IEEE Future NETWORKS™

Enabling 5G and Beyond

Distinguished Lecture

Insights into 6G Based on Today's Research

29 November 2023

IEEE

IEEE Future Networks – FutureNetworks.ieee.org

Collaboration

IEEE Antennas and Propagation Society · CAS · IEEE ComSoc IEEE Communications Society · IEEE Electronics Packaging Society · ITSS · MTT-S · IEEE Reliability Society · SSCS · IEEE VTS Connecting the Mobile World

Content

+ technical newsletter, podcasts, videos, articles

Events

IEEE Future Networks™ WORLD FORUM · IEEE Connecting the UNCONNECTED SUMMIT An IEEE Future Networks Program · IEEE 5G Workshop on First Responder and Tactical Networks

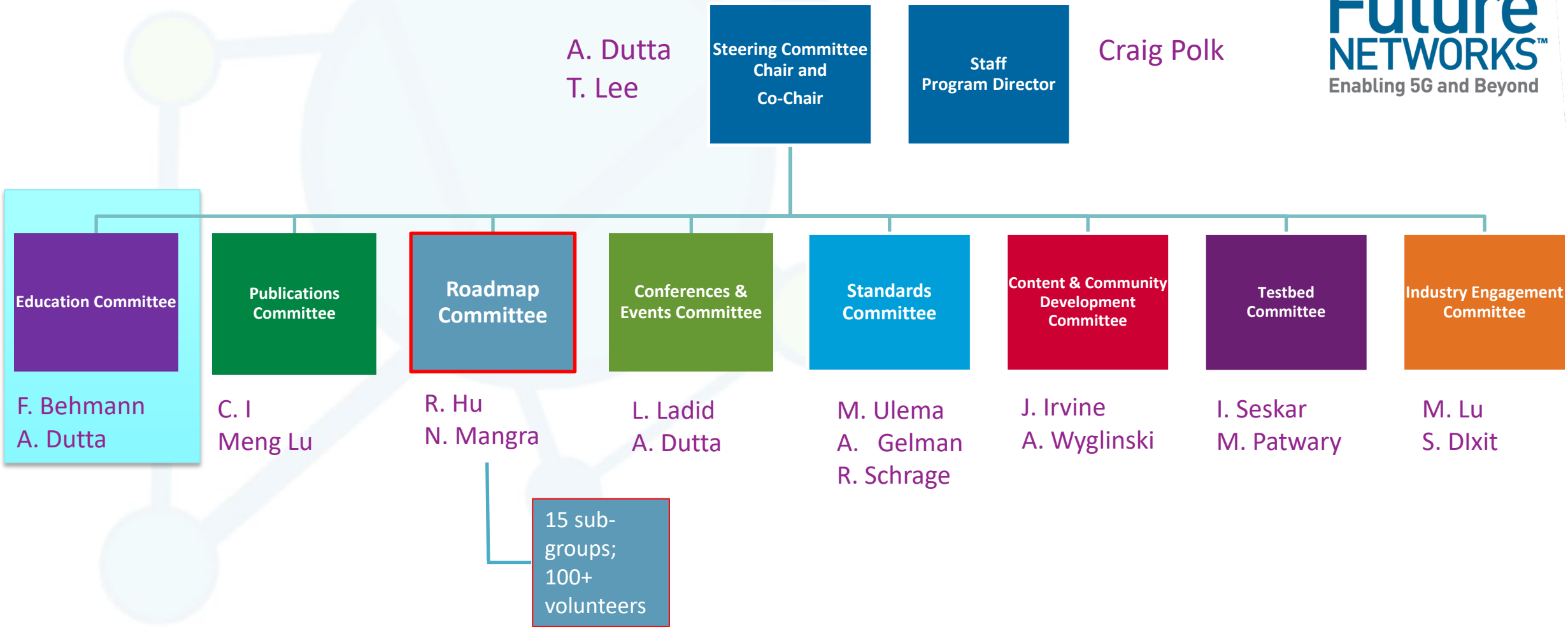
+ more!

Research & Education

IEEE INGR International Network Generations Roadmap

+ eLearning, webinar series, white papers, tutorials

IEEE Future Networks Organization Structure



Education

Education — 6 Working Groups →

Webinars	e-Learning Courses
Distinguished Lecturer Program	Summer School
Tutorials	Podcasts

Bi-weekly or Monthly meetings

Discussion on adding STEM outreach WG

Teach

Learn

Attend

Discover

- Webinar series, 9 during 2023, avg 286 registrants
- Podcasts - 5 guest appearances and 3 podcasts recorded
- 2-day Tutorial occurred September 21-22, 2023, 357 registrants
- 1 Virtual Distinguished Lecturer, 410 registrants / 1 planned for remainder of 2023 (this event)
- 3 In-person Distinguished Lecturer, 65 attendees / 3 planned for remainder of 2023
- Summer School / Student Leadership event held at Future Networks World Forum Nov 2023

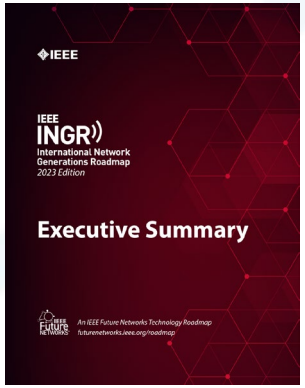
IEEE INGR Structure and Working Groups

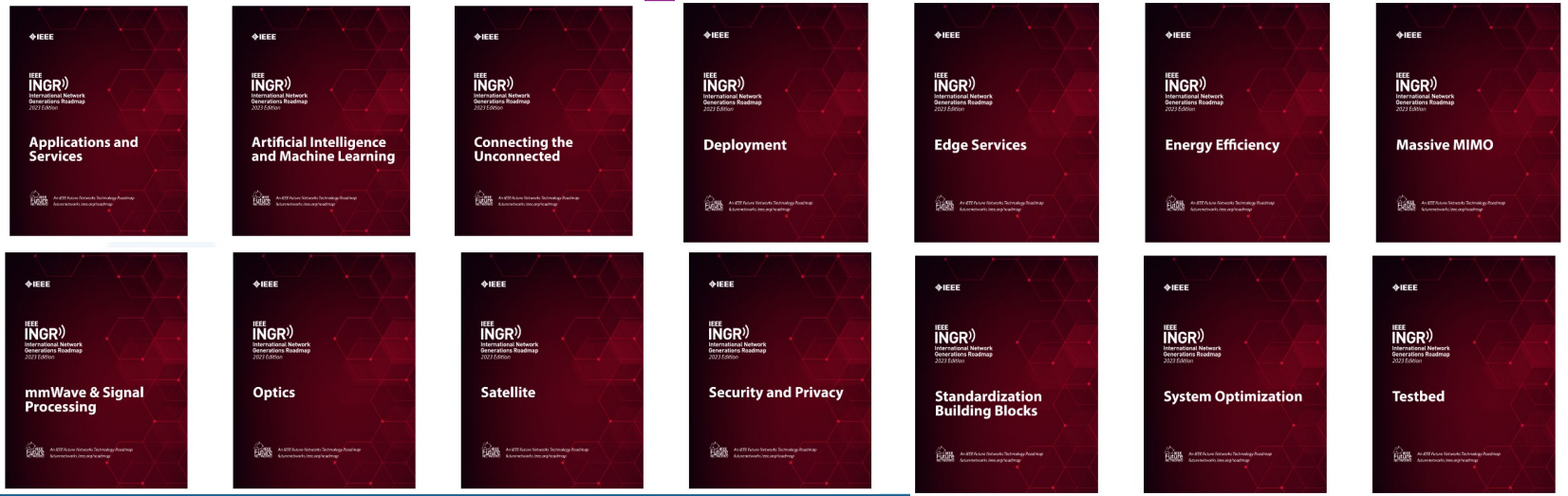
CATEGORY	DESCRIPTION	INGR WORKING GROUP CHAPTERS
User Access	This group describes how the users reach the network	• Satellites • Deployment • Connecting the Unconnected (CTU)
Network Components and Performance	This group describes how the networks are interconnected	• Edge Automation Platform • Massive MIMO • System Optimization • Optics • Quantum Information Technology (QIT) • mmWave
Systems and Standards	This group describes system standards and testability	• Standardization Building Blocks • Testbed • Energy Efficiency
Services and Enablers	This group represents all the elements that enable deployment, assure functionality and security and address impact on society and environment	• Security • Applications and Services • Artificial Intelligence and Machine Learning (AI/ML)

15 INGR Technical Working Groups

14 chapters

In 2023 Edition





https://futurenetworks.ieee.org/roadmap

IEEE
Advancing Technology for Humanity

UPCOMING EVENT

2023 Connecting the Unconnected Summit

Closing the Gender Digital Divide

IEEE Future NETWORKS™

IEEE Connecting the UNCONNECTED™ SUMMIT

4 December 2023 | https://ctu.ieee.org

IEEE GLOBECOM®

IEEE Global Communications Conference
4–8 December 2023 // Kuala Lumpur, Malaysia

IEEE ComSoc IEEE Communications Society

IEEE

UPCOMING EVENT

2023 6th IEEE 5G Workshop on First Responder and Tactical Networks

13 December 2023

8:30 AM – 5:00 PM EST

https://futurenetworks.ieee.org/conferences/2023-first-responder-and-tactical-networks-workshop

IEEE

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

IEEE Future NETWORKS

US Department of Defense
OUSD Research & Engineering

US Department of Homeland Security
Science & Technology Directorate

Prof Jeffrey Reed

Professor Jeffrey Reed is the Willis G. Worcester Professor of ECE. Professor Reed's research interests are wireless communications, wireless security, cognitive radio, software radio, telecommunications policy, and spectrum access. Reed has co-authored more than 500 articles and books. In addition, Reed co-founded several commercial companies, including Federated Wireless, which commercializes spectrum sharing; PFP Cybersecurity, which provides security solutions for IoT devices; and Cirrus360, which produces tools for rapid prototyping of O-RAN. Reed is the Founding Director of Wireless@Virginia Tech, a university research center, and co-founder of Virginia Tech's Hume Center for National Security and Technology, where he served as the Interim Director. He also served as the Interim Director of the Commonwealth Cyber Initiative and is currently its CTO. Dr. Reed is a Fellow of the IEEE For contributions to software radio and communications signal processing and for leadership in engineering education.

What to Expect from 6G Wireless

Dr. Jeffrey H. Reed
Willis G. Worcester Professor of ECE, Bradley Dept. of ECE, Virginia Tech
Founding Director of Wireless@Virginia Tech and CTO Commonwealth Cyber Initiative
reedjh@vt.edu

November 29, 2023

Outline

- Introduction
  - Casting 5G/6G with a historical perspective
  - Factors influencing next-generation standards development
    - Promising business use cases
    - Incomplete or not working aspects of the current standard
    - Political – e.g., sustainability, rural developing economies, IP positions, etc.
    - Research from industry, academia, and 3GPP Study Groups
- Status of 5G and 6G
- My predictions
- Examples from our related research: waveforms, xApps, geolocation, and security.
- Summary of Key Thoughts

Status

“3GPP standards are like Star Trek movies, only the even ones are good.”

-- Dr. Tom Rondeau, OSD

My Stance

All wireless standards are always hyped and followed by huge initial disappointments, that is until they finally succeed.

--- Me, 2023

Googling “5G disappointing” resulted in 16,400,000 hits


Wall Street Journal

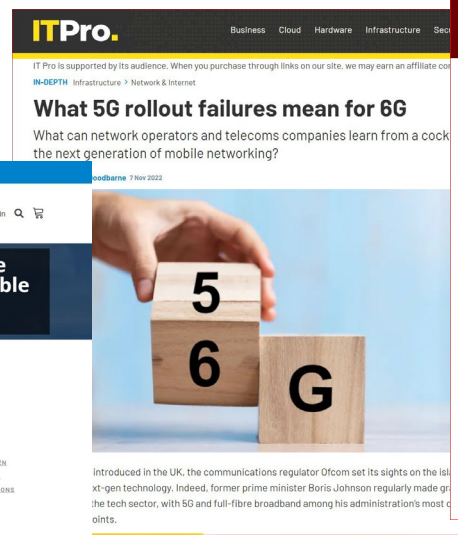
PERSONAL TECHNOLOGY. JOANNA STERN

It’s Not Just You: 5G Is a Big Letdown

The newest network won’t change how you use your phone—but you can still make the most of it


SYB

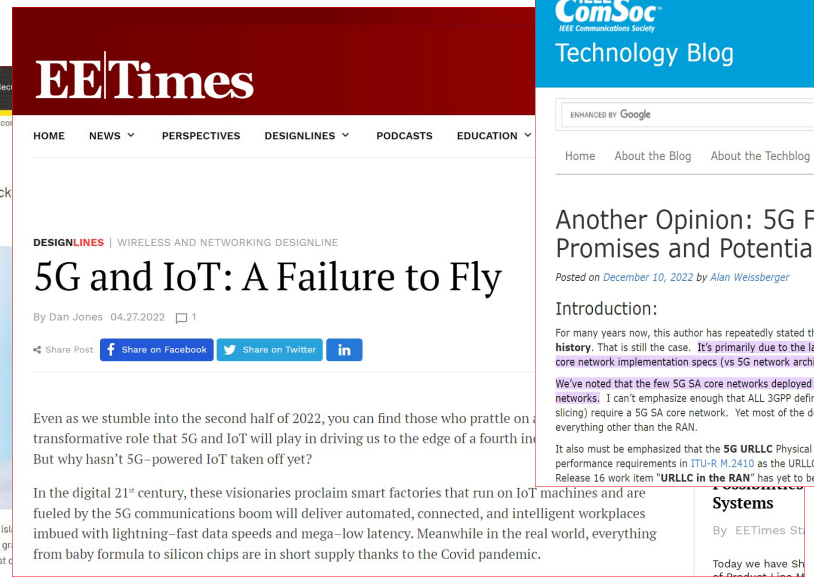
5G Is Failing In 2022: Why Haven’t More People Switched To 5G, Despite Knowing What It’s Capable Of?


ITPro.

What 5G rollout failures mean for 6G

What can network operators and telecoms companies learn from a cock

the next generation of mobile networking?


EETimes

DESIGNLINES | WIRELESS AND NETWORKING DESIGNLINE

5G and IoT: A Failure to Fly

By Dan Jones 04.27.2022

Even as we stumble into the second half of 2022, you can find those who prattle on

transformative role that 5G and IoT will play in driving us to the edge of a fourth in

But why hasn’t 5G–powered IoT taken off yet?

In the digital 21st century, these visionaries proclaim smart factories that run on IoT machines and are fueled by the 5G communications boom will deliver automated, connected, and intelligent workplaces imbued with lightning–fast data speeds and mega–low latency. Meanwhile in the real world, everything from baby formula to silicon chips are in short supply thanks to the Covid pandemic.


IEEE ComSoc

Technology Blog

Another Opinion: 5G Fails to Deliver on Promises and Potential

Posted on December 10, 2022 by Alan Weissberger

Introduction:

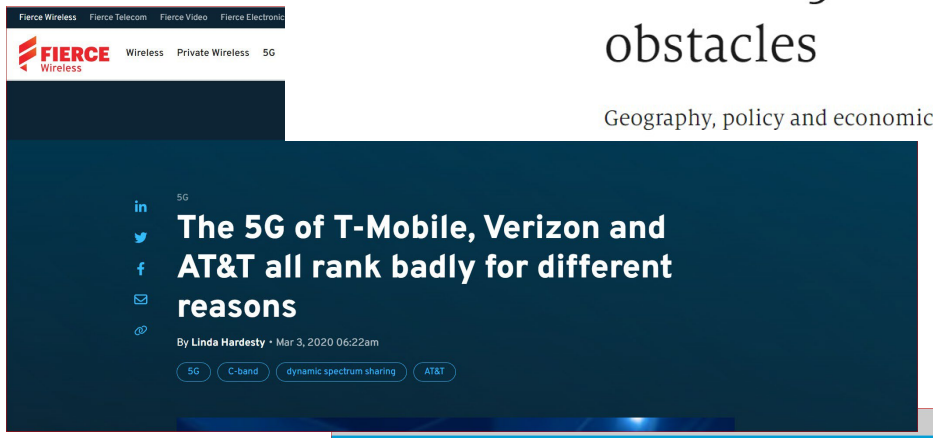
For many years now, this author has repeatedly stated that **5G would be the biggest train wreck in all of tech history**. That is still the case. It’s primarily due to the lack of ITU standards (really only one- ITU M.2150) and 5G core network implementation specs (vs 5G network architecture) from 3GPP.

We’ve noted that the few 5G SA core networks deployed are all different with no interoperability or roaming between networks. I can’t emphasize enough that ALL 3GPP defined 5G functions and features (including security and network slicing) require a 5G SA core network. Yet most of the deployed 5G networks are NSA which use a 4G infrastructure for everything other than the RAN.

It also must be emphasized that the **5G URLLC** Physical layer specified in ITU-R M.2150 does not meet the performance requirements in ITU-R M.2410 as the URLLC spec is based on 3GPP Release 15. Astonishingly, the 3GPP Release 16 work item “**URLLC in the RAN**” has yet to be completed, despite Release 16 being “frozen” in June 2020 (2

Archives

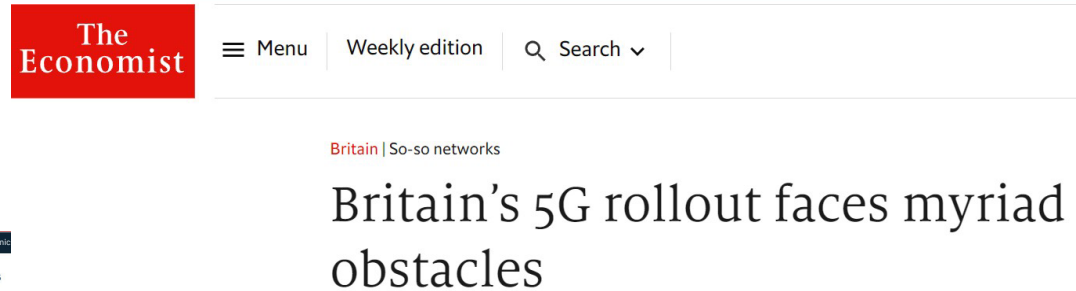
- March 2023
- February 2023
- January 2023
- December 2022
- November 2022
- October 2022
- September 2022
- August 2022
- July 2022
- June 2022
- May 2022
- April 2022
- March 2022
- February 2022
- January 2022
- December 2021
- November 2021


FIERCE Wireless

The 5G of T-Mobile, Verizon and AT&T all rank badly for different reasons

By Linda Hardesty • Mar 3, 2020 06:22am

5G C-band dynamic spectrum sharing AT&T


The Economist

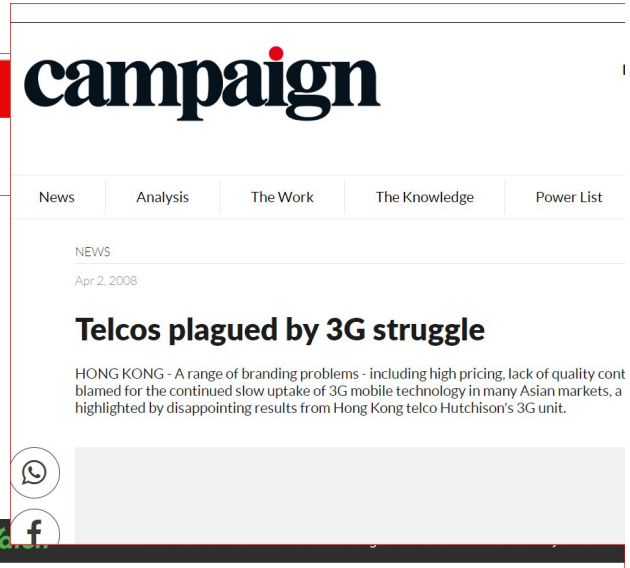
Menu Weekly edition Search

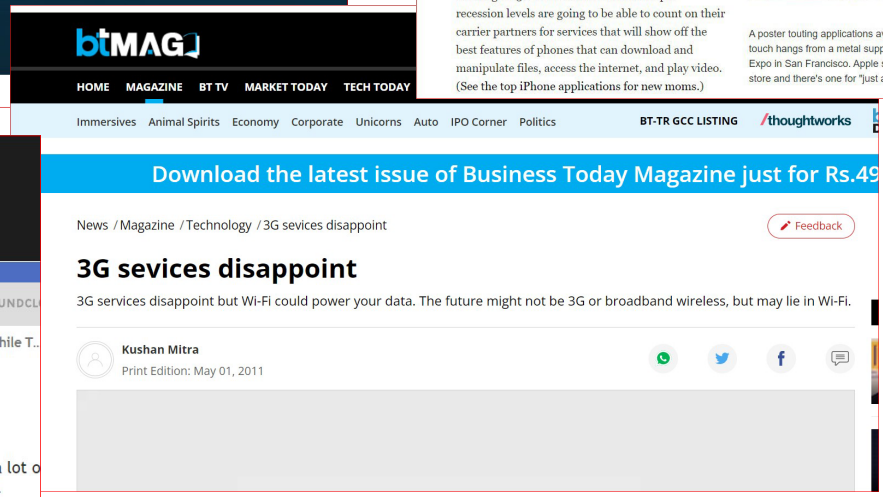
Britain | So-so networks

Britain’s 5G rollout faces myriad obstacles

Geography, policy and economics all play a role

It happened with 3G too





Googling "3G disappointment" resulted in 6,320,000 hits.

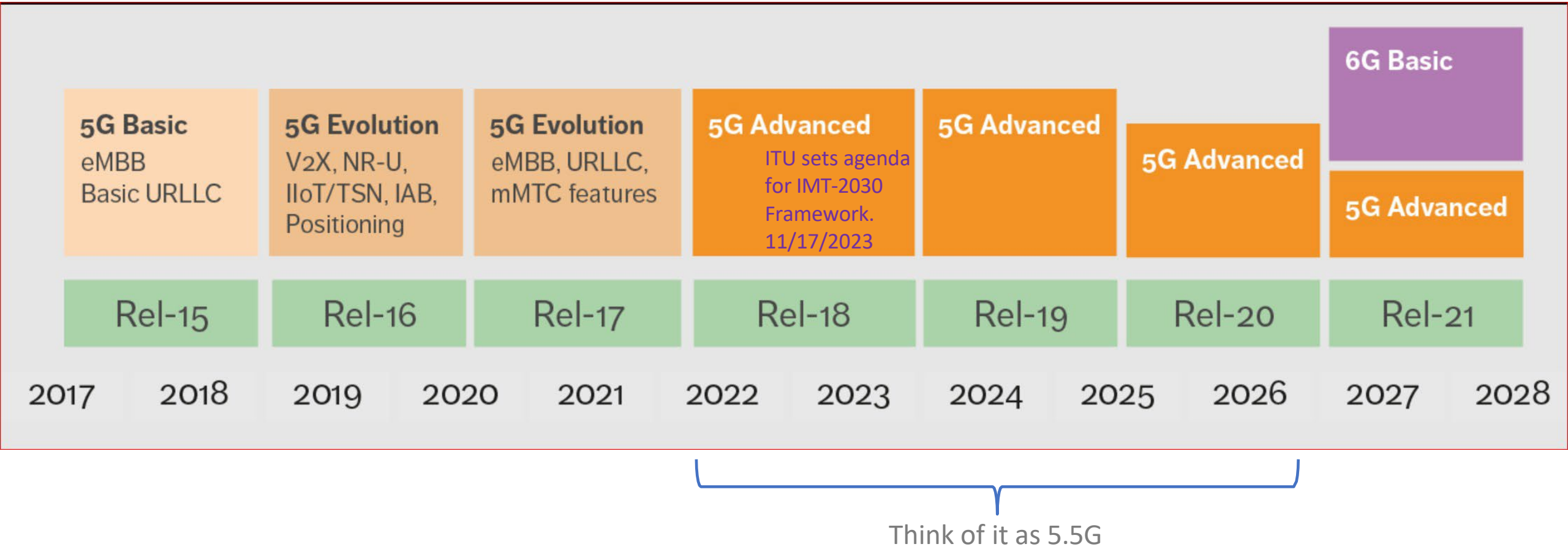
Nevertheless, 5G is VERY Complex and VERY Different from Past Standards

- Core Network Changes – in general dramatic structural changes to the network.
- Higher data rates, but we could have done that with LTE.
- Massive Machine-to- Machine Communications (we have not seen that impact).
- Lower latency – one of the true distinguishing things about 5G that has the potential to open up many new applications.

5G is still evolving, but many of the capabilities are yet to be demonstrated or demonstrated at scale.

A major driver of 6G will be to enable the realization of the 5G dream.

Timeline to Get to 6G



Source: https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/5g-evolution-toward-5g-advanced

Near-Term Timetable

Some Features of Release 18 – Freezed in March 2023

- Study on Artificial Intelligence (AI)/Machine Learning (ML) for New Radio (NR)
- Air Interface and NG-RAN
- Study on Evolution of NR Duplex Operation, e.g., sub-band full duplex (SBFD)
- Study on network energy saving
- Study on network-controlled smart repeaters
- More advanced Extended Reality (XR) technologies to enable more/new XR applications.
- Continue to enhance NR MIMO, sidelink and sidelink relay, positioning, dynamic spectrum sharing, multi-carrier communications, Non-Terrestrial Networks (NTN) and IoT NTN, multicast and broadcast, IAB technologies.
- Further reduction of NR Redcap (Reduced Capability) UE complexity

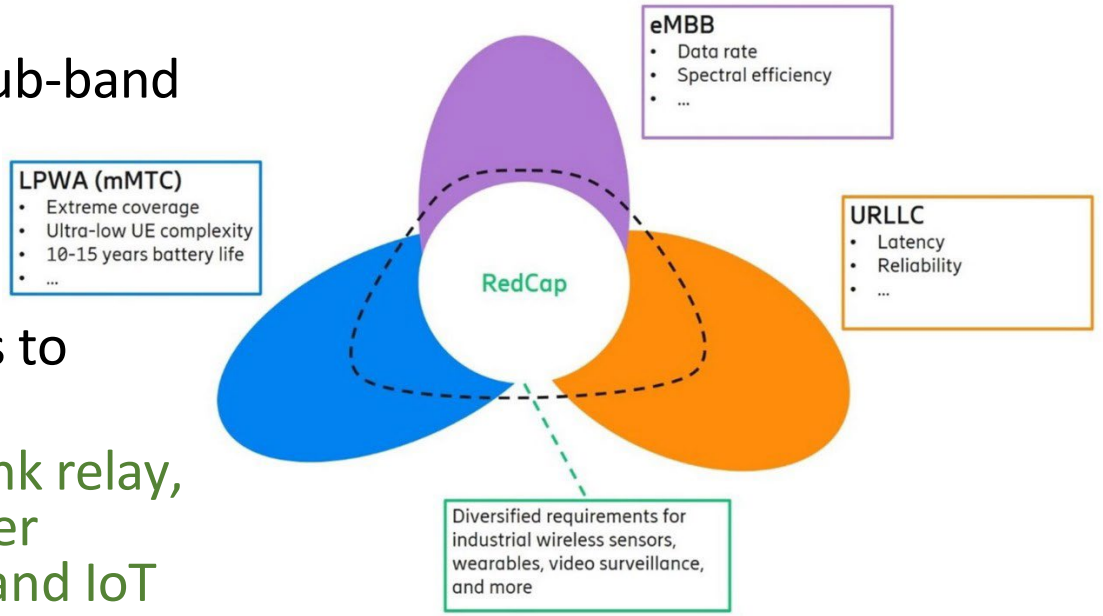


Figure source: https://www.rcrwireless.com/20230619/internet-of-things-4/ericsson-readies-5g-redcap-upgrade-to-enable-next-wave-of-cellular-iot

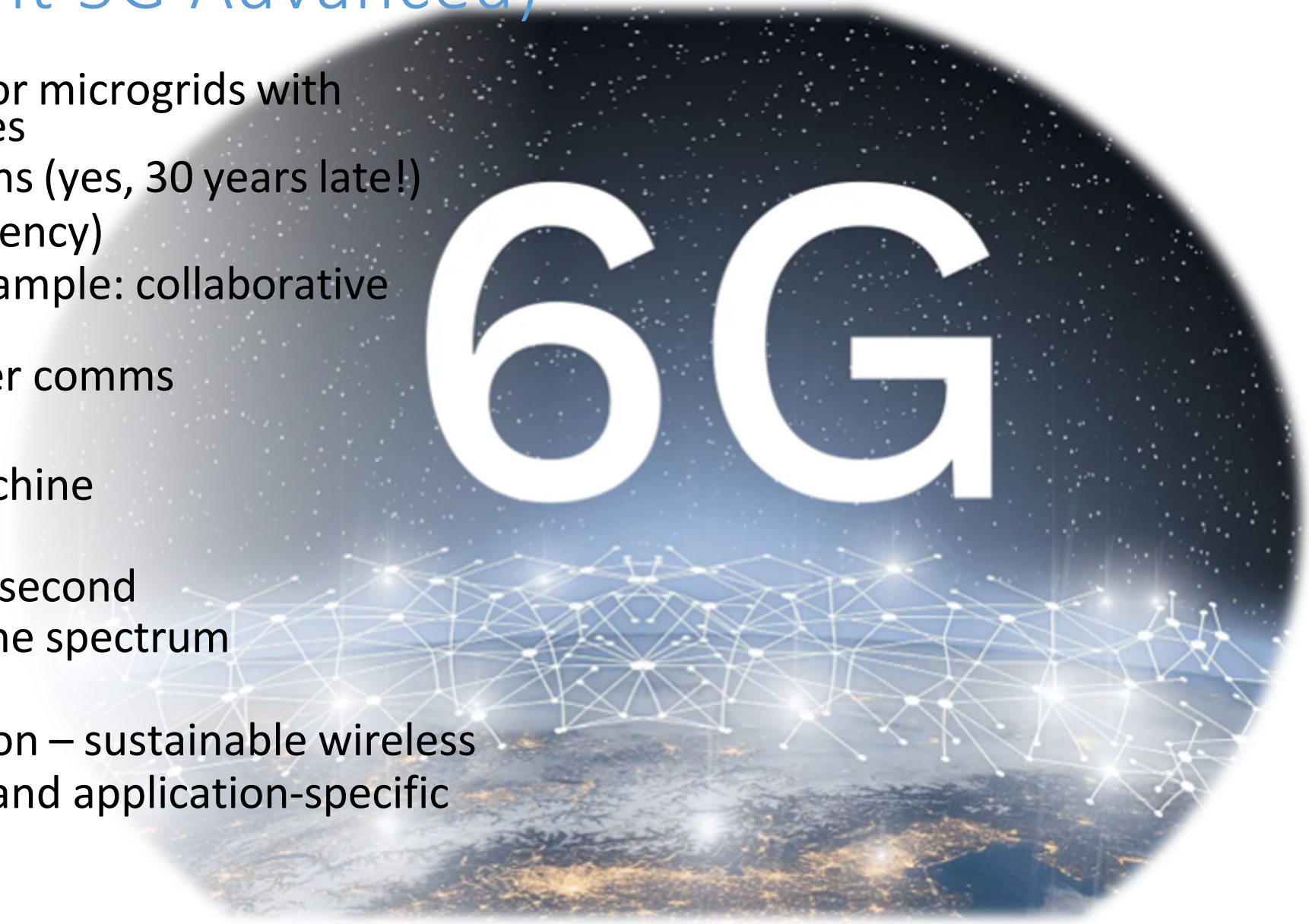
Medium Term Timetable

- **Early Release 19 Studies (may or may not end up in a standard) likely freeze Sept. 2025**
  - Network of Service Robots with Ambient Intelligence
  - Energy Efficiency as service criteria
  - Upper layer traffic steering, switching, and split over dual 3GPP access
  - Uncrewed Aerial Vehicles (Phase 3)
  - Satellite Access (Phase 3)
  - Roaming value-added services
  - AI/ML Model Transfer (Phase 2)
  - Integrated Sensing and Communication Ambient power-enabled Internet of Things
  - Localized Mobile Metaverse Services
  - Network Sharing Aspects
  - Future Railway Mobile Communication System (Phase 5)
  - Supporting Railway Smart Station Services

Long Term: 6G is approximately Release 21 (~ 2028) for the basic configuration

Drivers for 6G (& to some extent 5G Advanced)

- New applications
  - Grid control, especially for microgrids with renewable energy sources
  - Vehicular communications (yes, 30 years late!)
  - Digital twin (ultra-low latency)
  - Sensing and comms – example: collaborative vehicular radar
  - Dirt-cheap and low power comms
- Fix 5G
  - Massive Machine-to-Machine
  - Tbps throughput
  - Lower latency – sub-millisecond
  - Better management of the spectrum
  - Improve security
  - Lower power consumption – sustainable wireless
  - Metrics that are human and application-specific
  - Lower cost
  - More disaggregation

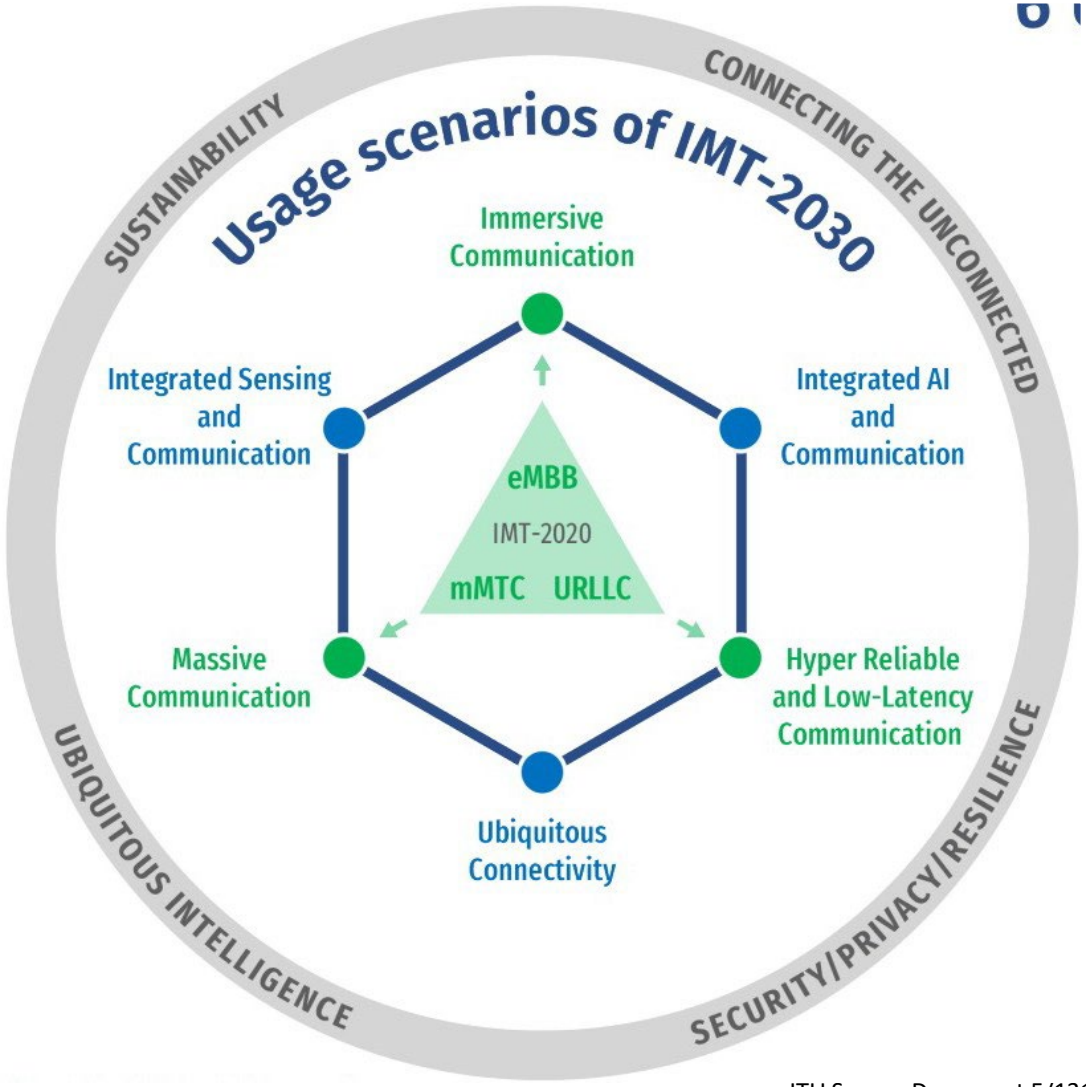


ITU Vision so Far

- Three pillars of 5G remain but have different titles.

NEW FOR 6G!

- Ubiquitous Connectivity
- Integrated AI and Communications
- Integrated Sensing and Communications



ITU Source Document 5/131

VIRGINIA TECH

What will 6G look like?

- Higher data rates to support holographic transmission, perhaps 50-100x current video requirements.
- Intelligent Reflective Surface (IRS) – the concept of a cell disappearing?
- AI/ML to orchestrate, manage, and optimize network
- Continued disaggregation – lessons from O-RAN (and hopefully a more competitive ecosystem)
- "Virtual spectrum" combined network and spectrum sharing
- Better integration of aerial, terrestrial, and satellite components
- Enterprise wireless networks (Private 5G)
- Sophisticated Non-terrestrial networks
- Human-centric services
- THz systems (although I am skeptical of its wide applicability to comms)
- Lower cost systems – complexity and power consumption – energy harvesting

Intelligent Reflective Surface Base Network

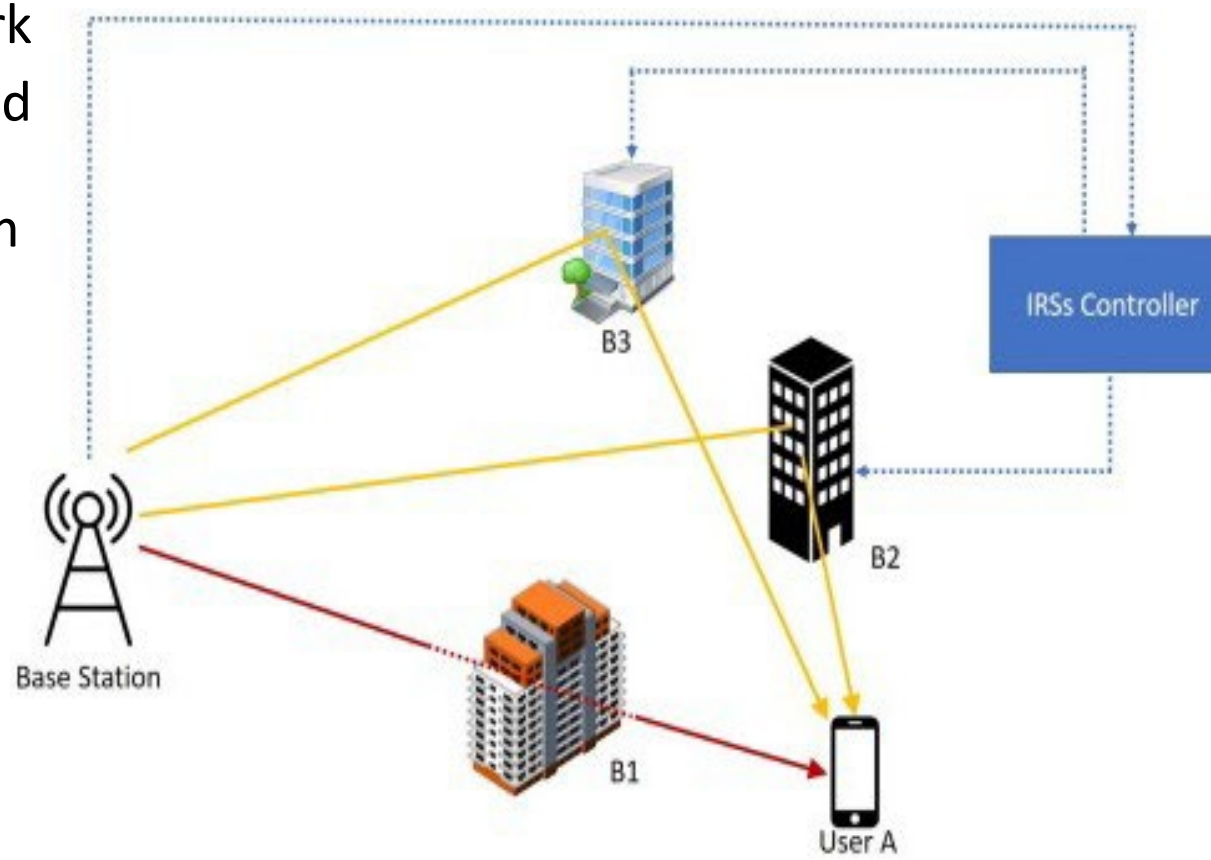


Image from ArXiv:1906.02360v1 [eess.SP] 5 Jun 2019

Examples of Relevant VT Research

- Vulnerability analysis of 5G
- Testing of AI-enabled systems
- O-RAN advances and prototyping (e.g., xApps, rApps)
- 5G underlay signaling
- NTN security
- 5G/6G testbed development
- UAV communications
- Human behavior & radio resource co-modeling
- Enhanced V2X based on physical risks
- Beamforming acquisition and tracking for extremely large arrays
- Geofencing 5G/6G for security
- Co-existence of 5G/6G and satellite comms
- Outdoor-to-indoor geolocation for firefighters
- Hands-on labs for learning O-RAN
- Age-of-Information scheduling for O-RAN
- AI-based interference rejection
- AI-native air interface design (channel estimation, receive processing, spectrum access)
- Distributed massive MIMO (algorithm design and hardware prototype)
- Waveform design for NextG (spreading over OFDM, OTFS, etc)

VIRGINIA TECH

Deep Learning Based Fast and Accurate Beamforming for Millimeter-Wave Systems

Tarun Cousik, Vijay Shah, Jeffrey Reed, Harry X Tran(AT&T Labs), Rittwik Jana(Google Inc)

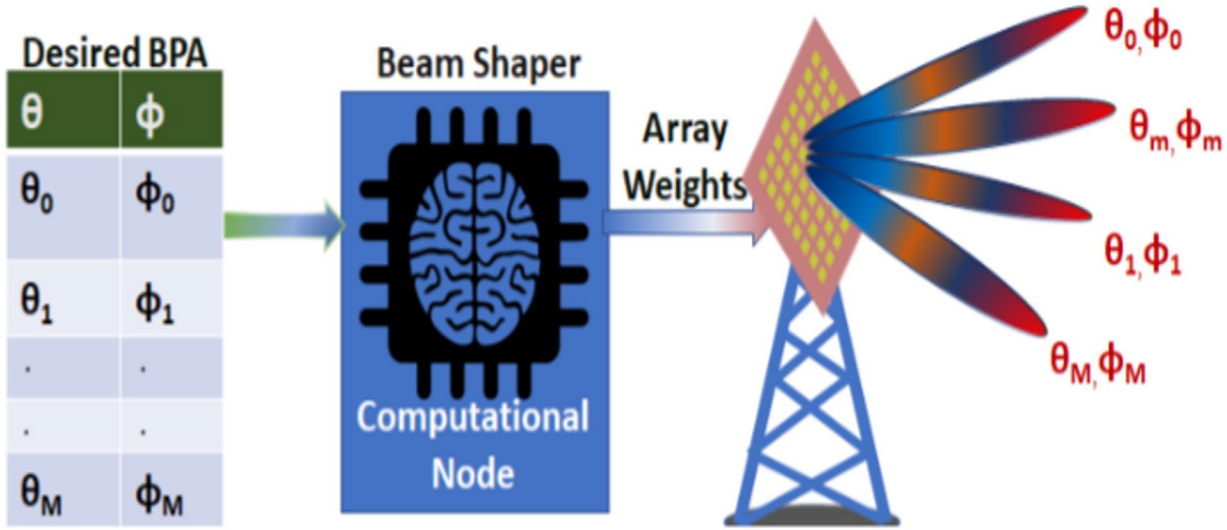
Sponsor: AT&T Labs, Air Force Research Labs

Background & Challenge:

- Conventional mmWave networks are reliant of SRAM based codebooks for beamforming.
- SRAM basd codebooks are expensive to scale and produce beams with limited precision but are used for their speed.

Proposed Solution:

Investigate if and by how Neural Networks can be used in replacing/alleviating SRAM based codebook design as CB size increases .

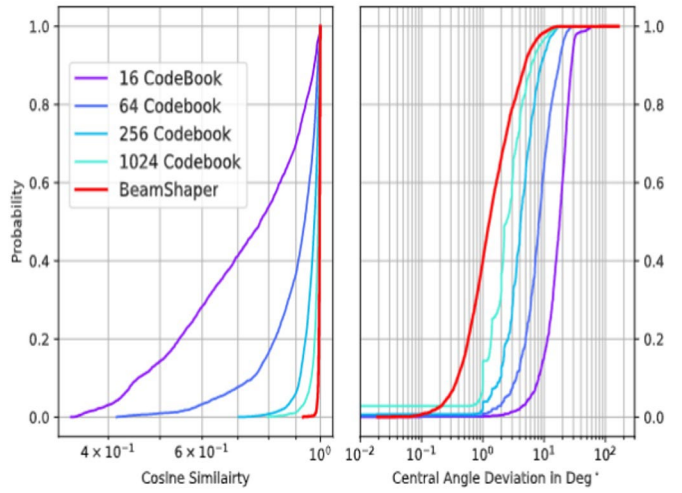


Approach:

- Generated patterns and excitation coefficients for a conventional 64-element 5G NR array with half dipole elements on a 802.11.15.c codebook. Resulting simulations generated beams offset by 0.1 degrees for a 60 by 60 sector in Az and Elv..
- Codebooks size was varied between 64 and 1024.
- Excitation coefficients generated for various beam pointing angles(BPAs) were mapped together using a DNN.
- Patterns generated from trained DNN, were compared to the ideal expected patterns as well as those obtained from various sized codebooks.

Results and Inference:

We compared the patterns generated by both approaches and found that the DNN based approach outperforms even the best codebook considered during the analysis in metrics such as central angle deviation(measures main beam displacement) and cosine similarity(checks what output pattern looks like compared to what it should look like)

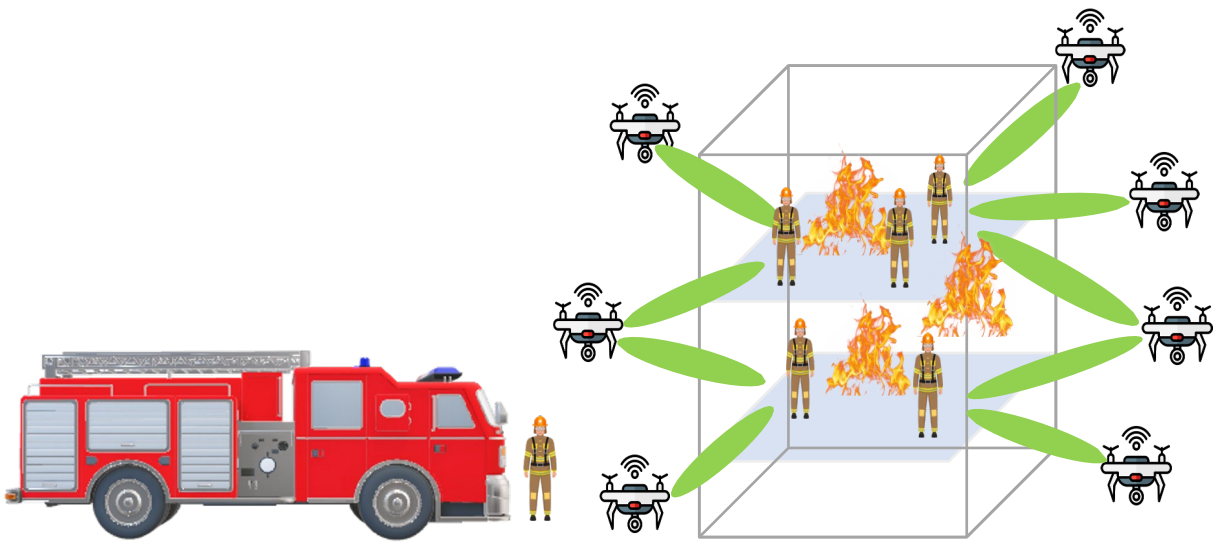


VIRGINIA TECH

Wireless @ Virginia Tech

5G based indoor localization in Emergency Networks

Gaurav Duggal, Prof. R. M. Buehrer, Prof. Jeffrey Reed, Dr. Vijay Shah, Dr. Nishith Tripathi,
Sponsor: NIST



Approach:

- Develop insights for Outdoor to Indoor scenarios using Electromagnetic Field Theory
- Design algorithms using the developed insights
- Simulate/ Prototype systems to evaluate the algorithms

The Problems:

- There is a need to localize both emergency responders and other at risk individuals during emergencies however this is challenging in indoor environments.
- Localization in Outdoor-to-indoor scenarios is extremely challenging.

Solutions will Enable:

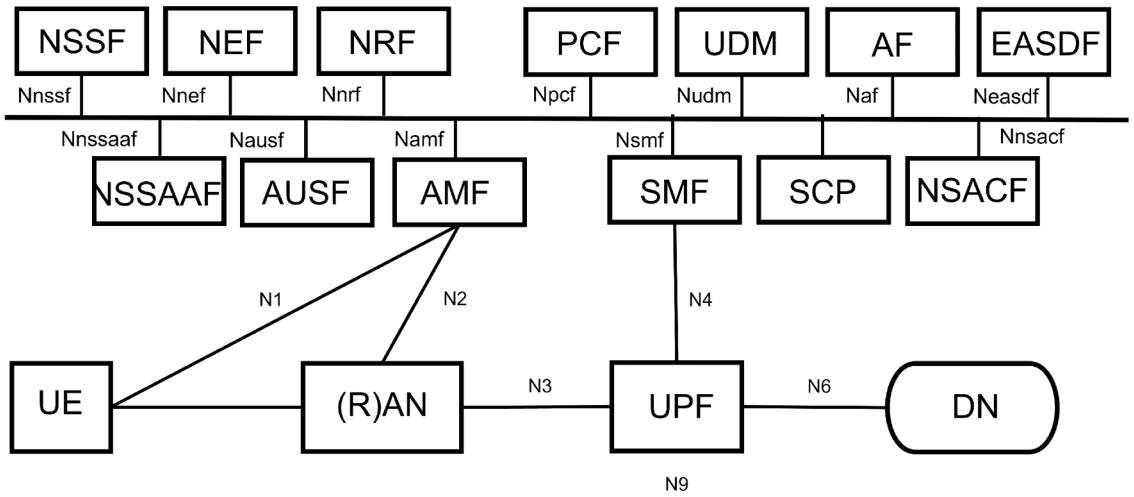
- Proposed standards for localization in 5G
- Aerial UAV base stations can be employed to leverage advantageous locations outside buildings to obtain better signal propagation conditions

Status:

- Developed an Outdoor to indoor Line of Sight probability model that characterizes the chance that a wireless link between an aerial base station and an indoor UE is Line of Sight
- Using Uniform Theory of Diffraction we have developed a floor wise model of NLoS bias for buildings
- These results are both peer reviewed in top Communications conferences and Journals

Mitigation of Security Vulnerabilities of 5G Signaling

Dimitri, Dr. Mai Abel-Malek, Prof. Jeffrey Reed, Prof. Nishith Tripathi
Sponsor: Air Force Research Lab



Current Research:

- Survey of Security Vulnerabilities of 5G Signaling.
- Used open-source software to show exposed clear-text messages sent during initial 5G SA attach procedure.
- Identified vulnerabilities in legacy (LTE) systems that are still present in current 5G networks.
- Develop test bed for different threat scenarios posed to 5G SA network.
- Develop solutions for mitigation of threats to security of 5G protocols.

The Problems:

- The complexity in 3GPP standards defining 5G technology has lead to security vulnerabilities in 5G signaling.
- Adversaries can exploit these vulnerabilities to attack the 5G network using widely available hardware & software.
- These attacks can include spoofing, denial of service, downgrading, and Identity disclosure & location tracking.

Status:

- 3GPP has implemented new algorithms to combat some of these issues found in LTE.
- As it stands, there is no current method implemented that allows the UE to verify the base station it is connecting to.
- The 5G network is still prone to attacks previously seen in legacy systems.
- We are currently researching methods to bolster existing 5G security methods, in addition to exploring new methods to secure 5G signaling traffic.

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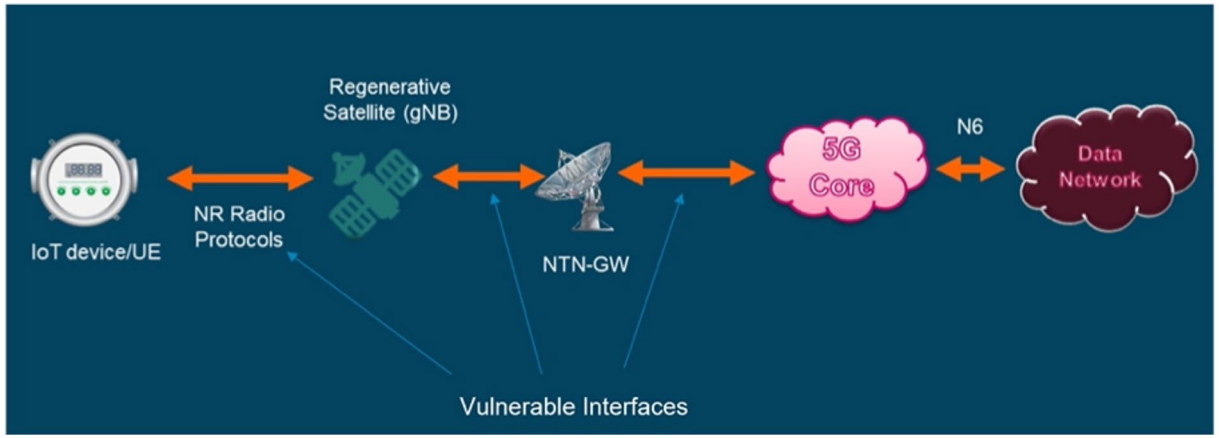
Wireless @ Virginia Tech

Securing a Non-Terrestrial Network (NTN)

Rahul Chintalapati, Dr. Nishith Tripathi, and Dr. Jeffrey Reed

NTN Architecture



Approach:

- Consider various interfaces and Nodes/Network Functions of different NTN architectures beyond the transparent payload architecture
- Identify NTN-specific security vulnerabilities for various scenarios
- Determine candidate strategies to enhance security of a 3GPP NTN by maximizing the reuse of 3GPP-defined security mechanisms and introducing new techniques where needed
- Develop the simulator/emulator design that can be realized in a future project.

Challenges:

- An easily accessible and 3GPP standard-compliant testbed infrastructure is needed for research and experimentation
- A testbed that represents an outdoor radio environment is needed
- There are unique challenges such as power accessibility, weather, and testbed connectivity in an outdoor testbed.

Objectives:

- Investigate implications of different NTN architectures and operational assumptions and identify security vulnerabilities of an NTN
- Develop the design of a simulator/emulator that can help evaluate various security vulnerabilities and candidate solutions

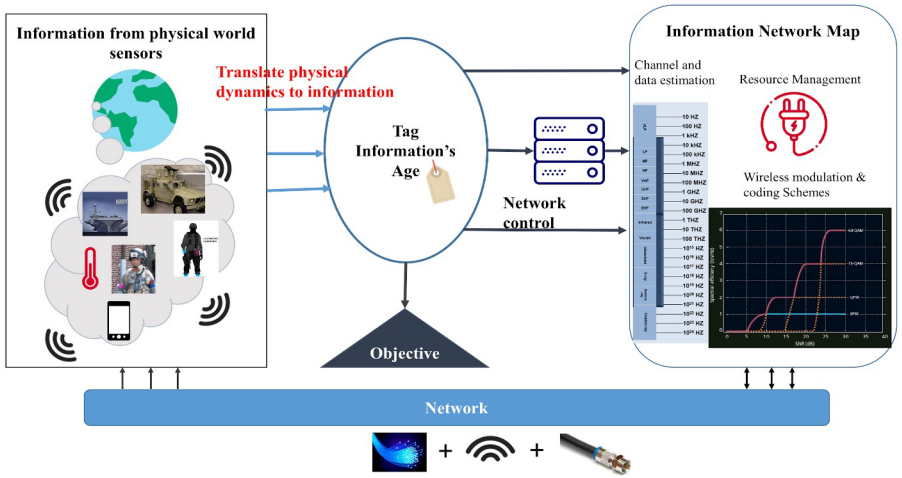
Status/Accomplishments:

- Overall Status: This project is in progress and will be completed in Summer 2023.
- Developed a survey of unique challenges of an NTN and 3GPP defined solutions .
- Identified security vulnerabilities of selected NTN scenarios.
- Identified 3GPP mechanisms that can be reused to enhance the security of an NTN.

Science of Tracking, Control, and Optimization of Information Latency

Tom Hou, Walid Saad, Wenjing Lou, Lizhong Zheng (MIT), Atilla Eryilmaz (OSU) Jeffrey Reed

Sponsor: Office of Naval Research (MURI program)



Understanding, characterizing, and harnessing a novel multi-mode AoI latency metric

Technical Objective :

- Address the military IoT information freshness and latency challenges by developing a foundational framework, based on the notion of **Multi-mode AoI** and **UAVoI** metrics
- Theoretically and experimentally explore the network science of multi-mode AoI in military IoT systems
- Develop new suite of tools to learn and optimize multi-mode AoI in dynamic military IoT systems
- Optimize the trade-off between multi-mode AoI, cost, and value of information under massive self-organizing IoT
- Develop security mechanisms to protect information freshness from AoI-centric adversarial attacks.

Deliverables: publications, intellectual properties, demonstrations https://www.youtube.com/watch?v=Cuvaw3KdEGY

Technical Approach:

Develop a foundation framework and a suite of new tools to track, control, and optimize **multi-mode AoI and UAVoI**

- **Technical Task 1:** Centralized Learning and Optimization of Multi-Mode AoI in Military IoT
- **Technical Task 2:** Decentralized AoI-Aware Information Measurement, Collection, and Management
- **Technical Task 3:** Self-organizing AoI-Aware Information Management for Massive IoT with Dynamics
- **Technical Task 4:** Information Security in AoI-Sensitive Military IoT
- **Technical Task 5:** Simulations and Experimental Demonstrations

Accomplishments:

- Designed and implemented H-score based modal decomposition algorithms for Hidden Markov Models (HMMs);
- Analyzed the sample complexity for modal decomposition algorithms using tensor decomposition;
- Developed a real-time 5G scheduler for AoI that can cope with dynamic channel conditions
- Developed a new framework that exploits learning mechanisms coupled with drone-based communications to minimize AoI.
- Developed mean-field approaches to schedule and optimize AoI in ultra dense IoT systems.
- Developed optimal de-centralized urgency-based caching, tracking, and communication strategies for large-scale distributed IoT networks.
- Developed multiple methods to ensure robust learning against security and privacy attacks in distributed IoT networks
- Video Game Demonstration – Identification and prioritization of critical information from complex military IoT systems.

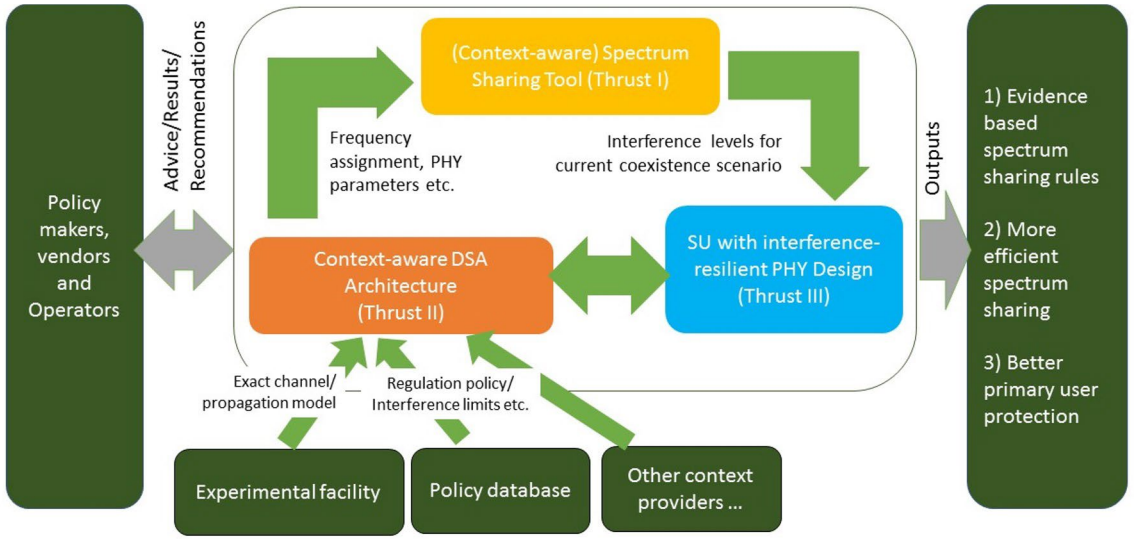
VIRGINIA TECH

Wireless @ Virginia Tech

Collaborative Research: SWIFT: Context-Aware Spectrum Coexistence Design and Implementation in Satellite Bands (ASCENT)

Dr. Vijay Shah (GMU), Carl Dietrich, Prof. Jeffrey Reed, Prof. Eric Burger

Sponsor: National Science Foundation



Approach:

- Create context-aware dynamic spectrum access (DSA) framework
  - Use operational context-related factors in prioritizing user classes and traffic types as well as frequency selection
  - Increase spectrum-sharing flexibility and efficiency
- Develop policy and context distribution architecture
  - Lightweight and robust distribution of infrequently-changing global context-dependent policies
  - Robust local distribution, observation/sharing of rapidly-changing operational context information

The Problems:

- Centralized spectrum sharing introduces single point of failure
- Relevant aspects of operational context other than user activity are not considered in current approaches

Solutions will Enable:

- Efficient and robust, context-dependent decentralized spectrum sharing
- Extensibility across multiple shared frequency bands
- Dissemination of context-dependent policy information to users
- Robust operation using conservative default policies if distribution of context information is interrupted or disrupted

Status:

- Simulation-based evaluation framework and context-aware DSA framework software developed and integrated
- Publications (Initial focus on 12 GHz band):
  - Z. Hassan *et al.*, "Spectrum Sharing of the 12 GHz Band with Two-way Terrestrial 5G Mobile Services: Motivations, Challenges, and Research Road Map," in *IEEE Comm. Mag.*
  - T. -s. R. Niloy, Z. Hassan, N. Stephenson and V. K. Shah, "Interference Analysis of Coexisting 5G Networks and NGSO FSS Receivers in the 12 GHz Band," in *IEEE Wireless Communications Letters*

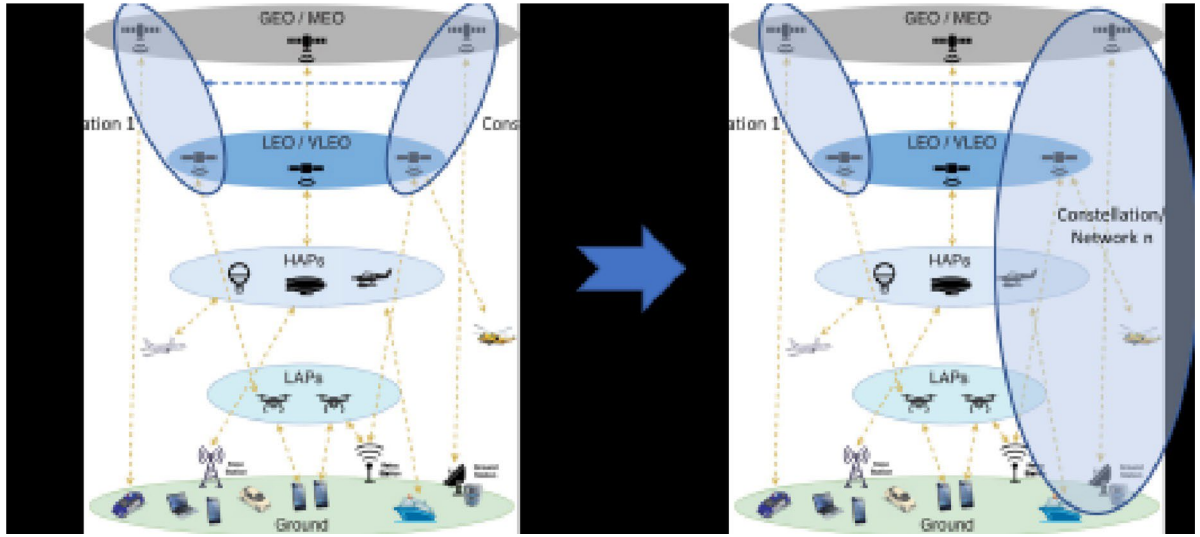
VIRGINIA TECH

Wireless @ Virginia Tech

Distributed Space and Terrestrial Networking Infrastructure for Multi-Constellation Coexistence

Jonathan Black (AOE/ECE/VTNSI), Carl Dietrich (W@VT), Jeff Reed (W@VT), Nishith Tripathi (W@VT), Vijay Shah (GMU)

Sponsor: NSF (CCRI grant)



Approach:

- Integrate and enhance existing satellite simulator and wireless testbeds to develop new capability that includes hardware-in-the-loop testing of lab-based spacecraft hardware
- End result will be a remotely-accessible, multi-domain network and cybersecurity research infrastructure, and a validated first-of-its-kind adaptive and assured space network communications emulator.

The Problems:

- New high-bandwidth, low-latency mega-constellations, (10,000+ LEO satellites), plus UAVs and other aerial platforms, have fast-changing network topology and latencies
- This complicates routing, transport protocols, and applications

Solutions will Enable Simulation/Emulation of:

- Multiple networks of distributed heterogeneous platforms in multiple domains, adaptive communications for multi-constellation coexistence, including interconnection that protects proprietary information
- Behavior of mega-constellations in solar storms, etc.

Status:

- Project awarded in spring 2023
- Planning/regular team meetings in progress
- Meetings have included personnel from related research projects that are potential users of the infrastructure to be developed in this project
- Students oriented, additional students recruited to begin development in fall 2023

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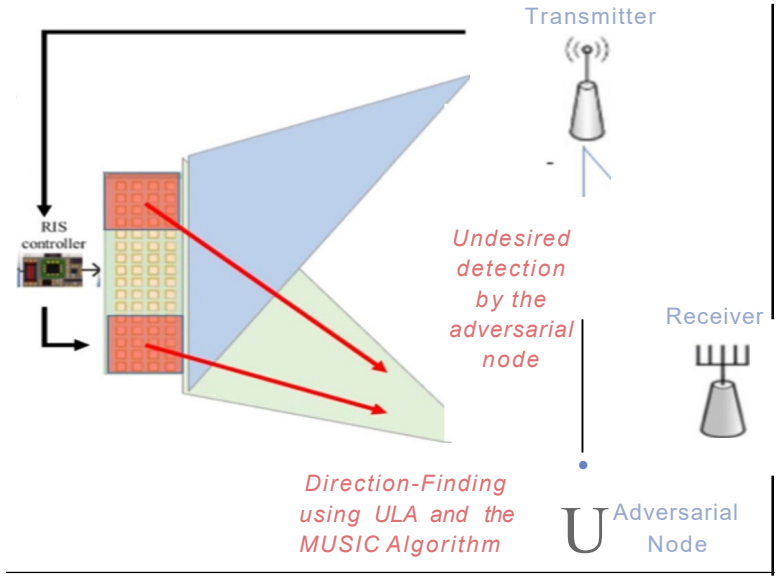
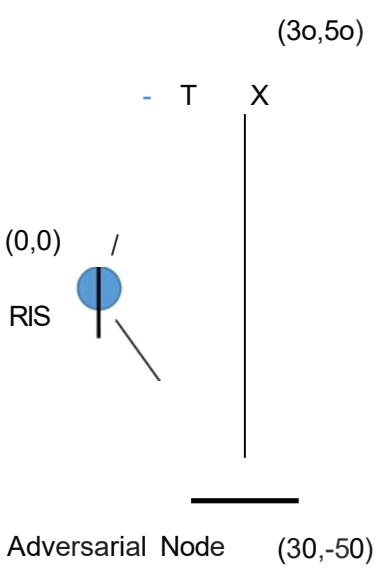
Wireless @ Virginia Tech

Probability-Reduction of Geolocation using Reconfigurable Intelligent Surface Reflections

Anders Buvarp, Dr. Daniel Jakubisin, Dr. William "Chris" Headley, Dr. Jeffrey Reed

Sponsor: Intelligent Automation, Inc.





Idea:

Implement SG/GG security by reducing the probability of geolocation and hence signal detection by the introduction of artificial multipath signals generated via reflections from a reconfigurable intelligent surface(RIS).

Applications:

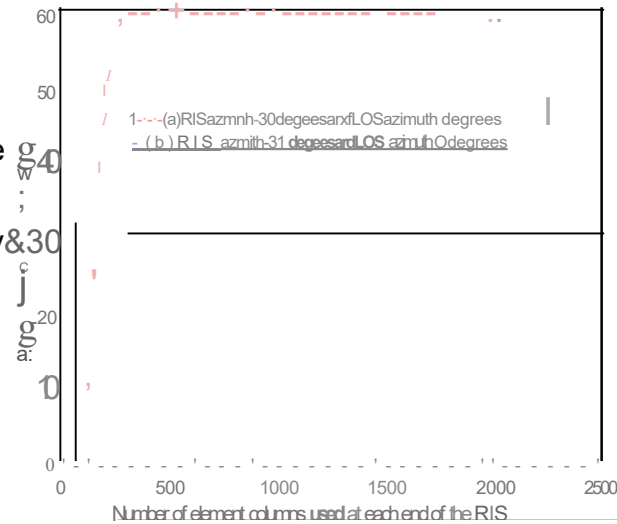
- Artificial Doppler (frequency) shift preventing location tracking
- Facilitate what appears to be naturally occurring interference to the adversary's receiver
- Anti-fragile communications by modulating a reflected high-power jammer
- Absorbing the radar waveform creating cloaking effect

Approach:

- Two correlated reflections are generated from the RIS by configuring elements on each end of the array
- The phase of the waveform reflection from each element maximizes the SNR at the adversarial node
- The adversarial ULA receives a total of three correlated signals
- The adversary attempts to detect the Angle-of-Arrival (AoA) in the pseudo-spectrum of the MUSIC algorithm
- In the presence of *multiple* correlated signals, MUSIC fails at detecting the AoA and hence the adversary is prevented from carrying out signal detection/decoding

Status:

- With strongly correlated signals, the pseudo-spectrum devolves into low fidelity, making it impossible to resolve the angles of the signals
- Geometry greatly influences the ability to defeat the MUSIC algorithm using a RIS
- Our approach was verified with 500 x 600 elements at each RIS end for two geometries;
  (a) equilateral triangle
  (b) isosceles triangle



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Summary

- Yes, 5G was hyped, and 6G will be too.
- Weakness, incomplete specifications, and enhancements of 5G standard will drive 6G.
- Improved specs of 6G can open new applications.
- 5G provides ultimate flexibility and has much runway to reach its full potential; don’t expect 6G to be a complete reworking of the network.
- Cost is a driver on many fronts.

"Prediction is very difficult, especially if it's about the future."

--Niels Bohr, Nobel laureate in Physics

"The best qualification of a prophet is to have a good memory. "

--Marquis of Halifax,

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Jeffrey Reed

DISTINGUISHED LECTURER PROGRAM SPEAKER

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29 November 2023

UPCOMING EVENTS

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