaching consensus on key technical requirements for all users. If this information is too sensitive, arrange for a relatively small group of experts to have the right level of security clearance.
- Get engaged with Standard Development Organizations (SDOs) and key proprietary solution owners in the commercial industry and encourage suppliers of federal equipment to also participate in development of solutions that will require coordination among commercial entities and federal systems with a view to not only technical but also economic viability.
- In cases where sharing among commercial entities is envisioned (e.g., sharing among multiple operators with common radios or sharing between licensed 3GPP and Wi-Fi or proprietary users), play an active role in bringing together appropriate SDO's.
- Continue the practice of spectrum related rulemaking that is technology agnostic, while ensuring all potential users of the shared spectrum evolve their technologies and are guided by a common set of rules to enable most efficient use of spectrum. The Commission should continue to avoid regulating CBRS GAA users beyond what is already done.

Advanced Spectrum Sharing WG – Charter Item 3

Improved Propagation Models

Propagation Modeling Enhancements for Improved Sharing

- Discussion of several popular/applied propagation models (e.g., ITU Irregular Terrain Model, Hata, Okumura, Egli/TM91-1, WINNER, R-6602 F-curves, FSPL, etc.)
  - All models generally have limitations, in terms of frequency ranges, detailed terrain/clutter modeling, etc.
  - Delicate balance between making more spectrum available and protecting incumbent services…
    - Suggest interference impact risk-informed analysis (depending on grade of incumbent services)
  - Some popular models (e.g., ITU ITM) could benefit from the incorporation of clutter modeling
  - Several improvements are possible (and in some cases, being implemented):
    - Recent advances in SAS propagation modeling in the 3.55 GHz band (e.g., CBRS 2.0: incorporating P.2108 clutter models for low antenna ht. base stations, transmit duty cycles, system loading factors, median propagation/reliability modes for all base stations)
  - Importance of measurement campaigns to improve/verify/validate models…
    - Examples include NTIA ITS measurement campaign, NASCTN efforts
    - Sensing measurement campaigns (e.g., AARL, crowd-sourced data, etc.)
    - Potential to integrate feedback mechanisms into models to refine estimates (for future study)

Bands that Improved Propagation Modeling could be Applied

- Generally focused on existing and potential future spectrum sharing bands (3.55 GHz, 6 GHz, 3.1-3.45 GHz, 7/8 GHz)
- Some improvements already underway (CBRS 2.0, BEL in 6 GHz band, etc.)
- Future refinements are possible in some bands (e.g., P.452 clutter modeling, etc.)
- Higher frequency bands are also being looked at (e.g., 10-100 GHz)
- The group has not yet taken a final position on this question…

Propagation Modeling Improvements

- Preliminary Recommendations for the FCC:
  - We encourage the Commission to continue to refine the effectiveness of propagation modeling used in the estimation of signal levels and harmful interference levels in spectrum sharing bands, by incorporating more realistic and advanced propagation modeling techniques (discussed above, and in the report).
  - We encourage the Commission to continue to incorporate appropriate clutter modeling techniques, including the appropriate risk assessments, to increase the accuracy of propagation modeling used for evaluating the coexistence of different services in spectrum sharing bands.
  - We encourage the Commission and all parties involved to continue to prove-out the reliability of propagation modeling through real-world measurement campaigns and related studies.

Advanced Spectrum Sharing WG – Charter Item 4

Spectrum Repurposing

Spectrum Repurposing

- We closely examined two recent repurposing efforts (C-band and 6 GHz) to identify opportunities for refining the process in the future

Spectrum Repurposing and Identification of Inter/Intra-band issues in C-band

- #1 - C band clearing of 280 MHz from 3.7-3.98 GHz
  - High priority effort to repack broadcast satellite users into more efficient use of 500 MHz
  - Lessons learned
    - Altimeter performance should have been tested earlier along with new filters
    - RTCA aviation standards groups could have specified better filters, allowing increased resilience to 5G receiver blocking and spurious emissions
    - Multi-stakeholder groups between the wireless industry and the FSS community worked well
    - Financial incentives were used to help with transition costs
  - Additional opportunities in the Upper C band
    - Currently used by satellite broadcast
    - SES plans to acquire Intelsat, potentially freeing up 100+ MHz of additional Upper C band[1]

Lower C Band	Upper C Band	Altimeter Band
3.7-3.98 GHz	3.98 – 4.2 GHz	4.2 – 4.4 GHz

- Japan's MIC has already approved the use of spectrum up to 4.1 GHz[2]
- Also UK revised guidance to enable easier access to medium/low power in 3.8 – 4.2 GHz band

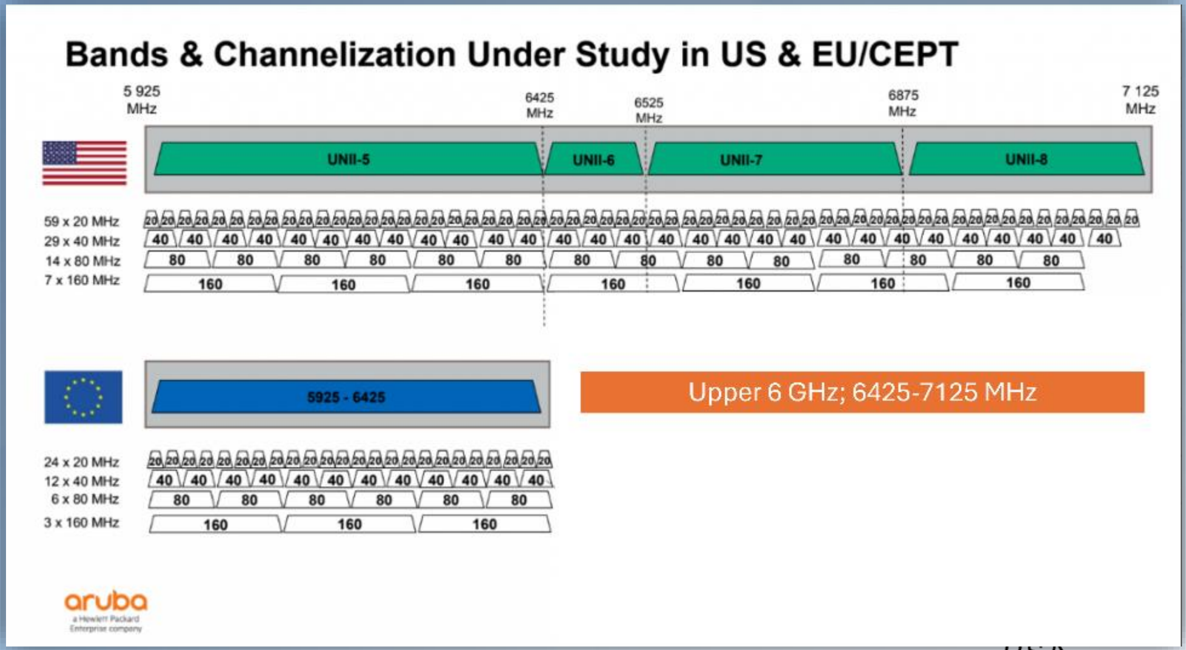
1 https://www.lightreading.com/5g/ses-intelsat-merger-might-free-up-more-c-band-for-5g

2 https://www.icao.int/MID/Documents/2023/WRC-23%20and%20FSMP-SG17/FSMP-WG17-WRC23Wrkshp42_Radar%20Altimeter%20and%205G%20status-Japan.pdf

Spectrum Repurposing and Identification of Inter/Intra-band issues in 6 GHz

- #2 - Allocation of 6 GHz spectrum for unlicensed use for Standard power applications
  - FCC decision to allocate 1200 MHz of spectrum
  - Automated Frequency Coordination (AFC) systems to coordinate with fixed microwave and broadcast auxiliary
    - Extensive interference analysis can help predict interference
  - Collaboration
    - Spectrum sharing groups leveraged work in the Win Forum and CBRS lessons to develop AFC requirements
    - Subsequently the FCC authorized the use of several AFCs for coordination
- #3 - UK and Europe evaluating sharing between Wi-Fi and licensed spectrum in upper 6 GHz
  - Two options being evaluated
    - Indoor/outdoor split
    - Variable spectrum split
  - UK "Spectrum Sandboxes" to evaluate technical analysis and economic evaluation
  - CEPT also evaluating with report targeted for July 2025

Separately, Hong Kong auctioned 300 MHz of 6 GHz for IMT $81M



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Spectrum Repurposing and Identification of Inter/Intra-band issues

- Preliminary Recommendations for the FCC
  - 1) FCC should consider lessons from C band repurposing
  - 2) FCC should evaluate the opportunity to free up the Upper C band up to at least 4.1 GHz
    - Work with the FAA and aviation to promote better altimeter performance and improved filters
    - Evaluate the impact of further repacking of satellite services
    - Evaluate the economic, competitive, and technical considerations for various licensing schemes
  - 3) FCC should consider additional opportunities for spectrum sharing using geographical and database solutions such as the AFC, where appropriate
  - 4) FCC should monitor the progress of Ofcom and CEPT evaluations of hybrid sharing between Wi-Fi and unlicensed spectrum and consider implications for sharing in the U.S.

Advanced Spectrum Sharing WG – Charter Item 6/8

Low-Power Coexistence; Sensors

Candidate bands for Contained usage and sharing mechanisms

Shift focus from indoor vs. outdoor spectrum use to containment

Key FCC questions addressed:

- Candidate bands for low-power, indoor-only operations*
- Sharing mechanisms for coexistence

Recommendations include:

- Identified candidate bands for contained use
- Technological solution recommendations for containment
- Enhancing measurement/reporting capabilities
- Addressing enforcement challenges

- 7, 8 GHz
- 11, 12, 18 GHz
- 37 – 37.6 GHz
- 100+ GHz (walls/roofs have very high attenuation; also high atmospheric attenuation near some frequencies)

* M. Calabrese and J. Dine, Open Technology Institute, "The Next Frontier in Spectrum Policy: Indoor-Only Sharing of Federal Bands," \https://d1y8sb8igg2f8e.cloudfront.net/documents/The_Next_Frontier_in_Spectrum_Policy_2024-11-25_141303_RP4Nq3g.pdf

Candidate bands for Contained usage and sharing mechanisms

Preliminary Recommendations

#1 Adopt a containment-centric spectrum management approach

- Isolated Environments: In a remote mining operation, wireless communication systems could operate at higher power with reduced risk of interference because the physical isolation acts as a natural containment measure
- Urban Settings: A smart factory in a metropolitan area could use RF shielding to ensure that its internal communications don't interfere with outdoor systems like cellular towers. Using proper containment, the factory's low-power IoT systems could share spectrum with surrounding networks without interference

#2 Define 'Contained Environments' and set measurable standards

#3 Encourage industry collaboration to standardize practices

- Automated Frequency Coordination: A warehouse automation system could communicate with the SAS to identify the best available frequencies for its operations, ensuring safe co-existence with nearby outdoor networks.

#4 Leverage technologies like Dynamic Spectrum Access (DSA) and RF shielding

- Dynamic Spectrum Access: A smart factory could use DSA to automatically adjust its communication systems based on real-time spectrum availability. If a frequency band becomes crowded, the factory's systems could switch to a less-congested band, ensuring efficient spectrum use.

#5 Enhance regulatory frameworks for enforcement and compliance

Advanced Spectrum Sharing WG – Charter Item 9

Efficiency/Sustainability

Small cell, low power networks deliver wireless data in an energy-efficient manner (UCSD)

Key Conclusions from SME Input (UCSD[1])

- Wireless signal dispersion creates losses that manifest as energy consumption in base stations and user devices to overcome propagation losses
- Minimizing losses by reducing transmission distance (as in small cell architectures) can enhance energy efficiency of mobile networks and extending battery life of UEs (phones)
- Localized traffic demand growth complements the opportunity to drive greater energy efficiency into mobile networks
- Deployment optimized for targeted local capacity demands is ~3X more efficient than uniform deployment
  - Normalized for coverage: 30 small cells consume ~1/3 of the power for the same coverage as a macro site[1]
- Modernizing existing network deployments is critical to reduce energy consumption
  - Small cell architectures that support lower power levels are compatible with incumbent systems in order to enable sharing
- Conclusions similarly apply to Wi-Fi as more efficient than macro mobile sites to serve traffic
  - Local networks serving local traffic are most efficient

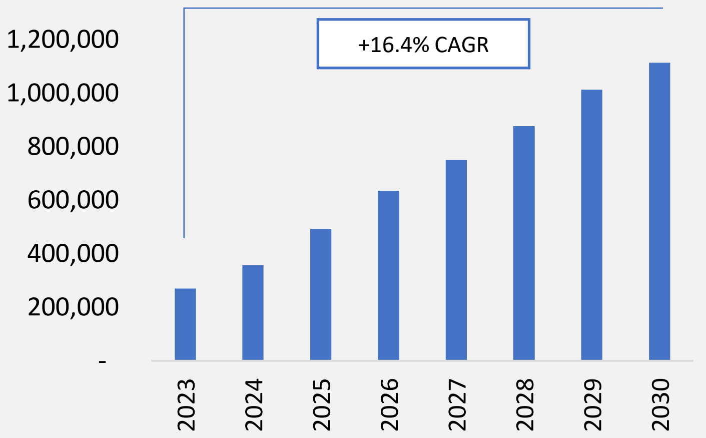
1. Gupta, Heidari, Jin, Bharadia (UCSD) “Densify & Conquer: Densified, smaller base-stations can conquer the increasing carbon footprint problem in nextG wireless”, March 2024. Found at: https://arxiv.org/html/2403.13611v1

Small cell networks are expanding

- Increases in data usage growth driving mobile capacity needs
- Small cell deployment increasing
  - In the US, outdoor small cells are expected to grow at a CAGR of 16.4%, from 497,420 at the end of 2023 to 3.1 million by 2034[2]
- Shared spectrum deployment increasing
  - Radios operate at lower power levels while augmenting local capacity
  - Additional power usage from spectrum access systems and related database energy demand requires further study

Figure 1. US small cells deployed (2023-2030)

S&P Kagan projections. Includes DAS

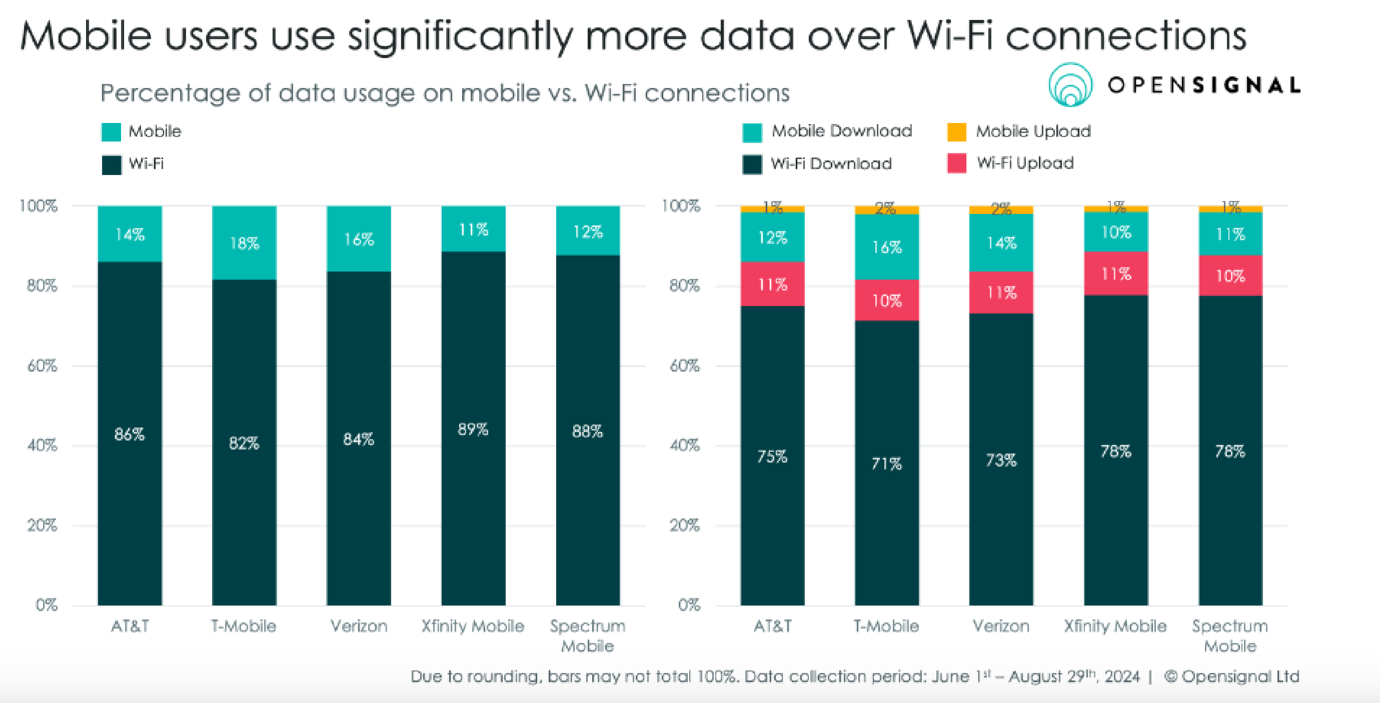


1. S&P Kagan. North America small cell projections through 2032 (subscription required)

Preponderance of indoor traffic is an opportunity for energy-efficient delivery

- Demand growth is happening in concentrated locations – homes and offices[1]
- 80%+ of mobile-originated traffic transits Wi-Fi[2]
  - Can be served by low-power Wi-Fi networks
- Reduced Wi-Fi energy consumption adds efficiency benefits [2]
  - Wi-Fi 6 reduces both energy consumption of access points and client devices by up to 51% compared to WiFi 5
  - Achieved through innovations such as dedicated beamformed radio signals and target wake time (TWT)

Open Signal measurement data, October 2024



1. See, e.g., Nokia: 90% of time spent indoors, 80% of mobile traffic originates indoors (https://www.nokia.com/networks/mobile-networks/small-cells/)
2. Open Signal, "Wi-Fi drives smartphone data consumption in the US, but trends vary across operators", October 31, 2024. Found at: https://www.opensignal.com/2024/10/31/wi-fi-drives-smartphone-data-consumption-in-the-us-but-trends-vary-across-operators
3. Wi-Fi Alliance, "Sustainability Benefits of 6 GHz Spectrum Policy", September 2023. Found at: https://www.wi-fi.org/system/files/SustainabilityBenefitsof6GHzSpectrumPolicy202307.pdf

Traffic usage trends – including dominance of video – complement efficiency trends and opportunities

Capacity Demands

- Streaming video leading usage increases
  - Highest proportion of video traffic volumes transiting fixed vs. mobile[1]

Top Apps in Category by App User Volume – Fixed (Table 9)

App Category and App	% of Users	User Volume
Video		
YouTube	35%	2.5 GB
Netflix	30%	4.2 GB
Amazon Prime	26%	2.6 GB
Disney+	21%	2.4 GB
Hulu	6%	3.1 GB

7X traffic on wireline via Wi-FI

Top Apps in Category by App User Volume – Mobile (Table 10)

App Category and App	% of Users	User Volume
Video		
YouTube	23%	334 MB
Netflix	5%	1.1 GB
Disney+	3%	565 MB
XVIDEOS	6%	148 MB
Amazon Prime	2%	1.3 GB

Source: Sandvine Internet Phenomena Report

1. Sandvine, "2024 Global Internet Phenomena Report", April 2024. Found at: https://www.sandvine.com/blog/sandvines-2024-global-internet-phenomena-report-global-internet-usage-continues-to-grow

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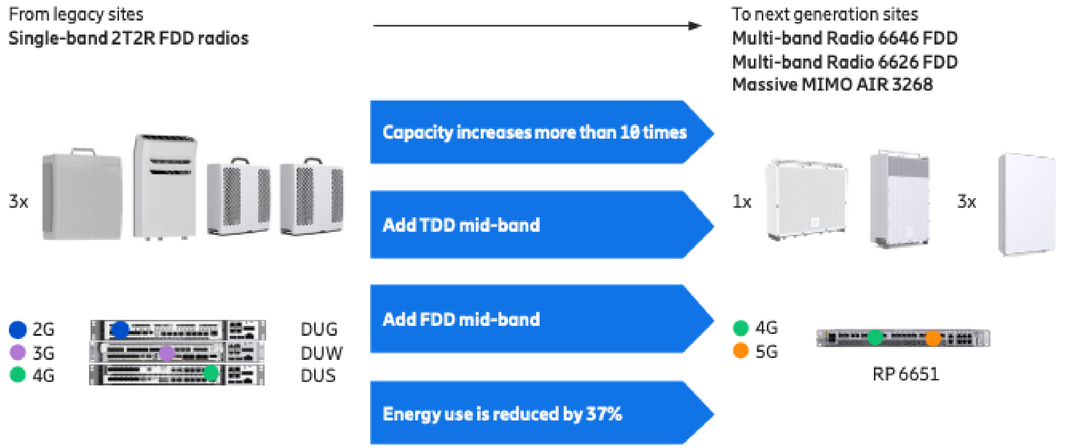
5G deployment, related network equipment modernization offer additional sustainability and energy efficiency opportunities

- The RAN with its active and passive equipment represents more than 75% of the service provider's network energy consumption[1]
- 5G and addition of new spectrum bands requires more equipment and energy consumption, all things equal
- But: Carrier Aggregation expands mid-band coverage with the help of low band. By moving data to a more energy-efficient 5G band where service providers often have a 100 MHz carrier, the energy per transferred bit can be reduced by a factor of 10 while improving user experience.

Figure 6: Site expansion and modernization – adding 5G mid-band and FDD spectrum



Capacity	1
Energy consumption (kWh)	100%
Output power per sector	400W
Spectrum [MHz]	800, 900, 1800, 2100

Capacity	>10x
Energy consumption (kWh)	63%
Output power per sector	680W
Spectrum [MHz]	700, 800, 900, 1800, 2100, 3500

via Ericsson

1. Ericsson, "On the road to breaking the energy curve", October 2022. Found at: https://www.ericsson.com/4aa14d/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2022/breaking-the-energy-curve-report.pdf

Continued progress in energy efficiency of wireless equipment

- Growth in traffic and broadband speeds has come without linear growth in power consumption[1]

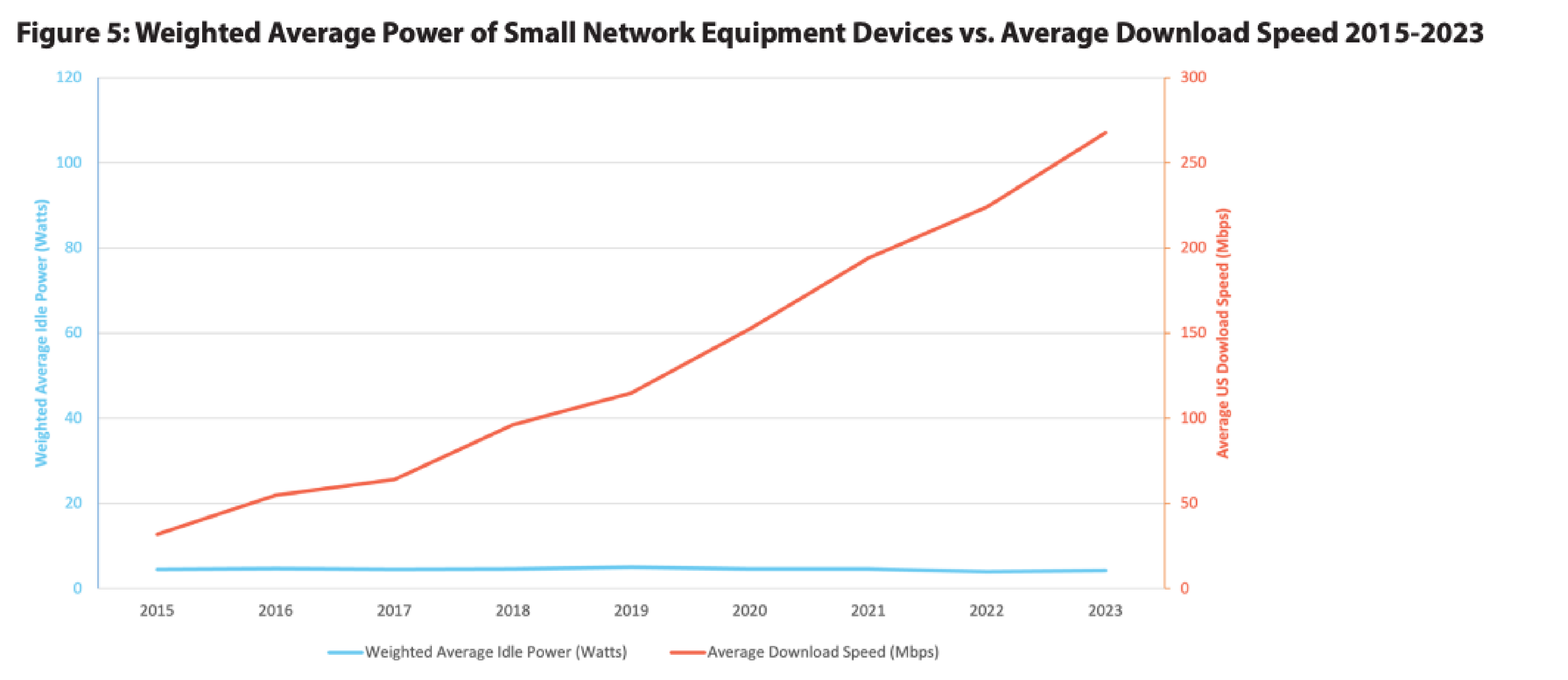


Table 2: Weighted Average Power Consumption for Small Network Equipment Categories 2015-2023

SNE Category	Average Weighted Power (in Watts)								
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Broadband Modem	6.67	7.11	8.12	9.36	9.65	9.43	9.76	9.21	9.41
Integrated Access Device	13.30	13.53	13.65	13.73	14.49	13.87	13.51	14.40	14.68
Local Network Equipment	6.44	5.62	5.28	6.79	7.64	7.21	7.55	6.36	7.31
Total Weighted Average	11.36	11.79	11.26	11.55	12.59	11.49	11.49	10.09	10.62

1. US Small Network Equipment Energy Efficiency Voluntary Agreement, Annual Report, September 2023.

Additional research

Inputs for future research to inform WG recommendations:

- Data exists to inform future research work that could further support TAC recommendations to FCC on spectrum energy efficiency
- Automation and AI applications have increased the energy efficiency of wireless networks in Europe
- Inputs from TAC member companies could help to complete the picture, including:
  - **Operator / OEM data**
    - Macro site power usage (radios and BBU)
    - Small cell radio power usage
    - Infra sharing and energy implications (different flavors of this, lessons learned from other countries)
      - Neutral host, Multi-Operator Core Networking (MOCN)
    - O-RAN opportunities (shared radio unit)
  - **SAS / AFC data**
    - Spectrum access system and related database power usage

TAC Advanced Spectrum Sharing WG Status

Thank you

FCC Technological Advisory Council Agenda – December 19, 2024

10:00am – 10:15am	Opening Remarks
10:15am – 11:30am	Advanced Spectrum Sharing WG Presentation
11:30am – 12:45pm	AI/ML WG Presentation
12:45pm – 2:00pm	Lunch
2:00pm – 3:15pm	6G WG Presentation
3:15pm – 3:30pm	Closing Remarks
3:30pm	Adjourned

FCC TAC Artificial Intelligence and Machine Learning Working Group - AIWG

AIWG WG Chairs: Lisa Guess, Ericsson
Adam Drobot, Stealth Software Technologies, Inc.

AIWG SWG Chairs: Ardavan Tehrani, Samsung
(Softwarization) Richard Kessler*

FCC Liaisons: Bahaman Badipour**,** Chrysanthos Chrysanthou, Rajat Mathur, Patrick Sun, Martin Doczkat – DFO, and Sean Yun – Alternate DFO

FCC Observers: Robert Acacio, Damian Ariza, Etemad, Kamran, Jonathan Lu, Mathew Miller, Joseph Prebble, and Aniqa Tahsin

Date: December 19th, 2024

Outline For Presentation

1. Artificial Intelligence and Machine Working Group (AIWG) Membership
2. Artificial Intelligence and Machine Learning Working Group (AIWG) Charter
3. AI/ML: Impacts on the Future of ICT and the FCC's Critical Role

    - Relating the Impacts to the FCC TAC AIWG Charter

        - Foundational Technical Issues: Cutting through the hype
        - Presaging rapid changes in the Network: Preparing the FCC for what's coming

    - The FCC's Strategic Goals: Navigating a changing landscape

4. A Summary of Progress on AIWG Charter Items
5. A Priority: The Transformation of the Network (Digitization, Softwarization, and AI)
6. White Paper Outlines for 2025

A. Appendices

Artificial Intelligence and Machine Learning Working Group Members

Name	Organization	Name	Organization
Bayliss, Mark	Visual Link Internet	Livingood, Jason	Comcast
Brenner, Dean (1)	SGE	Markwalter, Brian	Consumer Technology Association (CTA)
Clegg, Andrew (2)	Wireless Innovation Forum	Merrill, Lynn	NTCA
Daly, Brian K. (3)	AT&T	Mukhopadhyay, Amit	Nokia
Drobot, Adam T. (4)	Stealth Software Technologies	Nasielski, Jack	Qualcomm
Ghosh, Monisha (2)	University of Notre Dame	Nelson, Eric	NTIA Office of Spectrum Management
Gosain, Abhimanyu (3)	Northeastern University	O'Shea, Tim	Deepsig.Ai
Guess, Lisa (4)	Ericsson	Pankajakshan, Bejoy	Mavenir
Gupta, Sachin	NRECA	Peha, Jon M.	Carnegie Mellon University
Hatfield, Dale H.	University of Colorado	Raghothaman, Balaji	Keysight
Kessler, Richard (5)	Marvell	Sirbu, Marvin	SGE
Lan, Tian	SGE	Tehrani, Ardavan M.	Samsung
Lapin, Gregory	ARRL		

(1) TAC Chair, (2) SSWG Chairs (3) 6GWG Chairs (4) AIWG Chairs (5) Represented Marvell before 16 Oct 2024.

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Softwarization Sub-Working Group - Members

Name	Organization	Name	Organization
Ahmed, Shahid	NTT	Lan, Tian	SGE
Bayliss, Mark	Visual Link Internet	Markwalter, Brian	Consumer Technology Association (CTA)
Clegg, Andrew	Wireless Innovation Forum	Merrill, Lynn	NTCA
Daly, Brian	AT&T	Mukhopadhyay, Amit	Nokia
Dohler, Mischa	Ericsson	Nasielski, Jack	Qualcomm
Drobot, Adam	Stealth Software Technologies	Nelson, Eric	NTIA
Ghosh, Monisha	Notre Dame University	O'Shea, Tim	Deepsig.Ai
Gosain, Abhimanyu	Northeastern University	Raghothaman, Balaji	Keysight
Gupta, Sachin	NRECA	Regan, Michael	Comcast
Hatfield, Dale	University of Colorado	Sirbu, Marvin	SGE
Kessler, Richard (1,2)	Marvell	Tehrani, Ardavan (1)	Samsung
(1) Softwarization SWG Chairs (2) Represented Marvell before 16 Oct 2024.			

Artificial Intelligence and Machine Learning Working Group FCC Liaisons and Observers

Name	Organization	Name	Organization
Acacio, Robert	EMCD - Observer	Miller, Matthew	PRD - Observer
Ariza, Damian	PRD - Observer	Prebble, Joseph	PRD - Observer
Badipour, Bahman	PRD - Liaison	Repasi, Ron (1)	OET
Chrysanthou, Chrys	EMCD - Liaison	Sun, Patrick	OEA - Liaison
Etemad, Kamran	WTB – Observer	Tahsin, Aniqa	PRD - Observer
Keltz, Ira	OET – Acting Chief Engineer		
Lu, Jonathan	EMCD - Observer		
Mathur, Rajat	EMCD - Liaison		
Doczkat, Martin	FCC EMCD – FCC DFO		
Yun, Sean	FCC EMCD – FCC ADFO		
(1) Retired from FCC			

AIWG Charter

For 2024 there are ten items in the Artificial Intelligence, Machine Learning, Working Group (AIWG) Charter.

Bucket 1: AI and ML for Spectrum Sharing and Management

1.1 Explore the use of AI/ML methods to improve the utilization and administration of spectrum (licensed, unlicensed, and shared) based on the fundamental characteristics of propagation, interference, signal processing, and protocols. How could the scalability aspect of AI/ML algorithms support such methods by use of techniques such as parallelization, dimensionality reduction, sampling, and approximation?

1.2 How can AI/ML be leveraged to help better understand real-time spectrum usage, either at the front end (e.g., improved sensing) or the back end (e.g., improved analytics)?

AIWG Charter

For 2024 there are ten items in the Artificial Intelligence, Machine Learning, Working Group (AIWG) Charter (continued)

Bucket 2: Network Safety, Security, Assurance, and Performance

2.1 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 softwareized.

2.2 Explore and evaluate AI-enabled networks in optimizing long convergence time, memory complexity, and complex behavior of machine learning algorithms under uncertainty as well as how the highly dynamic channel, traffic, and mobility conditions of the network contribute to the challenges of AI networks.

2.3 How can AI/ML techniques be used to address the challenges of data quality, availability, privacy, and security in wired and wireless networks, such as data cleansing, data fusion, data anonymization, and data protection?

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AIWG Charter

For 2024 there are ten items in the Artificial Intelligence, Machine Learning, Working Group (AIWG) Charter (continued)

Bucket 3: Testing Regimes for AI/ML in Telecommunications

3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

AIWG Charter

For 2024 there are ten items in the Artificial Intelligence, Machine Learning, Working Group (AIWG) Charter (continued)

Bucket 4: Softwarization of Telecommunications

4.1 What are opportunities, for the Commission, to use AI/ML to improve its analysis of data presently collected and housed in databases like ULS?

4.2 What are the implications and complications of using AI/ML in optimizing wireless and wired networks performance by analyzing network traffic patterns, network failures, proactive corrective actions, network routing, and predicting network congestion?

AIWG Charter

For 2024 there are ten items in the Artificial Intelligence, Machine Learning, Working Group (AIWG) Charter (continued)

Bucket 4: Softwarization of Telecommunications

4.3 How can AI/ML techniques be used to support the integration and interoperability of wired and wireless networks, such as heterogeneous access networks, multi-domain networks, and adaptive network slicing?

4.4 How can AI/ML techniques be used to design and implement novel network architectures and protocols for wired and wireless networks, such as software-defined networking (SDN), network function virtualization (NFV), and information-centric networking (ICN)?

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AIWG Charter - Organization for 2024

The AIWG has taken the ten items in the Charter and organized them as four Buckets.

Subject	Area Covered	Responsibility
Bucket 1	**AI and ML for Spectrum Sharing and Management** 1.1 – 1.2	AI/ML Working Group **Functionality and Performance**
Bucket 2	**Network Safety, Security, Assurance, and Performance** 2.1 – 2.3	AI/ML Working Group **Functionality and Performance**
Bucket 3	**Testing Regimes for AI/ML in Telecommunications** 3.1	AI/ML Sub-Working Group **Softwarization**
Bucket 4	**Softwarization of Telecommunications** 4.1 – 4.4	AI/ML Sub-Working Group **Softwarization**

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AI/ML: Impacts on the Future of ICT and the FCC's Critical Role

3. AI/ML: Impacts on the Future of ICT and the FCC's Critical Role

- Relating the Impacts to the FCC TAC AIWG Charter

  - ➢ Rapid Technical Progress in AI/ML: Cutting through the hype – what's real and what needs to be fixed?

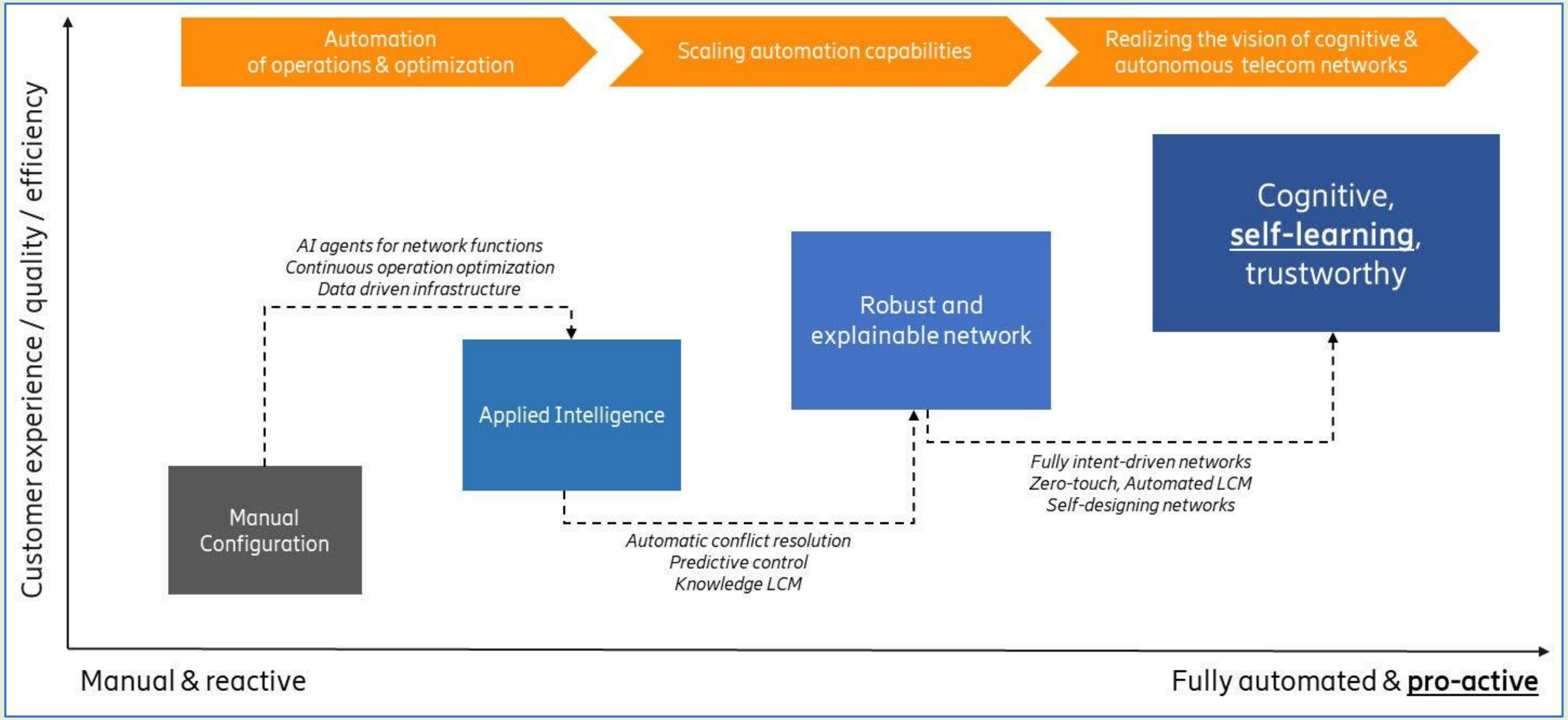
  - ➢ Presaging rapid changes in the Network: Preparing the FCC for what's coming

- The FCC's Strategic Goals: Navigating a changing landscape (Appendix A.2)

  - Broadband Availability and Coverage
  - Technical Leadership
  - Competitiveness
  - National Security
  - Operational Excellence

AI/ML: Impacts on the Future of ICT and the FCC's Critical Role

3. AI/ML: Impacts on the Future of ICT and the FCC's Critical Role



The AI/ML Journey for the Network – progression to Zero Touch (Courtesy Mischa Dohler)

AI/ML: Impacts on the Future of ICT and the FCC's Critical Role

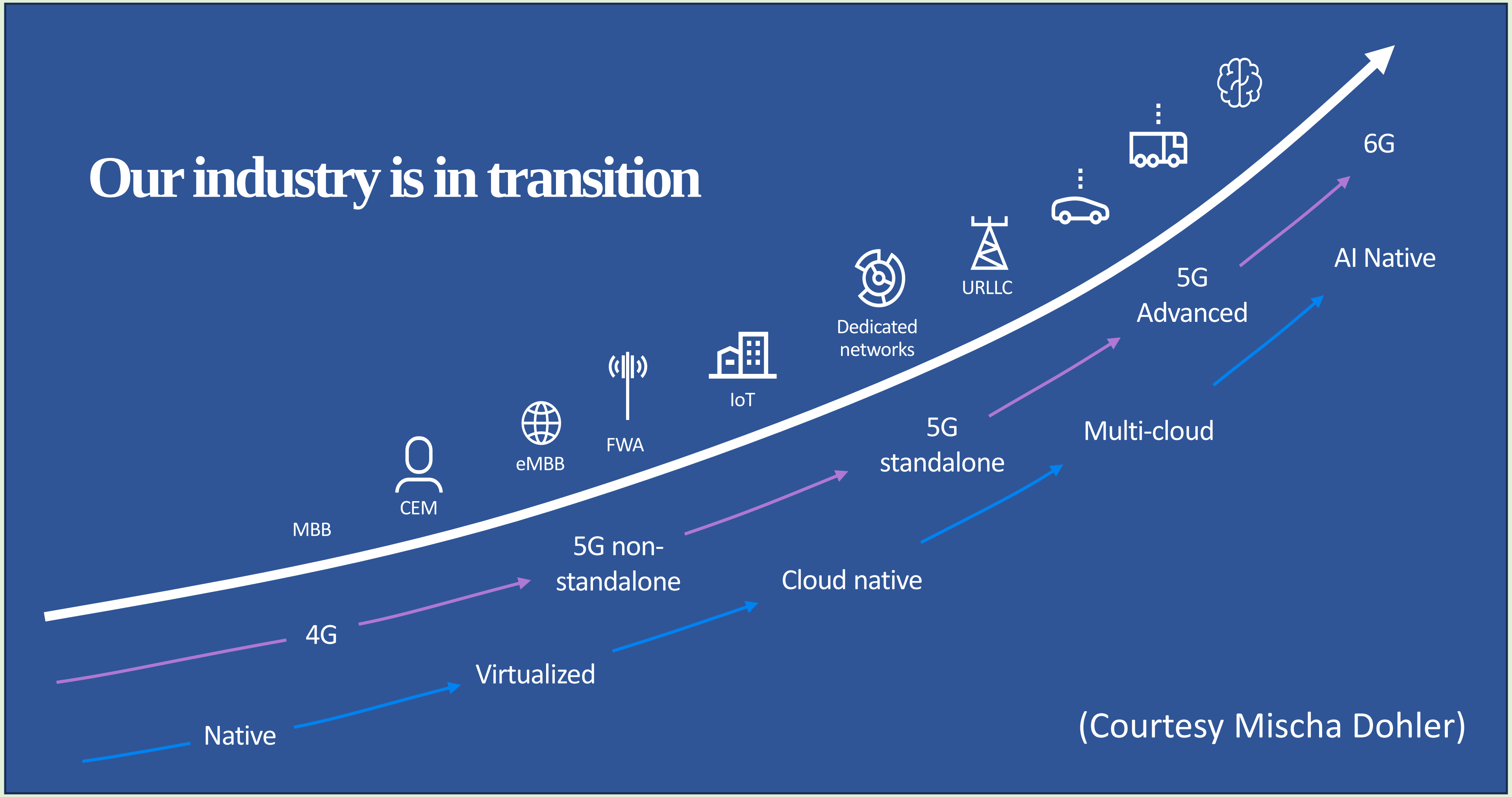
3. AI/ML: Impacts on the Future of ICT and the FCC's Critical Role

Where and when should AI/ML be used and where can it be trusted?

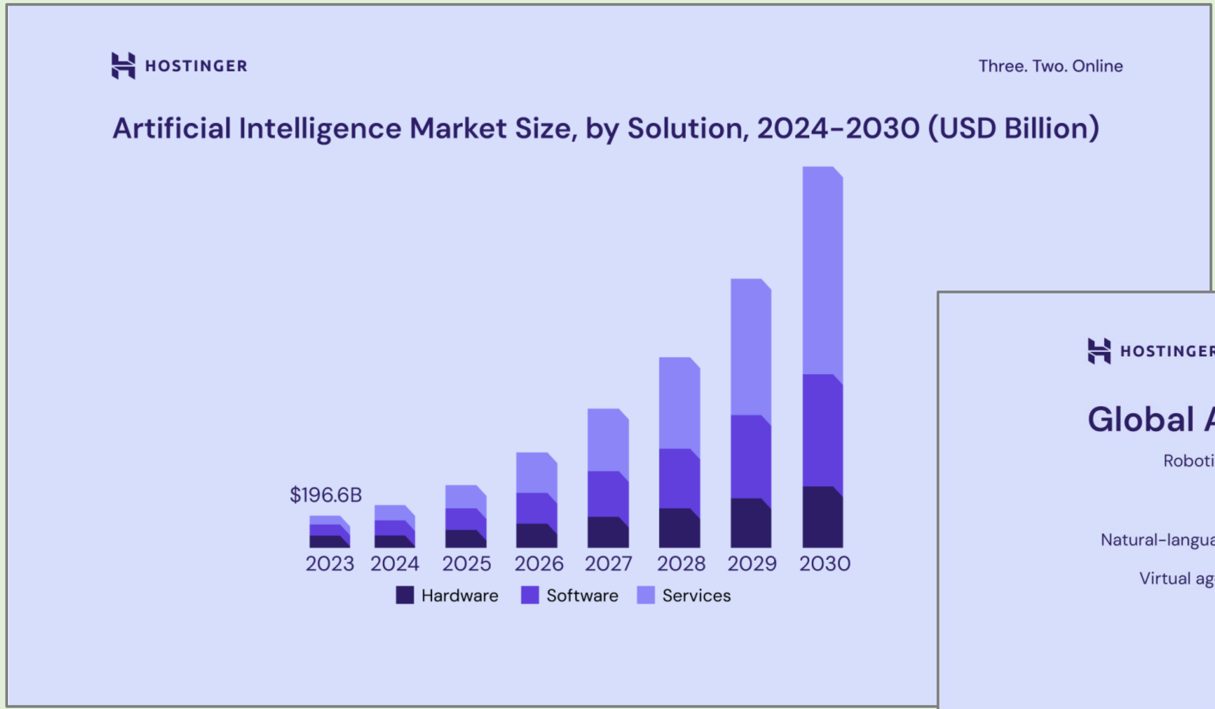
"Organizations can take an ethics-driven approach to building AI trust by deciding not just what they ***can*** build with AI, but what they ***should*** build. A strong governance model defines core principles and puts them into practice."

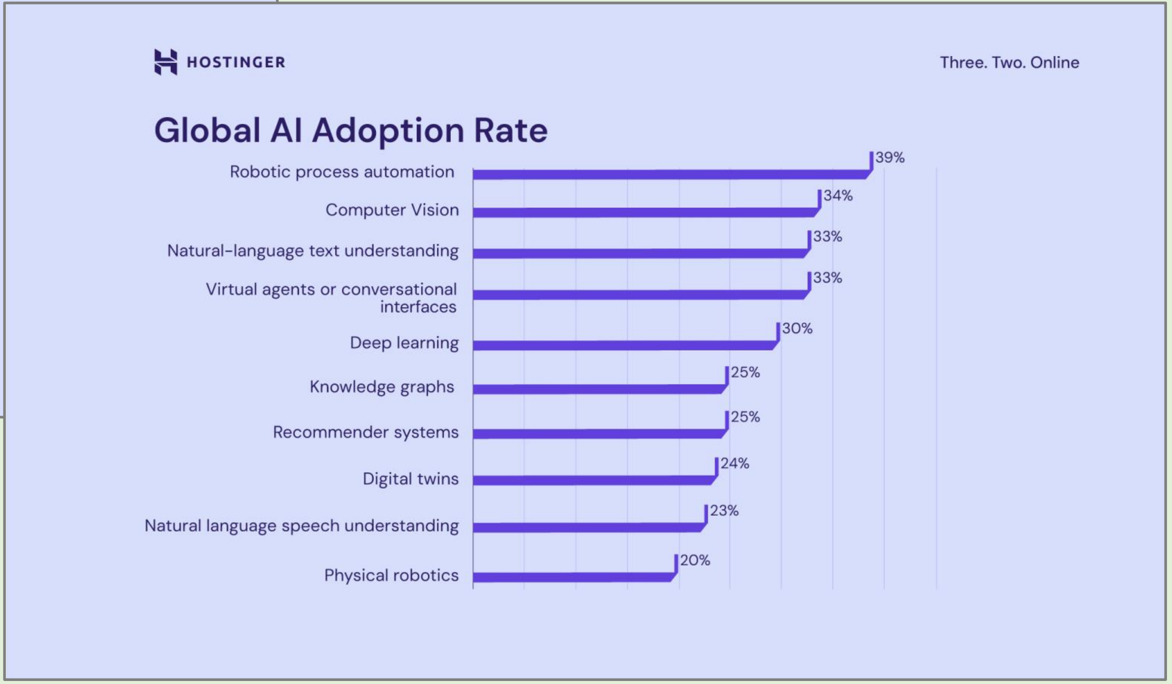
Source: McKinsey https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/responsible-ai-a-business-imperative-for-telcos and https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/charting-a-path-to-the-data-and-ai-driven-enterprise-of-2030

AI/ML: Impacts on the Future of ICT and the FCC's Critical Role



AI/ML: Impacts on the Future of ICT and the FCC's Critical Role





Source: https://www.hostinger.com/tutorials/ai-statistics

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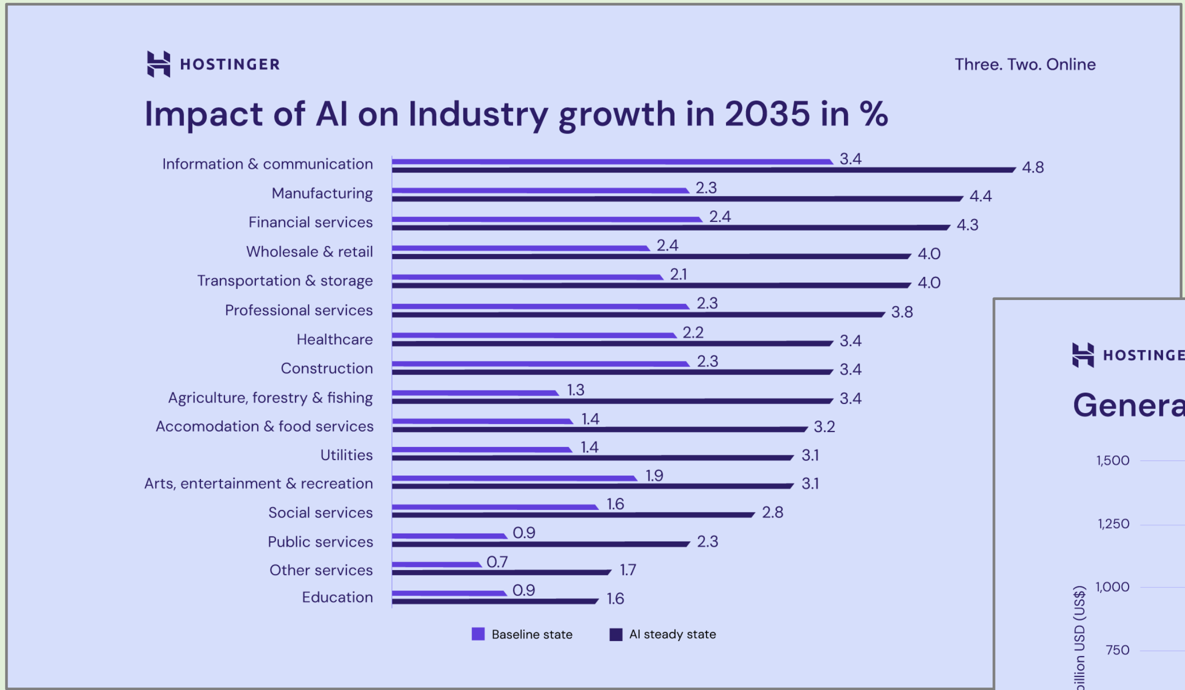
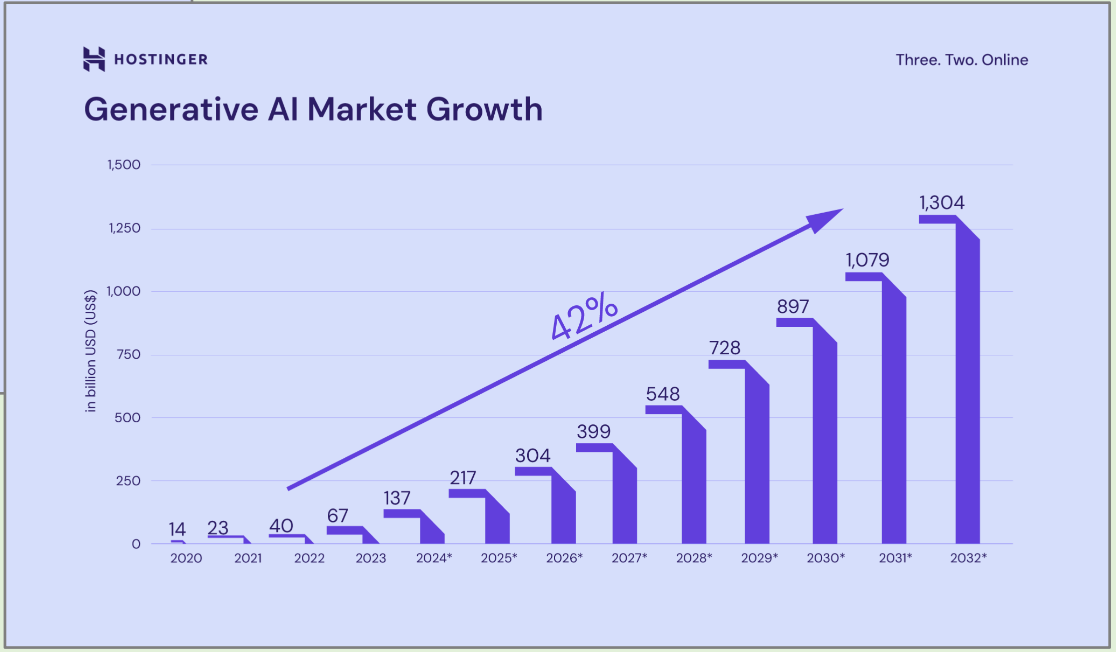
AI/ML: Impacts on the Future of ICT and the FCC's Critical Role





Source: https://www.hostinger.com/tutorials/ai-statistics

A Summary of Progress on AIWG Charter Items

4. A Summary of Progress on AIWG Charter Items

4.1 Bucket 1 The Evolution of Spectrum Sharing – from Today's Regime to Fully Automated Dynamic and Efficient Spectrum Sharing – The Long-Term Impact of AI/ML Technologies.

4.2 Bucket 2 Achieving Network Safety, Security, Assurance, and Performance in an AI/ML Native World.

4.3 Bucket 3 Testing Regimes for AI/ML in Telecommunications – An Essential Ingredient in delivering on the FCC's Strategic Goals - Assure that the AI/ML ingredients of the Network are fit for purpose and that the use of AI/ML to deliver a Network that best serves National needs and the FCC's Goals.

4.4 Bucket 4 Softwarization of Telecommunications – Taking advantage of Digital Transformation (including AI/ML) to maintain Technical Leadership and contribute to National Goals in Security and Competitiveness.

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **AI and ML for Spectrum Sharing and Management**

4.1.1 Explore the use of AI/ML methods to improve the utilization and administration of spectrum (licensed, unlicensed, and shared) based on the fundamental characteristics of propagation, interference, signal processing, and protocols. How could the scalability aspect of AI/ML algorithms support such methods by use of techniques such as parallelization, dimensionality reduction, sampling, and approximation?

Identified that Achieving Autonomous Dynamic and Efficient Spectrum Sharing is a long-term goal for the FCC. AI/ML can play a seminal role in achieving this goal. At the same time the underlying technologies that are necessary are not full understood and not fully mature.

The problem of Spectrum Sharing has three aspects: (1) Technical Solutions that balance the requirements for communications with the requirements to avoid harmful interference while making the best use of spectrum allocated to sharing; (2) Establishment of rights for protected parties, the exacting exercise of preemption requirements; and (3) Economic and operational viability of the solutions (including transition costs).

The problem is highly complex and when fully expressed has a high dimensionality that is beyond the capability of today's technologies. This necessitates approaches that are either approximate in nature or can significantly reduce the dimensionality to a tractable size as mentioned in the charter. The solution will take time!!! (See A.5)

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **AI and ML for Spectrum Sharing and Management**

4.1.2 How can AI/ML be leveraged to help better understand real-time spectrum usage, either at the front end (e.g., improved sensing) or the back end (e.g., improved analytics)?

The ability to understand real time spectrum usage is already here. Enumeration of approaches starts with sources of data:

1. Widescale deployment of sensors to gather space and time resolved usage data
    1.1 Static Sensor Network
    1.2 Mobile Sensors Deployed to gather statistical Data
2. Data from end user devices (A tap of the data processing used on today's radios}
3. Operator Data from base station equipment
4. Data Fusion from Earth and Space based assets.

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Network Safety, Security, Assurance, and Performance**

4.2.1 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 softwareized.

Observation: This question points to the fact that the Architecture of the Network will be profoundly affected by Digital Transformation, Softwarization, and within that the extensive use of AI/ML. The trend towards this has been in place for a considerable time, and there is major investment by industry (the Telecommunications sector in a considerable investor in AI/ML). To make sure that the Network Environment is safe, secure, and robust means that Software Testing is carried out extensively (with the help of AI/ML and includes any AI/ML components used in the Network) for all aspects of the Network (from individual components to the Network at a National level). The most significant aspects related to this question is the need for testing and certification. Additionally, methodologies based on probabilistic risk assessment to focus attention are worthwhile considering. That is, the adoption of a framework that is Telecommunications specific, and can be used reliably to measure progress in achieving a secure and safe Network. This is addressed in section 4.3.

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A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Network Safety, Security, Assurance, and Performance**

4.2.2 Explore and evaluate AI-enabled networks in optimizing long convergence time, memory complexity, and complex behavior of machine learning algorithms under uncertainty as well as how the highly dynamic channel, traffic, and mobility conditions of the network contribute to the challenges of AI networks.

Observation: At a System Level AI-enabled Networks are extremely complex and the questions posed are best addressed by the practice of System Engineering Principles. These involve the trade-offs between: Function, Intrinsic and Extrinsic Requirements, and Economics. At any point in time, it is important to understand: (1) what technology allows or does not yet; and (2) the time scale on which it will be mature for use. There are very many successful uses of AI/ML today characterized by use cases where the hardware (computing, storage, etc), available data, software , and current algorithms are capable of producing satisfactory results. These use cases are characterized by resource requirements that can be met and levels of complexity that can be addressed, We expect that the capability for handling higher levels of complexity and performance will evolve over time. The important factor is understanding when the technology and resource thresholds can be met to satisfy the requirements for deploying specific Network architectures.

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Network Safety, Security, Assurance, and Performance**

4.2.3 How can AI/ML techniques be used to address the challenges of data quality, availability, privacy, and security in wired and wireless networks, such as data cleansing, data fusion, data anonymization, and data protection?

1. **Data Cleansing:**
   - Anomaly detection (e.g., autoencoders) for noise removal
   - Predictive filling using regression models
   - Natural Language Processing (NLP) for automated parsing of unstructured data
   - Adaptive rules via reinforcement learning

2. **Data Fusion**
   - Multimodal fusion with attention mechanisms
   - Graph Neural Networks (GNNs) for relational data
   - Bayesian inference for uncertainty handling
   - Ensemble learning for robust aggregation

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Network Safety, Security, Assurance, and Performance**

4.2.3 How can AI/ML techniques be used to address the challenges of data quality, availability, privacy, and security in wired and wireless networks, such as data cleansing, data fusion, data anonymization, and data protection?

3. **Data Anonymization**
   - Generative Adversarial Networks (GANs) for synthetic data generation
   - Differential privacy with noise addition
   - Automatic Personally Identifiable Information (PII) masking via pattern recognition
   - Federated learning for decentralized data

4. **Data Protection**: **[and Cryptological Data sharing methods such as Multiparty Computing (MPC), Fully Homomorphic Encryption (FHE), and Differential Privacy (DP)]**
   - Intrusion detection with Recurrent Neural Networks (RNNs) and Convolutional Neural Networks (CNNs)
   - Adaptive authentication using user behavior
   - AI-optimized encryption key management
   - AI-driven threat intelligence for real-time responses

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A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

Testing of AI/ML used in Telecommunication Networks

As telecommunication networks adopt softwarization, virtualization, and integrate AI/ML technologies, the complexity and potential risks increase. Key challenges include ensuring performance, reliability, security, and ethical behavior of AI/ML systems in real-time, highly dynamic network environments, with distributed assets. Testing and certification frameworks need to address these issues, and more.

Ingredients for Testing, Validation, and Verification Approaches for AI/ML

- Model Validation and Verification: white box, black box testing, adversarial testing
- Dataset Validation: representativeness, bias, fairness, and completeness
- Performance Metrics: accuracy, latency, throughput, and resource usage
- Explainability and Interpretability
- Robustness and Stress Testing
- Regulatory and Ethical Testing

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A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items **- Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

Testing of AI/ML used in Telecommunication Networks

Many frameworks exist for AI/ML certification, across industry sectors and geographies. These provide a good baseline for current practices. To complicate matters, almost all of the Frameworks are also undergoing rapid evolution.

- General Standards / Frameworks:
  - NIST AI RMF: A voluntary framework that sets standards for managing AI risks, including testing and certification guidelines.
  - ISO/IEC 23894: An emerging standard for managing AI risks.
  - IEEE P2801 and P7009
  - ETSI (European Telecommunications Standards Institute) AI framework

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

Testing of AI/ML used in Telecommunication Networks

- Sector-specific frameworks:
  - Automotive industry: ISO 26262 (Functional Safety) and SOTIF (Safety of Intended Functionality).
  - Medical AI: FDA guidelines on Good Machine Learning Practices (GMLP) .
  - Finance: Frameworks for algorithmic fairness and transparency.
- Regional framework examples:
  - EU AI Act, ETSI ENI, Singapore Model AI Governance Framework
- Software Frameworks:
  - COSI from Cal Berkeley
  - Capability Maturity Model Integration (CMMI) from Carnegie Mellon

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

Testing of AI/ML used in Telecommunication Networks

- Aspects of telecom infrastructure that are impacted:
  - Control, Payload, & Management planes
  - Network Planning, Design, Development, Deployment, Operation, Maintenance, & Upgrades
- Test methodologies should be devised for various stages of the AI/ML lifecycle
- Datasets used for training AI/ML models should be tested/vetted continuously and thoroughly
- AI/ML models should be thoroughly tested before and during deployment
- Continuous evaluation and tuning of models in Operations is necessary
  - To anticipate environmental changes that may lead to failure of model
  - To trigger re-training
  - To trigger switching to different models
- There are common threads of testing, but also some domain and use case dependency

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

Testing of AI/ML used in Telecommunication Networks

Preliminary Recommendation Areas:

The wide use of AI/ML and various forms of software (as part of the accelerating trend towards softwarization) may change the way that the FCC eventually poses its rules and regulations for wireless systems, replacing hard formulas and radiated power limits with statements of behaviors and intent. It would be useful if the FCC convened a series of multi-stakeholder meetings on how such rules could be formulated. This should include how the AI/ML software would incorporate, safeguard limits. Eventually this would lead to revision of the FCC Guidance Documents. As part of this, the FCC should adopt one of the general testing frameworks and adapt it specifically to Telecommunication either directly or through appropriate industry bodies. The testing should be considered at the element, component, sub-system, and system level. It may also consider the broad use of emulations, simulations, and digital twins.

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

AI/ML for Network Testing

The use of AI/ML for improvement of testing effectiveness and efficiency is an important area requiring further analysis:

- Test case generation, regression testing, defect/fault prediction are all amenable to vast improvements using AI/ML
- Benefits include faster testing times, quicker identification of bugs, and reduction in manual interference and errors
- Scalability, Efficiency, Accuracy and Cost effectiveness
- Anomaly Detection during Deployment and Operations

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A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

AI/ML for Network Testing

Examples in other sectors

- Automotive: Simulation testing of AVs using AI-based simulation platforms like CARLA and LG SVL Simulator - synthetic generation of weather, road conditions etc., integration of real driving data, continuous testing, edge scenario generation
- Manufacturing & Robotics: AI-powered vision systems (e.g. Landing AI), virtual commissioning
- Healthcare: Clinical testing using synthetic datasets, AI based imaging, models for drug discovery
- Financial Services: Fraud detection, stress testing, compliance testing

Techniques

- Testing for CI/CD, Virtual testing with synthetic data and digital twins, predictive analysis, fault and root case analysis, ……….

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Testing Regimes for AI/ML in Telecommunications**

4.3.1 What approaches should be taken, if any, on testing and certification of AI/ML softwarization of network components, capabilities, and equipment?

AI/ML for Network Testing

Preliminary Recommendation Areas:

The increase of software driven functionality, control, management, and conduct of operations has profound impacts for the reliability, availability, and performance of today's Networks. The inclusion of AI/ML in Network functions only exacerbates the impacts. Another aspect is the crucial role of computing and data storage facilities that now represent a large fraction of what we call the Network. New AI/ML based Testing Frameworks, Adoption of Best Practices, and Data Sharing are necessary ingredients for taming the complexity of the evolving national Network. AI/ML is an emerging tool for dealing with the challenges posed and provides an avenue to both overcoming the inherent complexity and containing the cost of testing and certifications at all levels. The FCC should prepare itself (capabilities, facilities, and resources) to proceed in developing the necessary testing regimes.

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A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.1 What are opportunities, for the Commission, to use AI/ML to improve its analysis of data presently collected and housed in databases like ULS?

Observation: The FCC is an important source of Data for the Telecommunications Industry, for commercial and individual consumers, for verticals that rely on Telecommunications infrastructure and services, and for Government at the Local, State, and Federal level. The FCC also relies on the Data for its internal processes and for fact-based decision making. In exploiting the use of AI/ML (including Generative AI) to extract value for end-users the quality of the Data that the FCC maintains, and its completeness is critical. In general, there are multiple ways that AI/ML can be utilized in conjunction with the existing FCC databases (https://www.fcc.gov/licensing-databases/search-fcc-databases):

1. Use of AI/ML Techniques to assure the quality and accuracy of what is contained in the Databases and also to develop AI/ML based automated processes to assure the currency and validity of the Data. (A specific aspect of this for Rural Broadband is described in Appendix A.6)

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.1 What are opportunities, for the Commission, to use AI/ML to improve its analysis of data presently collected and housed in databases like ULS?

2. Classification and Characterization of information within the FCC data bases using both clustering and unsupervised learning techniques. This may be useful in identifying trends and patterns in FCC Data that are useful for the FCC in its deliberations, oversight, and administration roles. They are also useful for operators, vendors, and consumers seeking information that reflects availability of specific services, service choices, commercial opportunities, and other aspects that drive marketplace competition for Telecommunications. The analysis, judging by experiences in other domains, may significantly contribute to the reliability of the Network and better planning for Network improvements. In this context even greater value may be achieved if data from other sources can be incorporated in the AI/ML analysis. This would only be possible if third parties were willing or incentivized to share relevant data. In this regard there are reliable cryptographic methods to safeguard the underlying data but still allow analysis to be preformed without revealing protected or critical information.

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.1 What are opportunities, for the Commission, to use AI/ML to improve its analysis of data presently collected and housed in databases like ULS?

3. While one can ask for what patterns are present in existing data sets, a more frequent situation is the need to focus on a specific problem that could involve performance improvements, better utilization of assets and resources, optimization of processes, evaluation of options for new products and services, restoration of services in disasters and emergency situations, resolution of interference problems, administration of incentive and transition programs, rule enforcement, and understanding impacts of new network technologies and new network applications. The FCC Database are a significant building block in performing such analyses. These issues are best addressed with forms of supervised learning and Generative Artificial Intelligence (GAI). For this class of problems, it is frequently necessary to collect problem specific data and use it in conjunction with what already exists in the FCC databases – there is therefor a premium to establish a strong culture of data curation and the development of re-usable data catalogs that can effectively support AI/ML tools.

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.1 What are opportunities, for the Commission, to use AI/ML to improve its analysis of data presently collected and housed in databases like ULS?

> 4. A query layer for AI/ML applications that allows users to perform analyses on FCC Data employing ML and GAI techniques. This is applicable to general queries but could be greatly beneficial to determining best practices, licensing and compliance information, and process steps for engineering the Network. An ingredient for such queries is a trustworthy and comprehensive version of a Telecommunications specific Large Language Model (LLM). (Please see Appendix A.3)

Preliminary Recommendation Areas:

The development of a Data driven culture at the FCC, securing the capabilities, facilities, and resources for the use of AI/ML tools in practice, examining the FCC's role in the collection and curation of data, working with third parties on encouraging the sharing of data (under proper protection), and working within the Telecommunications ecosystem to develop a Telecommunications specific LLM. Creating a plan for the FCC in an AI-Native world, starting with a progression of significant projects to grow the FCC's capabilities.

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.2 What are the implications and complications of using AI/ML in optimizing wireless and wired networks performance by analyzing network traffic patterns, network failures, proactive corrective actions, network routing, and predicting network congestion?

Observation: The promise of AI/ML for future networks is:

Dramatically enhanced performance, reliability, scalability (i.e. effective handling of massive datasets); minimizing failure rates in the Network and its components; greatly reduced operational expenses (i.e. through automation of network management and control, eventually leading to autonomous zero-touch Networks); and significant new intelligent services and applications. Specifically, for the FCC this includes much better utilization of spectrum; affordable high bandwidth services for consumers and important industrial uses; greatly reduced energy consumption of the Nations Networks; and improved Reliability, Security, Cybersecurity, Privacy and Assurance of system services for critical applications. Lastly the integration and interoperability for heterogenous communication systems to provide complete area coverage in the US and its territories.

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.2 What are the implications and complications of using AI/ML in optimizing wireless and wired networks performance by analyzing network traffic patterns, network failures, proactive corrective actions, network routing, and predicting network congestion?

Observation We anticipate that in the journey to harness the promises of AI we will encounter challenges and complications in:

The established policies, legal rights, as well as fair access to Data; Data privacy and security risks; the maturity of AI technologies; elimination of inherent flaws (i.e. algorithm bias; model drift and aging, trustworthiness); complexity in implementation; resource consumption (compute, storage, power, etc.); and initial integration with legacy systems, and the transition to greater levels of automation.

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items **- Softwarization of Telecommunications**

4.4.2 What are the implications and complications of using AI/ML in optimizing wireless and wired networks performance by analyzing network traffic patterns, network failures, proactive corrective actions, network routing, and predicting network congestion?

Preliminary Recommendation Areas:

To address both the promise and the challenges, there is a need for organizations and bodies that would guide interoperability and develop and codify Network Architectures. This is a role where the FCC can serve as a convener and mediate the outcomes – either directly or by working with existing organizations. As AI/ML technologies continue to evolve, there is a need for a neutral guiding hand to help the players productively interact and collaborate well together. There are two aspects here: (1) to address issues that are unique and specific to the needs of United States in achieving goals for the national Network for National Security, Competitiveness, and Technological Leadership; (2) to promulgate the use of the technologies in harmonizing global standards and interoperability across international markets.

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.3 How can AI/ML techniques be used to support the integration and interoperability of wired and wireless networks, such as heterogeneous access networks, multi-domain networks, and adaptive network slicing?

Observation: AI/ML techniques can play a critical role in enhancing the integration and interoperability of wired and wireless networks. Machine learning algorithms can be used for dynamic network configuration, by automating network settings and optimizing resource allocation across Networks (i.e. mobile, core, metro, access and local networks, space-based networks etc.). This ensures seamless operation and adaptability to changing network conditions. Machine learning can also be used for Quality of Service (QOS) and Quality of Experience (QoE) realization. For example, AI would be utilized to classify and prioritize data traffic to ensure critical applications (e.g., video conferencing or emergency communications) receive proper settings and configuration across the wireless and wired and other networks. Similarly, AI algorithms can help with enhancing network interoperability. One example is to use AI/ML to optimize routing and manage connectivity through wireless or wired channels. AI tools can also be for network planning, deployments, operations, as well as maintenance and upgrades. For example, AI/ML could be used to model the coexistence of wired, wireless, and space networks, enabling optimal deployment strategies.

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.3 How can AI/ML techniques be used to support the integration and interoperability of wired and wireless networks, such as heterogeneous access networks, multi-domain networks, and adaptive network slicing?

Observation In summary, by using AI/ML techniques, wireless and wired networks can become more adaptive, efficient, and capable of handling diverse devices and applications, ensuring smooth integration of wired and wireless components. The heart of this is the exploitation of AI and other analytical techniques to solve the challenges of: complexity, heterogeneity, automation, and eventually autonomy.

The trajectory for achieving the full potential requires: (1) Technical progress in the capabilities of AI/ML platforms; (2) the adoption of standard interfaces and coordination across operators, vendors, regulators, and other stakeholders; (3) curation and sharing of essential data resources across the ecosystem; (4) potentially a greater use of physical and information sensors to close the decision loop/loops driven by AI/ML models; (5) growing the human skill sets within the telecommunications ecosystem to practice AI/ML and software skills at an acceptable level; (6) entirely new approaches to the regulations surrounding networks, their testing, and certification; (7) the use of AI/ML exacerbates the need for new mechanisms for the telecommunication industry to ingest and adopt end-users requirements; and lastly (8) likely changes in business models and relationships of players within the ecosystem.

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.3 How can AI/ML techniques be used to support the integration and interoperability of wired and wireless networks, such as heterogeneous access networks, multi-domain networks, and adaptive network slicing?

Preliminary Recommendation Areas:

The preliminary recommendations considered for 4.4.2 are also applicable to 4.4.3, including a need for organizations and bodies that would guide interoperability, form architectural structure, and a need for a neutral guiding hand to help the players productively interact and collaborate well together. Furthermore, the following initiatives shall assist with achieving the full potential trajectory as noted in the Observation section:

- Accelerate experimentation venues, testbeds, and demonstration projects shared across the US ecosystem
- To promote policies that encourage open sharing of data resources across the telecommunications ecosystem
- Encourage the sharing of sensitive data for training and analysis using privacy preserving cryptographic tools
- To mandate training programs on telecom related AI/ML and software skills, in order to train skilled telecommunications national workforce at acceptable levels.
- Devise new approaches to the regulations surrounding networks, their testing, and certification.
- Encourage use of AI/ML techniques in specific areas such as High Bandwidth Rural Networks (Appendix A.6)

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.4 How can AI/ML techniques be used to design and implement novel network architectures and protocols for wired and wireless networks, such as software-defined networking (SDN), network function virtualization (NFV), and information-centric networking (ICN)?

Observation: SDN and NFV are key enablers driving Softwarization of Telecommunications. SDN separates the control plane from the data plane in a network system and moves the network management to a central point, the controller, allowing for more flexible network management. AI will significantly improve this flexibility by automating the decision-making processes, enabling an Intelligent SDN.

Network Functions Virtualization (NFV) is a network architecture that virtualizes network functions, such as firewalls, routers, and load balancers, on commodity hardware. NFV separates network applications from hardware resources, such as storage, compute, and other network hardware. This allows network functions to be deployed as virtual machines (VMs) or containers that can be shared by all network applications. AI is starting to play a crucial role in NFV environments by automating complex network management tasks.

A Summary of Progress on AIWG Charter Items

4. **(Continued)** Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.4 How can AI/ML techniques be used to design and implement novel network architectures and protocols for wired and wireless networks, such as software-defined networking (SDN), network function virtualization (NFV), and information-centric networking (ICN)?

Observation: AI significantly improves the SDN and NFV network performance by enabling real-time data analysis, proactive issue identification and prediction, automated network management, optimized resource allocation, enhanced security, and faster troubleshooting, ultimately leading to reduced downtime and increased operational efficiency.

In summary, leveraging AI/ML ability to analyze vast amounts of network data (e.g. in real-time), allows for intelligent decision-making, proactive issue identification, and self-healing mechanisms, ultimately creating more efficient and adaptable network configurations (i.e. SDN, NFV or ICN) compared to traditional techniques.

A Summary of Progress on AIWG Charter Items

4. Progress on AIWG Charter Items - **Softwarization of Telecommunications**

4.4.4 (Continuation) How can AI/ML techniques be used to design and implement novel network architectures and protocols for wired and wireless networks, such as software-defined networking (SDN), network function virtualization (NFV), and information-centric networking (ICN)?

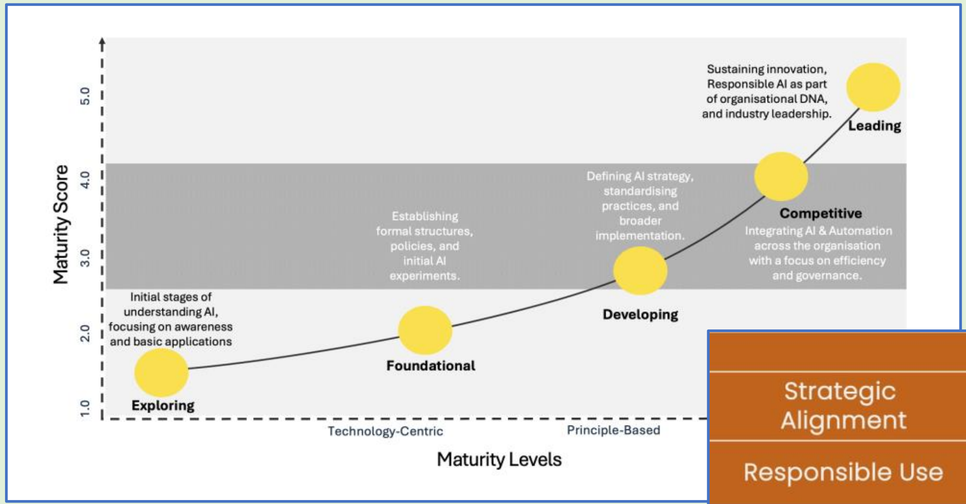
Preliminary Recommendation Areas:

The preliminary recommendations considered for 4.4.2 and 4.4.3 are also applicable to 4.4.4.

In addition, SDN and NFV technologies simplify the composition of the Network by using common distributed computing platforms and data storage that is rapidly replacing much larger numbers of specialized equipment. At the same time the complexity of the Network is increasing because of an explosion of function interface parameters running on the same computing plant. This requires the logical construct of the Network to be compatible with the physical assets and their constraints. What becomes increasingly important are models that accurately project resource requirements and at the same time rigorously capture the risks to the Network and its overall reliability. This is even more important with the additional risks introduced by AI/ML.

The Transformation of the Network

5. A Priority: The Transformation of the Network (Digitization, Softwarization, and AI)

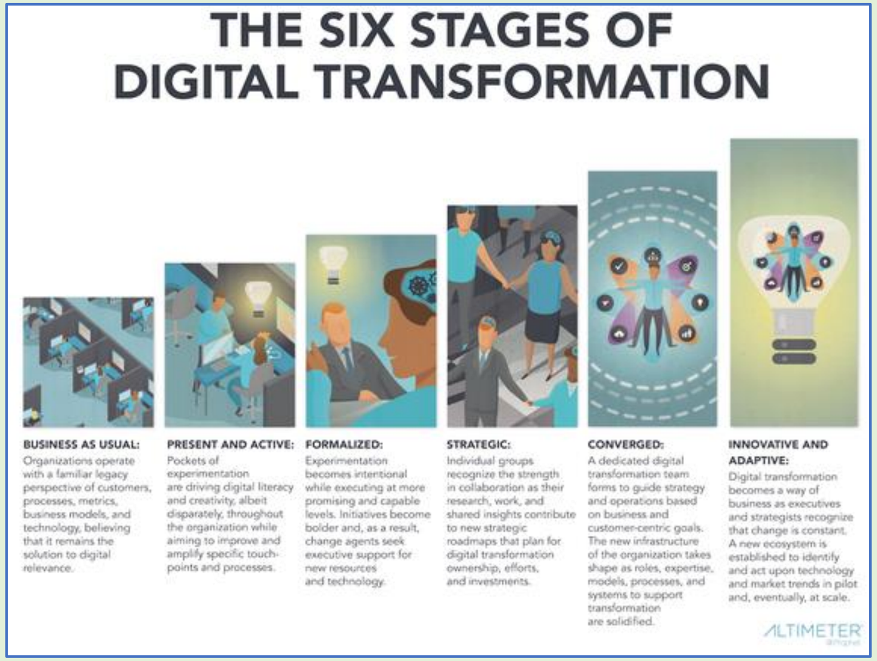


	EXPLORING	FOUNDATIONAL	DEVELOPING	COMPETITIVE	LEADING
	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5
Strategic Alignment Responsible Use Data & Security Governance Technology Readiness People Leveraging	Exploring what AI is and what it can bring to your organisation. The organisation does not yet have an AI model or solution in production.	Experimenting with Proofs of Concept (POCs) and pilots. The organisation is trying to put AI into production and can do so in limited ways.	Moving from POC / Pilot to an AI solution in production. Putting AI solutions into production still requires significant organisational work at this stage.	Scaling AI solution deployments efficiently as the number of deployed AI models increases. AI is a core competency and competitive advantage.	Transforming the organisation itself through the use of AI. The organisation uses AI in how it operates across many critical areas of the business.

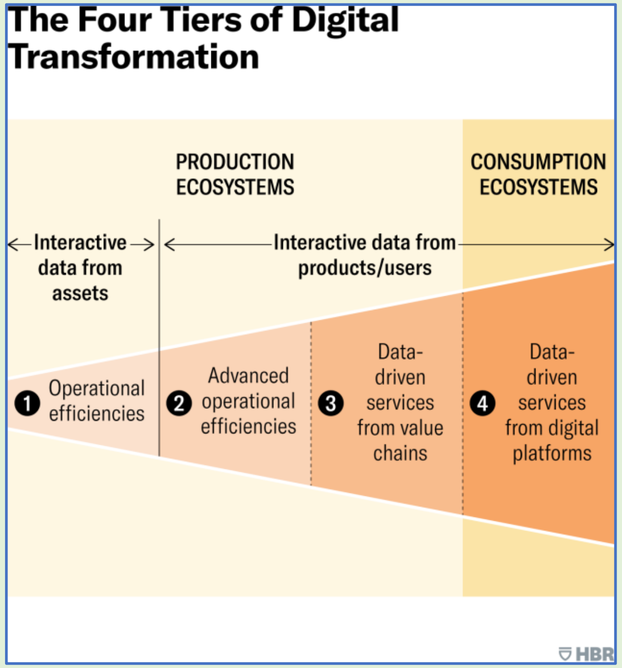
Source: https://cxai.au/how-to-measure-ai-maturity-the-ai-maturity-model/

The Transformation of the Network

5. A Priority: The Transformation of the Network (Digitization, Softwarization, and AI)



Source: https://7wdata.be/chief-marketing-officer/the-definition-of-digital-transformation/



Source: https://hbr.org/data-visuals/2021/09/the-four-tiers-of-digital-transformation

The Transformation of the Network

The 6 Levels of Network Automation and Autonomy

Level 0: The Network utilizes and is assisted by computer technology, but control, management, maintenance, and planning are predominantly manual functions.
Level 1: Some Network Components and Routine Network Functions are digitized and automated, but the oversight remains with human operators.
Level 2: Many Network resources allocations, configurations, and component settings are automated. A Level 2 Network would make extensive use of computer technology including AI/ML to assist in key functions and play a significant role in identifying adverse Network conditions and assist in their resolution.
Level 3: When the autonomous features are turned on, the Network is no longer primarily controlled and managed by a human operators. Level 3 autonomous features can fully run the Network, but only under limited conditions – nominal traffic patterns and congestion. When acceptable conditions aren't met, the Network will request that human operators take over partial or full Control and Management.
Level 4: Level 4 autonomous features can fully control and manage the Network which is self healing. Human operators still haver the ability to manually override the autonomous system.
Level 5: A Level 5 autonomous Network has full control and management functionality and can operate in all conditions, anywhere. It has trusted built in limits and is capable of isolating and fixing problems. A plug and play Network.

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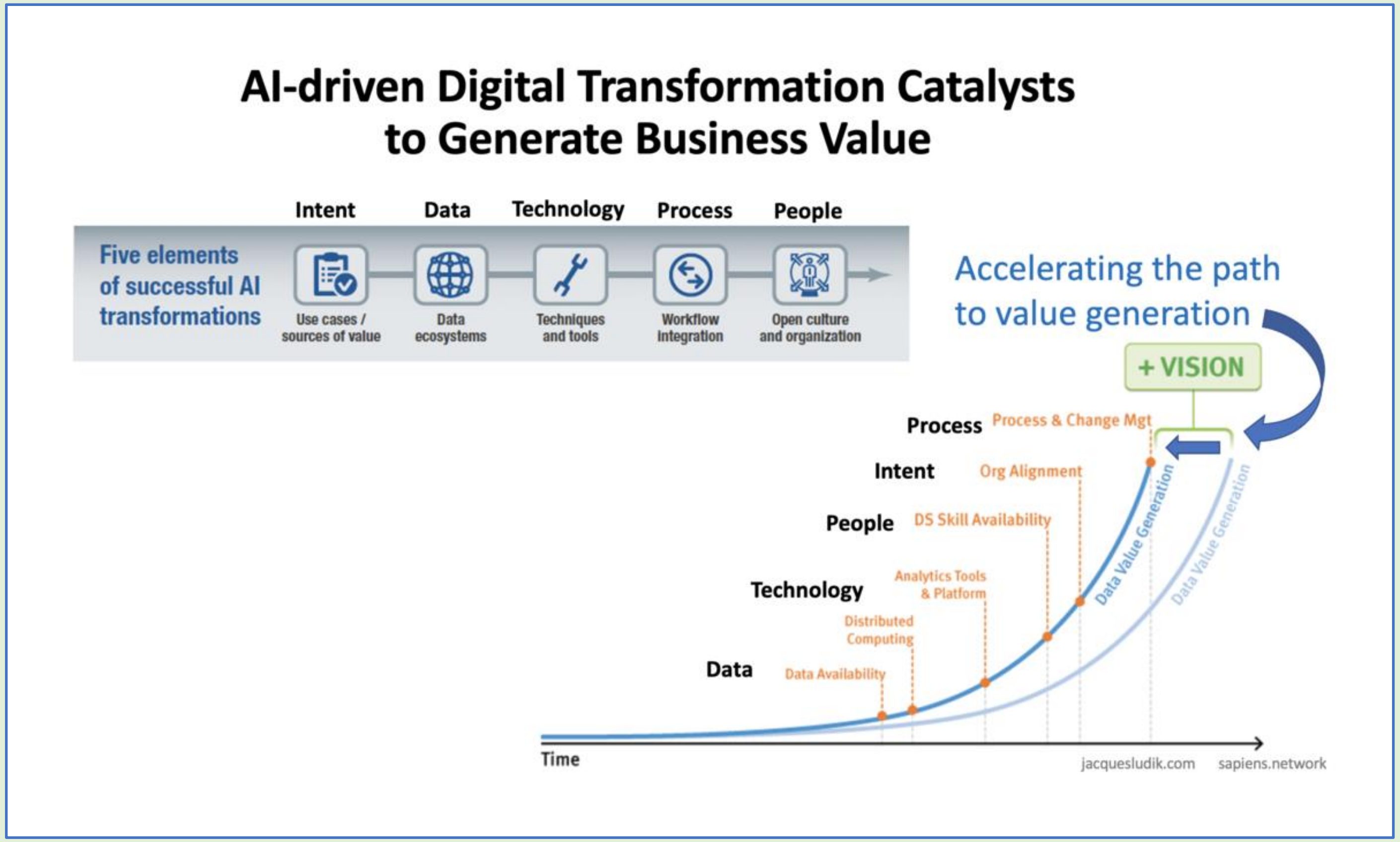
The Transformation of the Network

5. A Priority: The Transformation of the Network (Digitization, Softwarization, and AI)

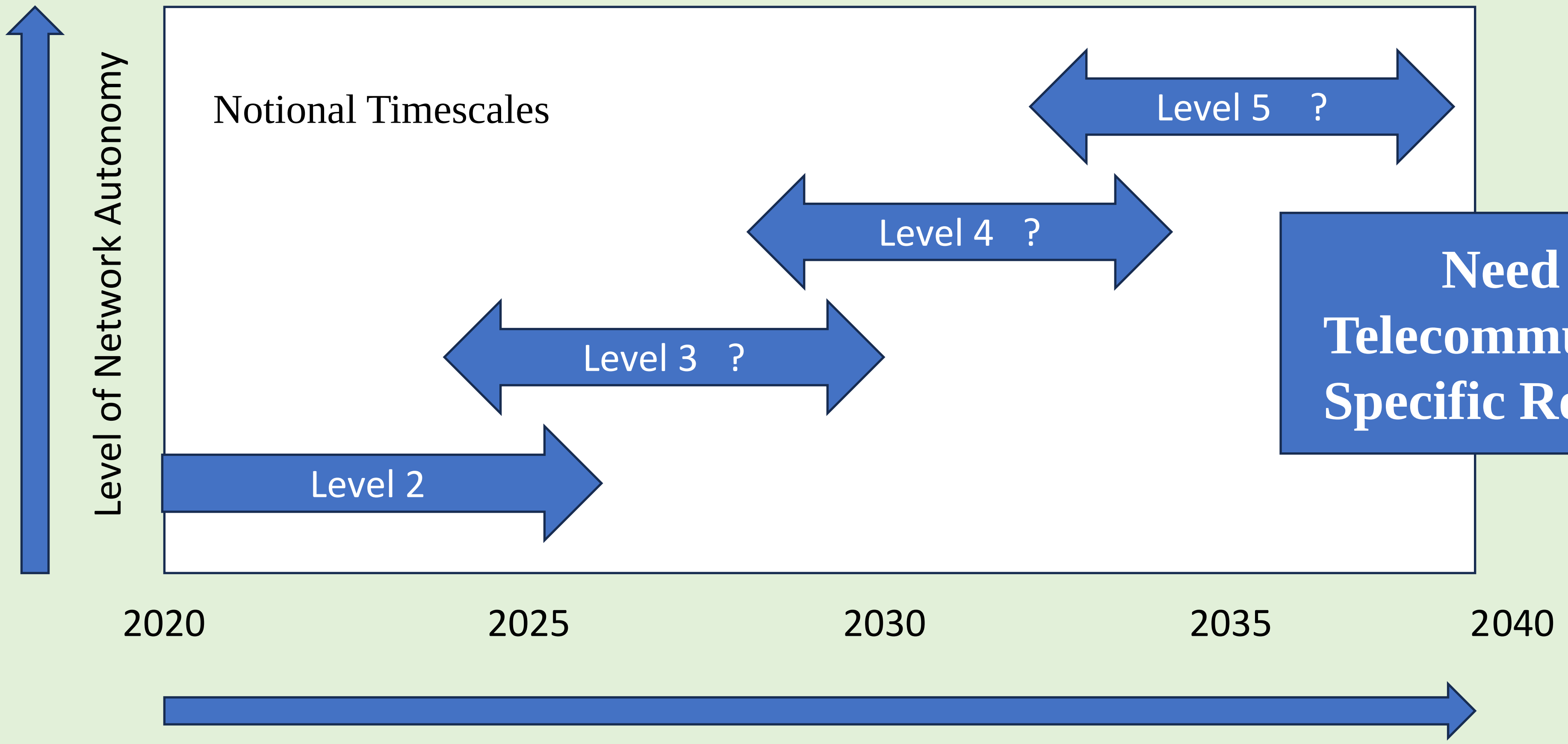


Source: https://miiafrica.org/2022/03/16/ai-driven-digital-transformation-of-the-business-enterprise/

The Transformation of the Network

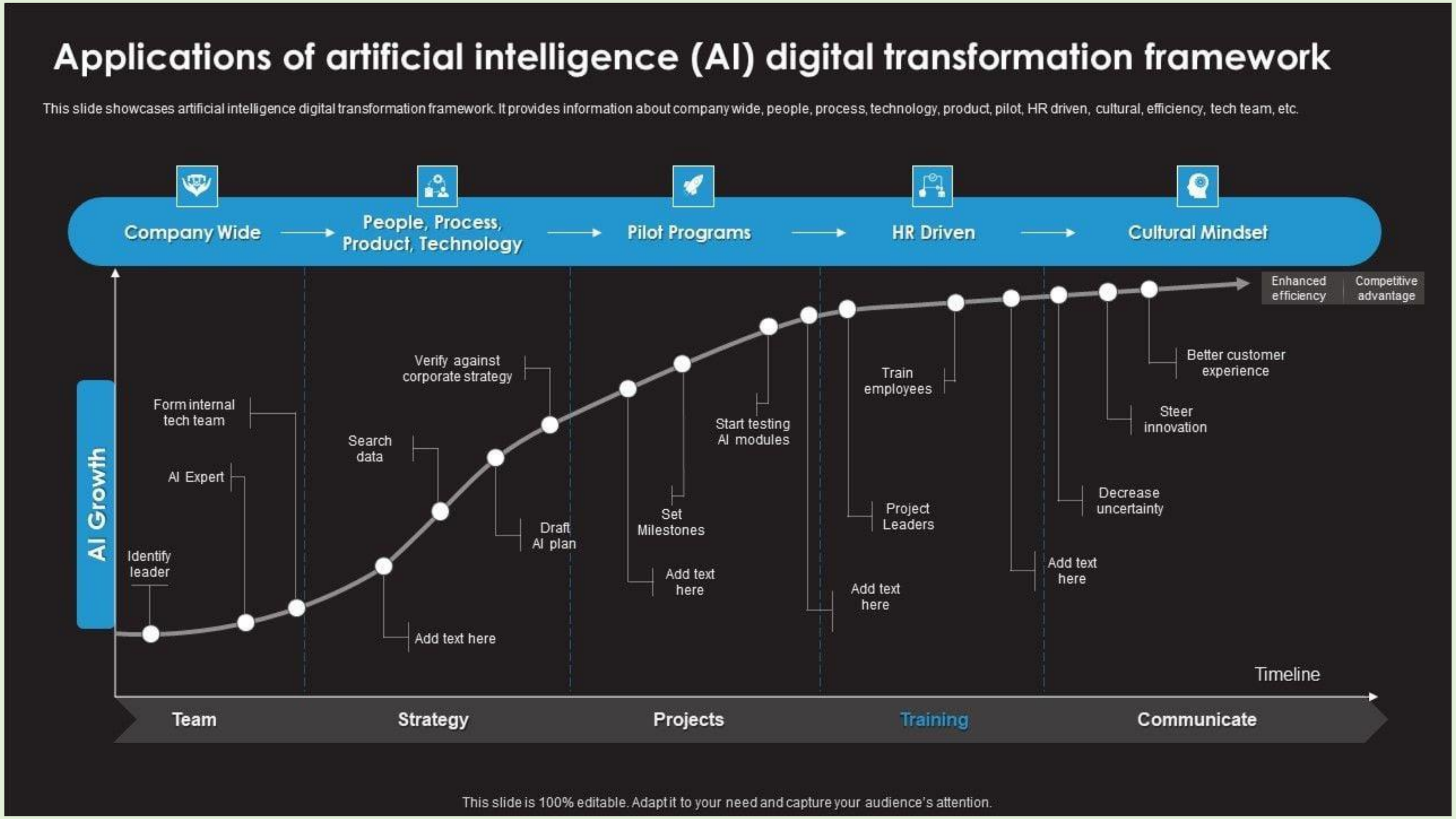
The Transformation Journey: Digitization, Softwarization, and AI/ML

The 6 Levels of Network Autonomy



Need for a Telecommunications Specific Roadmap!!!

The Transformation of the Network



A Template for the Organizational Journey

Source: https://www.slidegeeks.com/applications-of-artificial-intelligence-ai-digital-transformation-framework-introduction-pdf#images-1

Work Plan for 2025

6. What's Next: White Paper Outline for 2025 Deliverable

The detailed White Paper outlines are in Appendix A.7. They consist of four sections:

1. AI and ML for spectrum sharing and management
- **1.1 Introduction: AI and ML for Spectrum Sharing and Management**
- **1.2 How can AI/ML be leveraged to help better understand real-time spectrum usage?**
- **1.3 Conclusions and Recommendations**

2. Network safety, security, assurance, and performance
- **2.1 AI/ML in the Network**
- **2.2 Range of AI/ML Solution Characteristics: Challenges and Opportunities**
- **2.3 Techniques for Addressing Concerns with AI/ML Data**
- **2.4 Conclusion and Recommendations**

3. The Role of AI/ML in testing regimes and certification
- **3.1 Test and certification of systems with AI/ML (with recommendations)**
- **3.2 Use of AI/ML for improved Network testing (with recommendations)**

4. The Transformation of the Network – Digitization, Softwarization, and AI/ML
- **4.1 Digital transformation**
- **4.2 Digitization/Softwarization: Software defined networking, Network function virtualization (2020-2035)**
- **4.3 Business models and policies**
- **4.4 Implications for what the FCC does**

Appendices

Appendices

1. List of Speakers and Presentations
2. FCC Strategic Goals
3. Creating an LLM for Telecommunications
4. An Example: AI/ML for Open–RAN (Radio Access Network)
5. Propagation Models and AI for Spectrum Sharing
6. AI/ML for Rural High-Speed Broadband Coverage
7. White Paper Outline: The Transformation of the Network

Appendices

A.1 List of Speakers and Presentations

Andrew M. Clegg

CTO, Wireless Innovation Forum, and Spectrum Engineering Lead at Google

Background: Andrew Clegg is Spectrum Engineering Lead for Google, where he was one of the principal architects of the CBRS band. He also serves as the Chief Technical Officer for the Wireless Innovation Forum (WInnForum). He represents WInnForum on the FCC Technological Advisory Council where he Co-Chairs the Spectrum Sharing Working Group - SSWG.

Talk Title: What could we learn using AI/ML if we had access to (obfuscated) CBRS deployment data?

Abstract: This talk will describe the CBRS deployment data that are shared among Spectrum Access Systems each evening, from which aggregate interference calculations and other tasks are performed. The interchange specification is in Wireless Innovation Forum Technical Standard TS-0096. FCC rules prohibit the release of data about specific CBSDs (96.55(a)(3)), and permission from the SASs would need to be obtained to access even obfuscated data. A manner will be proposed to obfuscate the data (and additional proposals would be welcome), and then the question will be asked to the group if there is something to be learned by applying AI/ML techniques to the resulting dataset, if such a dataset were available.

linkedin.com/in/andrew-clegg-32935a2

Parul (Paula) Kapur

Founder Kap Ocean LLC

Background: Parul (Paula) Kapur is a Founder of Kap Ocean LLC, an Artificial Intelligence and Innovation consulting firm. Her focus is on Artificial Intelligence, Innovation and Partnership initiatives. Paula has expertise in Strategy, Policy, Ethics, Responsibility, Risk and much more. She focuses on Telecommunications, Medical, and Software technologies. Paula is also an Intellectual Property and Patent Attorney. She has a JD, a MS in Electrical Engineering and a BS in Biomedical Engineering. Moreover, Paula has been a Speaker and Panelist in various Artificial Intelligence, Innovation and Patents activities.

Talk Title: "Legislation, Regulations and Policies Related to Artificial Intelligence and Telecommunications."

Abstract: The presentation will focus on the current status of Legislation, Regulations and Policies related to the use of Artificial Intelligence and Machine Learning, generally applied to Telecommunications. In particular, discussion areas will include Executive Order No. 14410; National Telecommunications and Information Administration; Federal Communications Commission; Federal Trade Commission; European Union Artificial Intelligence Act; Intellectual Property & Artificial Intelligence; and State Legislation & Regulation. Moreover, topics such as robocalls, robotexts and deepfakes will be included in the presentation.

https://www.linkedin.com/in/parulkapur/
https://kapocean.com/index.html

Aniket Bera

Purdue University

Background: Dr. Aniket Bera is an Associate Professor at the Department of Computer Science at Purdue University. He directs the interdisciplinary research lab IDEAS (Intelligent Design for Empathetic and Augmented Systems) at Purdue, working on modeling the "human" and "social" aspects using AI in Robotics, Graphics, and Vision. He is also an Adjunct Associate Professor at the University of Maryland at College Park. He received his Ph.D. in 2017 from the University of North Carolina at Chapel Hill. He is also the founder of Project Dost. He is currently serving as the Senior Editor for IEEE Robotics and Automation Letters (RA-L) in the area of "Planning and Simulation" and the Conference Chair for the ACM SIGGRAPH Conference on Motion, Interaction and Games (MIG 2022). His core research interests are in using Machine Learning models for understanding human behaviors using multi-modalities, Augmented Intelligence, Multi-Agent Simulation, Social Robotics, Autonomous Agents, Cognitive modeling, and planning for intelligent characters.

Talk Title: “Building the Future with Machine Learning and Foundation Models: A Practical Guide.”

Abstract Follows

https://www.linkedin.com/in/abera/
https://www.cs.purdue.edu/homes/ab/

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Aniket Bera

Purdue University

Continued

Abstract: Machine learning (ML) and foundation models are at the forefront of technological innovation, driving significant advancements across various industries. This talk offers an introductory guide to understanding these powerful tools. We will explore the essential principles of machine learning, including supervised, unsupervised, and reinforcement learning, providing a solid foundation for understanding how ML models are developed and optimized. The discussion will then shift to foundation models, highlighting their architecture, capabilities, and transformative potential in areas such as natural language processing, computer vision, and more.
Real-world examples and practical applications will be showcased to illustrate how ML and foundation models are being utilized in telecommunications, customer service, and content creation, among other fields. These examples will demonstrate the tangible benefits and challenges of integrating these technologies into existing systems. By the end of this session, attendees will have gained a deeper understanding of the foundational concepts of ML and foundation models, as well as practical insights into their application in modern industries. This talk aims to equip industry leaders with the knowledge and tools necessary to leverage these technologies effectively, fostering innovation and building the future.

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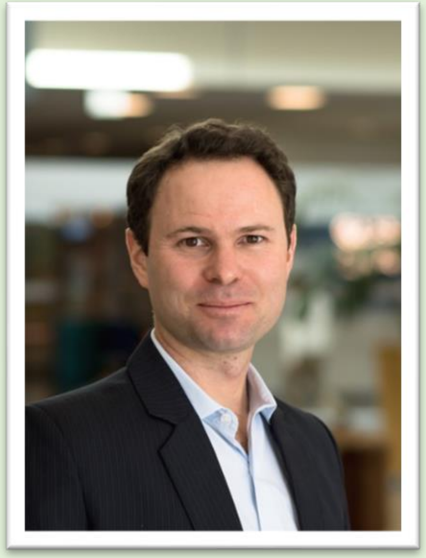

Etienne Chaponniere
Vice President
Technical Standards

Qualcomm

Background: Telecommunication professional with 25 years' experience in the cellular industry in ASIC design, System Engineering in 3G & 4G, technical standardization leadership, technical standards group chairmanship and board representation; Etienne Chaponniere, VP of Technical Standards, currently leads Qualcomm's standardization efforts in Artificial Intelligence, Security and regional standards worldwide. Etienne holds a Masters in Télécommunication from the École Polytechnique Fédérale de Lausanne (Switzerland)

Talk Title: "Regulatory and Legislative Landscape for AI/ML in Telecommunications."

https://www.linkedin.com/in/etienne-chaponniere-34203836/

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Tim O'Shea
CTO at DeepSig

and

Research Assoc. Professor
Virginia Tech University

DeepSig

Background: Tim O'Shea is a Research Assistant Professor at Virginia Tech and the CTO and Co-Founder at DeepSig Inc in Arlington, VA. He is focused on leveraging machine learning and data-driven approaches within the wireless physical layer to help improve baseband processing spectral efficiency, energy efficiency, and environmental awareness and automation in 5G, 5G Advanced, and 6G. His research focuses also include AI/ML applications in cryptocurrency, cybersecurity, generative applications, and other interesting emerging verticals.

He has run numerous applied R&D efforts for DARPA, NSF, DOD, IARPA, EU HORIZON-2020, Industry, and others. Previously he worked with wireless startups Hawkeye 360 and Federated Wireless in seed stage and held engineering R&D positions with both the US DOD and with Cisco Systems. He is the author of over 100 academic works and patents in this area and is involved in IEEE ComSoc, IEEE MLC ETI, Next-G Alliance, and OpenRAN Alliance, OpenRAN Policy Institute, the GNU Radio project and other efforts to accelerate AI driven communications system technology and its adoption within next generation RAN systems.

Talk Title: "AI/ML for Understanding Spectrum Usage."

https://www.linkedin.com/in/osheatim/
https://nationalsecurity.vt.edu/personnel-directory/oshea-tim0.html

Rajesh Gadiyar

VP of Engineering for Telco and Edge

NVIDIA

Background: Rajesh Gadiyar is the VP of Engineering for Telco and Edge at Nvidia. He is building technologies for virtualized 5G Radio Access Network (RAN) in the cloud. A key area of focus for him is the intersection of Artificial Intelligence (AI), Cloud Technologies and 5G/6G Networks. He works with communications service providers (CoSPs) to modernize their networks. Before joining Nvidia in 2022, Rajesh was the Vice President and Chief Technology Officer (CTO) for the Network Platforms Group at Intel. He led the architecture and product development efforts to accelerate cloud native network applications in 5G infrastructure, edge clouds, video processing and AI in Networking and delivered many generations of network server platforms. Prior to joining Intel, he led various engineering teams at Trillium Digital Systems and Wipro Ltd. Rajesh brings several years of experience in networking products, architecture, standards, and software development for Voice over IP, cellular, broadband, mobile telephony, and data networks. Rajesh has a B.S. in Electronics and Telecommunications engineering from National Institute of Technology, Trichy, India, and an MBA from UCLA Anderson School of Management. He is a regular speaker at industry events and conferences

Talk Title: “Digital Twin for 6G Networks.”

Abstract Follows

https://www.linkedin.com/in/osheatim/
https://nationalsecurity.vt.edu/personnel-directory/oshea-tim0.html

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Rajesh Gadiyar

VP of Engineering
for Telco and Edge

NVIDIA

Continued

Abstract: Digital Twins are becoming increasingly popular in many industry verticals. Digital twins offer up data and insights that can significantly improve the way their real-world versions operate. There is a real opportunity to create Digital Twins of next generation wireless networks that can foster research and rapid innovations in new algorithms to improve spectral efficiency, network capacity planning for operators, and rapidly debugging complex network issues. Nvidia has developed Aerial Omniverse Digital Twin – a site-specific, large-scale, and highly accurate platform for system level simulation of 5G, 5G adv and 6G radio networks. Our goal is to foster rapid innovations in 1) Tackling the design of the 6G air interface 2) Studying the effect of AI on the data and control plane of 5G/6G cellular networks and enabling cost-effective open RAN infrastructure. In this presentation, we will discuss the key goals and attributes of a network digital twin, present Aerial Omniverse Digital Twin as a possible solution, and discuss how the community can collaborate with Nvidia to drive innovations in this critical area.

Alex Jinsung Choi

SVP Head of T-Labs
Deutsche Telekom

and

Chair of O-RAN Alliance

Background: Dr. Alex Jinsung Choi is SVP of Strategy and Technology Innovation (STI) of Deutsche Telekom with responsibility for the Network Differentiation strategy to transform Deutsche Telekom's infrastructure to an open, distributed and cloud-native architecture with an automated production model. Dr. Choi is also Chief Operating Officer of the O-RAN Alliance. Dr. Choi has more than 20 years of experience in the mobile telecommunication industry & consumer electronics and has been thought leader driving forward key strategic and research topic in TelCo and AI. Dr. Choi was the first Chairman of the Telecom Infra Project (TIP) and previously served as CTO for SK Telekom. With the introduction of "NUGU", the first AI-based virtual assistant in Korea, Dr. Choi was influential in the development of AI solutions.

Talk Title: "O-RAN and AI/ML for Telecommunications."

https://www.linkedin.com/in/jinsung-choi-48a8b61/
https://www.o-ran.org/blog/o-ran-alliance-announces-its-new-chairman-of-the-board-and-new-coo
https://www.telekom.com/en/blog/515926-515926

Michele Polese

Assistant Research Professor
Electrical and Computer Engineering

Northeastern University

Background: Michele Polese is a Principal Research Scientist at Northeastern University, Boston, since March 2020, working with Tommaso Melodia. He received his Ph.D. at the Department of Information Engineering of the University of Padova in 2020 under the supervision of with Michele Zorzi. He also was an adjunct professor and postdoctoral researcher in 2019/2020 at the University of Padova. During his Ph.D., he visited New York University (NYU), AT&T Labs in Bedminster, NJ, and Northeastern University, Boston, MA. He collaborated with several academic and industrial research partners, including Intel, InterDigital, NYU, AT&T Labs, University of Aalborg, King's College and NIST.
He was awarded with the Best Journal Paper Award of the IEEE ComSoc Technical Committee on Communications Systems Integration and Modeling (CSIM) 2019, the Outstanding Young Researcher Award 2019 from the IEEE ComSoc EMEA Region, the Best Paper Award at WNS3 2019 and 2020, and the IEEE MedComNet Mario Gerla Best Paper Award 2020. His research interests are in the analysis and development of protocols and architectures for future generations of cellular networks (5G and beyond), in particular for millimeter-wave communication, Open RAN, and in the performance evaluation of complex networks.

Talk Title: "AI/ML for Open Radio Access Networks."

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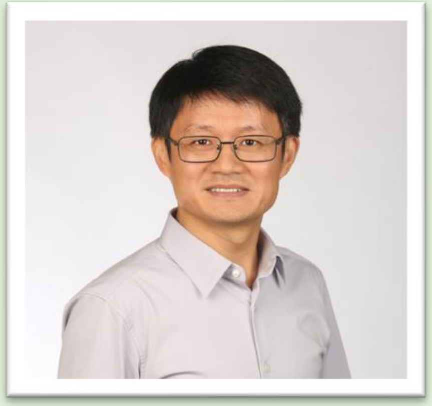

Cong Shen

Associate Professor
Electrical and Computer Engineering
University of Virginia

Background: Cong Shen is an Associate Professor of the Electrical and Computer Engineering Department at University of Virginia (UVA). He received the Ph.D. degree from the Electrical Engineering Department, University of California Los Angeles (UCLA). His general research interests are in the area of machine learning and wireless communications. In particular, his current research focuses on multi-armed bandits, reinforcement learning, in-context learning, distributed learning, and their applications in wireless communications and networking. He received the NSF CAREER award in 2022 and was the recipient of the Best Paper Award in 2021 IEEE International Conference on Communications (ICC). In recent years, he has published extensively in top AI/ML conferences (NeurIPS, ICML, ICLR, etc). He is a founding member of *SpectrumX*, an NSF Spectrum Innovation Center.

Title: Sequential Decision-Making for Spectrum Sharing and Management

Abstract: Spectrum management is crucial for optimizing the use of scarce wireless resources, particularly as demand intensifies with the proliferation of connected devices and services. With the success of AI/ML in many applications, it is natural to consider whether it can improve spectrum management in any meaningful way. Among the various ML tools, sequential decision-making is particularly suitable for spectrum sharing and management, enabling decisions that evolve over time based on observed conditions and learned patterns. In this talk, I will explore the synergies between the key techniques — such as multi-armed bandits, reinforcement learning, and Transformers — and the unique challenges of spectrum management. By systematically integrating these new tools with spectrum-sharing strategies, we can enhance spectrum utilization, reduce interference, and improve fairness across competing users.

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Nageen Himayat

Senior Principal Engineer
Intel Labs

Background: Nageen Himayat is a Senior Principal Engineer with Intel Labs. She leads the Trusted & Distributed Intelligence team conducting research on trustworthy and distributed AI/ML. Her research contributions span areas such as AI security, distributed ML, machine learning for networks, multi-radio heterogeneous networks, cross layer radio resource management, and non-linear signal processing techniques. Nageen has authored over 350 technical publications, contributing to several peer-reviewed publications, 3GPP/IEEE standards, as well as numerous patent filings. Prior to Intel, Nageen was with Lucent Technologies and General Instrument Corp, where she developed standards and systems for both wireless and wire-line broadband access networks. Nageen obtained her B.S.E.E degree from Rice University, and her M.S./Ph.D. degrees from the University of Pennsylvania. She also holds an MBA degree from the Haas School of Business at University of California, Berkeley.

Title: AI/ML in Wireless Networks: Learnings from the Intel/NSF Machine Learning for Wireless Networking Systems (MLWiNS) Program

Abstract: Artificial Intelligence and Machine Learning (AI/ML) Technologies are widely expected to play an integral role in the design and architecture of Next Generation Networks. The Intel-National Science Foundation (NSF) program on “Machine Learning for Wireless Networking Systems (MLWiNS),” funded research that leveraged AI/ML techniques for the design and architecture of Next-Gen wireless networks and developed techniques for efficient support for AI computations in resource-constrained networks. The talk will share insights from MLWiNS program and discuss potential impact of the research on Next-Gen networking standards.

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Martin Doczkat

FCC
Division Chief, Electromagnetic Compatibility Division
Office of Engineering Technology

Background: Martin Doczkat is the Division Chief of the Electromagnetic Compatibility Division in the Office of Engineering and Technology (OET) at the Federal Communications Commission (FCC), where he has been for eight years. Prior to joining the FCC, Martin provided consulting engineering services to various FCC licensees, including broadcasters. He is a member of the Institute of Electrical and Electronics Engineers (IEEE) as well as an active participant in many of their subordinate organizations, including the International Committee on Electromagnetic Safety (ICES), Antennas and Propagation Society (APS), Broadcast Technology Society (BTS), Communications Society (ComSoc), Electromagnetic Compatibility Society (EMCS), Engineering in Medicine and Biology Society (EMBS), Microwave Theory and Techniques Society (MTTS), and Standards Association (SA). He is a United States member of International Electrotechnical Commission (IEC) Technical Committee (TC) 106, a member of the Association of Federal Communications Consulting Engineers (AFCCE), and a licensed professional engineer (PE) in the District of Columbia. He holds a Bachelor of Science (BS) degree in Electrical Engineering from The Pennsylvania State University (PSU), and two Master of Science (MS) degrees, in Systems Engineering and Electrical Engineering, from The George Washington University (GWU).

Title: **"Artificial Intelligence, Machine Learning, Data and Database Usage of and Interests to the Federal Communications Commission."**

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https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division

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Tian Lan

Professor ECE at George Washington University

Background: **Tian Lan** is a professor at the Department of ECE, George Washington University in DC and the Director of Human-centric Autonomy and Robotics (HART) lab. His research interests include optimization, machine learning, and relevant applications to network management, cloud/edge computing, and cyber security. The research has been supported by NSF, DARPA, ONR, ARO, USMA, Meta, CISCO, and AT&T. Tian Lan has received 6 best paper awards (e.g., IEEE Signal Processing Society, INFOCOM, Globecom, and Mobihoc) and 6 industry research awards (from AT&T, CISCO, and META), as well as several faculty and innovation awards. He is currently serving as an Associate Editor at IEEE/ACM Transactions on Networking, a Fellow of National Quantum Lab at UMD (NQL), and the IEEE Region 2 (Eastern US) Chapter Coordinator.

Talk Title: AI/ML for Intelligent Decision-Making in Network Control and Optimization

Abstract: AI/ML has demonstrated tremendous success in many challenging tasks with superhuman performance. It enables a vision of fully “self-driving” networks, which sense the operating environment, learn, reason, manage, and optimize themselves. In this talk, we present some recent research progress on AI/ML-driven networking and focus on several important use-cases of AI/ML technologies in network routing, network prediction/planning, network slice management, and network virtual function orchestration. We also discuss some key challenges in this space, such as the need for explainability, scalability, generalizability and transferability, speed and energy efficiency, and human oversight/feedback.

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Jason Livingood

Vice President of
Technology Policy Product
and Standards

Background: Jason Livingood leads Comcast's technology policy and standards R&D and helps define future products. He is also chair of the board of the IETF Administration LLC, an active IETF & BITAG contributor, and is involved in a wide range of other industry groups. He is currently leading a key project to deliver ultra-low latency network features to end users.

Talk Title: AI & ML Applications in the Comcast Network

Abstract: This talk described how AI and ML is used in Comcast's network today. A key example is the Octave AI platform that was rushed from the lab to production with the onset of COVID work from home changes, which added significant capacity simply by applying AI to smarter spectrum management. Other examples include automating network impairment detection and repair, and even self-healing logic before issues are noticed by end users. These technologies also extend into the home network, optimizing WiFi and applying malware protection and other end user services.

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Balaji Raghothaman

Chief Technologist, 6G
Keysight Technologies

Background: Balaji Raghothaman is currently Chief Technologist, 6G, at Keysight Technologies, where he is shaping the company's 6G technology strategy and roadmapping, and leading key industry and academic collaborations and early proof-of-concepts. Balaji is also active in O-RAN where he is currently co-leader of the Research Platforms stream in the nextG Research Group. Prior to Keysight, Balaji was an Engineering Fellow at Commscope / Airvana.

Talk Title: What do we need to do to ensure fool proof and reliable performance of AI/ML algorithms on wireless networks ?

Abstract: AI/ML approaches are being attempted or postulated across the board in wireless network, from the RF and physical layers to higher layers, as well as throughout the network lifecycle, from planning to deployment to maintenance. Many tangible use cases are in play, such as traffic steering, dynamic spectrum sharing, slice management, beam steering, and energy efficiency, to name just a few. It is necessary to ensure that the AI/ML methods will provide a stable network performance, do not lead to unexpected or catastrophic outcomes in response to outlier stimuli, and will gracefully recover from faults or undesirable scenarios. This talk will focus on the role of proper testing and validation frameworks for AI/ML-infused networks, including the underlying training data sets.

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Athul Prasad

Senior Manager,
Emerging Technologies

Samsung Research America, Inc.

Background: Dr. Athul Prasad is a senior manager within the emerging technologies team at Samsung Research America, leading Samsung's strategy and external engagements. He is also the vice-chair of the AI-RAN alliance working group #3 (AI-on-RAN). Dr. Prasad has led multitude of projects related to 5G machine learning and artificial intelligence for physical and medium access control layers (L1/2) of wireless systems, and was a Nokia delegate to 3GPP RAN1 (radio physical layer) working group on various 5G and 5G-Advanced topics. He received an MBA from Massachusetts Institute of Technology where he was a Sloan Fellow, and doctor of science, D.Sc. (Tech) in electrical engineering from Aalto University.

Talk Title: Key trends in AI and its impact on the future of wireless networking

Abstract: This talk will focus on the latest trends in the field of artificial intelligence (AI) and machine learning (ML) and its implications on wireless network automation. The talk also will cover the implications of AI/ML on power consumption and possible approaches that could mitigate this impact. The implications of AI on the future of wireless networking is significant, especially in terms of its potential to minimize network operational expenses which could maximize the potential for network operators to invest more on network infrastructure assets that enable new revenue monetization opportunities.

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Nakjung Choi, Ph.D.

Distinguished MTS,
Department Head Mobile Network Systems,
Network Systems and Security Research

Nokia Bell Labs

Background: Dr. Nakjung Choi received the BS and PhD degrees from the School of Computer Science and Engineering, Seoul National University, in 2002 and 2009, respectively. He is currently leading MNS (Mobile Network Systems) department in NSSR (Network Systems and Security Research) at Nokia Bell Labs, Murray Hill, USA, and DMTS (Distinguished MTS). Also, he has received several awards such as Best Paper Awards, Awards of Excellence and Edison Patent Award 2024 - Telecommunications. His research is on end-to-end network orchestration and automation, network control cross domains, 5G/5G-A/6G, dynamic network slicing, carrier-grade cloud-native, SDN/NFV, edge/fog computing & networking, and Open Radio Access Network (O-RAN).

Talk Title: Softwarization of Telecommunications - Role of AI/ML for Telecommunications in Representative Use Cases

Abstract: Telecommunications networks are becoming true software systems, implementing both operational functions and management capabilities as a collection of SW modules interworking via application programming interfaces (APIs). The consequences of softwarization and the uptake of AI/ML go beyond pure implementation and network deployment aspects. By using these technologies, telecommunication networks both become and are required to be more flexible, self-organizing and autonomous. They natively use AI for functions and autonomous management. In this talk, we first review industry technology trends, NFV, SDN, Cloud, Network Slicing and O-RAN from a telecommunications perspective, and give some representative use cases to show how AI/ML can contribute to intelligent network management in research and standard areas.

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Mischa Dohler

Vice President,
Emerging Technologies

Ericsson, Inc.

Background: Dr. Mischa Dohler is a Vice President Emerging Technologies at Ericsson Inc. in Silicon Valley, working on cutting-edge topics of 5G/6G, AR and Generative AI. He serves on the Spectrum Advisory Board of Ofcom and on the AI/ML Technical Advisory Committee of the FCC. He is a Fellow of the IEEE, the Royal Academy of Engineering, the Royal Society of Arts (RSA), the Institution of Engineering and Technology (IET); the AP Artificial Intelligence Association (AAIA); and a Distinguished Member of Harvard Square Leaders Excellence. He is a serial entrepreneur with 5 companies; composer & pianist with 5 albums on Spotify/iTunes; and fluent in several languages. He has had ample coverage by national and international press and media and is featured on Amazon Prime. He is a frequent keynote, panel and tutorial speaker, and has received numerous awards. He has pioneered several research fields, contributed to numerous wireless broadband, IoT/M2M and cyber security standards, holds a dozen patents, organized and chaired numerous conferences, was the Editor-in-Chief of two journals, has more than 300 highly-cited publications, and authored several books. He is a Top-1% Cited Innovator across all science fields globally. He was Professor in Wireless Communications at King's College London and Director of the Centre for Telecommunications Research from 2013-2021, driving cross-disciplinary research and innovation in technology, sciences and arts. He is the Cofounder and former CTO of the IoT-pioneering company Worldsensing; cofounder and former CTO of the AI-driven satellite company SiriusInsight.AI, and cofounder of the sustainability company Movingbeans. He also worked as a Senior Researcher at Orange/France Telecom from 2005-2008.

Talk Title: AI/ML in 5G & 6G Networks: Optimizing Performance and Shaping Future Architectures

Abstract: This presentation focuses on the pivotal role of AI/ML in optimizing the performance of 5G and emerging 6G telecom networks. By analyzing network traffic patterns, predicting congestion, and addressing network failures in real-time, AI/ML enhances network efficiency and ensures proactive corrective measures to maintain service quality. We will also explore how AI/ML facilitates seamless integration between heterogeneous access networks and enables dynamic multi-domain interoperability, crucial for next-generation adaptive network slicing. Additionally, we will examine the role of AI and specifically Generative AI in the context of designing novel network architectures and protocols.

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Mérouane Debbah

Professor at Khalifa University of Science and Technology

Background: Mérouane Debbah is Professor at Khalifa University of Science and Technology in Abu Dhabi and founding Director of the KU 6G Research Center. He is a frequent keynote speaker at international events in the field of telecommunication and AI. His research has been lying at the interface of fundamental mathematics, algorithms, statistics, information and communication sciences with a special focus on random matrix theory and learning algorithms. In the Communication field, he has been at the heart of the development of small cells (4G), Massive MIMO (5G) and Large Intelligent Surfaces (6G) technologies. In the AI field, he is known for his work on Large Language Models, distributed AI systems for networks and semantic communications. He received multiple prestigious distinctions, prizes and best paper awards (more than 40 IEEE best paper awards) for his contributions to both fields and according to research.com is ranked as the best scientist in France in the field of Electronics and Electrical Engineering. He is an IEEE Fellow, a WWRF Fellow, a Eurasip Fellow, an AAIA Fellow, an Institut Louis Bachelier Fellow, an AIIA Fellow and a Membre émérite SEE. His recent work led to the development of NOOR (upon it release, largest language model in Arabic) released in 2022, Falcon LLM (upon its release, top ranked open source large language model) released in 2023 and the Falcon Foundation in 2024. The Falcon Model Series and The Falcon Foundation have positioned the UAE as a global leader in the generative AI field. He is actually chair of the IEEE Large Generative AI Models in Telecom (GenAINet) Emerging Technology Initiative and a member of the Marconi Prize Selection Advisory Committee

Talk Title: TelecomGPT: Next Generation AI Telecom Network

Abstract: The evolution of generative artificial intelligence (GenAI) constitutes a turning point in reshaping the future of technology in different aspects. Wireless networks in particular, with the blooming of self-evolving networks, represent a rich field for exploiting GenAI and reaping several benefits that can fundamentally change the way how wireless networks are designed and operated nowadays. To be specific, large language models (LLMs), a subfield of GenAI, are envisioned to open up a new era of autonomous wireless networks, in which a multimodal large model trained over various Telecom data, can be fine-tuned to perform several downstream tasks, eliminating the need for dedicated AI models for each task and paving the way for the realization of artificial general intelligence (AGI)-empowered wireless networks. In this talk, we aim to unfold the opportunities that can be reaped from integrating LLMs into the Telecom domain. In particular, we aim to put a forward-looking vision on a new realm of possibilities and applications of LLMs in future wireless networks, defining directions for designing, training, testing, and deploying Telecom LLMs, and reveal insights on the associated theoretical and practical challenges.

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Appendices

A.2 FCC Strategic Goals

FCC Strategic Goals

- Pursue a “100 Percent” Broadband Policy: The COVID-19 pandemic put a spotlight on the serious broadband gaps that exist across the country, including in rural infrastructure, affordability for low-income Americans, and at-home access for students. This continuing digital divide means millions of Americans do not have meaningful access to essential infrastructure for 21st century success. In response to the COVID-19 pandemic and the challenges that many Americans face, the agency should advance access to communications that are essential for Americans to work remotely, learn remotely, receive healthcare, and engage in commerce. To this end, the FCC will pursue policies to help bring affordable, reliable, high-speed broadband to 100 percent of the country.

- Promote Diversity, Equity, Inclusion and Accessibility: The FCC will seek to gain a deeper understanding of how the agency’s rules, policies, and programs may promote or inhibit advances in diversity, equity, inclusion, and accessibility. The FCC will pursue focused action and investments to eliminate historical, systemic, and structural barriers that perpetuate disadvantaged or underserved individuals and communities. In so doing, the FCC will work to ensure equitable and inclusive access and facilitate the ability of underserved individuals and communities to leverage and benefit from the wide range of opportunities made possible by digital technologies, media, communication services, and next-generation networks. In addition, the FCC recognizes that it is more effective when its workforce reflects the experience, judgement, and input of individuals from many different backgrounds. Advancing equity is core to the agency’s management and policymaking processes and will benefit all Americans.

FCC Strategic Goals

- Empower Consumers: Consumers who are well informed about their rights and what they're buying are more confident and more likely to participate in the digital economy. The FCC will tackle new challenges to consumer rights and opportunities stemming from the COVID-19 pandemic, plans for post-COVID recovery, and digital transitions. The FCC also will pursue effective enforcement and new approaches to protect consumers from unwanted and intrusive communications, phone-based scams, telephone privacy issues, and other trends that affect consumers. The FCC will work to enhance competition and pursue policies that protect the competitive process to improve consumer choice and access to information. The FCC will work to foster a regulatory landscape that fosters media competition, diversity, and localism. The FCC also must work to ensure the availability of quality, functionally equivalent communications services for persons with disabilities

- Enhance Public Safety and National Security: The FCC will pursue policies to promote the availability of secure, reliable, interoperable, redundant, and rapidly restorable critical communications infrastructure and services. The FCC also will promote the public's access to reliable 911 and emergency alerting and support public safety's access to first responder communications. The FCC will work in coordination with Federal and state, local, Tribal, and territorial government partners and industry stakeholders to support disaster response and to ensure the nation's defense and homeland security.

FCC Strategic Goals

• Advance America's Global Competitiveness: The FCC will take action to promote investment and advance the development and deployment of new communications technologies, such as 5G, that will allow the nation to remain a global leader in an increasingly competitive, international marketplace. The FCC will identify incentives and policies to close security gaps and accelerate trustworthy innovation. The FCC will work with its federal partners to advocate for U.S. interests abroad.

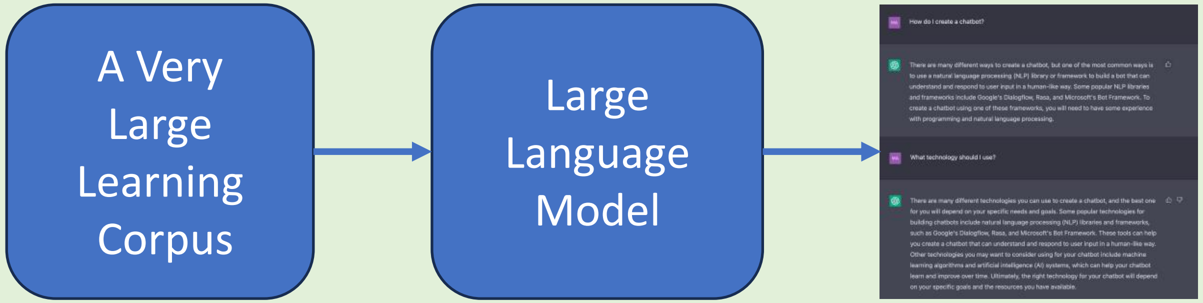
• Foster Operational Excellence: The FCC should be a model for excellence in government by effectively managing its resources, maintaining a commitment to transparent and responsive processes that encourage public involvement and decision-making that best serves the public interest, and encouraging a culture of collaboration both internally and across government agencies.

Appendices

A.3 Creating an LLM for Telecommunications

LLM Basics

Large Language Models (LLMs) are AI systems designed to understand and generate human-like text based on vast amounts of data.



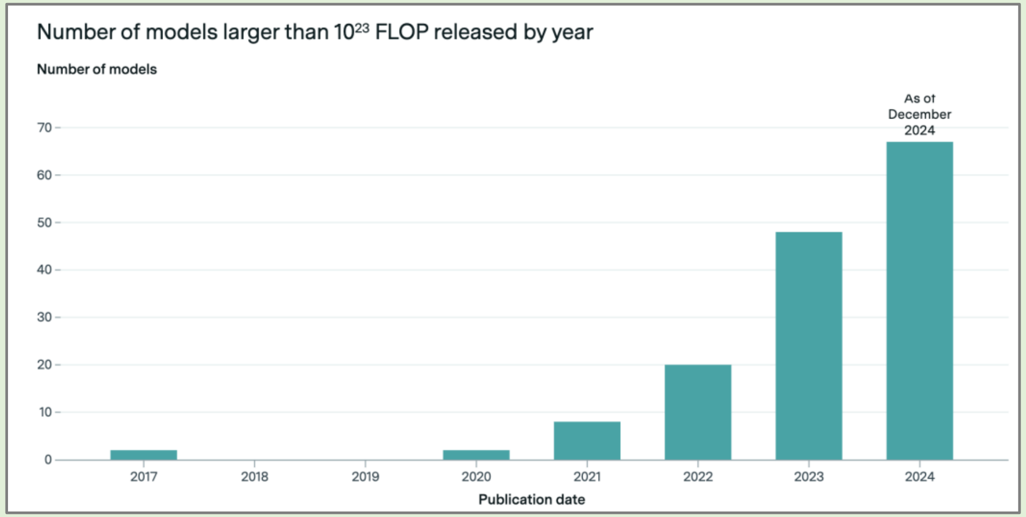
Common Steps:

1. Input Encoding
2. Model Architecture
3. Training Process:
4. Fine-Tuning
5. Output Generation

Examples:
Decoder-only models (GPT-x models)
Encoder-only models (BERT, RoBERTa, ELECTRA)
Encoder-decoder models (T5, BART)

The Growth of LLM is Accelerating

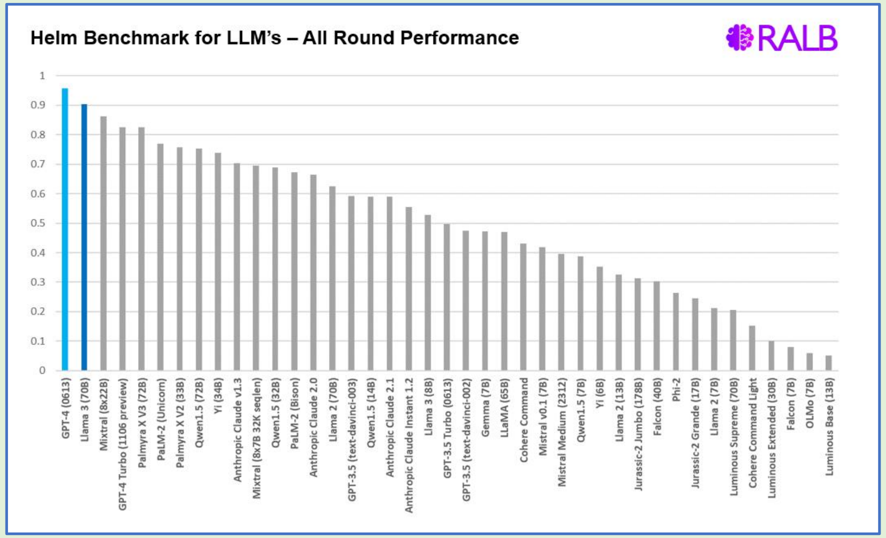
- **As AI investment increases, we are seeing an exponential growth of LLMs**
  - In 2017, only two models exceeded 10^{23} FLOP in training compute;
  - By 2020, this grew to 4 models;
  - By 2022, there were 32 models,
  - By 2024, there were 147 models.
- **U.S. companies contribute the greatest number of LLMs.**
  - Over half of known large-scale models were developed in the United States.
  - A quarter were developed in China, and this proportion has been growing in recent years.
  - The European Union trails them with 16 models, while the United Kingdom has developed 18.
- **More than half of LLMs are publicly available.**
  - 55 large-scale models have downloadable weights.

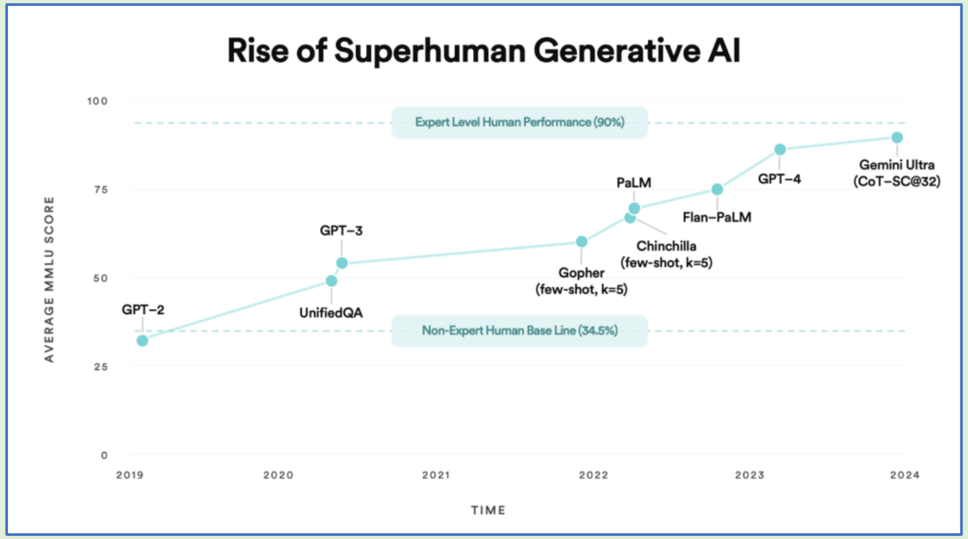


Source: epoch.AI https://epoch.ai/data/large-scale-ai-models

Achieving Superhuman Performance in Many Tasks

LLMs have demonstrated super-human performance in many challenging tasks, quickly approaching expert-level human performance.





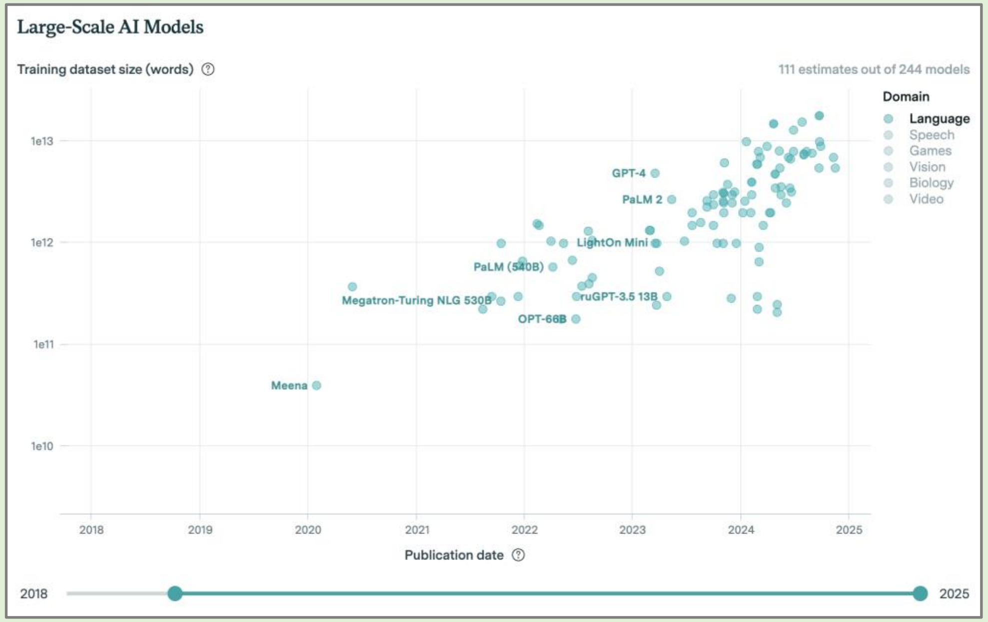
Source: ralb.ai
https://www.linkedin.com/pulse/comparing-giants-look-llm-performance-benchmarks-gaurav-kumar-3s90c/

Source: Foundation Capital.
https://foundationcapital.com/why-2024-will-be-the-year-of-inference/

What Makes LLMs Work

- Emergent properties from model scale (100+ billion parameters)
- Training with massive amounts of data

Growth of number of model parameters

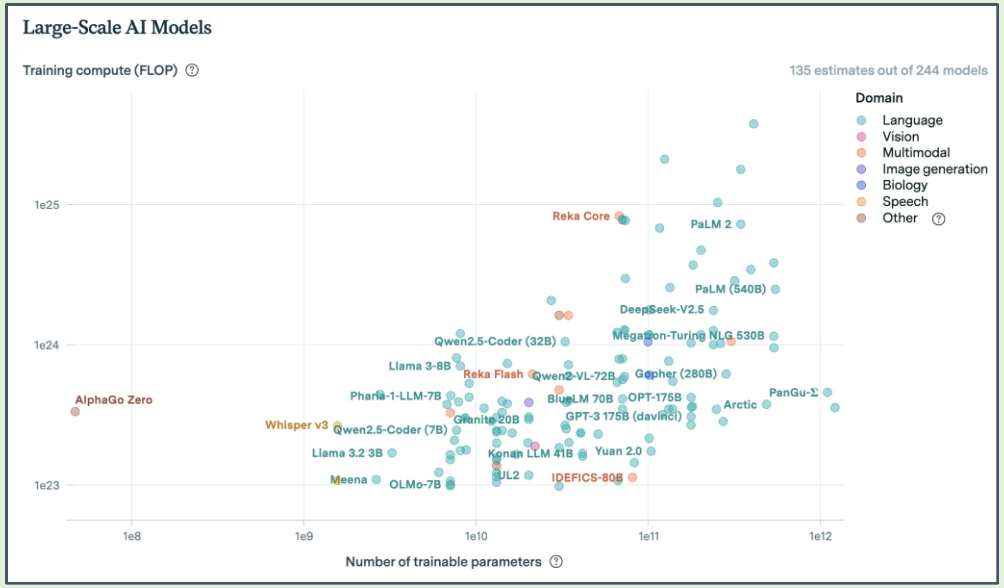


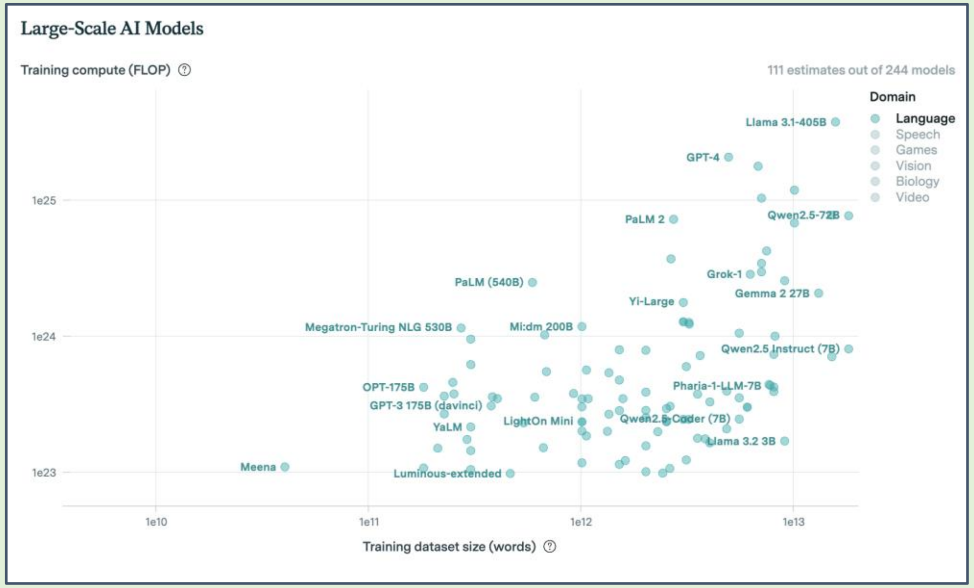
Growth of size of training dataset

Source: epoch.AI https://epoch.ai/data/large-scale-ai-models

High Cost of Developing LLMs

- Large model size and large datasets imply large compute, expensive inference, and costly training.





Compute (FLOPs) vs. LLM model size

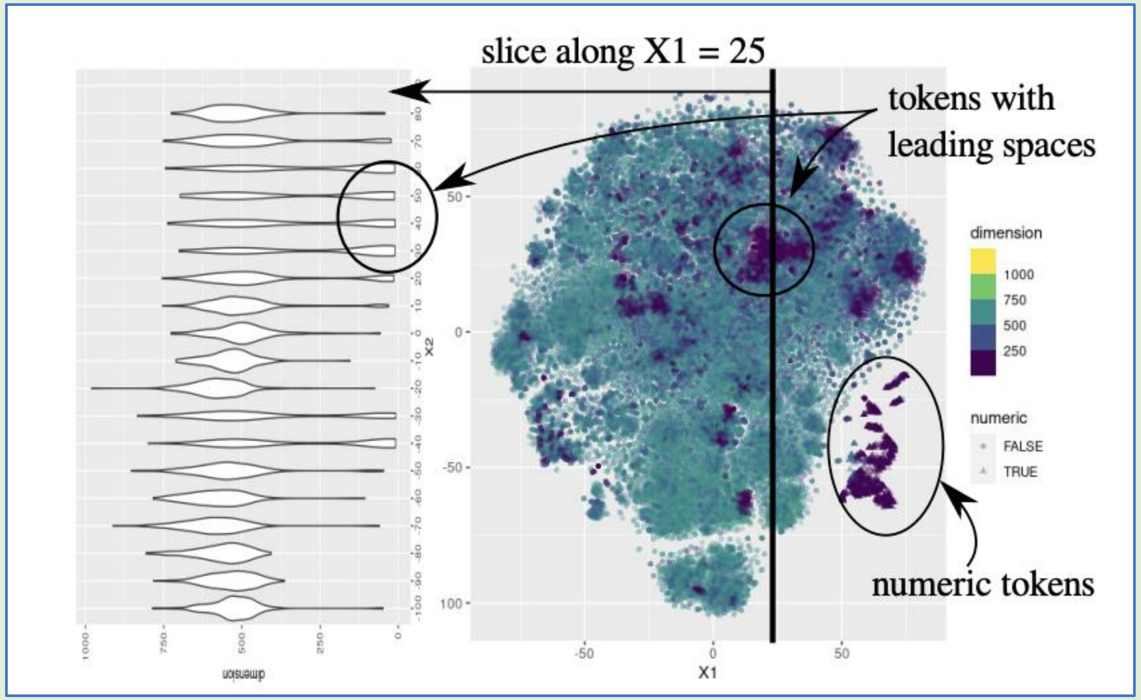
Compute (FLOPs) vs. dataset size

Takeaway: These result in a small number of very powerful foundational LLMs today.

Source: epoch.AI https://epoch.ai/data/large-scale-ai-models

The Rise of Domain-Specific LLMs

- Generalist LLM are proficient in a vast variety of tasks.
- For any specific domain, the generation is often based on a much smaller subset of the training data.
- Recent theories on LLM have shown that the relevant tokens for a specific domain (like math) are often concentrated on isolated "islands".
- Domain-specific LLMs can offer:
  - Lexical Specificity
  - Contextual Nuances
  - Conceptual Depth of Domain Specific Knowledge
  - Data Rarity
  - Specialized Inference

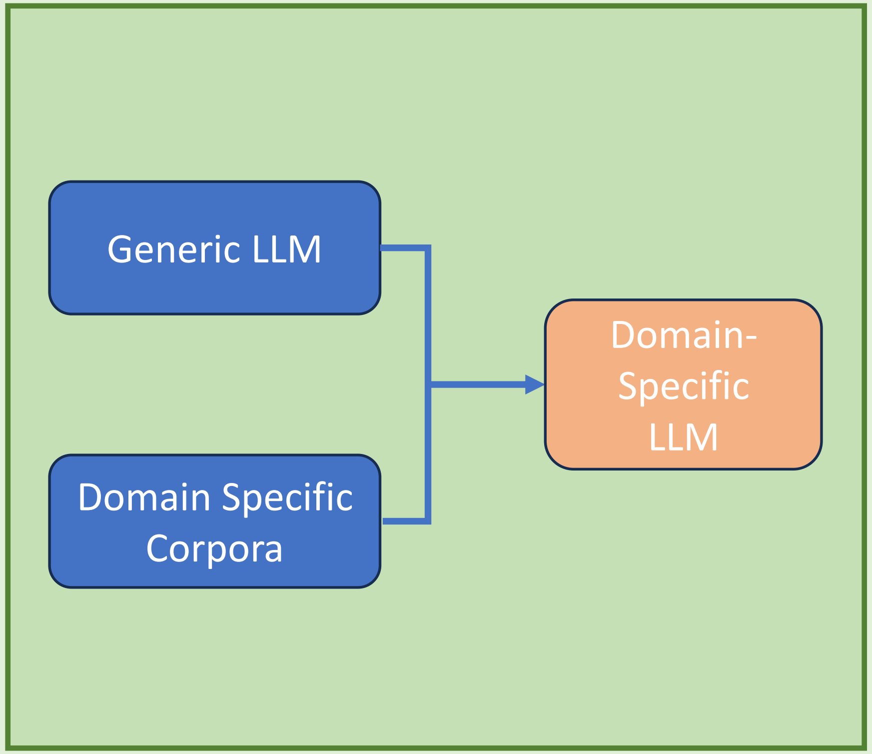


Estimated local dimension for GPT2.
Numeric tokens are all in an isolated "Strata".
Source: The structure of the token space for LLM.
https://arxiv.org/pdf/2410.08993

The Rise of Domain-Specific LLMs

Domain-specific LLMs have:

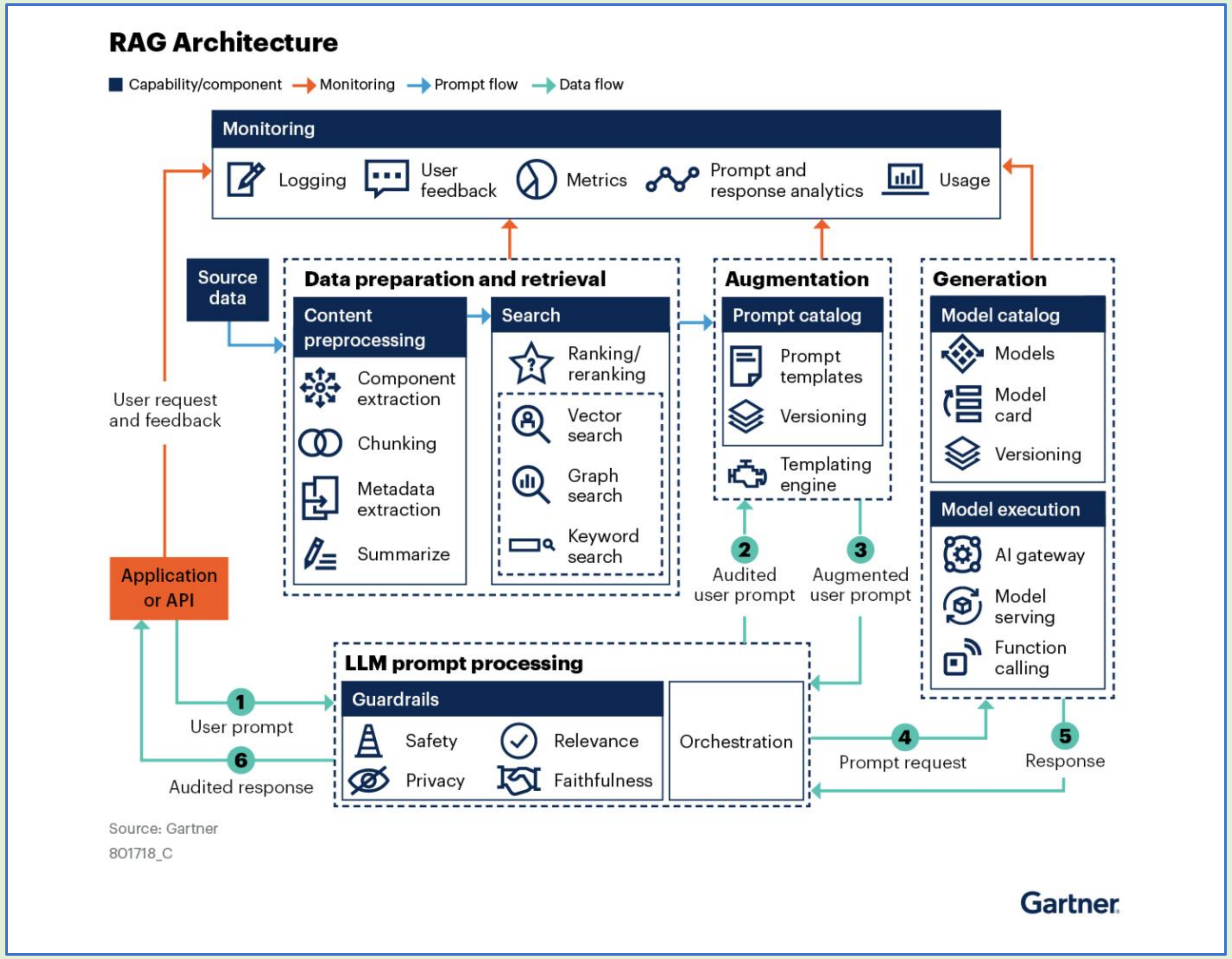
- Specialized understanding of terminology related to specific use cases.
  - e.g., better understanding of terminologies and concepts in specific context.
- Better privacy for domain-specific data.
  - e.g., patient data in healthcare, driver data in transportation, user data in telecom.
- Fewer hallucination problems.
  - i.e., significantly better performance on field-specific benchmarks.



The Rise of Domain-Specific LLMs

- RAG is an architecture for improving LLM response accuracy. Discover advancements that inject structured and unstructured data into LLMs for more accurate results.

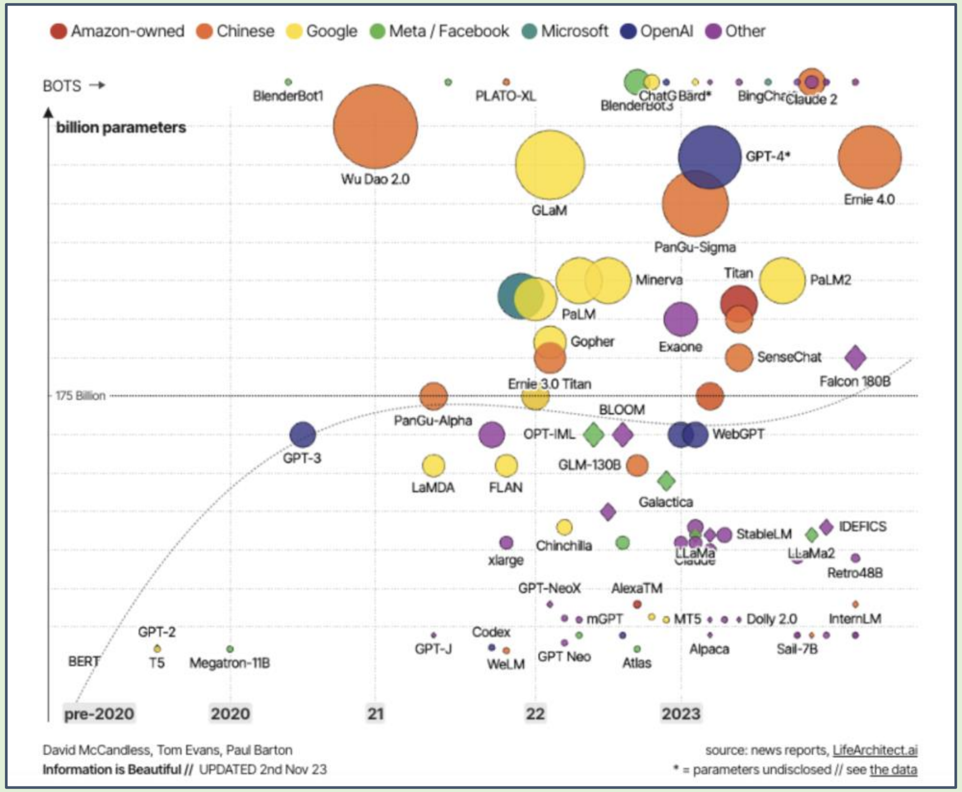
Auto-generating reliable responses to user queries – based on an organization's private information and data – remains an elusive goal for enterprises looking to generate value from their generative AI apps. Sure, technologies like machine translation and abstractive summarization can break down language barriers and lead to some satisfying interactions, but, overall, generating an accurate and reliable response is still a significant challenge.



Source: https://www.gartner.com/en/documents/5354963

Examples of Domain-specific LLMs

Considerable recent investment and growth in domain-specific LLMs, leading to transformative impacts on many fields.



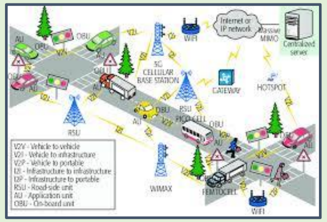
LLMs	Domain	Data	Training Method
MedPaLM2 [26]	Medical	Multiple Med QnA Datasets	Supervised Fine-Tuning (SFT)
ChemLLM [27]	Chemistry	Scientific Publications	Two-stage SFT
BloombergGPT [28]	Finance	Financial + General	Pre-training
FinGPT [15]–[19], [29]	Finance	Financial	SFT+ RAG
Xuanyuan [30]	Finance	Finance + General	Continue Pretrain + Hybird Tuning
BioGPT [31]	Biology	PubMed	Pre-training
BioMistral [32]	Biology	PMC Open Access Subset	Continue Pretrain + SFT
ChatLaw [23]	Legal	Chinese Legal Documents	SFT + RAG
SaulLM [24]	Legal	Legal Documents	Continue Pretrain + SFT
Galactica [33]	Science	Scientific Documents	Prompt Pre-training
Mozi [34]	Science	RedPajama [35] Arxiv	SFT + RAG
Llema [36]	Math	Proof-Pile-2	Continue Pretrain
WizardMath [20]	Math	GSM8k [21] + MATH [22]	SFT + RLEIF [20]
DeepSeek Math [37]	Math	DeepSeek Math Corpus	Continue Pretrain + SFT + RLHF
StarCoder 2 [38]	Code	The Stack 2 [38]	Fill-In-the-Middle (FIM) [39]
Code Llama [25]	Code	Proprietary	Continue Pretrain + FIM + SFT
Codestral [40]	Code	Proprietary	Pre-training
TelecomGPT	*Telecom*	*Public Telecom Documents*	*Continue Pretrain + SFT + DPO [41]*

Source: TelecomGPT: A Framework to Build Telecom-Specific Large Language Models. Zou et al. https://arxiv.org/pdf/2407.09424

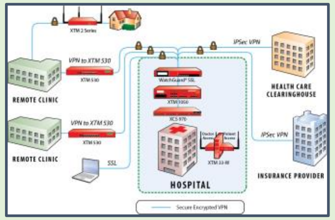
Summary: Recent exponential growth of domain-specific LLMs.

Opportunities of Telecom LLM

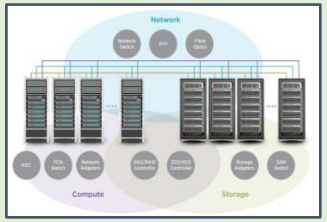
Vehicular Network



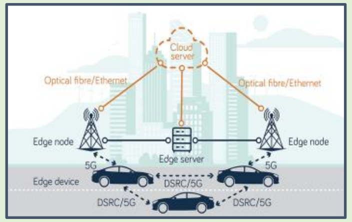
Healthcare



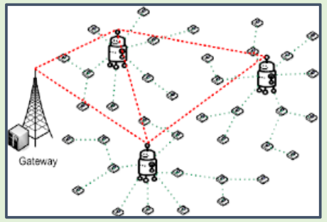
Cloud Network



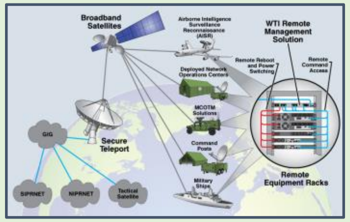
Edge Network



Sensor Network



Military Network



Network Representations and CSP data

Telecom LLM

Potential Capabilities

Generation problems in Telecom

- Telecom domain question answering
- Test-case generation
- Automated network configuration
- Recommendation for troubleshooting
- Code generation and refactoring

Classification problems in Telecom

- Network intrusion/attack detection and classification.
- Network event/state classification
- Network traffic classification
- User feedback analysis

Optimization problems in Telecom

- LLM-aided reward function design
- Human-in-the-loop reinforcement learning for network control
- LLM-based protocol design
- LLM-based planning and optimization

Prediction problems in Telecom

- Network event/state forecasting using pre-trained LLMs
- Network demand forecasting
- Multi-modality LLMs for prediction

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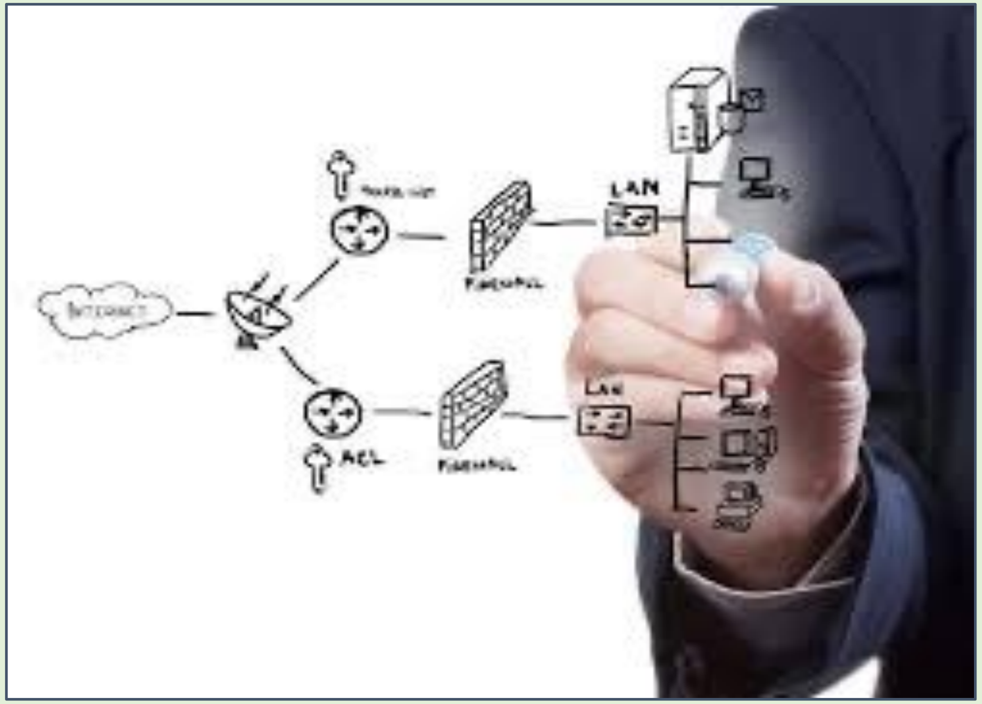
Potential Application Area #1

Telecom LLMs can facilitate network construction, improve network design, and optimize network operation and performance.



Examples:

- Network topology synthesis
- Automated network configuration.
- Learning-based traffic engineering.
- Network code generation and refactoring.
- LLM-based protocol design.
- Human-in-the-loop learning for network control.
- LLM-based planning and optimization.
- Network event/state forecasting using pre-trained LLMs.

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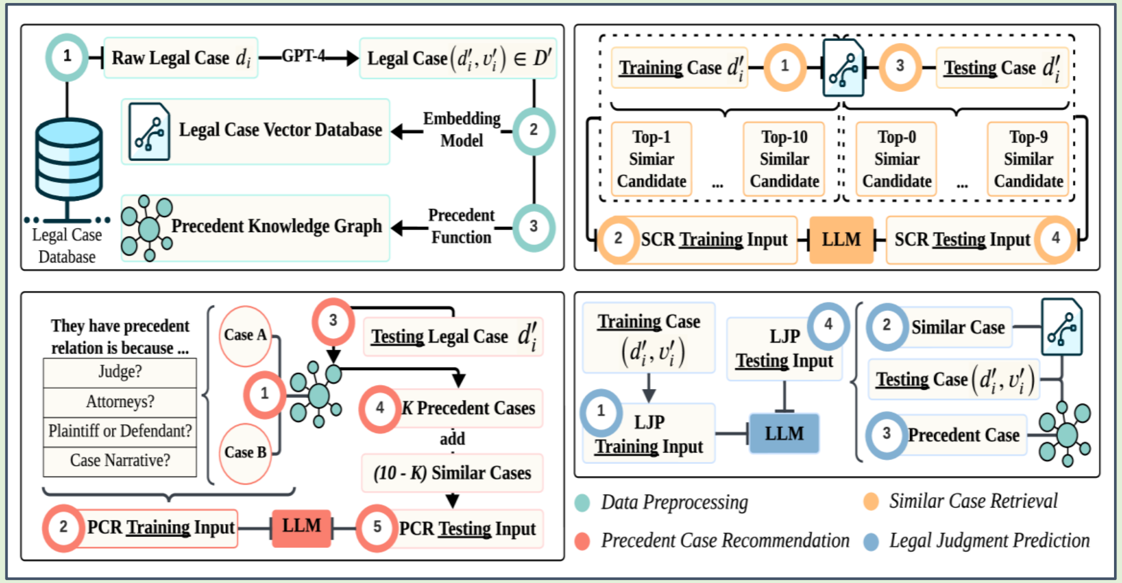
Potential Application Area #2

Telecom LLMs can support and automate many tasks related to network administration, regulation, and litigation.



Source: LawLLM: Law Large Language Model for the US Legal System

Examples:

- Telecom Q&A.
- Recommendations for trouble-shooting.
- Test-case generation.
- Compliance verification.
- Knowledge map for telecom rules and policies.
- Telecom document processing.
- Customer assistance and services.
- Litigation and legal reasoning.
- Generating policy and administration recommendations.

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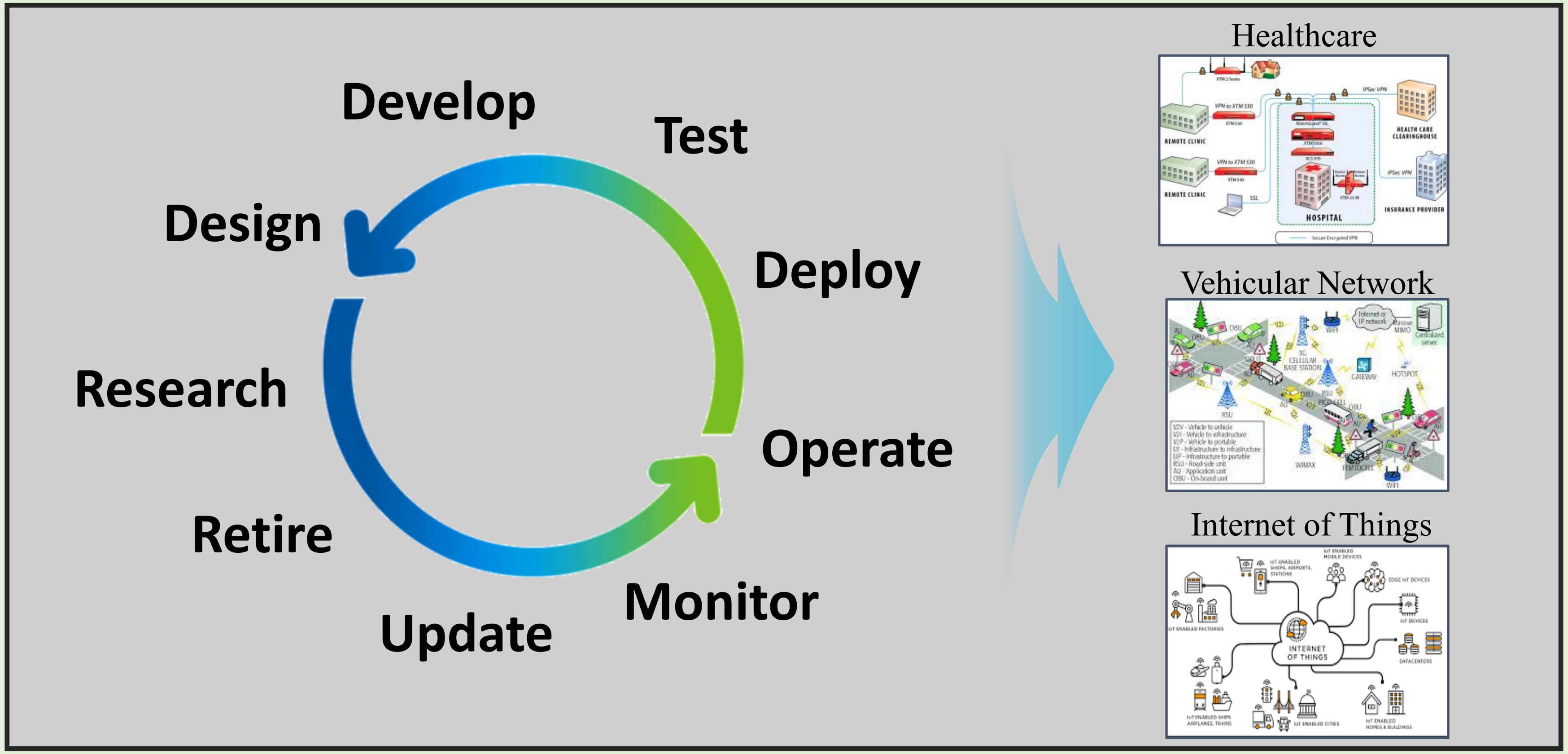
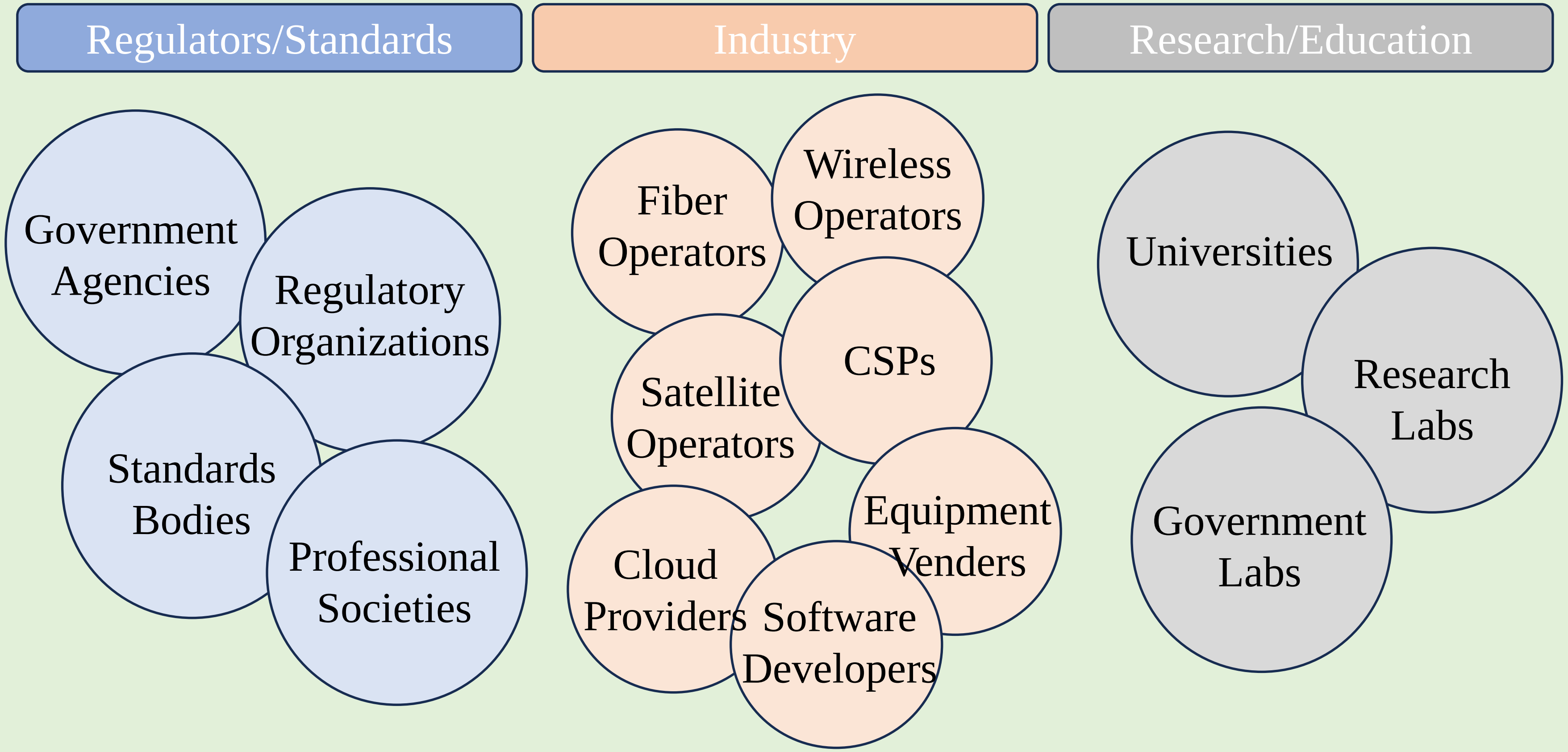
Potential Application Area #3

Telecom LLMs can support various downstream applications from smart healthcare to intelligent transportations throughout their lifecycle.



Telecom Ecosystem

- Telecom LLMs will transform many areas of the telecom ecosystem.



Takeaway: Building telecom LLMs requires a roadmap through collaboration of all stakeholders.

Trends and Status of Telecom LLMs

Operators and AI partners are forming alliance to build telecom LLMs

- Developing industry-specific LLMs equipped with comprehensive understanding of product range.
- Providing new services to telecom customers by identify novel use-cases.

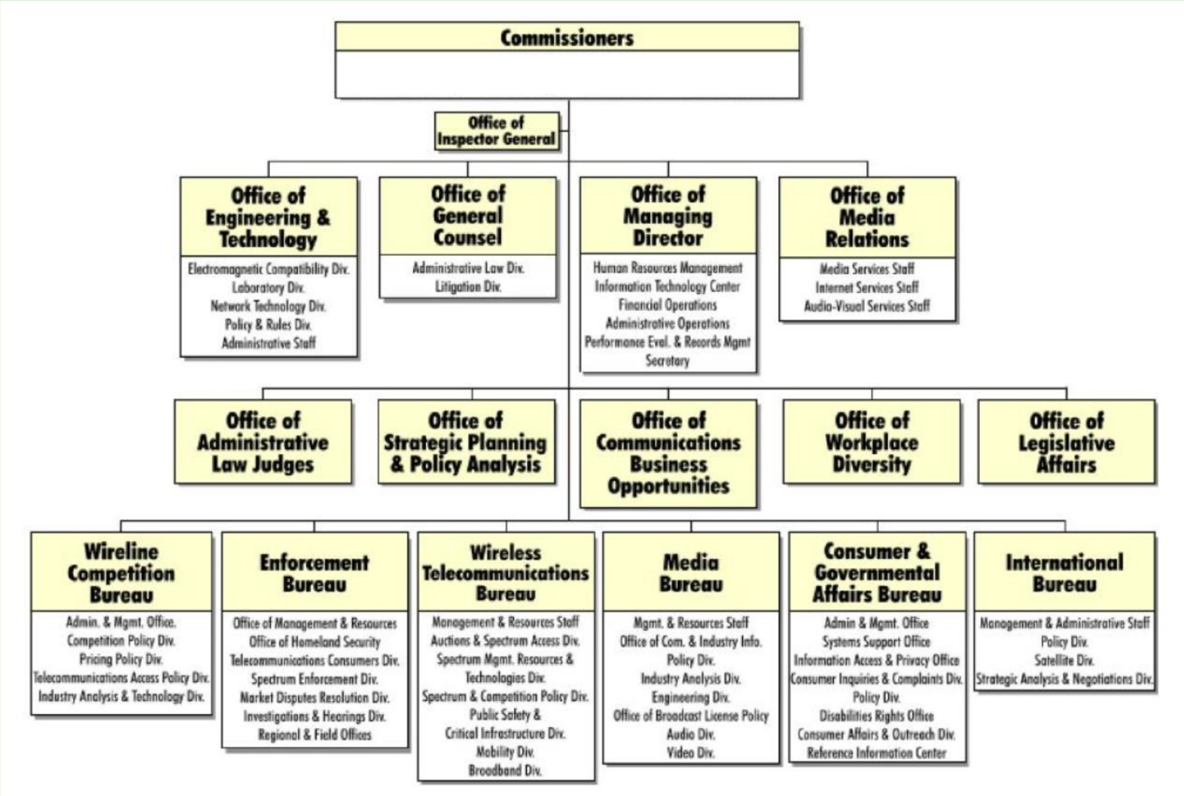
Operators and Partners	Contents
SKT, Anthropic	AI startup Anthropic gets $100M to build custom LLM for telecom industry
Global Telco AI Alliance: SKT, Singtel, e&, Deutsche Telekom, SoftBank.	Global Telco AI Alliance Founding Parties Sign Agreement to establish a Joint Venture Focused on Co-developing and Launching a Multilingual Telco LLM
Ericson	Adopting neural language models for the telecom domain
AT&T, Unsupervised	AT&T sees $100 million in telco AI 'opportunities'
Verizon	Verizon unveils new AI tools to transform customer experience
Amazon	Tele-LLMs: A Series of Specialized Large Language Models for Telecommunications

Summary: Telecom already generates big volumes of high-quality data. The advancement of LLM techniques offers promising opportunities to train on such data and to automate many tasks in the telecom field.

Telecom LLM for FCC

Telecom LLMs can support support the responsibilities of many FCC offices.

Summary: Developing various domain-specific LLMs and training them on specific datasets can support the responsibilities of many FCC offices.

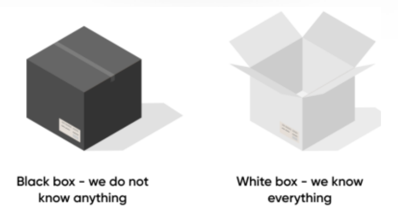


Source: The Federal Communications Commission: Current Structure and its Role in the Changing Telecommunications Landscape, 2017. Link

Future Opportunities

- Future telecom LLMs need to address a number of notable challenges, to improve their applicability to telecom problems that may impact critical infrastructures and large-scale applications.

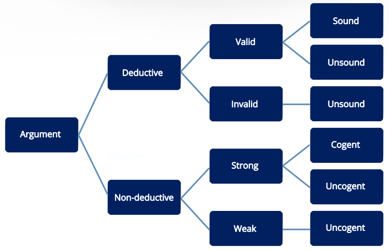
Explainability



Explainable artificial intelligence (XAI)

Uncertainty Quantification

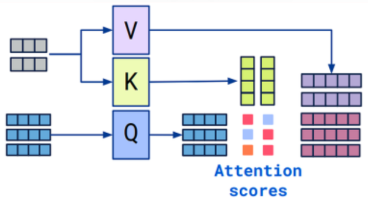
Expressive Reasoning



Neuro-symbolic AI

Chain of thought (CoT)

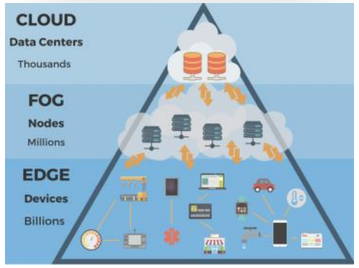
Post-attention Architectures



State Space Models (SSM)

Mixture of Experts (MoE)

Pushing LLM to Network Edge



Sparse Models

Knowledge Distillation

Model Pruning

Takeaway: Many exciting opportunities ahead of us!

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- Tele-LLMs: A Series of Specialized Large Language Models for Telecommunications. Maatouk et al. https://arxiv.org/pdf/2409.05314
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- Large Language Models for Telecom: Forthcoming Impact on the Industry. Maatouk et al. https://arxiv.org/pdf/2409.05314
- Large Language Model (LLM) for Telecommunications: A Comprehensive Survey on Principles, Key Techniques, and Opportunities. Zhou et al. https://arxiv.org/pdf/2405.10825
- SK Telecom and Deutsche Telekom develop LLM for telcos. https://www.telekom.com/en/media/media-information/archive/sk-telecom-and-deutsche-telekom-to-jointly-develop-llm-1051746
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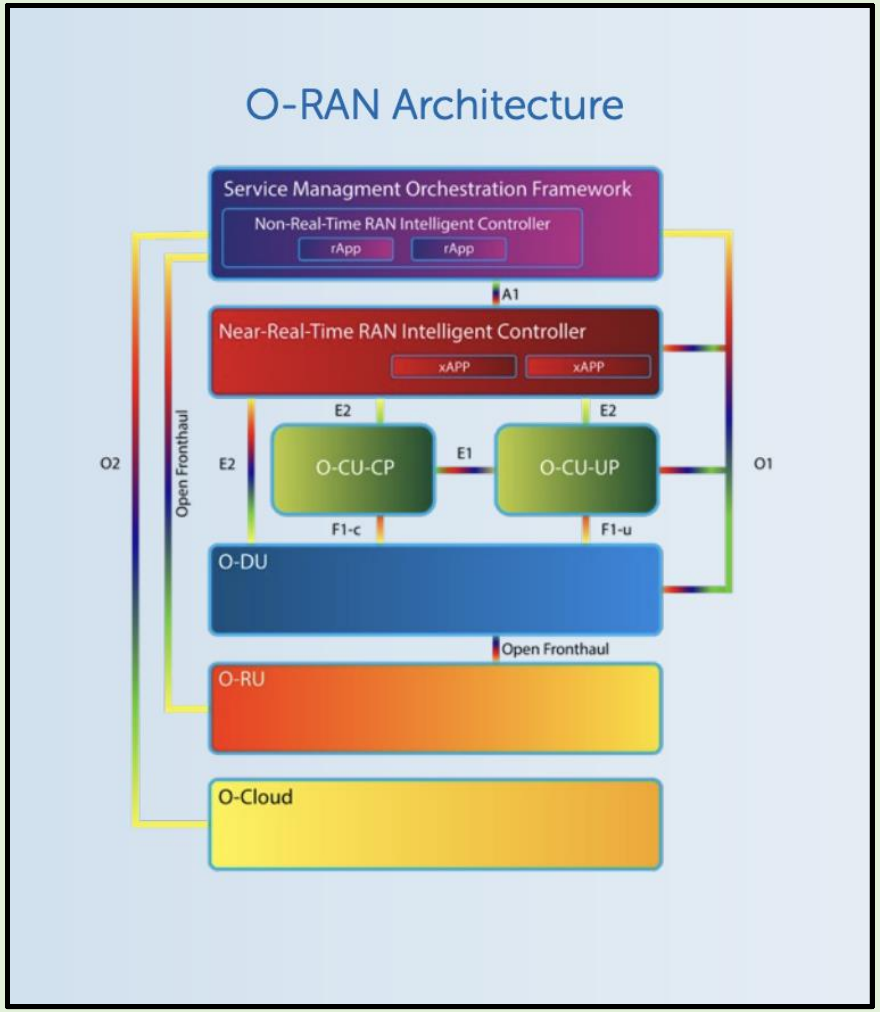
- A brief introduction to (large) language models. Sachin Kumar. https://courses.cs.washington.edu/courses/cse473/23au/slides/473-LMs.pdf
- Data insights. epoch.AI. https://epoch.ai/data/large-scale-ai-models
- Understanding Large Language Models: Foundations and Safety. Dawn Song and Dan Hendrycks. https://rdi.berkeley.edu/understanding_llms/s24
- What is Domain-specific LLM? https://aisera.com/blog/domain-specific-llm/#:~:text=A%20Domain%2Dspecific%20LLM%20is,Generic%20LLMs%20in%20specialized%20fields.

Appendices

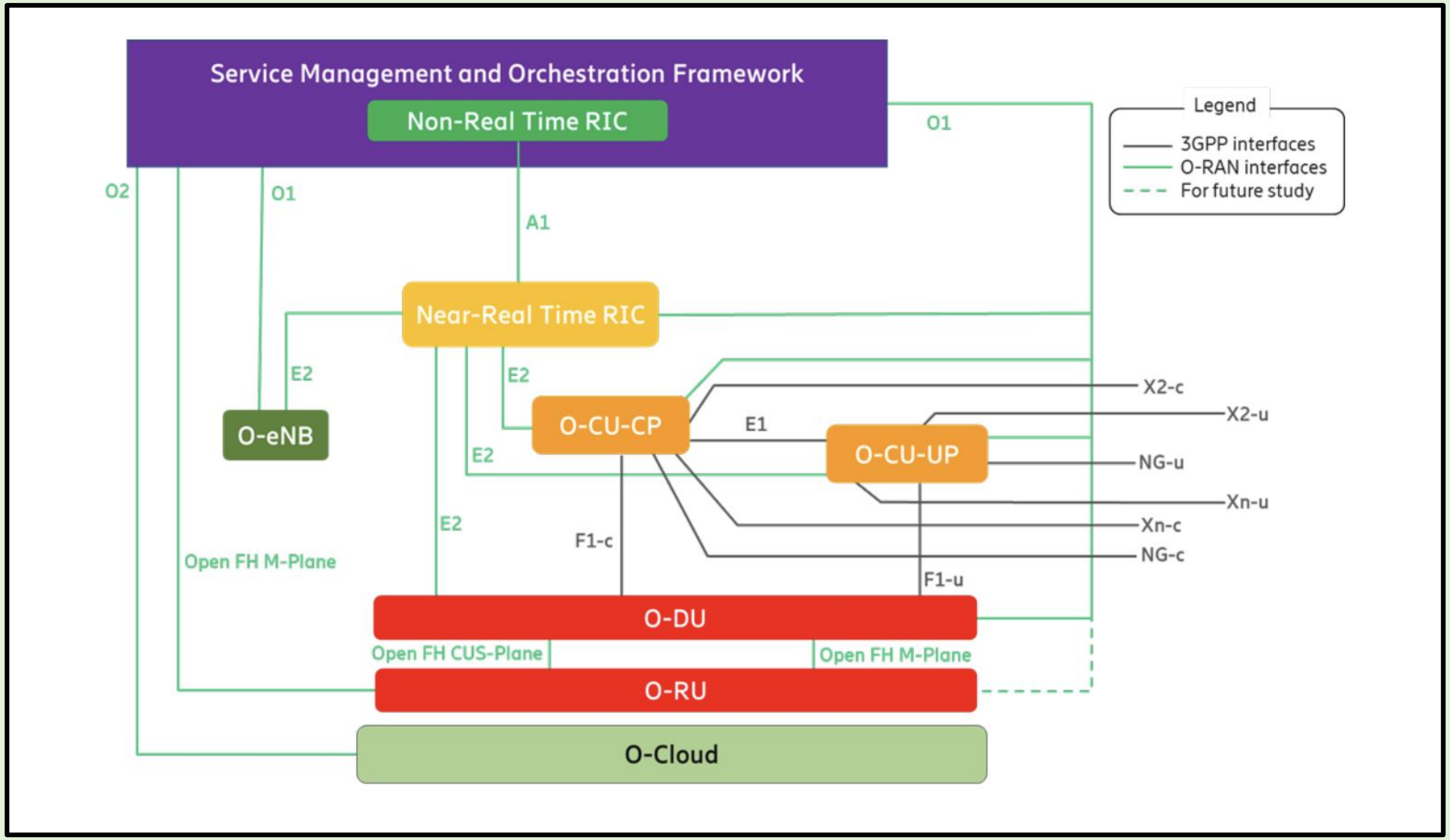
A.4 An Example: AI/ML Open – RAN (Radio Access Network)

Open RAN and AI



Source: https://public.o-ran.org/display/NGRG/Introduction

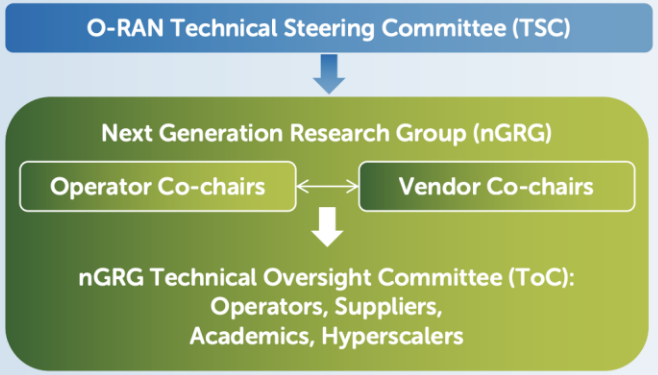
Open RAN and AI



Open RAN and AI

O-RAN Next Generation Research Group (nGRG) Structure and Research Streams

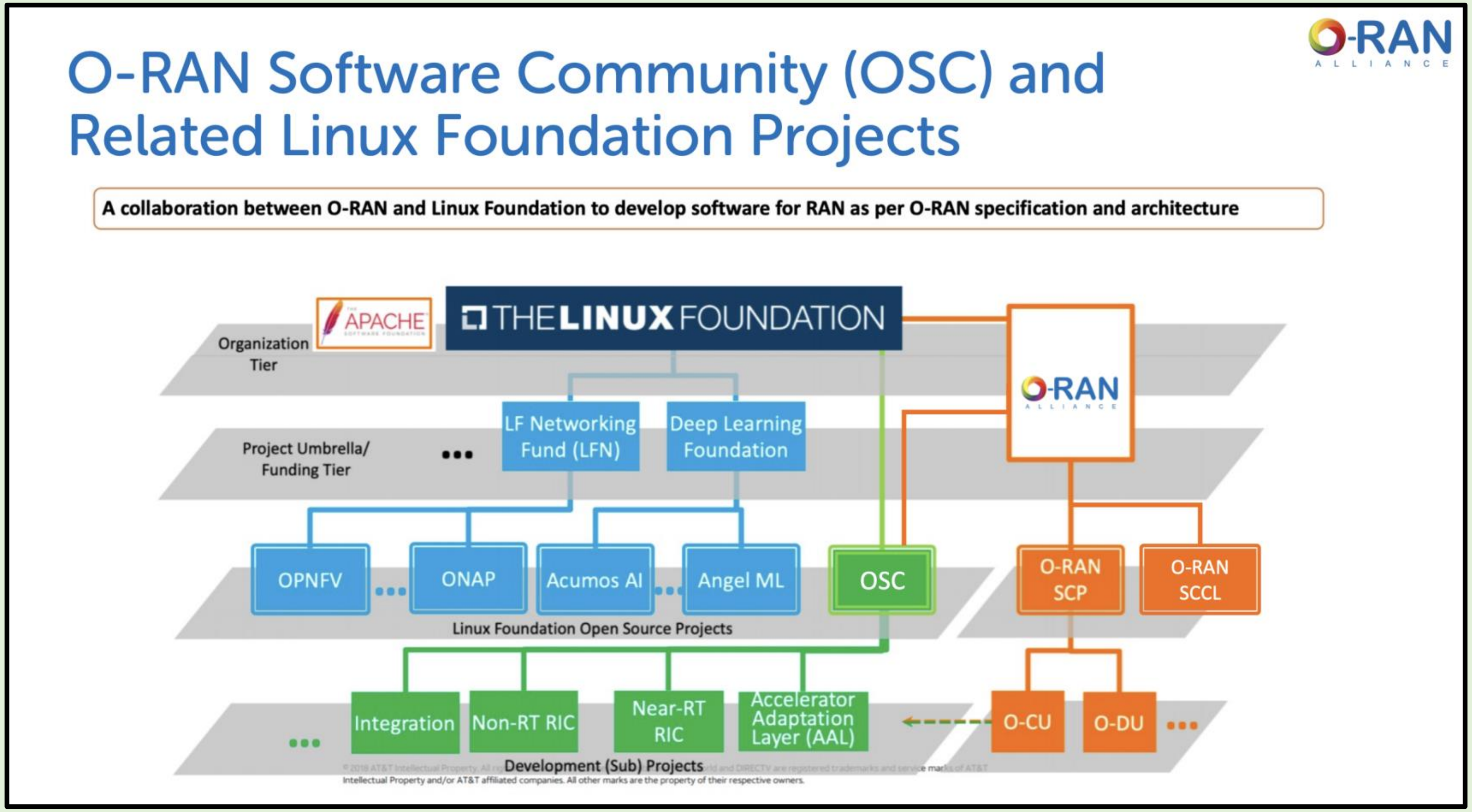
The nGRG focuses on research of open and intelligent RAN principles in 6G and future network standards



	Research Streams
RS01	6G use cases and standard gap analysis
RS02	Architecture towards 6G O-RAN
RS03	Native AI and cross domain AI
RS04	Native security
RS08	nG Research Platform

Source: https://public.o-ran.org/display/NGRG/Introduction

Open RAN and AI



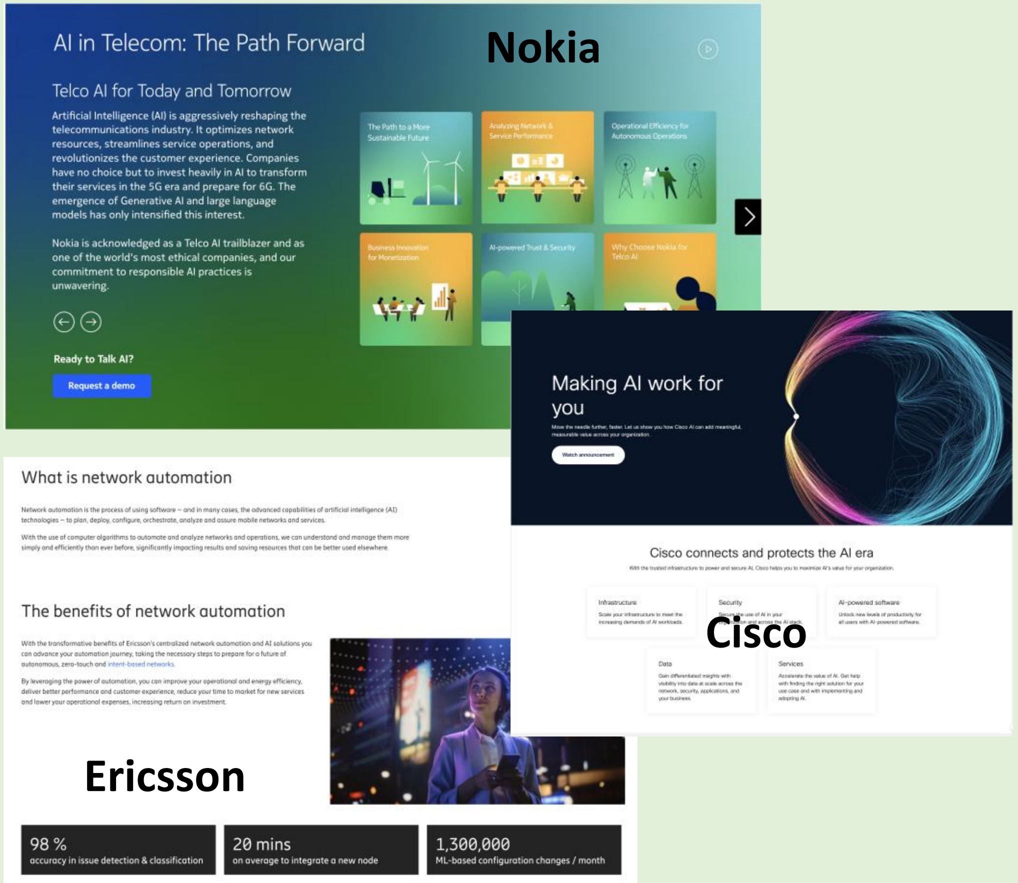
Source: https://public.o-ran.org/display/NGRG/Introduction

Appendices

A.5 Propagation Models and AI for Spectrum Sharing

Spectrum Sharing - Digital Twins and Propagation Modeling

1. Propagation Models and AI for Spectrum Sharing (Part of Bucket 1)



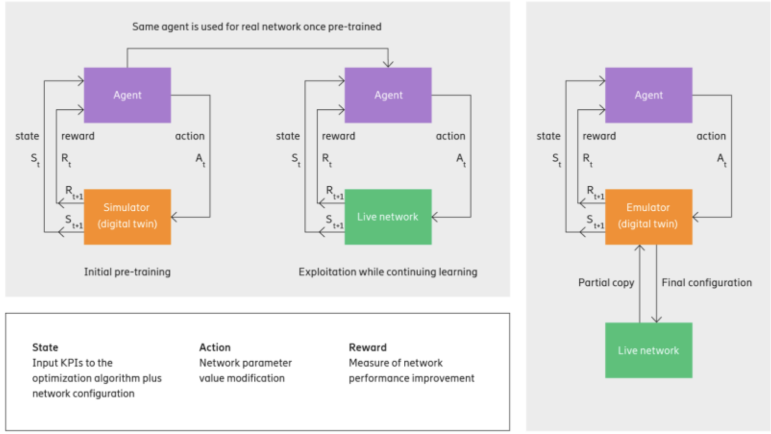


Figure 25: Live networks using simulators and emulators as digital twins

Ericsson

Digital twins enabling rewards from first implementation

Digital twins are a suitable solution to avoid the effects of erratic initial explorations on live mobile networks. Exploration is performed on an external entity that mimics the behavior of the live network. Once the agent has acquired all the necessary knowledge from the digital twin, the achieved policy can be safely applied to the live network. From that moment onwards, the agent will decide optimal actions on the live network, while continuing to learn from its feedback and also allowing a configurable degree of controlled exploration.

Typically, two types of digital twins can be considered for initial offline learning: emulators and simulators, as shown in Figure 25. An emulator contains a partial replica of the live network, providing accurate results but requiring big data techniques for efficient operations. A simulator is a software program that models the behavior of a network based on a set of hypothetical scenarios. In many cases, simulators are suitable to capture general trade-offs and trends.

1. Propagation Models and AI for Spectrum Sharing (Part of Bucket 1)

UTE Nomadic
SP Sensors
TP Sensors
OSU Tech 1
OSU Tech 2
OSU Tech 3

CP Network

UTE Mobile
SP1 Node 1
SP1 Node 2
SP1 Node 3
SP1 Node ....
SP1 Node N

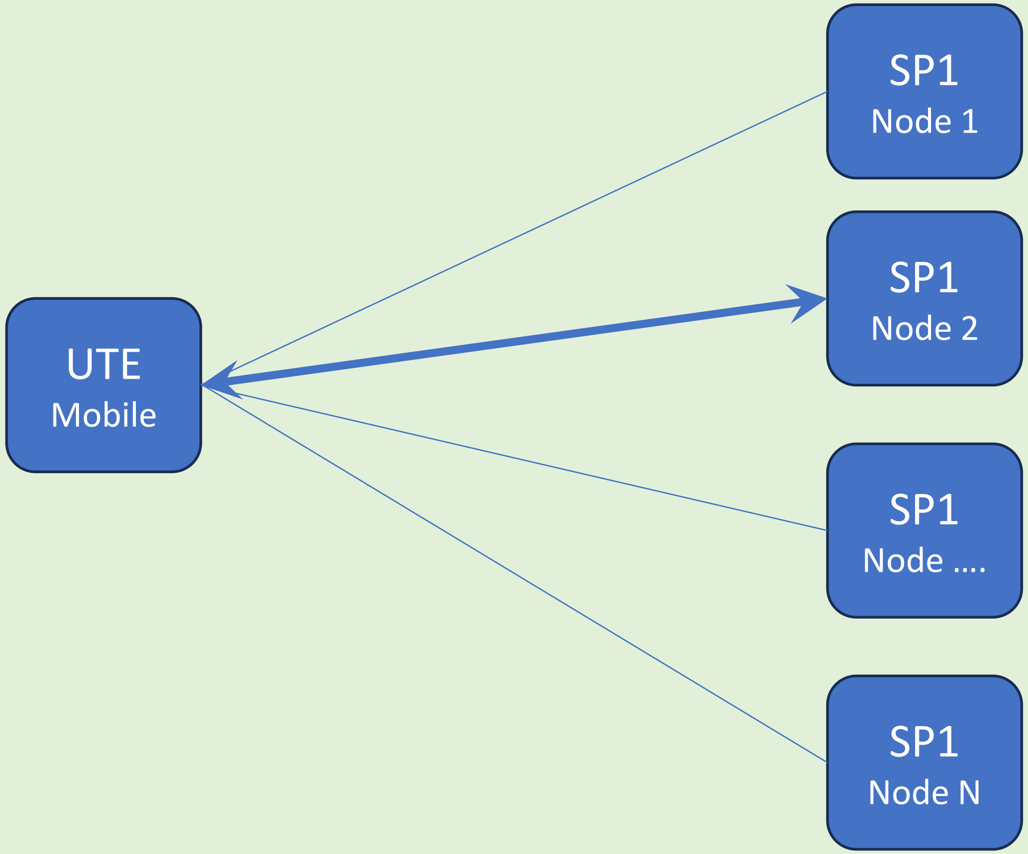
UTE Fixed
SP2 Node 1
SP2 Node 2

CPE Fixed
PSU
PSU

CP	Consumer/Customer Premise
OSU	Other Spectrum User
PNU	Private Network User
PSU	Protected Spectrum User
SP	Service Provider
TP	Third Party
UTE	User Terminal Equipment

Spectrum Sharing - Digital Twins and Propagation Modeling

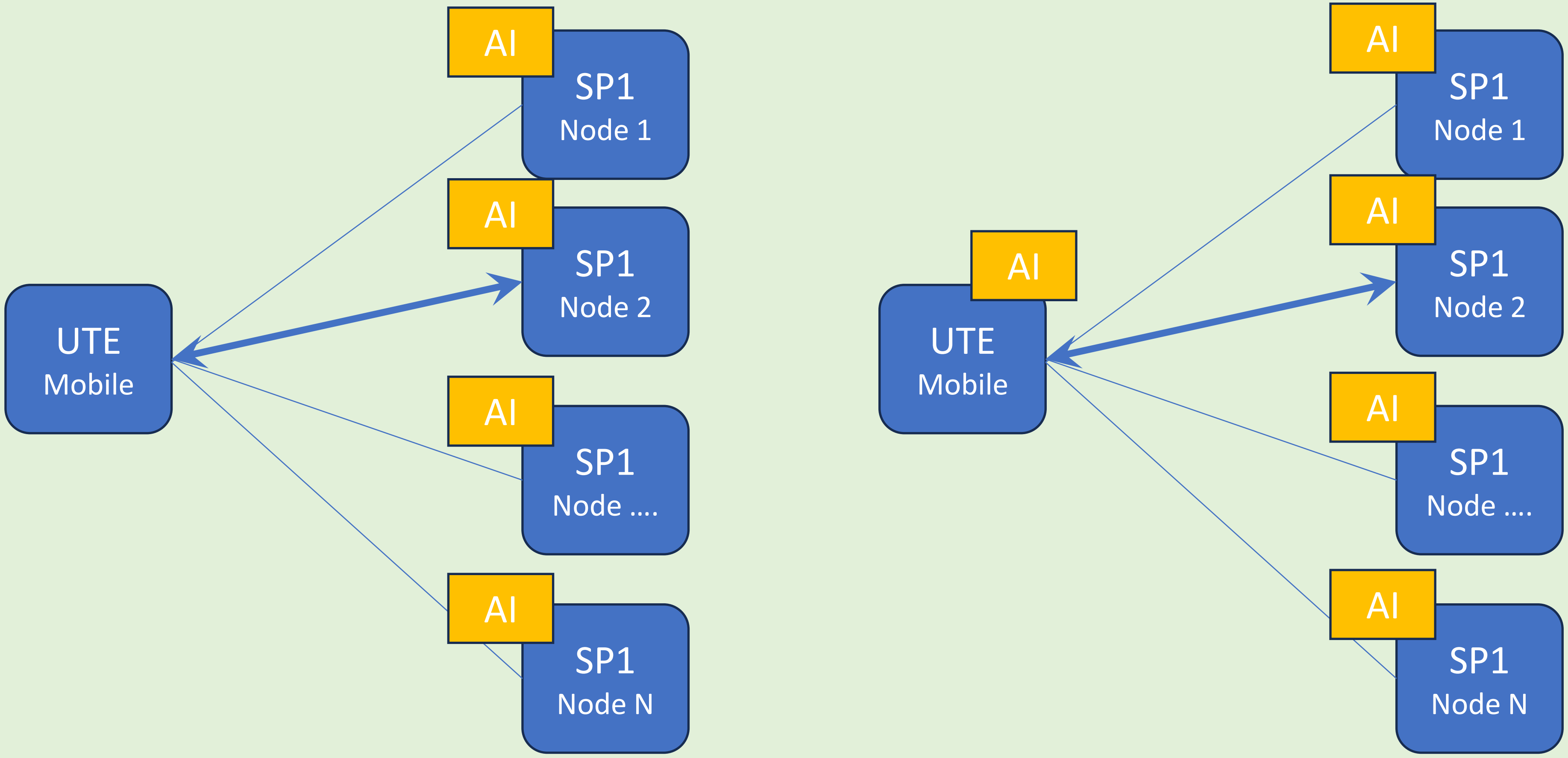
1. Propagation Models and AI for Spectrum Sharing (Part of Bucket 1)



1. Provide Best Service to UTE
2. Minimize
   - Signal Elsewhere
   - Power
   - Etc
3. Optimize Parameters for Local Conditions
4. Guarantee Protection for PSUs
5. Co-Exist with other spectrum users
6. Contribute to Maximize Available Spectrum

Spectrum Sharing - Digital Twins and Propagation Modeling

1. Propagation Models and AI for Spectrum Sharing (Part of Bucket 1)



Spectrum Sharing - Digital Twins and Propagation Modeling

1. Propagation Models and AI for Spectrum Sharing (Part of Bucket 1)

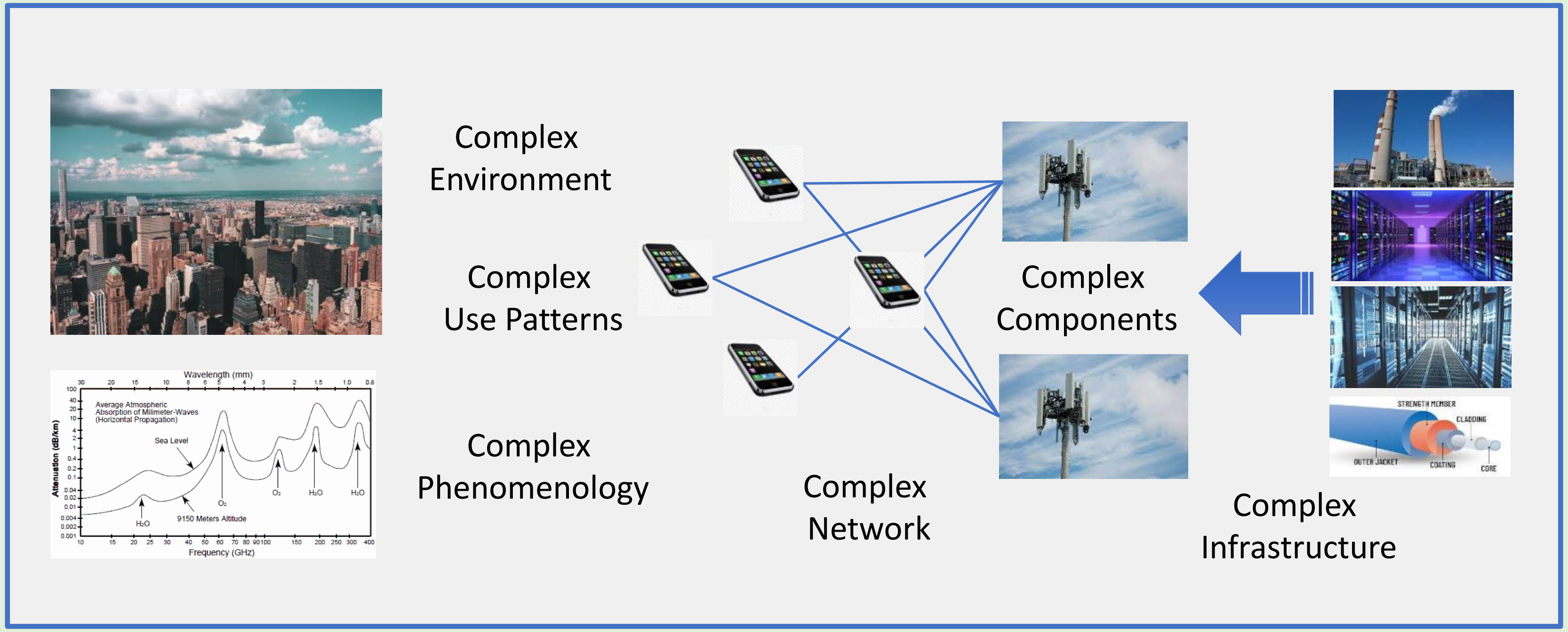
Parametrized Statistical Models a la 3GPP (TIM)
Generative Channel Models (ML Models Conditioning on use cases - TIM) Proof points but not widely used.
Fast Ray Tracing Models (TIM) (Calibrated with local measurements)

Data Driven Models (ITS)
Existing work on CBRS

Using ML to Choose the model for each location and local conditions with a time dimension (Peha)

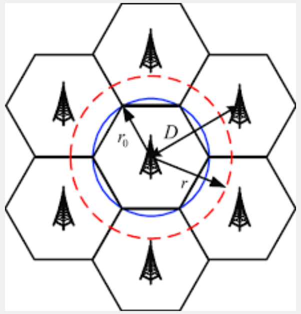
Spectrum Sharing - Digital Twins and Propagation Modeling

2. Continuation of Discussion on Spectrum Sharing (Digital Twins and Automation)

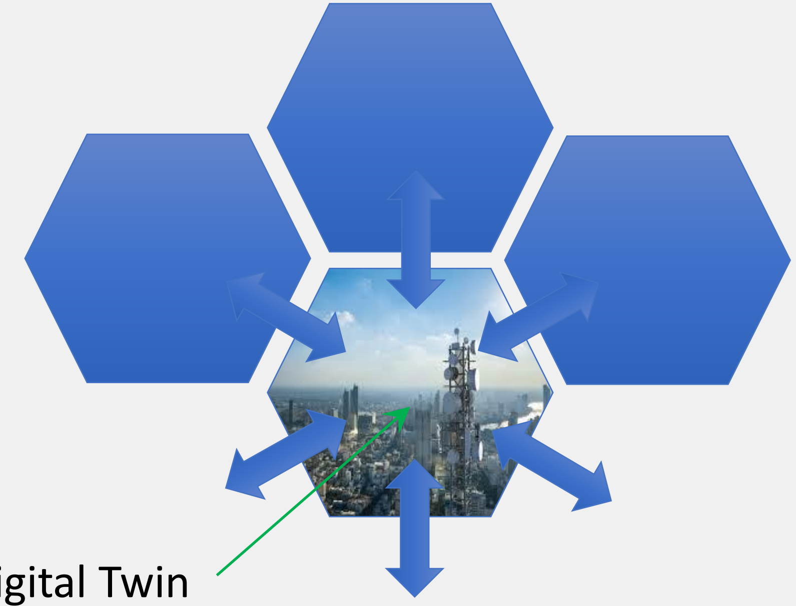


Spectrum Sharing - Digital Twins and Propagation Modeling

2. Continuation of Discussion on Spectrum Sharing (Digital Twins and Automation)



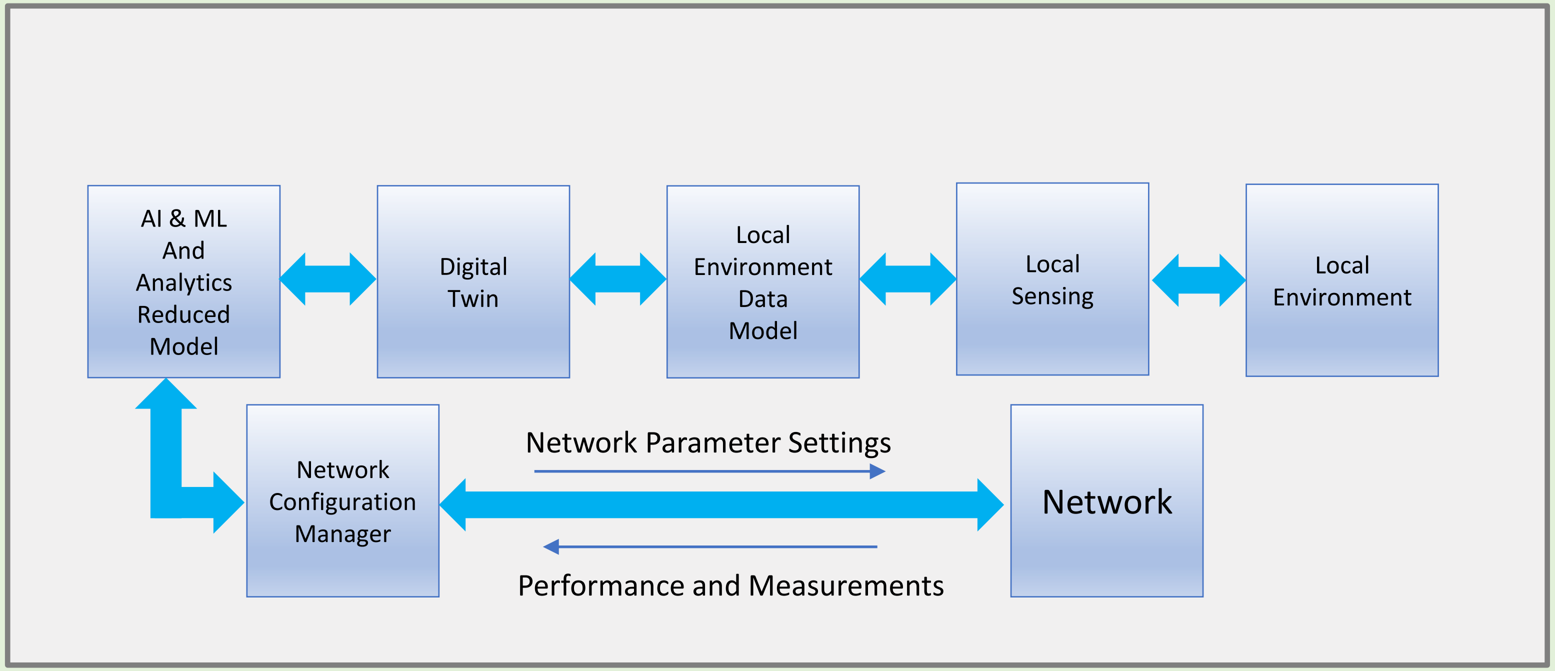
Reduced Data Shared With Neighboring Cells



Granular Local Digital Twin

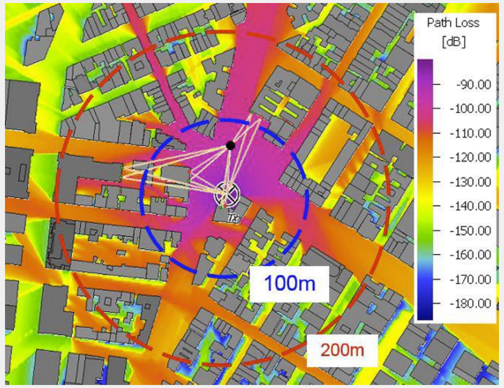
Spectrum Sharing - Digital Twins and Propagation Modeling

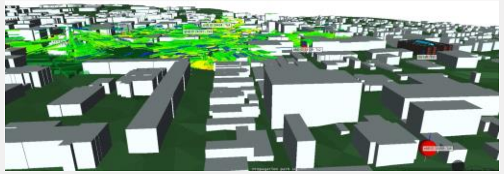
2. Continuation of Discussion on Spectrum Sharing (Digital Twins and Automation)

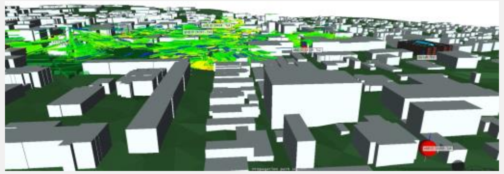


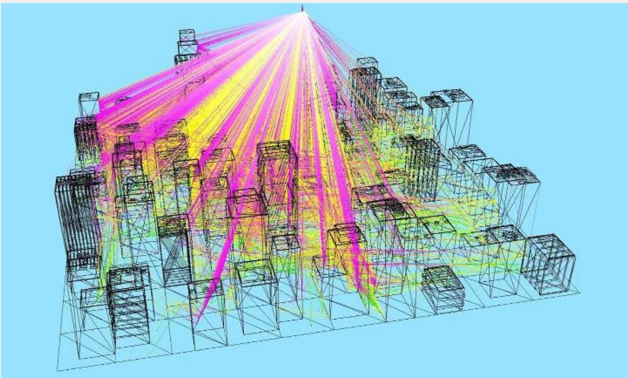
Spectrum Sharing - Digital Twins and Propagation Modeling

- Progression of approaches to Network Management









Many Techniques Available – but the problem is data and the temporal Variation in the Local Environment – that can be solved!!!

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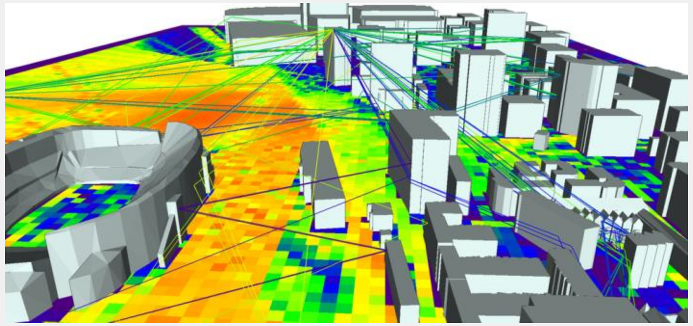
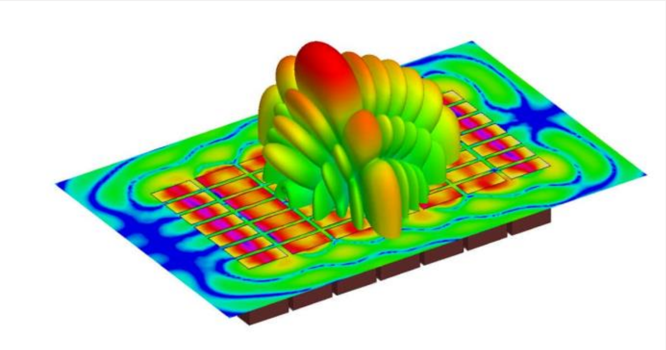
Spectrum Sharing - Digital Twins and Propagation Modeling

- Progression of approaches to Network Management



Large Scale Local Simulations



Individual Components

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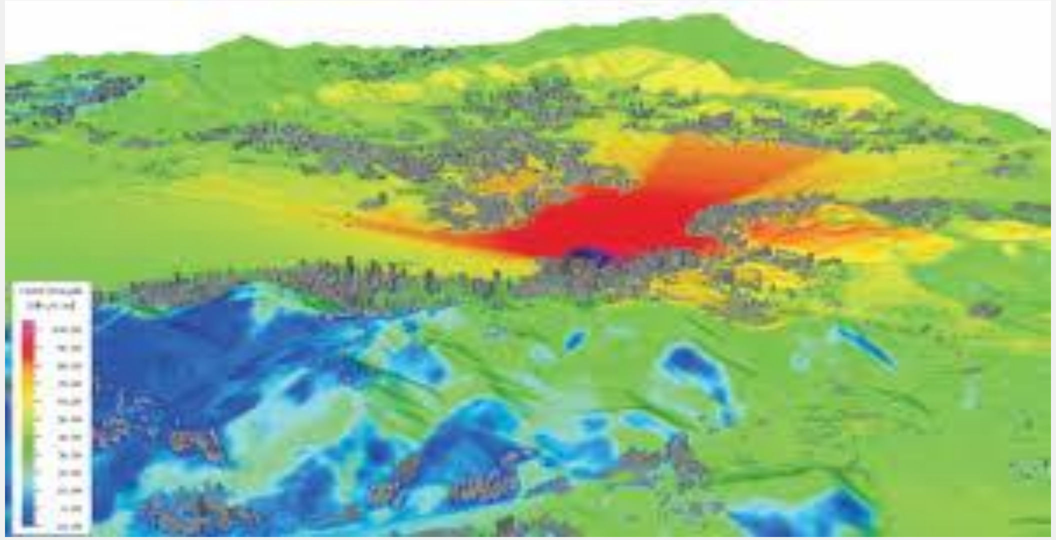
Spectrum Sharing - Digital Twins and Propagation Modeling

- Progression of approaches to Network Management



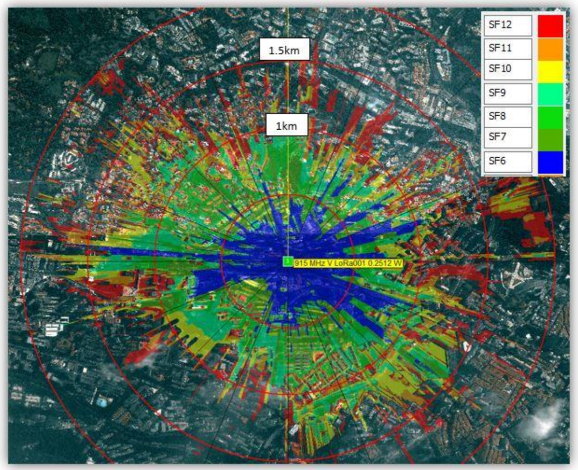


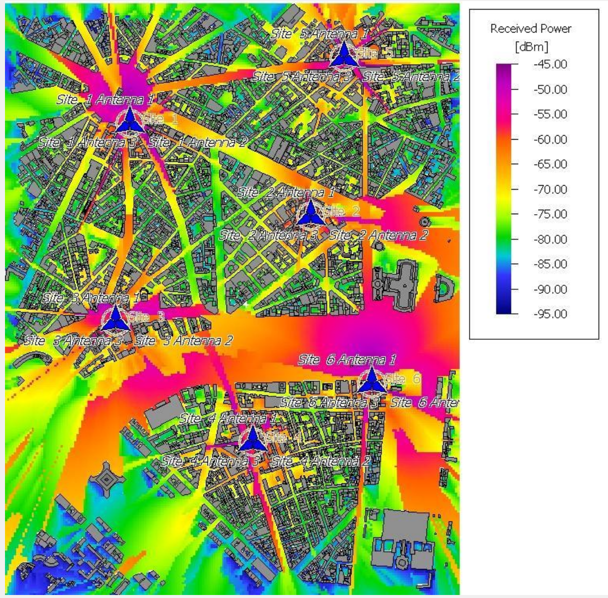
Figure 4: LoRa GW coverage in heavy urban environment (GW 5m AGL, EP 3m AGL, 24dBm EIRP)

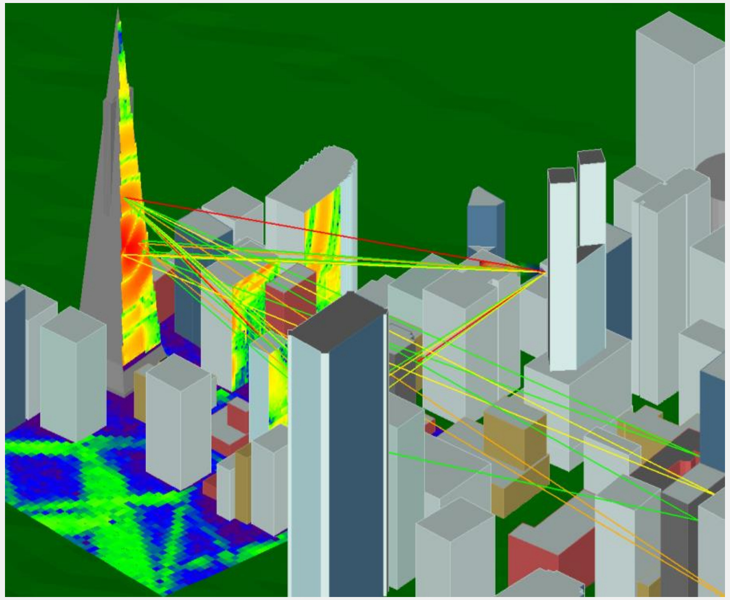
Large Scale/High Resolution Results – HPC Simulations

Spectrum Sharing - Digital Twins and Propagation Modeling

- Progression of approaches to Network Management

Complex Environments





Appendices

A.6 AI/ML for Rural High-Speed Broadband Coverage

AI/ML for Rural High-Speed Broadband Coverage

1. Eliminating Inaccuracies in Data in Maps

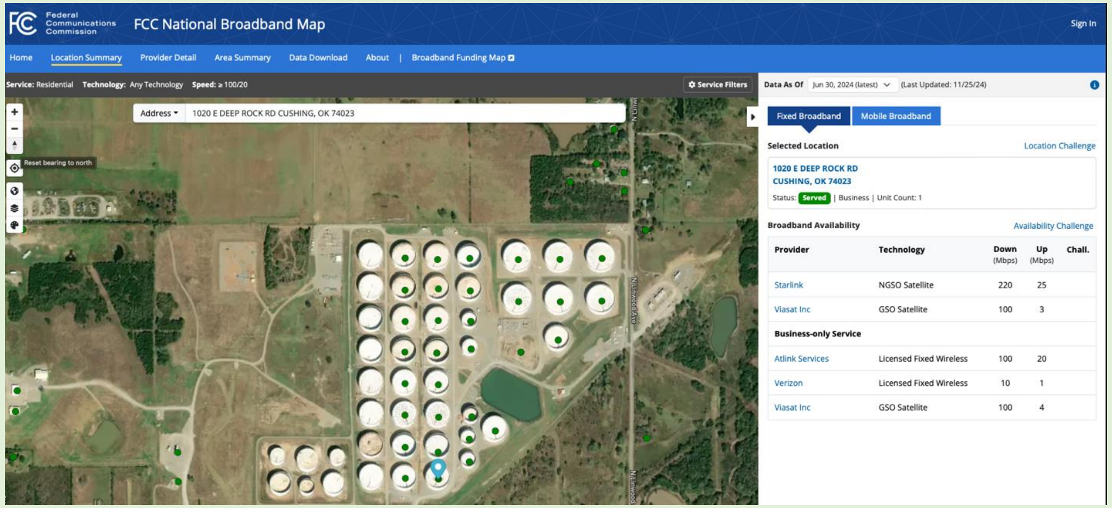
The FCC National Broadband Map comprises of the Fabric and broadband availability data. The Fabric is all of the Broadband Serviceable Locations (BSL) in the nation. The availability data determines if a BSL is served (>100/20Mbps available), underserved (>25/3 and <100/20 Mbps available) or unserved (<25/3 Mbps available). Various agencies use the FCC Maps to determine if a BSL are eligible for federal funding. BEAD is a $42.5 Billion program by the NTIA that is using the FCC Maps to determine which BSLs are eligible.

There are many BSLs in the fabric that are incorrectly identified. Some locations are identified as residences or business when they are not while other locations which are residences and businesses are not identified at all keeping them from accessing federal funds for broadband. The example below shows the town of Cushing which stores over 13% of the US Oil Reserves. Many Oil Containers are identified as Businesses. Just above these containers, several residences are not included as BSL at all. Both of these scenarios cause issues for rural ISPs that are attempting to build to these locations. Either federal funds are frivolously spent on building to locations that will never take service reducing the total amount available for Bonafide locations or federal funds are unavailable for locations that need them the most.

AI/ML for Rural High-Speed Broadband Coverage

1. Continued -NRECA recently requested NTIA to true up locations before processing BEAD awards.https://www.cooperative.com/programs-services/government-relations/regulatory-issues/Pages/NRECA-Urges-Location-True-Up-Process-Before-Final-BEAD-Awards.aspx

AI/ML can be effectively utilized in cleaning the data of the fabric to accurately identify features in a building to classify them as residences or businesses. This would increase the fidelity of the data. Creation of such Broadband LLM will decrease waste, increase efficiency and help connect all of America. Information from Rural Operators such as Electric Cooperatives, Municipalities and Telephone Cooperatives can be used to fine tune the data entering the LLM.



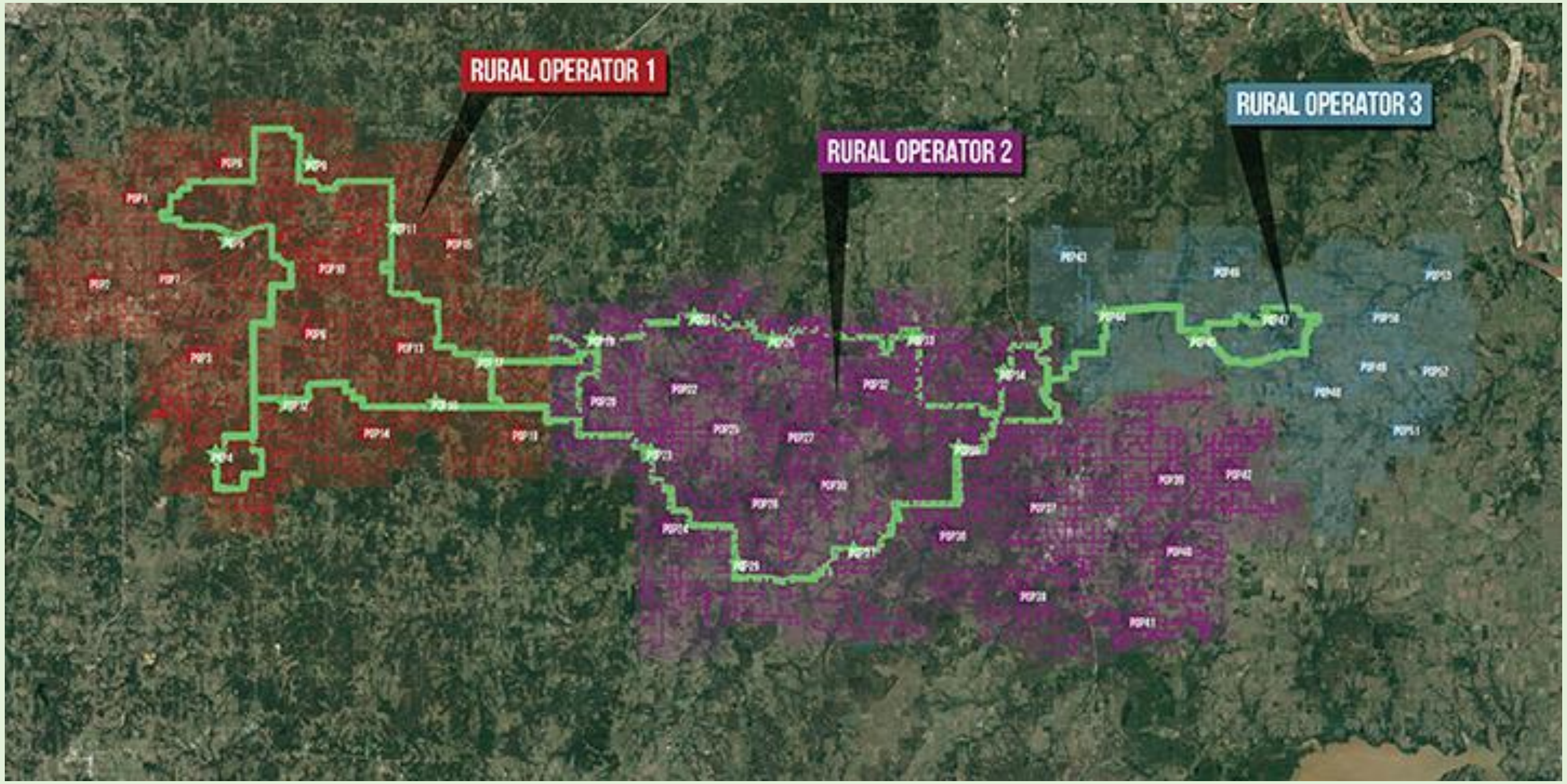
AI/ML for Rural High-Speed Broadband Coverage

2. Creating Access to Middle Mile Networks

Most rural ISPs do not have access to Middle Mile Networks that connect their networks to large data centers. This affects the resilience and sustainability of their network. In most circumstances Rural ISPs have access to one or maybe two MM providers who sell them transit. Many times, both providers are on the same conduit providing only a false sense of redundancy. A lack of competition also leads to higher prices and unsustainable networks. Having access to a robust Middle Mile Network in rural areas helps in closing the digital divide. A National Middle Mile Network Map does not exist, and most rural operators are not able to find other MM providers in their geographic area easily. A considerable amount of Middle Mile has been built in America using public funds such as the BTOP program and the NTIA Middle Mile Program. Data about these networks is not readily available in a centralized location.
AI/ML can be utilized to create such a map from data scraped from public sources. The FCC National Broadband Map (wireline) can be a good source of data from which such a Middle Mile Map can be extrapolated. Such a map will help 5G/6G operations as well as these network operators will be able to get bandwidth to towers without building their own fiber networks.

AI/ML for Rural High-Speed Broadband Coverage

2. (Continued) Creating Access to Middle Mile Networks



Source: https://bbcmag.com/a-middle-mile-model-for-rural-operators-4/

AI/ML for Rural High-Speed Broadband Coverage

3. Environmental Assessment for New Deployment Projects

Rural Territories have low density and are large deployments serving a small number of subscribers. A fiber deployment project starts with environmental assessment. Traditionally this is done with a desktop survey that identifies at-risk areas and then a field survey for the at-risk areas. The Field Survey is expensive and can potentially take months to complete. In most circumstances, there are no significant findings as fiber deployment disturbs very little earth. Analysis of desktop surveys using AI/ML to better identify at-risk areas can substantially reduce the time and cost for fiber deployment projects. Such an analysis will take into consideration the new guidelines posted by the NTIA and parse right of ways where utilities already exist. This is especially important in rural areas where the deployment can exceed thousands of miles, and an environmental assessment may take months or years to complete and may end up costing more than the cost of deploying fiber itself.

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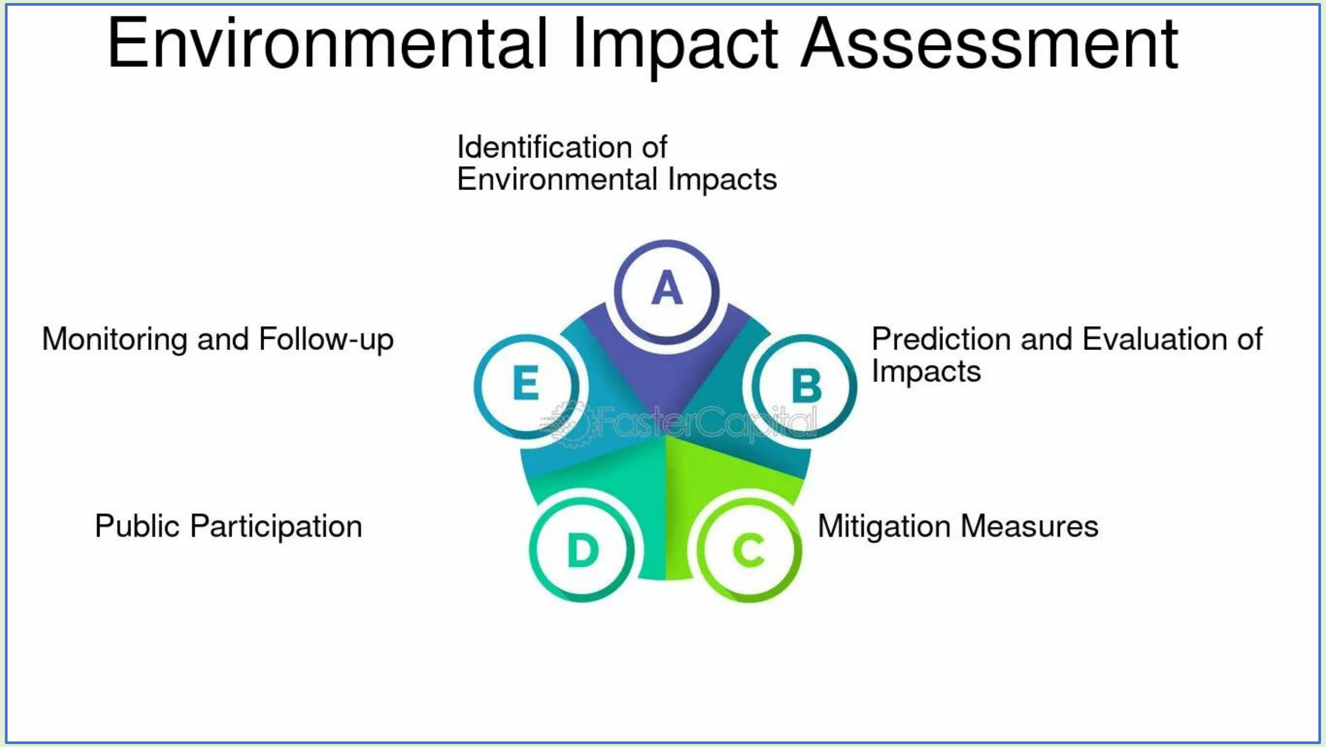
AI/ML for Rural High-Speed Broadband Coverage

3. **(Continued)** Environmental Assessment for New Deployment Projects

References: https://broadbandusa.ntia.doc.gov/sites/default/files/2024-04/FAQ_NEPA_for_BEAD.pdf



AI/ML for Rural High-Speed Broadband Coverage

4. Design, Engineering, Permitting and Operations Automation

Over the next 4 years over $100 Billion will be spent in deploying Fiber in the US. A significant portion of this will come from the BEAD program and more will come from other State and Federal programs as well as private equity. These new networks in rural areas, spanning thousands of miles with low density of subscribers will face design, engineering, permitting and operations challenges given the short timeline in which they must be operational. Rural Operators are generally smaller ISPs with limited resources. However, rural ISPs will largely be responsible for building the networks from BEAD and other federal and state funding sources.

Automation in design, engineering, permitting and operations of network will enable rural ISPs to deploy and operate these networks with greater efficiency and this can be achieved by utilizing AI/ML. For instance, network designs using AI/ML can identify optimal paths that have low environmental risk and lower permitting requirements. Further, AI/ML can help design fiber networks that are resilient while still economical by identifying which parts are most at risk with changing climate and need to

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AI/ML for Rural High-Speed Broadband Coverage

4. (Continued) Design, Engineering, Permitting and Operations Automation

be underground instead of aerial. AI/ML can also be utilized to drive automation in operations where switches or router are zero configuration and learn from the network and auto configure themselves. Outages can be managed more efficiently by intelligently rerouting traffic and cyber-attacks can be warded off by having AI/ML solutions that recognize and thwart such attacks.

AI/ML for Rural High-Speed Broadband Coverage

4. (Continued) Design, Engineering, Permitting and Operations Automation

4.1 AI/ML for Rural Engineer of Projects

It is anticipated that AI/ML can and is being used in the design phase for rural broadband fiber projects.

The initial mapping of the areas using AI to determine the locations of potential BSLs (broadband service locations) has been initiated with the FCC Broadband Mapping and Data Collection. Currently field verification is still required to ensure all locations are correctly labeled and new locations are timely added. (Verification is done during the final review phase).

Using the BLS location and LIDAR data allows AI fiber planning tools to complete initial route layouts.

- Use of road and easement layers to determine best route placement.
- Use of Environmental resource layers to determine routes where cultural, shovel test surveys, and other species data including tribal land crossing can be reviewed for best routing versus cost and extension of timelines for project.

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AI/ML for Rural High-Speed Broadband Coverage

4. (Continued) Design, Engineering, Permitting and Operations Automation

4.1 AI/ML for Rural Engineer of Projects

- Use of LIDAR date to identify buried locations for culverts, driveways other utilities to determine best placement for crossing roads or other obstacles.
- Use of AI/ML to provide least cost construction methods with timeline options for final review.

Using design Date to complete construction sheets.

- Complete single field review to determine discrepancies from AI design to human intervention.
- With markups, AI designed is finalized. Ai create BOM along with plans and specification.

Summary:

- AI will eliminate the initial site trip to locate BSLs.
- AI will eliminate the engineering field staking (only single trip by engineer)

AI reduces the human time in design and reduces time for route development and environmental review to reduce the overall time prior to construction

AI/ML for Rural High-Speed Broadband Coverage

4. (Continued) Design, Engineering, Permitting and Operations Automation

4.1 AI/ML for Rural Engineer of Projects

Image provided by Alaska Imaging

AI/ML for Rural High-Speed Broadband Coverage

4. (Continued) Design, Engineering, Permitting and Operations Automation

4.2 AI/ML for Rural Engineer for Make Ready

AI/ML is being used in the Pole Make Ready design phase for rural broadband aerial fiber projects.

In remote areas, drones with LIDAR are used to capture data from rural villages. The LIDAR data provides the following:

- Existing location for poles mounting heights, wire size, anchor and other facilities on the poles.
- Existing location for NID's, power meter and obstacles for placement of fiber and electronics.
- Heights and distances between each cable at midspan

The LIDAR data allows for all make ready designs to be completed using AI as follows:

- Existing pole type, cable and anchor placement
- Existing midspan clearances for NESC and determine if pole requires easement approval

AI/ML for Rural High-Speed Broadband Coverage

4. (Continued) Design, Engineering, Permitting and Operations Automation

4.2 AI/ML for Rural Engineer for Make Ready

AI with LIDAR Pole data the majority of Make Ready Process can be automated

- Automatic input of pole data into pole line design programs for loading calculations
- Determine if existing poles are overloaded or do not comply with NESC
- Determination of class size required to meet new loading requirements
- Determine location for new anchors/cable on poles and if existing facilities require relocating
- Develop make ready cost and schedule for make ready work

Images provided by Alaska Imaging

AI/ML for Rural High-Speed Broadband Coverage

4. (Continued) Design, Engineering, Permitting and Operations Automation

References

• "Fiber Optics: Critical Infrastructure for AI and Rural Connectivity", Dec. 9, 2024, Henry Klimowicz, Baker Botts L.L.P.
https://www.jdsupra.com/legalnews/fiber-optics-critical-infrastructure-1285113/

• Pioneering the Future: How AI and Broadband Integration are Transforming Rural America
Samantha Frick, T-Mobile, October 24, 2024
https://www.linkedin.com/pulse/pioneering-future-how-ai-broadband-integration-rural-america-frick-q8eec/

• "Report: AI Could Drive Rural Data Center and Broadband Growth", May 8, 2024
https://www.telecompetitor.com/report-ai-could-drive-rural-data-center-and-broadband-growth/

• "Building AI-ready telecommunication infrastructure: A comprehensive guide", December 29, 2023
https://www.iotglobalnetwork.com/iotdir/2023/12/29/building-ai-ready-telecommunication-infrastructure-a-comprehensive-guide-49381/

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Appendices

A.7 White Paper Outline: The Transformation of the Network

Appendices

AI and ML for Spectrum Sharing and Management

1.0 Explore the use of AI/ML methods to improve the utilization and administration of spectrum (licensed, unlicensed, and shared) based on the fundamental characteristics of propagation, interference, signal processing, and protocols. How could the scalability aspect of AI/ML algorithms support such methods by use of techniques such as parallelization, dimensionality reduction, sampling, and approximation?

1.1 **Introduction: AI and ML for Spectrum Sharing and Management**

1.1.1 Utilization of Spectrum

1.1.2 Spectrum Administration

1.1.2.1 Propagation

- Local Models
- Basic High Resolution Geometric (Terrain, Buildings, Foliage, Weather Conditions, Materials, Time Variability, Roads,) – Sources of Data
- Clutter Models
- Holographic Models
- Adaptive Methods

1.1.2.2 Antenna Patterns and Capabilities

1.1.2.3 Sensor

1.1.2.4 User Equipment

1.1.2.5 Independent Sensor Network Observations

1.1.2.6 Estimation of location data for radiators

Appendices

AI and ML for Spectrum Sharing and Management (Continued)

- 1.1.2.2 Interference
- 1.1.2.3 Signal Processing
- 1.1.2.4 Protocols
- 1.1.2.5 Sensing
- 1.1.2.6 Measurements (Closed loops)

1.1.3 Scalability of AI Algorithms
- 1.1.3.1 Parallelization
- 1.1.3.2 Dimensionality Reduction
- 1.1.3.3 Sampling (Sparse Arrays)
- 1.1.3.4 Approximation
- 1.1.3.5 Hybrid Methods

1.1.4 System Level Models
- 1.1.4.1 Sources of Data
- 1.1.4.2 Simulations
- 1.1.4.3 Emulations
- 1.1.4.4 Digital Twins

Appendices

AI and ML for Spectrum Sharing and Management (Continued)

1.1.5 Infrastructure
- 1.1.5.1 Connectivity
- 1.1.5.2 Computing
- 1.1.5.3 Storage
- 1.1.5.4 Software
- 1.1.5.5 Data
- 1.1.5.6 Operations (Lisa

1.2 How can AI/ML be leveraged to help better understand real-time spectrum usage, either at the front end (e.g., improved sensing) or the back end (e.g., improved analytics)?

1.2.1 Introduction: AI and ML for understanding Spectrum Usage

1.2.1.1 Technologies for Collecting Usage Data
- Commercial Systems
- Crowd Sourcing
- RSRP Data
- Speed Testing Apps
- Sensor Networks

1.2.1.2 Domains of Application

1.2.1.3 Analytical and AI/ML Techniques for Classifying and Understanding Data

1.3 Conclusions and Recommendations

References and Bibliography

Appendices

Network Safety, Security, Assurance, and Performance

2.1 Introduction: AI/ML in the Network

2.1.1 Present and Future Network Environments

- Automation
- Digitization
- Softwarization
- Growth of the Network
- Changing Usage Patterns

2.1.2 AI/ML Methods and Techniques

2.1.3 Infrastructure for Connectivity, Data, Computing, and Storage

2.1.4 Other Important Technologies and Analysis Methods

2.1.5 Influence of End-User Applications (both for the Operators and Consumer)

2.1.6 Network Performance and Intrinsic Requirements

- Safety
- Security
- Control
- Operations
- Scalability
- Interoperability
- Recoverability
- Economic Factors

2.1.7 Resource and Capabilities Requirements

Appendices

Network Safety, Security, Assurance, and Performance (Continued)

2.2 Range of AI/ML Solution Characteristics: Challenges and Opportunities

2.2.1 Use of AI/ML in the Network

- Control
- Management
- Operation
- Maintenance and Upgrades
- Planning
- Optimization
- End of Life and Retirement

2.2.2 Technical Challenges

- Convergence Times and Learning-cycles
- Memory Complexity
- Predictable Behaviors
- Dealing with Uncertainty and Variability
    - Dynamic channel conditions
    - Variable traffic patterns
    - Mobility

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Appendices

Network Safety, Security, Assurance, and Performance (Continued)

2.3 Techniques for Addressing Concerns with AI/ML Data

2.3.1 Data Protection

- Security
- Cybersecurity
- Privacy
- Availability

2.3.2 Data Quality and Data Processing

- Data governance
- Data architecture
- Data cleansing
- Data fusion
- Data anonymization
- Data protection

2.4 Conclusion and Recommendations

Appendices

i) References
ii) List of Significant AI/ML Network Projects
iii) Relevant Standards Bodies working on AI/ML
iv) AI/ML Bibliography

Appendices

The Role of AI/ML in Testing Regimes and Certification

Section 1: Test and certification of systems with AI/ML

- **3.0 Introduction to the Role of AI/ML in Testing Regimes and Certification**
- **3.1 Overview of the types of use cases where AI/ML could be used**
  - 3.1.1 System configuration
  - 3.1.2 Operational regimes
- **3.2 Labs, facilities, infrastructure for test and certification**
  - 3.2.1Large scale digital twins – Complexity vs realism trade off
  - 3.2.2 Hardware in the loop vs fully virtual, real-time vs. quas-real-time
- **3.3 Frameworks, test methodologies**
  - 3.3.1 Testing Data, Models, Performance
    - 3.3.1.1 AI Workload emulation and testing (for data centers)
    - 3.3.1.2 Model Compute workload, failure rate, …
    - 3.3.1.3 Data sufficiency, coverage, bias,
      - Synthetic vs real time
      - Universally available data sets
    - 3.3.1.4 Model explainability, training and validation loss,
  - 3.3.2 Continuous testing through lifecycle
    - 3.3.2.1 Retraining vs replacing model
    - 3.3.2.2 Incremental test during CI/CD (continuous integration, continuous deployment)
- **3.4 Recommendations**

Appendices

The Role of AI/ML in Testing Regimes and Certification (Continued)

Section 2: Use of AI/ML for improved testing
3.5 Introduction: Use of AI/ML for Network and Network Component Testing
3.6 Efficient, faster test regimes through intelligent, automated test sequencing
- 3.6.1 Automatic Conversion of specifications into test regimes
- 3.6.2 Intent-driven test creation
- 3.6.3 Identification and elimination of superfluous testing

3.7 Use of ML-based models in digital twins
- 3.7.1 Model all relevant aspects of behavior – communication performance, energy performance, compute workload performance, etc.

3.8 Big questions
- 3.8.1 Should FCC testing guidance be updated for new devises that are utilizing AI/ML ?

3.9 Recommendations

Appendices
1) References
2) Bibliography use of AI for Testing
3) Testing Frameworks and Organizations

Appendices

The Transformation of the Network – Digitization, Softwarization, and AI/ML

Section 1

4.1 Digital transformation

- 4.1.1 Mindset: Collecting data and using data to factually drive processes
- 4.1.2 Drivers of Digital transformation
  - 4.1.2.1 Computing and Data Storage
    - Distributed computing/storage
    - Hierarchical computing/storage
  - 4.1.2.2 Data
  - 4.1.2.3 Connectivity
  - 4.1.2.4 Virtualization: General purpose constructs that allow processing in software
  - 4.1.2.5 Mobility
    - Ubiquitous connectivity
    - Required supporting infrastructure to enjoy digital transformation anywhere
- 4.1.3 Virtualization
- 4.1.4 Agent based Architectures and Orchestration
- 4.1.5 The Data Lifecycle – From collection to curation
- 4.1.6 Levels of Practice: Organizational Capabilities
- 4.1.7 Technical and Human Factors
- 4.1.8 Importance of Ecosystems

Appendices

The Transformation of the Network – Digitization, Softwarization, and AI/ML (Continued)

Section2

4.2.1 Digitization/Softwarization: Software defined networking, Network function virtualization (2020-2035)

4.2.1.1 Explaining the value of Digitization, and why is it important
4.2.1.2 What it really means for telecommunications
4.2.1.3 Substitution with General Purpose Computing

- Specialized HW creates complexity and expenses
- Where does Specialized Hardware play in the lifecycle of the network
- What will replace it and how? Where is AI/ML appropriate?

4.2.1.4 Connectivity follows progress in Computing
4.2.1.5 Multi-tenancy – requirements coming from outside of telecom

- Interconnected general purpose computing infrastructure

4.2.1.6 The elements that make radio are now software running on computing components and the outcome is determined by their performance,

- Software defined radios: using software to compensate for analog impairments
- To have electronic analog components perform at the levels we have not seen before (i.e. MIMO antennas)
- Moving towards Plug & Play network/Radio nodes
- vCore and vRAN on COTS servers

4.2.1.7 Unified management and automation for end-to-end softwareized network functions

Appendices

The Transformation of the Network – Digitization, Softwarization, and AI/ML (Continued)

Section 3

4.3 Business models and policies:

4.3.1 Implementing all in software: how vendors can differentiate their solutions?
4.3.2 The role of Integration
4.3.3 The impact of automation and autonomy in Network control and management
4.3.4 Need to include underlying compute and data storage infrastructure
4.3.5 The structure of computing and storage: Embedded, Local, Edge, Intermediate, Cloud, computing (2020-2035)

- Embedded compute
- Local compute
- Edge computing: Offering distributed computing and storage at the edge of the network rather than the core.
- Intermediate facilities
- Cloud computing: Offering a pool of virtual and dynamically scalable computing, storage, and memory resources and services to clients on demand over the Internet

4.3.6 Other infrastructures and supporting technologies
4.3.6 Meeting the needs of end-users

Appendices

The Transformation of the Network – Digitization, Softwarization, and AI/ML (Continued)

Section 4

4.4 Implications for what the FCC does

4.4.1 Digital transformation is changing the pattern of communication.
4.4.2 Significant re-architecture of the network
- How to be maintain interoperability between operators, and how to stay compatible with international standards,
- Meeting Strategic Goals: The best infrastructure for the US, Technical Leadership, and Competitiveness

4.4.3 What are the implication If no interoperability?
4.4.4 Progress in AI/Machine Learning (2020-2035+)
4.4.5 The table stakes: Achieving end to end full observability, analysis, insights, and predictions with AI
4.4.6 Impacts on and needs of other verticals (Agriculture, Automotive, Education, Healthcare, Housing, Law Enforcement, Manufacturing, State and Local Government, …….)
4.4.7 Conclusions and Recommendations

Appendices
1) References and Bibliography
2) List of Significant Associations and Organizations
3) Standards Bodies
4) Frameworks

FCC Technological Advisory Council Agenda – December 19, 2024

10:00am – 10:15am	Opening Remarks
10:15am – 11:30am	Advanced Spectrum Sharing WG Presentation
11:30am – 12:45pm	AI/ML WG Presentation
12:45pm – 2:00pm	Lunch
2:00pm – 3:15pm	6G WG Presentation
3:15pm – 3:30pm	Closing Remarks
3:30pm	Adjourned

Federal Communications Commission Technological Advisory Council Meeting

Lunch Break

December 19, 2024

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FCC TAC
6G WG

Chairs: Brian Daly (AT&T)
Manu Gosain (Northeastern University)

FCC Liaison: Martin Doczkat

Date: Dec 19, 2024

2024 6G Working Group Team Members

Bayliss, Mark	Visual Link Internet		**Thompson, Michelle**	Open Research Institute
Bhatt, Tejas	Marvell		**Young, David**	ATIS
Brenner, Dean	Special Government Employee			
Cataletto, Michael	Scientel Solutions		**Daly, Brian**	AT&T
Chakraborty, Tusher	Microsoft		**Gosain, Manu**	Northeastern University
Clegg, Andrew	Wireless Innovation Forum			
Ditchfield, Skyler	GeoLinks			
Drobot, Adam	Stealth Software Technologies		**Acacio, Robert**	FCC
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Mukhopadhyay, Amit	Nokia		**Young, Janet**	FCC
Nasielski, Jack	Qualcomm		**Yun, Sean**	FCC
Nicols, Roger	Keysight Technologies		**Acacio, Robert**	FCC
Noland, Madeline	ASTC			
Henry, Daniel	NTIA			
Tehrani, Ardavan	Samsung			
Thakker, Rikin	NCTA			

AGENDA

- Charter Review
  - Topics covered in 2024
  - Topics to be covered in 2025
- Recap of Aug 29 (if applicable)
- State of the Industry (3GPP, IEEE, ORAN, ITU)
- Charter Topic Updates
  - Pull from June and Aug Meeting Slides (prune topic areas to 1-2 slides each)
  - Update New Material since Aug (SME presentations, discussion etc)
- Advisements
- Proposed Plan for 2025
- Summary of SME and Meetings

Charter Review

6G WG Charter Topics Covered in 2024

- Provide information on the development and deployment of 6G technology, make recommendations and provide insights on new developments and expectations from technological and regulatory perspectives that FCC should pay attention to.

- How is 6G progressing or expected to progress at standards and international fora? What are the key points of emerging consensus or disagreement?

- What are competing 6G visions and expectations on key technological points between operators to compare and contrast?

6G WG Charter Topics Covered in 2024

- What are the opportunities for using mmW/terahertz bands for 6G systems?

- How is 6G technology envisioned to enhance or be utilized in various verticals, including autonomous driving, augmented and virtual reality, edge computing, emergency alerting, and smart cities?

- How will 5G/6G networks support massive volume of mobile and IoT and XR devices with low-latency and seamless connectivity for near- and non-real time, trending toward real-time applications?

- How does 6G ensure the security and privacy of users' data and identity in various scenarios, such as visible light communication (VLC) ?

6G WG Charter Topics To Be Covered in 2025

- How do openness and customization capabilities in 6G benefit supporting flexibility and agile services and its coexistence with 5G?

- What are the infrastructure needs for 6G? How can the FCC proactively address them?

- What are the potential privacy and security risks that 6G networks will need to address regarding massive data collection and processing, as well as the ethical and social impacts of emerging applications such as brain-computer interfaces and holographic communications?

- How does 6G ensure the security and privacy of users' data and identity in various scenarios, such as distributed ledger technologies, physical layer security, distributed AI/ML, THz bands, and quantum communication?

6G WG Charter Topics To Be Covered in 2025

- What is the status of small satellite development? What frequency bands are under consideration for non-terrestrial network (NTN) use? What services are envisioned?

- How does 6G ensure the security and privacy of users' data and identity in various scenarios, such as distributed ledger technologies, physical layer security, distributed AI/ML, visible light communication (VLC), THz bands, and quantum communication?

State of the Industry

ITU

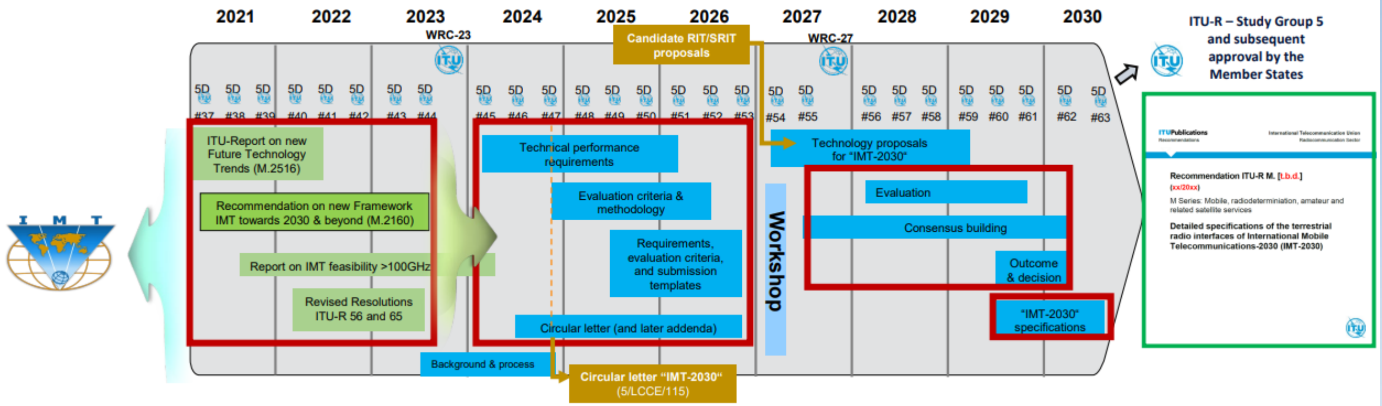
IMT Family History

		IMT-2000 (3G)	IMT-Advanced (4G)	IMT-2020 (5G)	IMT-2030 (6G)
Report (FTT)	Future Tech Trends (FTT)	-	-	Rep. ITU-R M.2320	Rep. ITU-R M.2516
		-	-	Nov 2014	Nov 2022
Recommendation (Vision/Framework)	Vision	Rec. ITU-R M.687 & M.816	Rec. ITU-R M.1645	Rec. ITU-R M.2083	Rec. ITU-R M.2160
		Feb/Mar 1992 → 1997	June 2003	September 2015	November 2023
Reports (Requirements, evaluation methodology and submission template)	Technical Performance Requirements	Rec. ITU-R M.1034	Rep. ITU-R M.2134	Rep. ITU-R M.2410	Future work
		Feb 1997	2008	2017	
	Submission Template	8/LCCE/47 + Add	Rep. ITU-R M.2133	Rep. ITU-R M.2411	
		1998	2008	2017	
	Evaluation Methodology	Rec. ITU-R M.1225	Rep. ITU-R M.2135-1	Rep. ITU-R M.2412	
		Feb 1997	2009	2017	
Recommendation (Radio Interface Tech.)	RIT Specifications (1st release)	Rec. ITU-R M.1457	Rec. ITU-R M.2012	Rec. ITU-R M.2150	
		May 2000	Jan 2012	Feb 2021	

- 9 trends

Ubiquitous intelligence	Ubiquitous computing	Immersive multimedia and multi-sensory interactions	Digital twin and virtual world	
Smart industrial applications	Digital health and well-being	Ubiquitous connectivity	Integration of sensing and communication	Sustainability

ITU-R Timeline and Process

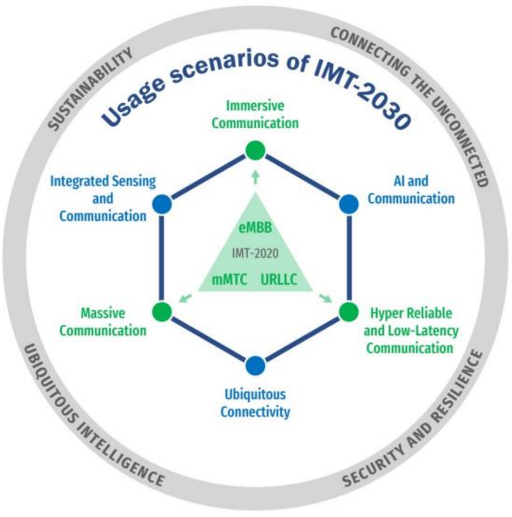


Note 1: WP 5D #59 will additionally organize a workshop involving the Proponents and registered Independent Evaluation Groups (IEGs) to support the evaluation process
Note 2: While not expected to change, details may be adjusted if warranted. Content of deliverables to be defined by responsible WP 5D groups

Framework → **Requirements and Evaluation criteria** → **Evaluation and Consensus building** → **Specification** → **Approval**

ITU Framework for IMT-2030 - the "Wheel" and "Palette"

Usage scenarios and overarching aspects of IMT-2030



So called "Wheel diagram"

Usage scenarios

Extension from IMT-2020 (5G)

- eMBB ➡ Immersive Communication
- mMTC ➡ Massive Communication
- URLLC ➡ HRLLC (Hyper Reliable & Low-Latency Communication)

New

- Ubiquitous Connectivity
- AI and Communication
- Integrated Sensing and Communication

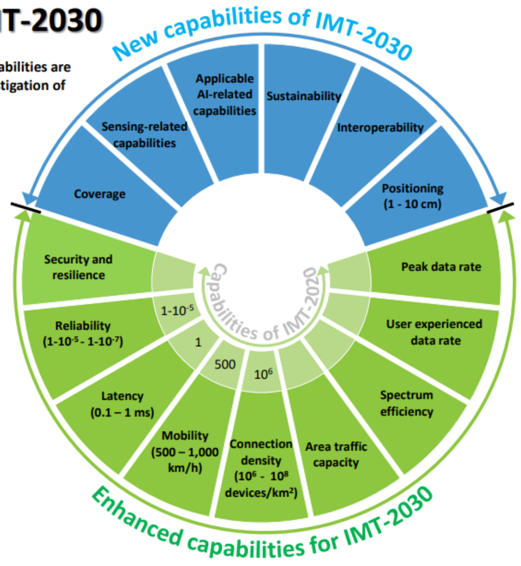
4 Overarching aspects:

act as design principles commonly applicable to all usage scenarios

Sustainability, Connecting the unconnected, Ubiquitous intelligence, Security& resilience

Capabilities of IMT-2030

NOTE: The range of values given for capabilities are estimated targets for research and investigation of IMT-2030.



So called "Palette diagram"

The range of values given for capabilities are estimated targets for research and investigation of IMT-2030.

All values in the range have equal priority in research and investigation.

For each usage scenario, a single or multiple values within the range would be developed in future in other ITU-R Recommendations/Reports.

- 9 trends

Ubiquitous intelligence	Ubiquitous computing	Immersive multimedia and multi-sensory interactions	Digital twin and virtual world

Smart industrial applications	Digital health and well-being	Ubiquitous connectivity	Integration of sensing and communication	Sustainability

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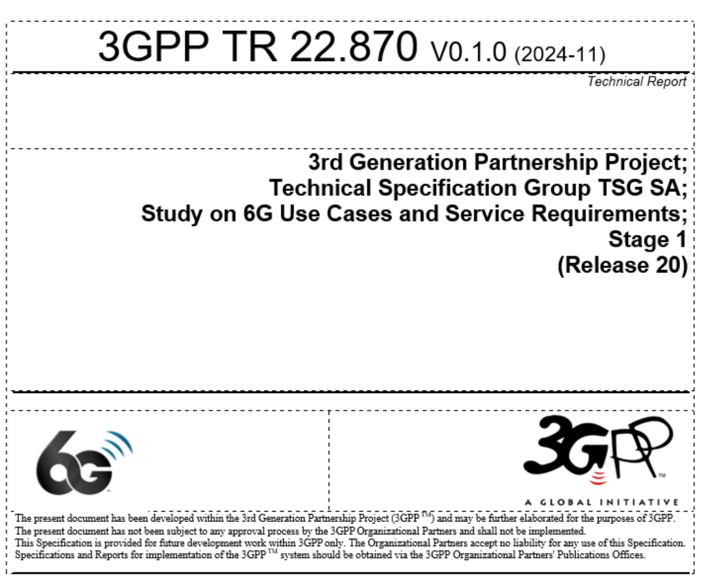
3GPP

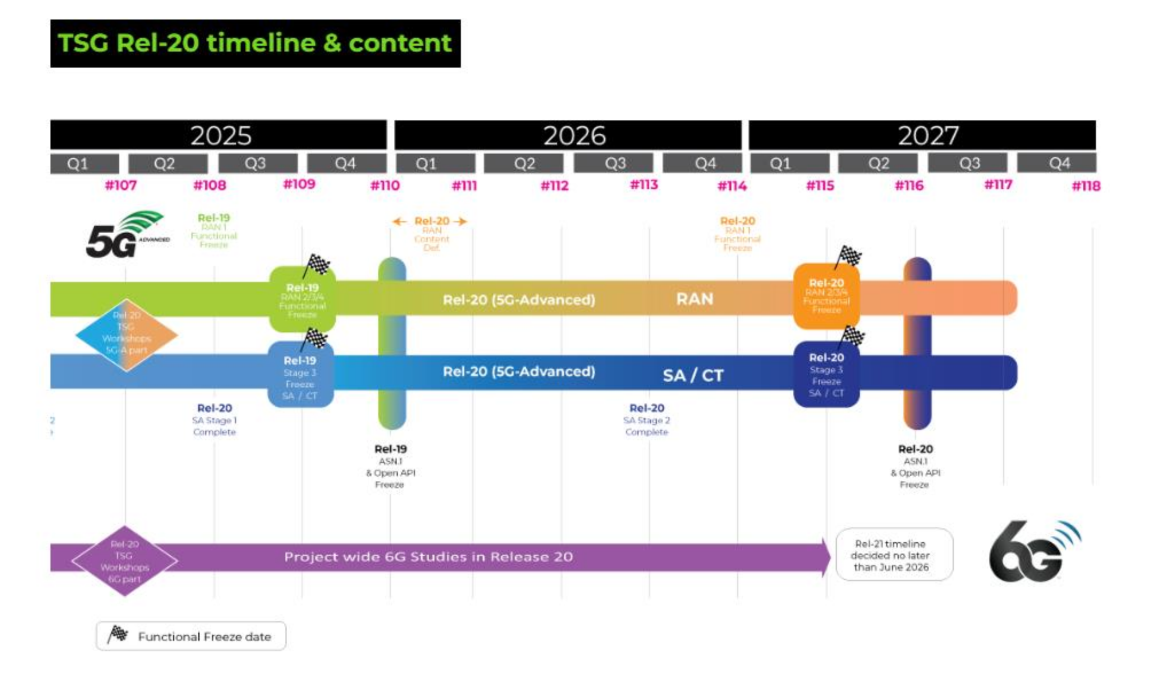


3GPP TR 22.870 V0.1.0 (2024-11)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group TSG SA;
Study on 6G Use Cases and Service Requirements;
Stage 1
(Release 20)

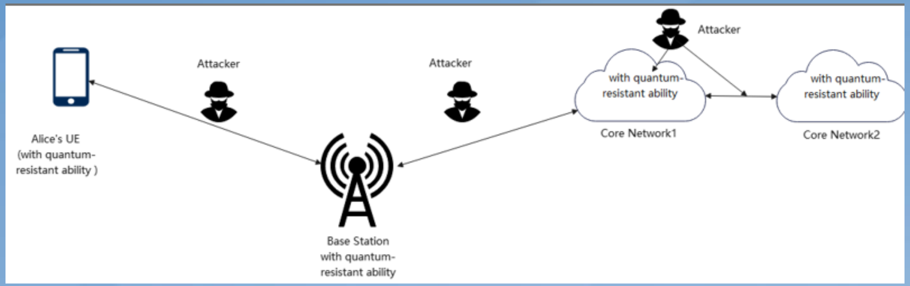
The present document has been developed within the 3rd Generation Partnership Project (3GPP™) and may be further elaborated for the purposes of 3GPP.
The present document has not been subject to any approval process by the 3GPP Organizational Partners and shall not be implemented.
This Specification is provided for future development work within 3GPP only. The Organizational Partners accept no liability for any use of this Specification.
Specifications and Reports for implementation of the 3GPP™ system should be obtained via the 3GPP Organizational Partners' Publications Offices.



- Rel-20 SA1 6G study has started
- Rel-20 content to be decided in 1H2025
  - Release 20 content defined in two steps with 5G Advanced and 6G work staggered and decisions made separately
- 3GPP workshop on 6G to be held in March 2025
  - Vision & Priorities for the Next Generation
  - RAN, System Architecture, Core Network & Protocols
- Rel-21 will have the specification work on 6G and the TSG RAN IMT-2030 submission

<u>Very Early</u> Insights into the 3GPP SA1 Study

- **Network Security for 6G**
  - it is expected that cloud deployments will play an even more important role in 6G
  - 6G network shall provide trust and security mechanisms for secure access to and communication with network elements
  - 6G system may provide security protection for communication against the potential attacks posed by quantum computing
- **AI**
  - 6G system will be built on the cloud, optimized for ubiquitous computing, and natively provide computing services (e.g., in forms of infrastructure services, platform services, and software services)
  - By incorporating standardized interfaces, robust security protocols, and advanced resource management frameworks, 6G can facilitate efficient and secure access to network resources.
  - Position 6G networks as comprehensive platforms for distributed computing and AI services, aligning with the evolving demands of the technology landscape and provide resource as a service.
- **Integrated Sensing & Computing**
  - wide area multi-dimensional sensing that provides spatial information about unconnected objects as well as connected devices and their movements and surroundings.
  - Example use cases: coordination of search and rescue missions in large disaster areas, safety assistance for vulnerable pedestrians, high-resolution topographic maps, low-altitude UAV supervision



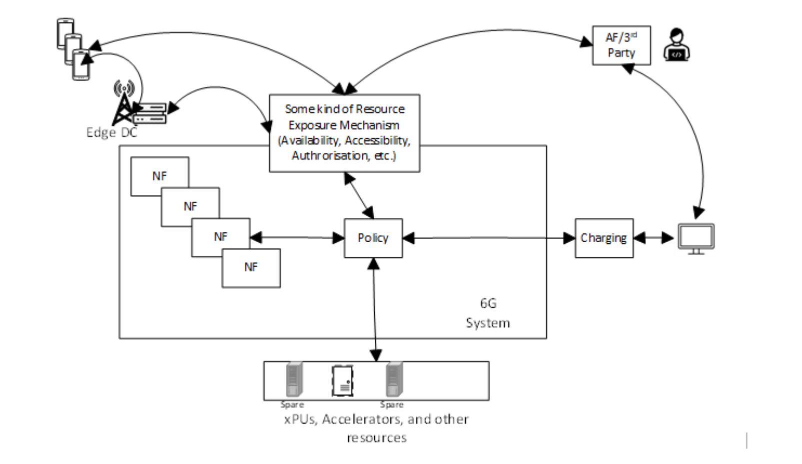


Figure 6.1.1-1: Illustration of network resource usage and exposure to 3rd party

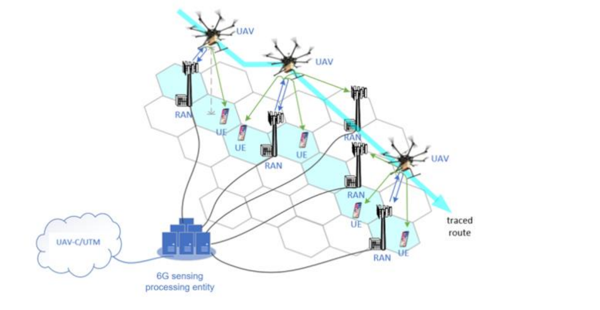


Figure 7.4.1-1: Low-altitude UAV trajectory tracing by 6G system

<u>Very Early</u> Insights into the 3GPP SA1 Study

- **Ubiquitous Connectivity**
  - ensuring network access in all locations, such as remote areas, regions with challenging geographical conditions (e.g., mountains, forests), airspace for aerial operations (e.g., drone operations), as well as the open ocean
  - realized by using both Terrestrial Networks (TN) and Non-Terrestrial Networks (NTN) (including satellites, High-Altitude Platform Stations (HAPS), air-to-ground networks, and unmanned aerial vehicles (UAVs)) in a transparent manner for the end user, fulfilling the required Quality of Service (QoS) criteria, such as bit rates and latency, to support daily needs
- **Resilient positioning in satellite networks**
  - dependency on GNSS results in major threats and risks, in case of unavailability or disruption of GNSS (jamming, spoofing or obstructions)
  - 6G system with satellite access may provide positioning service with 3GPP technologies, independently of non-3GPP positioning technologies (e.g. GNSS)
- **Immersive Communication**
  - Interactive gaming, Seamless Immersive Reality in Education
- **Fixed Wireless Access**
  - provide optimized network capabilities for FWA (e.g., support stationary devices).
- **Sustainability**
  - improve energy efficiency of 6G system compared to 5G system

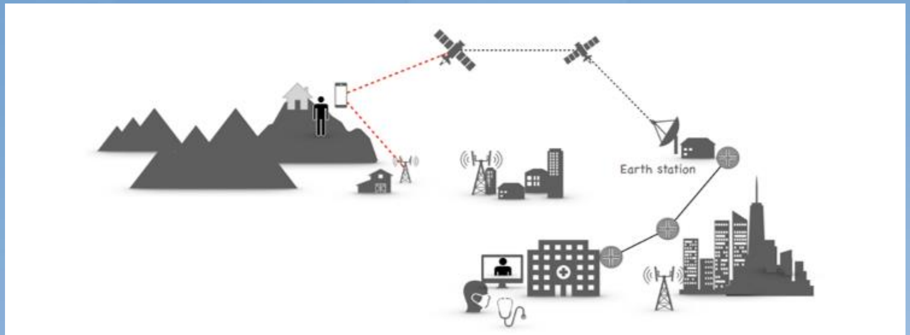
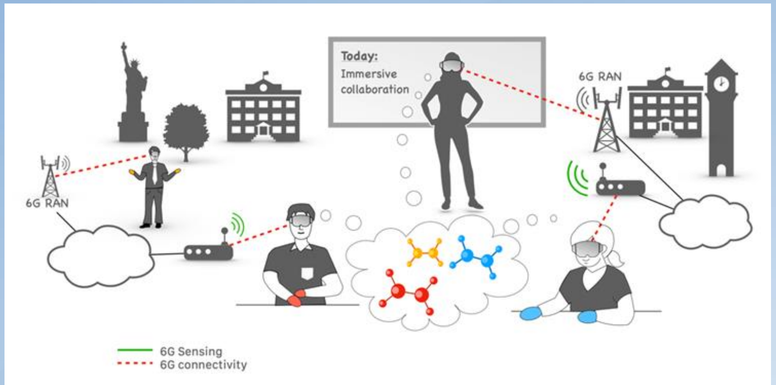


Figure 8.1-1: Ubiquitous Network: "Connectivity at Remote Locations"



O-RAN Alliance

- Planning underway for a ORAN Alliance-3GPP workshop in April 2025
  - Discussing how O-RAN's open interfaces and architecture can be harmonized with 3GPP's standardized protocols.
  - Ensuring seamless integration and interoperability between solutions developed by both organizations, including the use of AI/ML for network automation, optimization, and intelligent management.
  - Defining the vision and key requirements for 6G, building on the foundations of 5G and Open RAN principles.

- ATIS Open RAN Committee (ORC)
  - Examines topics associated with the use and deployment of open Radio Access Networks in North America.
  - Evaluates O-RAN Alliance specifications for possible transposition into ATIS standards and, as needed, proposes changes to O-RAN Alliance specifications to meet unique North American requirements for the O-RAN Alliance's consideration.

Press Room > ATIS, O-RAN ALLIANCE Agree on Transposition of O-RAN Specifications to ATIS Standards

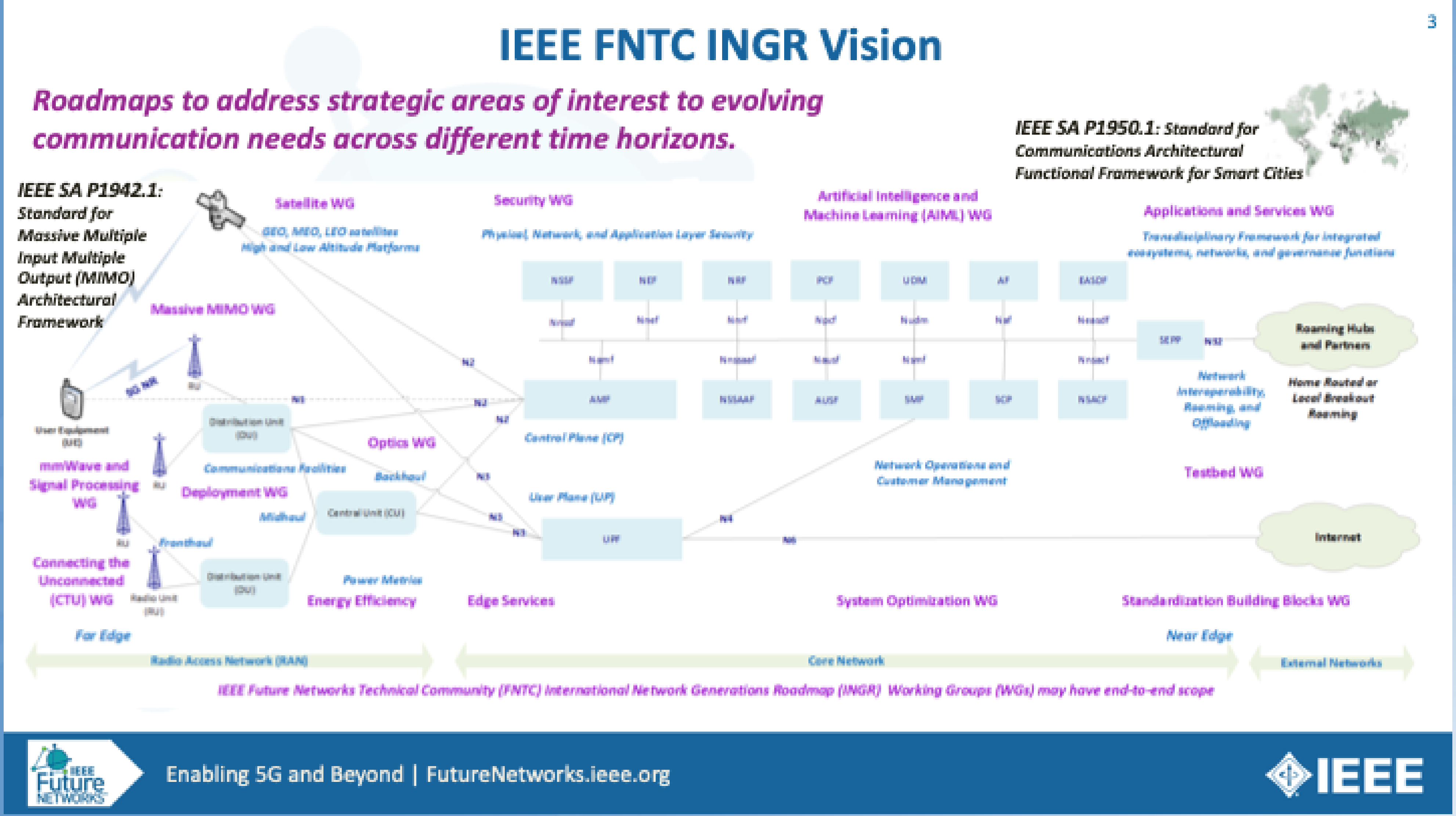
August 1, 2024

ATIS, O-RAN ALLIANCE Agree on Transposition of O-RAN Specifications to ATIS Standards

ATIS and the O-RAN ALLIANCE today announced the joint signing of a Memorandum of Understanding (MoU) that enables the transposition of O-RAN ALLIANCE specifications to ATIS standards.

The MoU establishes a joint process to identify O-RAN specifications for adoption by ATIS. This transposition is a major step toward advancing the adoption of Open Radio Access Network (RAN) in North America, by giving O-RAN ALLIANCE specifications the benefit of recognition by ATIS, an accredited standards body with broad membership from North American industry. It furthers both organizations' mutual objectives to advance the industry towards more intelligent, open, virtualized and global standards-compliant mobile networks. The agreement announced today builds on an earlier MoU between the parties that addressed cooperation on Open RAN issues, including Open RAN security as well as stakeholder requirements for Open RAN. It emphasizes ATIS' commitment to creating innovative standards for mobile networks that leverage the latest technical and architectural advances.

IEEE Future Networks Technical Community



IEEE Future Networks Technical Community

IEEE 5G/6G Innovation Testbed

The IEEE 5G/6G Innovation Testbed brings together industry participants across the broad range of 5G/6G technologies to enable win-win collaboration opportunities and contribute to the roadmap for future technological direction.

- A cloud-based end-to-end 5G network testing and innovation platform
- Use cases: Interoperability and conformance testing, load testing, sandbox innovation, proof of concepts, security tests, and more
- Flexible: connect your hardware and upload your software components
- Reduced-cost experimentation and development for interdependent industry players will speed up innovation in a time of cost-cutting
- Opportunities for academia as an educational tool, workforce preparation, and for research or capstone projects
- ***Project open worldwide for any industry or academic organization to participate***

IEEE 5G/6G InnovationTestbed testbed.ieee.org

IEEE

State of US Govt Efforts around 6G

US Govt initiatives impacting 6G

National Security Council	National Spectrum Strategy	National Standards Strategy
Principles for 6G: Open & Resilient by design (April 2023) 1.Trusted Technology and Protective of National Security 2.Open and Interoperable Innovation 3.Secure, Resilient, and Protective of Privacy 4.Affordable, Environmentally Sustainable, and Globally Connected 5.Spectrum, Novel Materials, Manufacturing 6.Standards & International Collaborations	**4 pillars (November 2023)** 1.Spectrum Pipeline, 5 bands for study 2.Collaborative Long-Term Planning for Spectrum Needs 3.Spectrum Innovation, Access, and Management through Technology Development, including National Spectrum Research and Development Plan 4.Expanded Spectrum Expertise and Elevated National Awareness	**8 priority areas including 4 directly relevant to future networks (May 2023)** 1.Communication and Networking Technologies 2.Semiconductors and Microelectronics 3.Artificial Intelligence and Machine Learning 4.Positioning, Navigation, and Timing Services

principles-for-6g.pdf National Spectrum Strategy - November 2023 US-Gov-National-Standards-Strategy-2023.pdf

Spectrum Perspectives from WRC-23

WRC-23 resolutions likely impacting 5G-Adv/6G

- Identification of **3.3-3.4** GHz for IMT
- **Upper 6 GHz band** (6.425-7.125 GHz) is identified for IMT, not only in **EMEA** but also per footnote in **Mexico**, **Brazil**, and **some Asian** countries.
  - Recognition of the use of wireless access systems (WAS)/RLAN for some countries is also part of the identification deal
  - The top 100 MHz (7025-7125 MHz) were identified for IMT for the Asia Pacific region. Potentially, **additional countries in Americas and Asia Pacific** can join the upper 6 GHz band footnote @ WRC-27, identifying the entire 700 MHz for IMT.
- **New IMT/6G** Agenda Item for WRC-27 **is approved**, which gives positive outlook enabling suitable studies to be conducted. Bands agreed for study are:
  - **4400-4800 MHz** (in EMEA and Asia)
  - **7125-8400 MHz** (excluding 7250-7750 MHz in Europe due to use by NATO)
  - **14.8-15.35 GHz** (global)

US position at WRC-23 and NSS

- Following new bands were proposed by the US delegation at WRC-23 as study item towards WRC-27 for wireless broadband use:
  - **3.1-3.3 GHz**: DoD determined that sharing is feasible if certain advanced interference mitigation features and a coordination framework to facilitate spectrum sharing are put in place. Additional studies will explore dynamic spectrum sharing and other opportunities for private-sector access in the band, while ensuring DoD and other Federal mission capabilities are preserved, with any necessary changes.
  - **12.7-13.25 GHz**: The FCC is further considering options for flexible use of the 12.7- 13.25 GHz band (the "Upper 12 GHz band"), which has in-band and adjacent-band federal operations that may need to be protected
- The NSS proposed these additional bands for further investigation by the US government:
  - **7.125 – 8.4 GHz** (on a licensed and/or unlicensed basis); a variety of mission-critical Federal operations in this band (including Fixed, Fixed Satellite, Mobile, Mobile Satellite, Space Research, Earth Exploration Satellite, and Meteorological Satellite services) that will make it challenging to repurpose portions of the band while protecting incumbent users from harmful interference
  - **37 – 37.6 GHz;** further studied to implement a co-equal, shared-use framework allowing Federal and non-Federal users to deploy operations in the band

7.125-8.4 GHz is the only common range between WRC-27 Agenda Items and National Spectrum Strategy

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Charter Topic Updates

Standardization, Development and Use Case(s) towards 6G

- WG received an update on the first 3GPP SA1 6G Use Case Workshop held in May [1]
- Workshop objective was to bring 3GPP closer to the ongoing initiatives of various global/regional research organizations and MRPs related to the 6G use cases.
  - This collaborative effort is of utmost importance as SA1 undertakes the task of defining the requirements and use cases for 6G starting from Rel-20.
  - >200 participates plus almost 400 remotely
- Invited workshop presenters included: GSMA, NGMN, 5GAA (automotive), 5G-ACIA (industrial), 5GMAG (multimedia), Satellite (GSOA), TCCA (public safety), Wireless Broadband alliance, B5GPC (Japan), 6G forum (South Korea), IMT2030 Promotion Group (China), Bharat 6G alliance (India) ATIS Next G alliance (North America), and 6G-SNS (Europe).
- No priority or ranking of the 6G use cases discussed during the 3GPP Stage-1 workshop on IMT2030 use cases

[1] https://www.3gpp.org/technologies/stage1-imt2030-uc-ws

Some Potential Drivers for 6G:

Some Potential Drivers for 6G: A table view

	Security	AI	Immersive Com	Sustainability, Energy Efficiency	Ubiquitous and resilient coverage	Sensing	"Smart life"	Native Vo6G	FWA-FWC	LPWA	Northbound API	Healthcare	Autonomous Driving	Positioning	Backward Compatibility
GSMA	✓	✓	✓	✓				✓							
NGMN	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓
5GAA	✓	✓	✓	✓	✓	✓							✓	✓	
5G-ACIA	✓	✓	✓	✓		✓					✓				✓
5G-MAG	✓	✓	✓	✓	✓	✓	✓				✓				
GSOA	✓				✓									✓	
TCCA	✓	✓			✓										✓
WBA	✓	✓				✓									
B5GPC	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	
6GForum	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	
IMT-2030RG	✓	✓	✓	✓	✓	✓	✓							✓	
B6GA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
NextGA	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓		✓	
6GSNS-ICE	✓	✓	✓	✓	✓	✓	✓					✓		✓	
ITU	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	

Note: Non-exhaustive list, showing the topics appearing in at least two presentations

IEEE802 & WFA (How is 6G progressing or expected to progress at standards and international fora?)

200+ IEEE Working Groups Developing NEW Standards

IEEE 802.11 and ongoing standards development

- IEEE 802 LAN/MAN Standards Committee standard development covers both Wireless & Wired Media
- Focus on link and physical layers of the network stack
- Leverage IETF protocols for upper layers

In progress: New 802.11 Radio technologies are under development to meet expanding market needs and leverage new technologies

- P802.11be – Extremely High Throughput in 2.4, 5 and 6 GHz bands, aka Wi-Fi 7
- P802.11bf – WLAN Sensing
- P802.11bh – Randomized MAC Addresses
- P802.11bi – Enhanced Data Privacy
- P802.11bk – 320 MHz Ranging
- P802.11bn – Ultra High Reliability
- P802.11bp – Ambient Power Communication

IEEE802 & WiFi-Alliance

Multiple working groups addressing throughput, spectral efficiency and low latency through enhancements to Wi-Fi

- 802.11be - WiFi 7 2.4GHz, 5GHz and 6GHz supported
  - Wider channels (40, 80, 160, 240, 320MHz)
  - Better modulation (4096-QAM)
  - Backward compatibility with 11a/b/g/n/ac/ax
  - Standard targets throughput minimum of 30Gbps, expect 40Gbps+
- 802.11bf - WLAN Sensing is the use of received WLAN signals to detect features of an intended target in a given environment
- 802.11bn - Ultra High Reliability
- AI/ML Standing Committee - Current applications focus on performance improvement parameter selection for channel access control and link adaptation, multi-user parameters, contention window sizes, channel usage, improved BSS transition

How is 6G technology envisioned to enhance or be utilized in various verticals?

State of the Art

3GPP continues to work on 5G NR and discussions for 6G have started

Some evolution of 5G NR has been towards automotive vertical

- V2X is the most notable example

However, most evolution has been towards eMBB enhancements

- Focus is on higher data rate, coverage extension and lower latency
- Addressing the quick refresh cycle associated with smartphones

5G NR deployment in automotive is ongoing

Evolution Towards 6G

Evolution should enable new use cases to increase value

New services and increased value needs to be added in a cost-effective manner

Leverage different components of the vehicle to deliver these services

Enable new & enhanced services in a cost-effective manner using "reuse & synergy"

Automotive Requirements for Beyond 2030

Ubiquitous Connectivity is key for most automotive use cases

Secure, Reliable, resilient, low latency, high-mobility communication for safety, advanced driving and remote vehicle services.

Enhanced communications for immersive multimedia, immersive infotainment/applications in vehicle,

Pedestrian protection by improved location information availability of UE (<1 m)

Enabling 6G technologies

Functional-Critical automated driving services → Resilient Communication

Improve service continuity → Hybrid TN and NTN Architecture

Improved Sensing Capabilities → Integrated Sensing and Communications

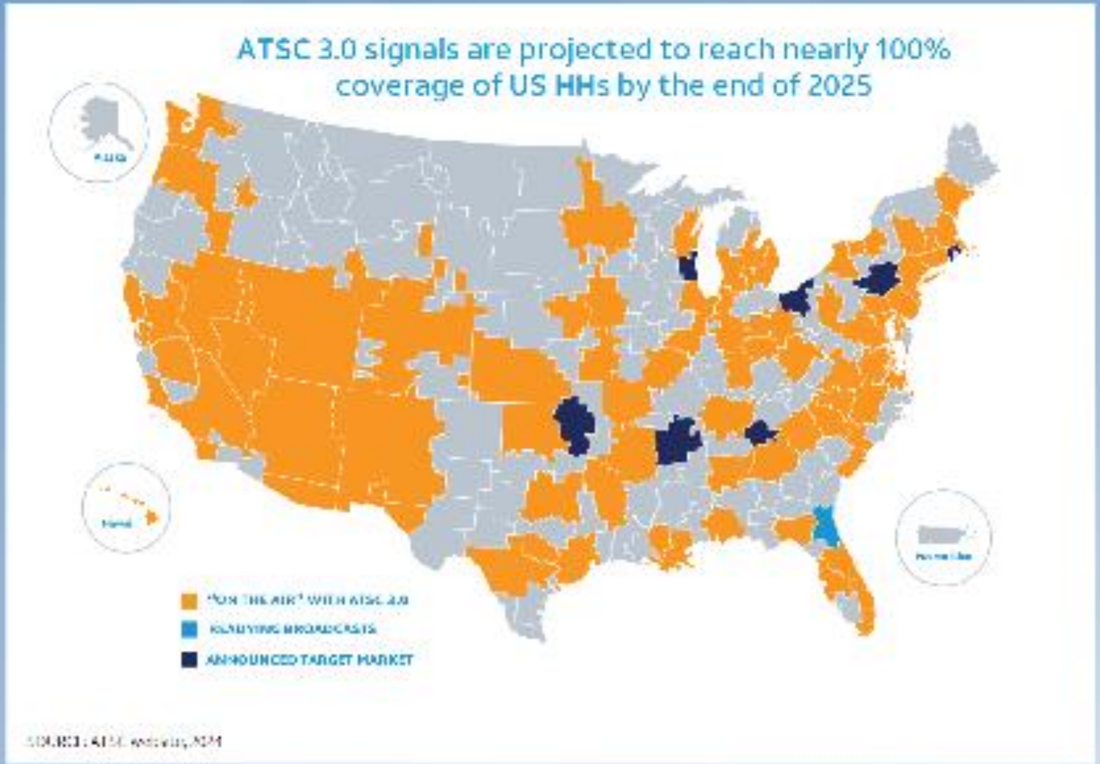
Antenna Placement outside the vehicle → Refractive Meta Surfaces

ATSC 3.0

ATSC 3.0 was adopted by the FCC in 2017 to enable a convergence with broadband streaming by providing for the transmission of video, audio, and data in a standard IP format

Datacasting on ATSC 3.0

- Enables a low-latency push of information to all devices in a metro area / region
- Allows for reliable, time-sensitive communications across regional areas and in congested environments
- Complementary to Cellular/Broadband



ATSC 3.0-enabled Datacasting Benefits: Complementary to Cellular

Additional Content Offload

- Ability to integrate with strained cellular and broadband networks to offload popular or surging content and improve network efficiency

Hyperlocal

- Targeted broadcasting transmissions enable myriad use cases
- Enhanced GPS, localized emergency alerts, personalized content and dynamic ad insertion

Increased Network Capacity

- Provides an alternative data route to end devices, decongesting the data pathways
- More content can be cached at edge and quickly delivered to consumers

Fast Download Speeds

- A single 6 MHz broadcast channel can match or exceed traditional broadband download speeds: 50 Mbps+

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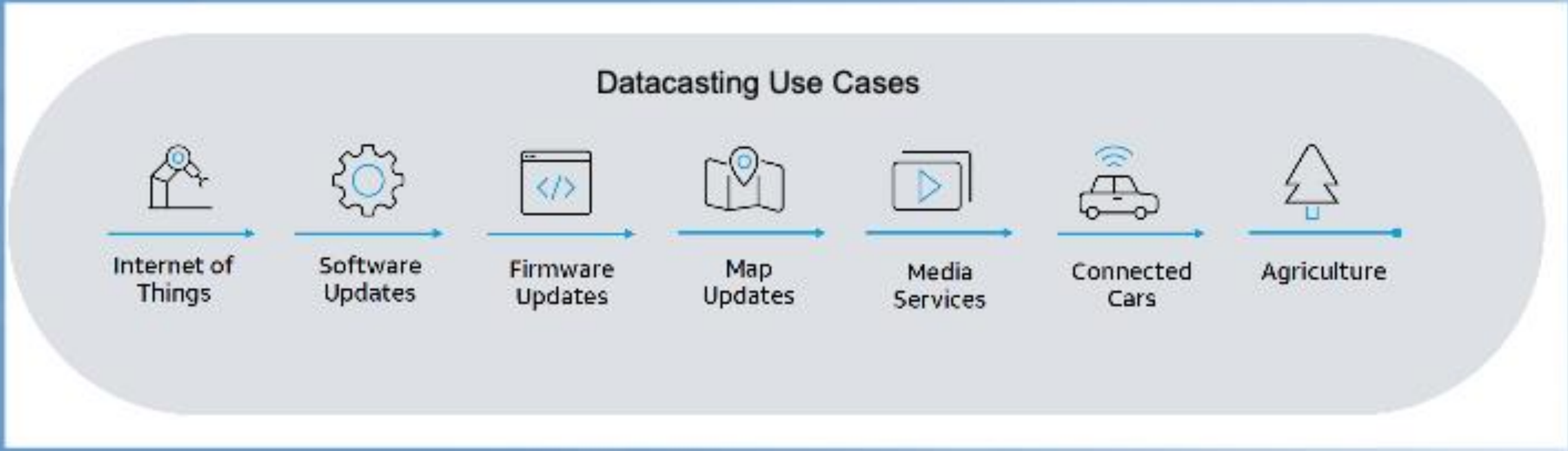
Datacasting Use Cases

AT&T (and others) - dongle containing an ATSC receiver for datacasting services, connected via Bluetooth/WiFi to an external device

Use cases include:

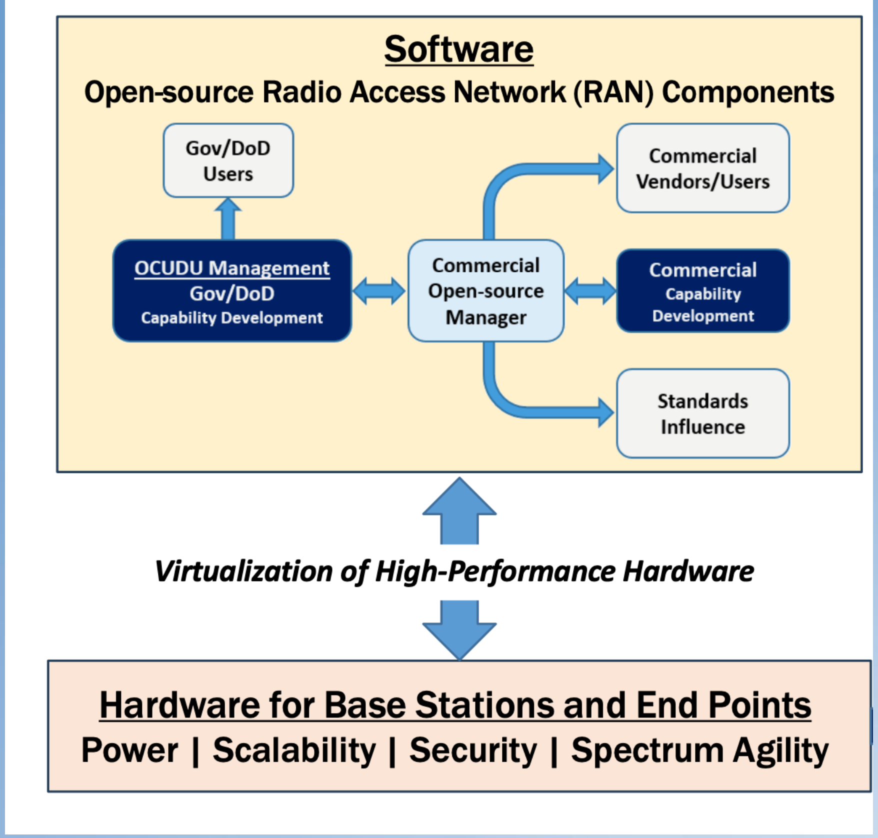
- Digital signage
- Firmware updates



Open Architectures for 6G

Key Benefits:

- Secure
- Customizable
- Interoperable
- Flexible
- Transparent
- Cost Effective
- Drives Innovation



Source: FutureG US DoD

Improve government capabilities with frameworks, algorithms, and architectures enabling more secure, resilient, real-time adaptable, flexible cellular networks that can serve dynamic deployments at the tactical edge.

Affecting 6G Standards through open source alternatives

Augmented and Virtual Reality: XR/VR/AR 6G Use Case Requirements

Defining XR:

- Persistent spatial internet with personalized digital experiences
- Spans both physical and virtual worlds
- Shared virtual space in VR/MR
- Digitally enhanced physical space with AR

Requirements

Motion to Render to Photon Latency = Edge Processing + 5G Round trip time + Device processing

100X Network Capacity

0.1-10 Gbps per User

Drivers

Physical, digital, virtual, immersive interactions will take human augmentation to next level via ubiquitous, low-power joint communication and sensing

Spatial compute enables immersive interaction with 3D digital content

Digital twins digitize the complex physical world in the metaverse

Augmented and Virtual Reality: XR/VR/AR 3GPP Enhancements

3GPP enhancements for XR

Low Power Modes Rel 15/16

Uplink Enhancements: Rel 16

XR Burst Handling Rel-17

Device latency and power efficiency in Release 18

Study Items

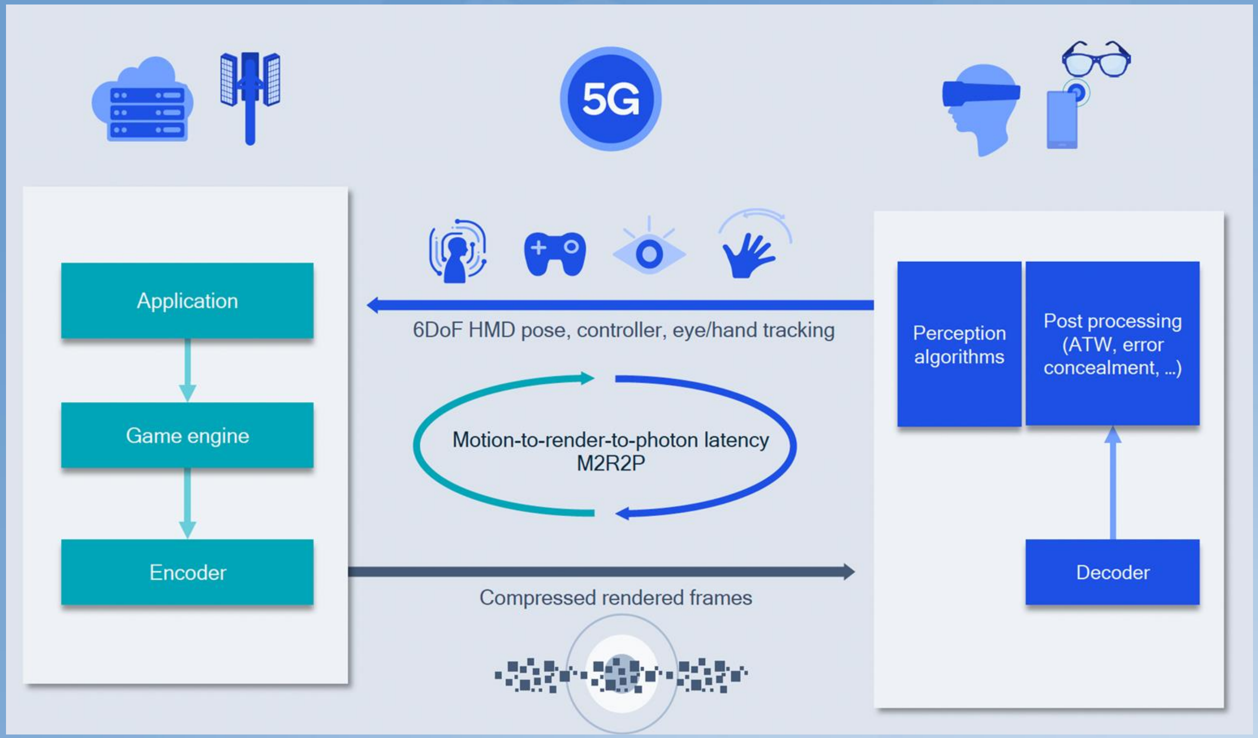
Align transmission to multimedia cadence

QoS based on multimedia payload

Staggering UE traffic arrivals at gNodeB

Sleep after low latency uplink transmission

Low Latency Mobility



Source: Qualcomm

Simultaneous in-band Transmit and Receive

Full Duplex : Key issue is Self-interference

Mitigation: Cancellation and suppression of self-interference

Issues: Analog cancellation scales with array size so ill-suited for large arrays in 5G

- Analog to Digital Converters do not follow Moore's law 1 bit/decade improvement
- Deployment within a brownfield environment and TDD configuration changes

Benefits: Increased Data rate for high data transfer applications in 6G

Utility in 6G Joint sensing and Communications

Subband Full Duplex

SBFD is a technique for TDD bands where component carrier BW is split into non-overlapping uplink and downlink subband(s) to enable simultaneous Tx/Rx at the gNB side. Leverages the benefits of full duplex communication while reducing interference mitigation requirements

SBFD is studied in 3GPP Rel-18 as advanced duplexing technology for 5G-advance/6G and is in specification phase in Rel-19

Key Challenges: Self-interference and clutter echo Inter-gNB and Inter-UE cross link interference

Key Benefits: System capacity improvement and enables new use-cases, e.g., ISAC

Enable further latency reduction and

Higher throughput improves UL-coverage and reduces UL latency

International Advancements and Competition in PNT

In addition to the Global Positioning System (GPS)

- BeiDou(China): Provides global PNT with robust, layered structure.
- GLONASS (Russia): Emphasizes regional coverage and strategic autonomy.
- Galileo (EU): Adds high accuracy, complimentary redundancy and independence. Expands Device Market.

Integrating PNT Resiliency in 6G

- Resilient PNT Integration, Layered Failure Modes.
- Benefits of 6G-PNT Integration: Enhanced navigation and timing accuracy across urban areas and indoors. Reduced reliance on satellite-only systems vulnerable to external threats.
- Prototype Opportunity: Leverage late-stage 5G to test and refine PNT resiliency approaches.

Advisements & Next Steps

Advisements

- The Commission should monitor the initial work in 3GPP, specifically the SA1 Study on 6G Use Cases and Service Requirements, for insights into the potential use cases that will be developed by 3GPP in Release 20, and implications to telecommunications policy.

- The Commission should monitor the outcomes of the 3GPP 6G Workshop in March and the joint ORAN-3GPP workshop targeted for April to gain an insight into the evolution towards 6G.

- Integrated Sensing and Communications (ISAC), Native AI in RAN and Non-Terrestrial Network Integration topic areas will provide new service delivery opportunities for 6G Networks.

Plan for 2025

- Final deliverable due in September 2025
- WG Meetings will continue Thursday’s from 4-5 PM Eastern
- WG will monitor and report on the work in 3GPP, especially the 6G study, the March 2025 workshop, and the joint ORAN-3GPP workshop
- WG will have additional SME presentations addressing the Charter items, specifically will focus on these topics:
  - mmWave and THz
  - Public Safety
  - Positioning and Timing
  - Integrated Sensing and Communication
  - Open RAN & 3GPP Alignment

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Summary of SME Presentations

SME Speakers

Organization	Topic	Speaker	Summary
NEXT G ALLIANCE An ATIS Initiative	NGA perspective on 3GPP SA-1 Use Case Workshop	Mr. David Young	• Sustainability native 6G: Privacy and Trust, Digital Equity and quality of Life Key value indicators (KVI) • Target shared investments in 6G Proof of Concepts and testbeds • Multi-sensory XR, Digital Twin, Connected vehicles, Cooperative Robots, Massive Sensors enabling new solutions • KPI's for positioning, reliability, sensing and sustainability
Hewlett Packard Enterprise	An update and roadmap for IEEE 802 Standards	Ms Dorothy Stanley	• Investigate WLAN support of Artificial Intelligence/ Machine Learning • IEEE 802.11 Working Group Standards development and Wi-Fi Alliance Interoperability Certification ecosystem enable a robust market ecosystem • Roadmap goals include: improve reliability of WLAN connectivity, reduce latencies, increase manageability, increase throughput including at different SNR levels, and reduce device level power consumption
Qualcomm	6G For Automotive	Dr Shailesh Patil	• Allow deployment of 6G without requiring hardware upgrade for already deployed 5G vehicles • Improved remote driving using reliable communication • Use transparent meta surfaces to replace RF cables for cost benefits • Remote Intervention for Automotive Safety Integrity Level (ASIL)

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SME Speakers

Organization	Topic	Speaker	Summary
Qualcomm	XR Evolution for 6G	Mr Hemanth Sampath	• XR is evolving to be the next computing platform • Target shared investments in 6G Proof of Concepts and testbeds • Multi-sensory XR, Digital Twin, Connected vehicles, Cooperative Robots, Massive Sensors enabling new solutions • KPI's for positioning, reliability, sensing and sustainability
CEWI NETWORKS	Evolution of digital broadcasting technology, from ATSC1.0 to 3.0	Mr Colin Smith	• Investigate WLAN support of Artificial Intelligence/ Machine Learning • IEEE 802.11 Working Group Standards development and Wi-Fi Alliance Interoperability Certification ecosystem enable a robust market ecosystem • Roadmap goals include: improve reliability of WLAN connectivity, reduce latencies, increase manageability, increase throughput including at different SNR levels, and reduce device level power consumption
FutureG Wireless Technology Office, Department of Defense	DoD Perspective on 6G	Dr Martin Weiss	• Allow deployment of 6G without requiring hardware upgrade for already deployed 5G vehicles • Improved remote driving using reliable communication • Use transparent meta surfaces to replace RF cables for cost benefits • Remote Intervention for Automotive Safety Integrity Level (ASIL)

SME Speakers

Organization	Topic	Speaker	Summary
RICE	Full Duplex Wireless	Dr Ashutosh Sabarwhal	•In Band Full Duplex has the main issue of self-interference •In Band Full Duplex has significant opportunity using Massive MIMO systems •Analog Self interference suppression is hard and does not scale linearly with large array sizes • Studies on split array architectures for Massive MIMO systems
VIRGINIA TECH	A Day Without Space: Enhancing Positioning, Navigation, and Timing (PNT) Resiliency	Prof David Simpson	•The growing dependencies and threats with PNT call for integrating space-based and terrestrial PNT systems for enhanced resilience. Rapidly growing Chinese PNT expertise and capabilities with accurate, available and resilient PNT integrated under the BeiDou program that could gain strong market and global geopolitical support. Potential future scenarios that will require new approaches to retain and, in some areas, regain U.S. PNT primacy. Immediate and long-term strategies to address current and emerging challenges.

SME Speakers

Organization	Topic	Speaker	Summary
institute imdea networks	Visible Light Communication for 6G	Dr Domenico Giustiniano	• Transmitting 5G OFDMA waveforms over VLC (with 10 MHz bandwidth) • It can be integrated in WiFi chipsets (802.11bb standard) • Ambient IoT/Battery-free - 3GPP Release 19 Study Item • Uplink transmissions are challenging on VLC systems – Energy expensive, directional and unpleasant – Leverage Backscatter chirp using very low power
Qualcomm	Sub Band Full Duplex for 6G	Dr Kiran Mukkavilli	•Subband full duplex (SBFD) is a novel duplexing scheme for TDD bands • Component carrier BW is split into non-overlapping uplink and downlink subband(s) to enable simultaneous Tx/Rx at the gNB side. Leverages the benefits of full duplex communication while reducing interference mitigation requirements • Key Challenges: Self-Interference and Clutter Echo, Inter gNodeB and UE cross link interference

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Thank You

FCC Technological Advisory Council Agenda – December 19, 2024

10:00am – 10:15am	Opening Remarks
10:15am – 11:30am	Advanced Spectrum Sharing WG Presentation
11:30am – 12:45pm	AI/ML WG Presentation
12:45pm – 2:00pm	Lunch
2:00pm – 3:15pm	6G WG Presentation
3:15pm – 3:30pm	Closing Remarks
3:30pm	Adjourned