IEEE Future NETWORKS

Enabling 5G and Beyond

Future Networks: A 10-Year Vision from INGR

IEEE 7th World Forum on the Internet of Things (WF-IoT 2021)

June 22, 2021

Ashutosh Dutta, JHU APL, Fellow of the IEEE,
IEEE Future Networks Founding Co-Chair

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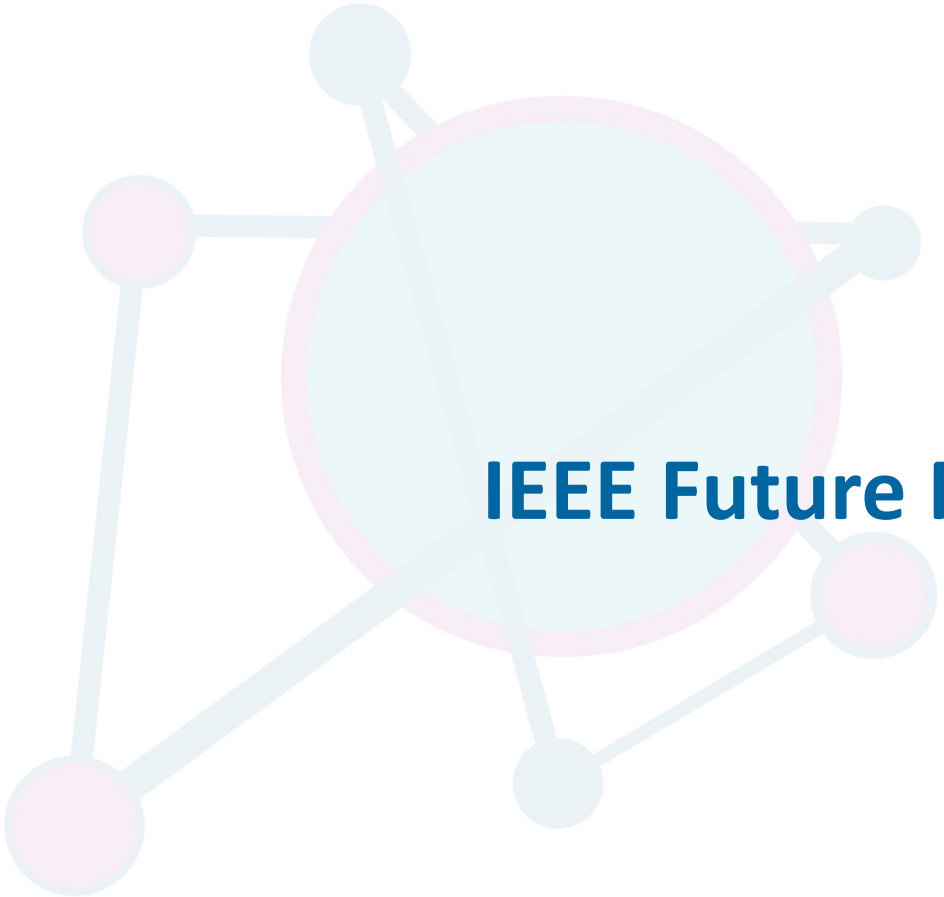
IEEE INGR and Applications & Services WG Co-Chair

IEEE

Future Networks: A 10-Year Vision from INGR

IEEE Future Directions and Future Networks Initiative (FNI)

IEEE International Networks Generations Roadmap (INGR)



IEEE Future Networks

IEEE Future Directions Coverage for 2021

IEEE BLOCKCHAIN™

IEEE Future NETWORKS™
Plus Public Safety

IEEE Digital Reality
Plus AI/ML

IEEE QUANTUM

Digital Privacy

Small Project: Low-Earth-Orbit (LEO) Satellites & Systems

IEEE Roadmaps Committee (IRC)

Small Project: Smart Lighting

Small Project: Telepresence

TechNav AI

Graduated Initiatives

IEEE brain

IEEE BigData

IEEE Smart Cities

IEEE CLOUD COMPUTING

IEEE SMARTGRID

IEEE rebooting COMPUTING

IEEE CYBER SECURITY

IEEE SOFTWARE DEFINED NETWORKS

IEEE lifesciences

IEEE Internet of Things

IEEE SUSTAINABLEICT™

IEEE TRANSPORTATION ELECTRIFICATION COMMUNITY

Key Stakeholders

IEEE Societies

Industry

Government, Academia, Students

IEEE OUs

IEEE STANDARDS ASSOCIATION

IEEE EDUCATIONAL ACTIVITIES

Initiative Profile

- Launched August 2016
- Technical Activities Board Funded
- 20+ Participating Societies/OUs

IEEE Future Networks Initiative

IEEE Future NETWORKS

FutureNetworks.ieee.org

Collaboration

IEEE ComSoc IEEE Communications Society | IEEE Photonics Society | IEEE SA | IEEE VTS Connecting the Mobile World | IEEE computer society | MTT-S

20+ IEEE societies

Content

technical newsletter, podcasts, videos, articles

Events

IEEE 5G WORLD FORUM connecting the UNCONNECTED challenge

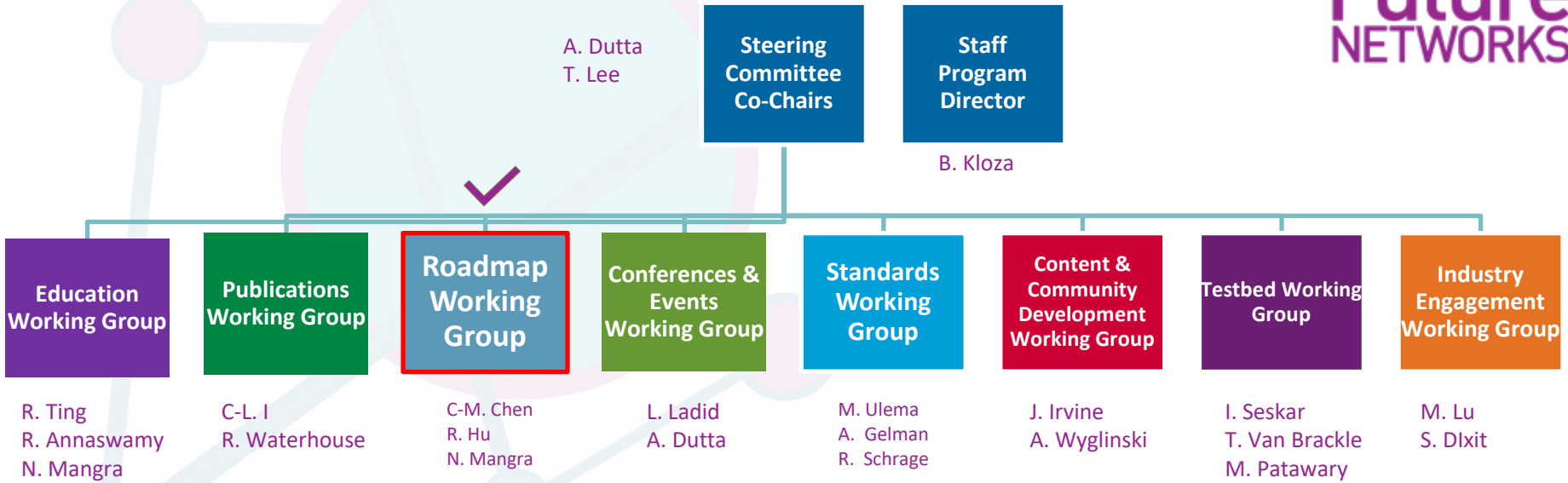
+ vertical workshops, standards forum

Research & Education

IEEE INGR International Network Generations Roadmap

+ eLearning, white papers, tutorials, webinar series

IEEE Future Networks Initiative Organization Structure

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Bridging the 4G/5G Gap: Telecommunications Roadmap for Implementation
A 2-part course focused on the technical aspects in applications, permitting and licensing negotiations, and deployment of next generation networking
Virtual Event: 10 March 2021
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Michael I. Jordan explains why today's artificial-intelligence systems aren't actually intelligent
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'You're assuming fiber is there:' The less-talked about roles of fiber in 5G networks
For the last three decades, the demand for mobile data has grown exponentially, driving tremendous capacity expansions and the need for more network infrastructure, especially as 5G networks
Tweets by @IEEEFutureNtwks
IEEE Future Networks @IEEEFutureNtwks
ICYMI, @VanillaPlus has a good opinion piece on how the #6G value plane will turn revenue dreams into reality. It notes that standalone 5G will herald an unprecedented range of use cases, revolutionizing service delivery and #monetization: bit.ly/3s1CB2a #futurenetworks
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This tweet is brought to you by the letter C. Here's a new #IEEESGNF "The 5 Cs of IoT" video, featuring @ETSI_STANDARDS' @adrian_sorase. He shares how
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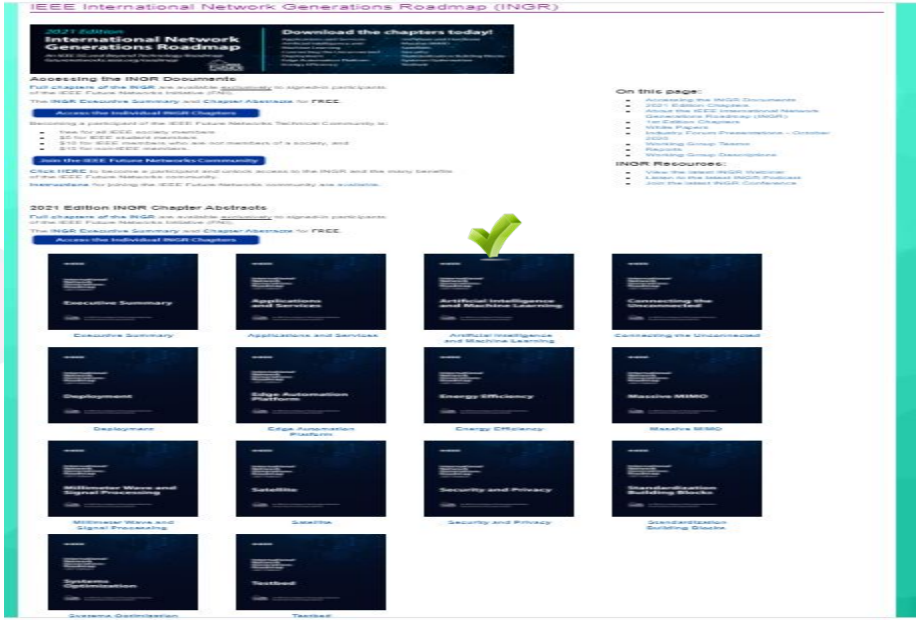

IEEE International Network Generations Roadmap (INGR)
International Network Generations Roadmap
Download the chapters today!
Accessing the INGR Documents
2021 Edition INGR Chapter Abstracts
Executive Summary
Applications and Services
Artificial Intelligence and Machine Learning
Connecting the Unconnected
Deployment
Edge Automation Platform
Energy Efficiency
Massive MIMO
Millimeter Wave and Signal Processing
Satellite
Security and Privacy
Standardization Building Blocks
Systems Optimization
Testbed

Background

International Network Generations Roadmap (INGR) Initiative

5G may be viewed as a network of networks and may drive evolutions in various ecosystems that result in shifting industry structures and adjacent industry boundaries.

Roadmaps help address some of the technical and engineering risks and opportunities associated with the new technology migrations.

The INGR roadmap may be used to stimulate an industry-wide dialogue for coordinated development and deployment of 5G and Future Networks.

A roadmap needs to evolve and adapt to ecosystem changes in order to avoid becoming obsolete, e.g. IEEE International Roadmap for Devices and Systems (IRDS) experience

Refer to IEEE Executive Summary for additional details

INGR Editions

Scope.

- High-level perspective and projection of how the industry could evolve
- Highlights of common needs
- Challenges to achieving those needs
- Potential solutions to those challenges

Projections

- INGR projections for the next 10 years:
  - Key Timeframe points at 3, 5, and 10 years.

Foundation for future editions

- This INGR 1st edition was released in 2019 and laid the foundation for subsequent editions that will include a description and evaluation of 6G and other future network enhancements.

2021 Edition

- Extend the range and depth of the First Edition

IEEE INGR 2021 Edition

Executive Summary

Applications and Services

Artificial Intelligence and Machine Learning

Connecting the Unconnected

Deployment

Edge Automation Platform

Energy Efficiency

Massive MIMO

Millimeter Wave and Signal Processing

Satellite

Security and Privacy

Standardization Building Blocks

Systems Optimization

Testbed

https://futurenetworks.ieee.org/roadmap

IEEE INGR Structure and Working Groups

CATEGORY	DESCRIPTION	INGR WORKING GROUP CHAPTERS (2021 Edition Focus)
Access	Describes how the users are able to reach the network	• Massive MIMO • mmWave and Signal Processing • Hardware • Energy Efficiency
Networks	Describes how the networks are interconnected	• Optics • Edge Automation Platform • Satellites
System and Standards	Describes system standards and testability	• Systems Optimization • Testbed • Standardization Building Blocks
Enablers and Users	Represents all the elements that enable deployment, assure functionality and security and address impact on society and environment	• Connecting the Unconnected (CTU) • Security and Privacy • Deployment • Artificial Intelligence and Machine Learning (AI/ML) • Applications and Services

Massive MIMO WG

INGR Massive MIMO WG Focus

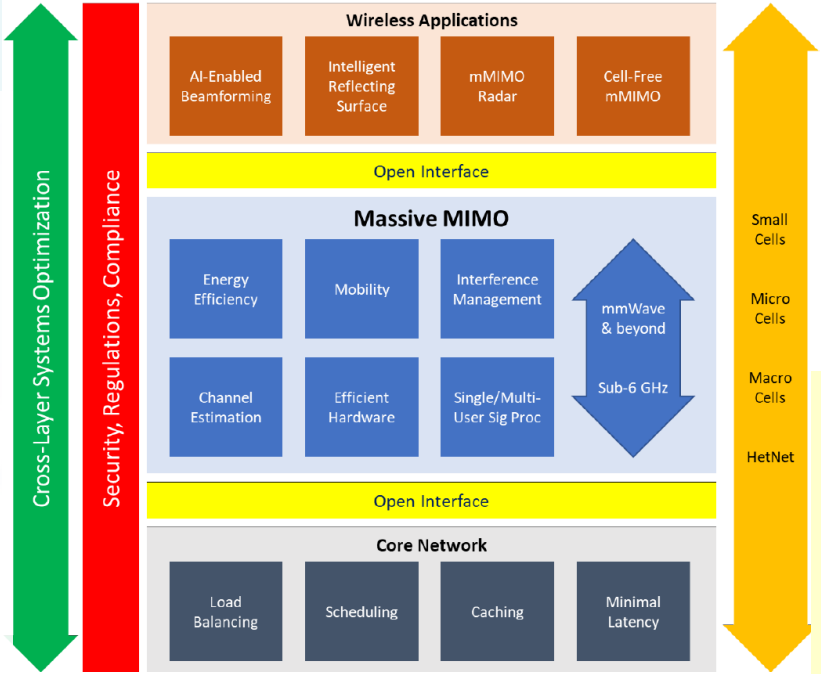
- Framework to support large number of active users with massive connectivity

INGR Massive MIMO Chapter Highlights include

- **mmWave for HetNet**
- **Network Planning and Operation**
- **MAC-PHY Cross-Layer Design**
- **Efficient Receiver Architecture Design**
- **Secure Communications**
- **AI/ML**
- **other related topics.**

WG Recommendations / Potential 2022 Edition Topics

- **Massive MIMO systems deployments in different configurations**, e.g., TDD, FDD, indoor/outdoor, small cells, etc.
- **Massive MIMO hardware implementation architectures**: e.g., digital, analog, hybrid.
- **Massive MIMO RAN** transition from a passive network layer to an intelligent decision- making network component.
- **Transition from cell-based** topology to a dynamic, self-optimizing beam-based wireless ecosystem.



Massive MIMO Ecosystem

IEEE INGR Massive MIMO WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-massiveMIMO@ieee.org

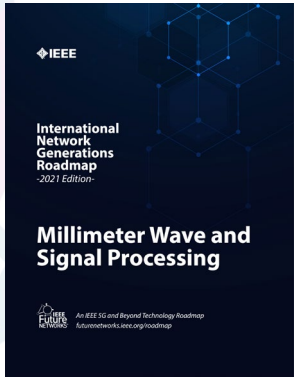
Millimeter Wave and Signal Processing WG

INGR mmWave and Signal Processing WG Focus

- Millimeter-wave architectures, hardware capabilities, and signal processing techniques to enable 5G systems to achieve enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC),and massive machine type communications (mMTC).

INGR mmWave and Signal Processing Chapter Highlights include

- **Mid band and high band deployments** of 5G hardware, and define 6G with potential use of high millimeter-wave bands (70- to 300-GHz)
- **High Bandwidth channels** to support 5G & 6G "Super-Enhanced" Use Cases
- **Active and Passive Components**
- **Design for 5G Test, Last Mile Communications, mmWave Base Stations, Mesh-Networked Terminals & Handsets** – includes over-the-air (OTA) testing at component, cell and array levels
- **Design for Multiple Use Cases with Reconfigurable Hardware** – includes testing for resiliency, QoS and optimum utilization of resources



IEEE INGR Millimeter Wave and Signal Processing WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-mmWave@ieee.org

WG Recommendations / Potential 2022 Edition Topics

- Continue to **monitor analog, digital and hybrid beamforming technologies**.
- Continue to **monitor the competing advanced packaging technologies** for different substrate materials and processability for low-cost millimeter-wave modules
- Address in future editions the **pros and cons of different 5G waveforms** and their impacts on data rate, peak to average ratio and spectral efficiency.
- Address in future editions on **supply chain and security/trust issues**
- Address the concerns on **health, safety of 5G millimeter-wave radiation**

Energy Efficiency

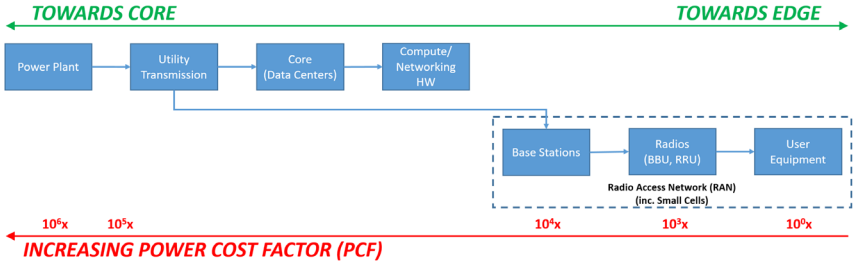
INGR Energy Efficiency WG Focus

- Ensure awareness, resources, and proper linkages are captured and disseminated in a meaningful way for pragmatic (and therefore minimal) utilization of energy and associated carbon footprint for global communications networks (including mobile telephony and fixed IP networks).

INGR Energy Efficiency WG Areas of Interest include:

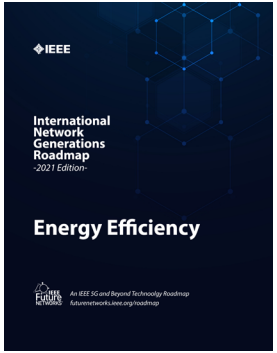
- **Energy-Efficient Architectural Framework**
  - **Systems of Systems (SoS)**
- **Network Efficiency –** Edge Optimization, EE System Design Philosophies, Micro-to-Macro Assessment, 3GPP DTx, Data Centers
- **Small Cell Migration –** Macro-to-Micro Control Plane, Real-time Power Optimization, mmWave Impacts, Cell-free Architectures
- **Base Station Power -** Massive MIMO Impacts, Multi-band Support, Telemetry/Analytic Needs, Energy-centric Feedback Loops
- **Economic Factors -** Technical/Economic Analysis Enablement, Industry Metrics, Socioeconomic Impact, Energy-centric Network Simulation Models
- **Grid/Utility - Utility-level Impacts/Risks, Networking Electricity, Real-time Energy Market Impacts**

R_x The 5G Power Value Chain



Potential Energy Efficiency Topics for INGR 2022 Edition includes:

- **Systems of Systems (SoS) Enhancements**
- Workshops and detailed examination of additional applications, and low and high-fidelity usability studies.
- Tools, standards, databases, and new consortiums of collaboration



IEEE INGR Energy Efficiency WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-energy@ieee.org

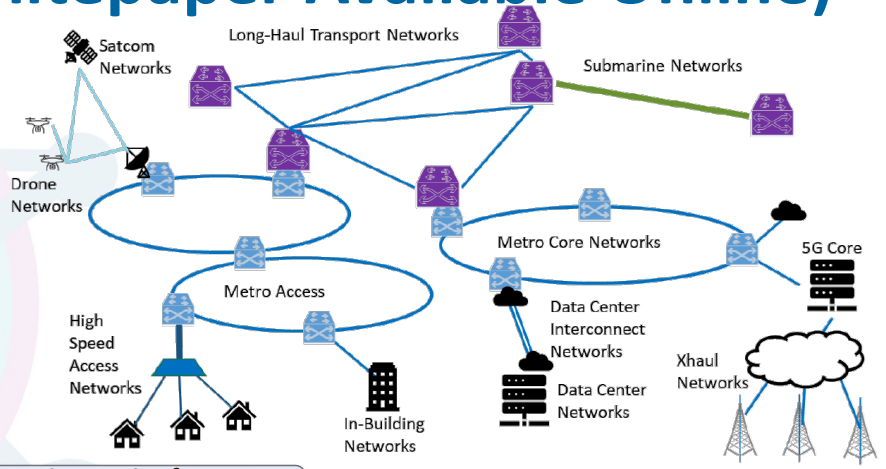
Optics – New WG (Whitepaper Available Online)

INGR Optics WG Focus

- Identify and build roadmaps for key optical technologies
- Emphasis will be placed on new and emerging technologies and network evolution trends that are expected to shape future (optical) networks.

INGR Optics WG Areas of Interest include:

- **Data centers**: emergence of co-packaged optics that combining optical interfaces into the electronic processor or switch chips.
  - **Optical switching**: potential to improve energy efficiency in data centers
- **Light Fidelity (LiFi):** access networks provides higher capacity, while reducing the RF interference from an increasing number of IoT devices.
- **Xhaul** approaches to radio access networks will evolve to higher speeds and greater use of DWDM, while adapting to tight latency constraints.



Potential Optics Topics for INGR 2022 Edition includes:

- Optical Xhaul (front/mid/backhaul) Networks.
- High Speed Access Networks
- Co-packaged Optics / Data Center Networks
- In-Building Optical Networks
- Optical Networks in Space
- Optical Fibers/SDM
- Quantum Communications

IEEE INGR Optics WG

- ***Roadmap Details – Refer to INGR WG Whitepaper***
- ***WG Participation –*** 5GRM-optics@ieee.org

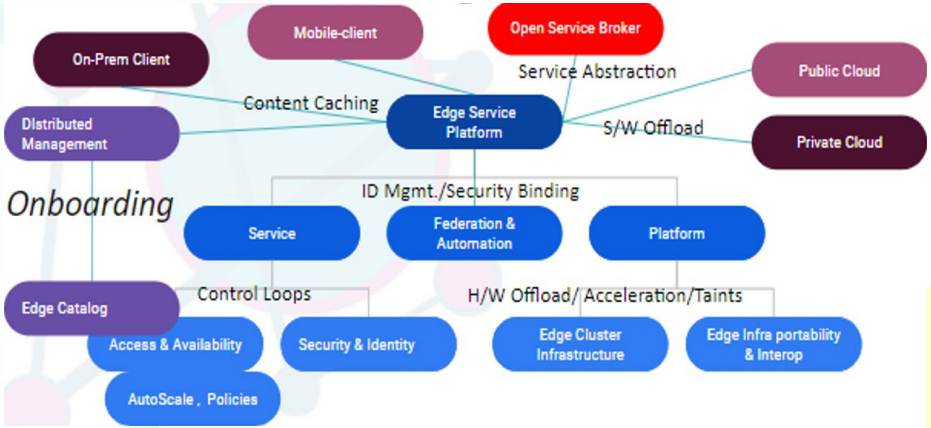
Edge Services WG (formerly Edge Automation Platform WG)

INGR Edge Services / EAP Focus

- Enable an edge ecosystem through promoting an interface between hardware and software modules
- Edge platform should be easy to build, operate and consume through provisioning and life cycle automation

INGR Edge Services / EAP Chapter Highlights include

- **Mobile Edge Architectural Framework:** includes Compute & Storage, Edge-as-a-Service (EaaS), Edge Computing based on virtualization and VMs, Service Mesh, etc.
- **Security at the Edge** includes server or device certification, and edge infrastructure, and all entities or services in the EAP ecosystem.
- **FCAPS for Edge Microservices**



WG Recommendations / Potential 2022 Edition Topics

- Define standards for INGR.EAPF.**Offloading**, INGR.EAPF.**Acceleration**, INGR.EAPF.**Catalog**.
- **Best Practices for Security for Edge** working with Security WG.
- **Cloud Native & Edge Native Services** and applicability to Edge Service Framework.
- **Observability and Closed Loop automation** using AI/ML for Edge Service latency reduction, throughput optimization.
- **Service Level Objective (SLO) applicability** to Service Level Indicators (SLI) and Service Level Agreements

IEEE INGR Edge Services WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-eap@ieee.org

Satellite WG

INGR Satellite WG Focus

- Define a new body of standards where the satellite 5G component is fully integrated with terrestrial systems.

INGR Satellite Chapter Highlights include

Topic	Scope
Applications & Services	5G satellite applications for urban, rural and remote areas. Need to expand for 5G and 6G
Use Cases and Reference Architectures	**13 use cases** are discussed including LEO/MEO/GEO satellites, UAV and HAPs. **Three reference architectures** of 5G satellites including non-virtualized for near-term (3 years), separate virtualized for mid-term (5 years) and integrated virtualized for long-term (10 years)
New MIMO based PHY	A multi-user MIMO and challenges in terms of capacity, robustness and security
Antenna and Payload	Various antenna systems for ground stations, satellite feeder links, user links, inter satellite links and end users
AI/ML	Classification of ML techniques for Non-Terrestrial Networks is described
Edge Computing	Network function virtualization, computation offloading, MEC caching, deployment and orchestration
QoS/QoE	QoS and QoE are discussed in terms of UE to satellite propagation delay and access delays, also QoS architecture is discussed
Security	Secure air interface, network architecture, trust management, end-to-end security management, etc.
Network Management	Mobility management, radio resource management and routing are described. Also, SDN and NVF
Standardization	Current status on 3GPP, ITU, ETSI, IEEE standardization activities on 5G satellite and NTN networks is discussed. WRC-19 decisions & WRC-23 plans

WG Recommendations / Potential 2022 Edition Topics

- **Network virtualization and softwarization and orchestrators standard**, e.g. ETSI MANO for satellite system interoperability
- **MIMO communications** to increase capacity and improve physical layer security.
- **mmWave communications** while addressing weather impairments and the large Doppler shifts.
- **AI/ML** methods to address routing, resource allocation, cross-layer optimization, and handover decision.
- **Scalable and distributed mobility management, e.g.** multipath routing schemes and protocols capable of routing data packets through multi-operator satellite constellations.

IEEE INGR Satellite WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –***

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Systems Optimization WG

INGR Systems Optimization WG Focus

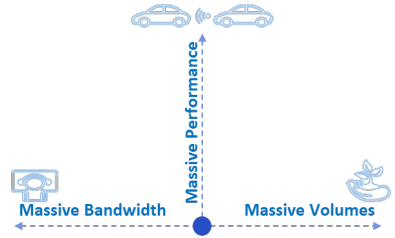
- Identify key problems of future highly complex and self-organizational networks to generate solutions to achieve self-organization, and to demonstrate the proposed features within the scientific community.

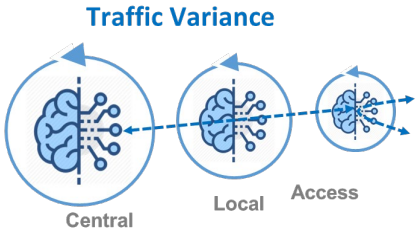
INGR Systems Optimization WG Areas of Interest include:

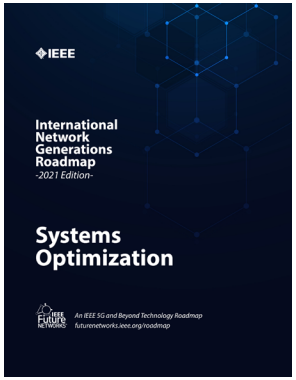
- **Architectural Framework** discussion on Sense, Discern, Infer, Decide, and Act (SDIDA)
- **Dynamic optimization** across self-optimizing fabrics that will incorporate both end-to-end and localized performance and adapt to network dynamics.
- **Mechanisms for Peering and Resource Negotiation/Allocation** that support (near) real time discovery, peering, and negotiation/allocation of heterogenous resources from disparate entities.
- **Support of Federation Across Domains** to support discovery and optimized allocation of resources across domains.
- **Models for Fabrics of Autonomous Systems** that can identify system dependency and deadlocks and detect behavioral properties in advance of actual field deployments.
- **Testbeds for Systems Optimization** for research and validation.

Potential Systems Optimization Topics for INGR 2022 Edition includes:

- Perform an in-depth **gap analysis** with current industry standards
- Enable **studies** (research, verification) via 5G testbeds
- **Publications** to inform/guide/socialize systems optimization directions/focus areas
- **Collaborations** with O-RAN OSC, ONAP, Linux Foundation for open-source frameworks
- Engagement, education, and socialization







IEEE INGR Systems Optimization WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation*** – 5GRM-sysopt@ieee.org

Testbed WG

INGR Testbed WG Focus

- Collaborate with existing 5G testbeds to make those available to the IEEE communities (industry & academia) to ease the deployment of 5G & accelerate the development of next generation network (e.g., 6G).
  - Key deliverables include the specification and/or standards for functional testing, rapid prototyping, proof of-concept, etc.

INGR Testbed Chapter Highlights include

- Drivers and Technology Targets reported from the R&D community, e.g. latency, reliability, data rate, etc.

WG Recommendations / Potential 2022 Edition Topics

- Testbed WG is in the process of creating a directory of communication and networking testbeds to maximize national and international collaboration.
  - The survey is available at the IEEE INGR Testbed WG website at https://futurenetworks.ieee.org/testbeds
- Benefits include:
  - Visibility to the many available testbeds for increasing utilization
  - Access to and development of interesting experiments using multiple testbeds, including scaling or combining special resources, e.g., wireless robots.
  - Collaboration between testbed users and developers across platforms
  - Establish a community of researchers for 5G and beyond testbeds.

Technology Gaps	Potential Way Forward
Lack of Scale	PPP (Government, industry and academia cooperation; cooperative approach from the existing testbeds)
Proliferation of specialized (vertically) testbeds without common elements	Cooperative approach from the existing testbeds; open source contribution, workshops for engagement, and professional community engagement)
Lack of 5G feature (eMBB, mMTC, URLLC) optimized experimentation platform	Open source hardware and software platform, (white-box component from OEM or equivalent)
Lack of inter-testbed cooperation	Introduction of certification on testbed vertical compliance and interoperability to promote cooperation and component reuse.
Lack of use cases	Public events, such as hackathons, exhibitions, school level and university (UG/G/PG) research promotion in partnership with industry.
Lack of platform for universal data sharing	Promotion and demonstration of the value/requirement of the data generated from users, applications and networks; develop technology and business models for data sharing along with standard (certain level of commonality, while generating or offline translation between different data set formats)
Lack of skills, experimental testbed to help the companies to collaborate and develop proof-of-concept.	Establish dedicated testbed for skill enhancement. IEEE provides online webinars to facilitate live events, if possible from a testbed site.

IEEE INGR Testbed WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-testbed@ieee.org

Standardization Building Blocks WG

INGR Standardization Building Blocks WG Focus

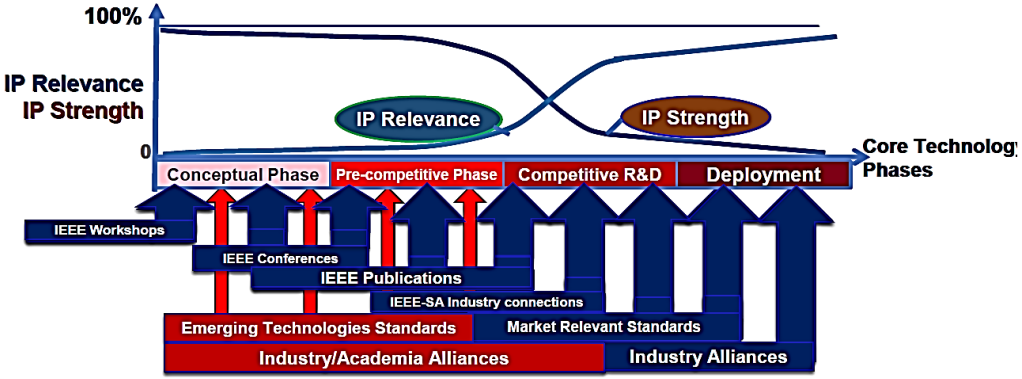
- Wide range of global standards, consortia, and alliance activities enabling and defining future networks' regulatory environment, use cases, architectures, technical interface specifications, compliance, and test requirements over a ten-year time horizon.

INGR Standardization Building Blocks Chapter Highlights include

- **Cooperation** between SDOs and Open-Source Communities. E.g. IEEE-SA Open-Source Program
- **Cooperation** among SDOs/Fora, e.g. ITU-T SG13, TM Forum, BBF, etc
- **Standardization of Emerging Technologies**

WG Recommendations / Potential 2022 Edition Topics

- **Standardization ecosystem** that allows the standard development in all phases of technology life cycle, from conceptual to the deployment.
- **Proactive approach** to harmonize standardization with their vision for long-term technology evolution without prejudice



IEEE INGR Standardization Building Blocks WG

- *Roadmap Details – Refer to INGR WG chapter*
- *WG Participation –*

5GRM-standards@ieee.org

Connecting the Unconnected (CTU)

INGR CTU WG Focus

- (i) to increase the visibility of the need to connect the unconnected with affordable access in the era of 5G
- (ii) develop, fine-tune and standardize the various technology components for open platforms to meet global requirements of those still not connected to the Internet
- (iii) collaborate with the industry to help develop solutions for the unconnected across the globe

INGR CTU WG Areas of Interest include:

- **Least cost wireless front-haul and backhaul** through beamforming and MIMO in refarmed spectrum, and the use of RF spectrum white spaces including the TV bands, in addition to other access technologies,
- **Trust, security and privacy** that meets the capabilities of the user community,
- **Simplified and intuitive human computer interfaces (HCI),**
- **Micro-operator ecosystems** to encourage local coverage and enablement of rollout of sustainable services, and
- **A dedicated network slice for the CTU use case**

IEEE INGR Connecting the Unconnected (CTU) WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-connecting@ieee.org

Potential CTU Topics for INGR 2022 Edition includes:

- Addressing the "digital divide."
- Partner with relevant organizations to devise a program that can deliver services and applications to meet those needs through a competitive challenge.
- Novel business models for any CTU solutions to be commercially sustainable

Security WG

INGR Security WG Focus

- 5G security considerations for different layers (physical, network, and application).
  - **Security challenges and opportunities**.

INGR Security Chapter Highlights include

- **Foundational Concepts**: NIST CyberSecurity Framework and SecurityThreat Models
- **Security and Privacy Domains**: Security focus on Management and Orchestration, Edge, Third Parties, Data Privacy, Satellite, Virtualized RAN, Massive MIMO, Spectrum, Physical Layer, Security Monitoring and Analytics, Predictive/ Proactive Security and 5G Digital Forensics.
- **Security Use-Cases for various Verticals**: Security focus on Applications, Critical Infrastructure Systems, AI/ML, Interoperability, Industrial Control Systems (ISC), Safety & Security, etc

WG Recommendations / Potential 2022 Edition Topics

- **2022 Edition** to include additional coverage of data sharing and privacy, satellite communication, physical layer security, identity and access management, application security KPI/SLA, etc.
- Perform an **in-depth security gap analysis** with current industry standards
- **Enable studies (research, verification)** via established 5G test-beds
- **Publications** to inform/guide/socialize 5G security directions/focus areas.
- **Collaborations with ONF, ORAN, Linux Foundation** to develop an open source security framework
- **Engagement, education and socialization**, e.g. conferences, webinars, world forum

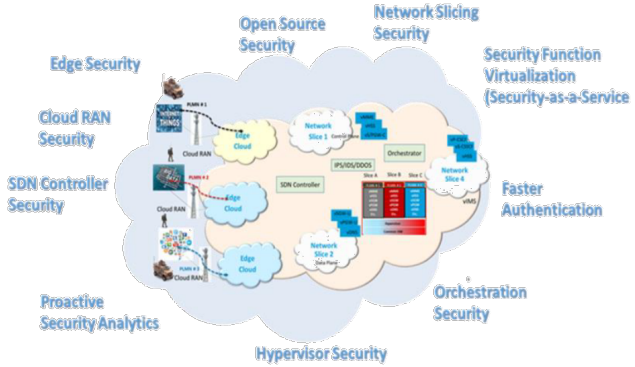


Figure 1. Various Security Pillars for 5G Networks

IEEE INGR Security WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-security@ieee.org

Deployment WG

INGR Deployment WG Focus

- Tactical challenges of deployment in and around public right of way – including private properties adjacent to the public right of way affected by local government zoning/planning, and to highlight the particular needs and perspectives of local governments and municipal agencies where applications for deployment of wireless communications facilities will be reviewed and permitted.
- Serve as a bidirectional conduit for the
  - Public sector, governmental, and tribal stakeholders to communicate their goals and concerns to the wireless industry vendors who are specifying and designing future network products, equipment, and systems.
  - Wireless industry to communicate their goals and concerns to the public sector, governmental, and tribal stakeholders who are responsible for enforcing federal, state, and local laws and regulations, and who are responsible for managing public property.

INGR Deployment WG Areas of Interest include:

- **Local government factors** and perspectives affecting deployment.
- **Legislative, regulatory and engineering factors** affecting deployment.
- **Public/community/resident factors** and perspectives affecting deployment.
- **Technology challenges and trends** affecting deployment.

Potential Deployment Topics for INGR 2022 Edition includes:

- Deployment strategies and stakeholder engagement. Stakeholder groups include semiconductors and equipment manufacturers, carriers/operators, local governments and agencies
- Education includes active countering of misinformation and pseudoscience.
- **Case studies** for the above.

IEEE INGR Deployment WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-deployment@ieee.org

Artificial Intelligence / Machine Learning (AI/ML) WG

INGR Artificial Intelligence / Machine Learning (AI/ML) WG Focus

- Provide the Roadmap based on research and industry advancement to deliver the AI/ML vision beyond 5G.
- Identify and define the taxonomy and state of *AI (sense, think, and act like a human)* and *ML (detection, classification, segmentation, predictions, and recommendations)*.
- Survey existing frameworks that support AI/ML workloads for different domains and identify a reference architecture to compare emerging protocol stacks and infrastructure elements.

INGR AI/ML WG Areas of Interest include:

- **Network Automation**
- **Network Slicing**
- **Network Digital Twins**
- **Security**
- **Dynamic Spectrum Access**
- **Cloud Computing**
- **Multi-access Edge Computing**

Potential AI/ML Topics for INGR 2022 Edition include

- **Cross-team collaboration with other FNI WGs** for AI/ML augmentation.
- **Investigate additional 5G and Future Networks areas** where technology gaps can be closed using AI/ML, e.g. Quantum Computing and Security.
- **Set priorities for future development** to include both technological advances and AI/ML developments that are being undertaken by other organizations, e.g. ETSI, 3GPP, etc.
- **Develop an AI/ML based management and orchestration framework**.
- **Define how open source and open architectures can be used and adopted**, e.g. a joint effort for Open RAN technologies may be adopted by industry via the O-RAN Alliance and Telecom Infra Project (TIP).
- **Develop and demonstrate AI/ML 5G and Future Networks use cases**

IEEE INGR Artificial Intelligence / Machine Learning (AI/ML) WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation*** – 5GRM-AIML@ieee.org

Applications and Services WG

INGR Applications and Services WG Focus

- Provides a sustainable **transdisciplinary framework** across end-to-end ecosystems in urban and non-urban areas, and caters to different stages of priorities, resources, and technologies.

INGR Applications and Services Chapter Highlights include

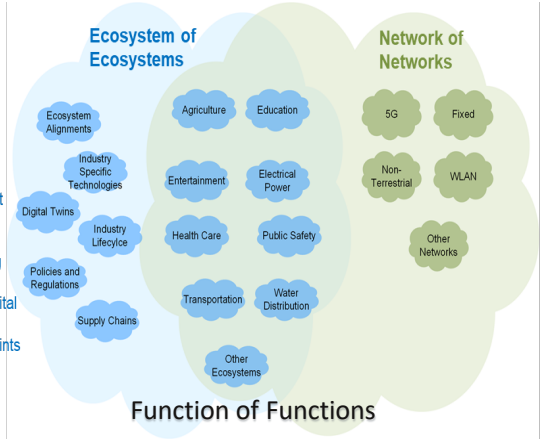
- **Applications and Services Framework**
  - **Ecosystem of Ecosystems:** intra-ecosystem and inter-ecosystem alignments. **Eight ecosystems** are addressed – Agriculture, Education, Electrical Power, Health Care, Media and Entertainment, Public Safety, Transportation, and Water Distribution & Wastewater Treatment.
  - **Network of Networks:** Future networks components (**access, service delivery, operations and service management, and network extensions**), use case categories and deployment drivers, and network operations enhancements.
  - **Function of Functions:** strategic, tactical and operational **governance** functions.
- **Scenarios:** Smart Cities, Smart Regions, and Pandemic Response Scenarios

WG Recommendations / Potential 2022 Edition Topics

- **Framework Enhancements** – Additional details on ecosystem enhancements, cross-ecosystem touchpoints, and KPIs
- **Inter-INGR WG Collaboration**, e,g, AI/ML use cases, Comprehensive Plans, Rural Development, Trust, Multi-tiered security, etc

Key Enablers

- Governance
- Contextual Data Models
- Data Policies and Management
- Stakeholder Engagement
- Trust and Privacy
- Multi-Tiered Security
- Investments and Funding
- Competing Priorities
- Connectivity and the Digital Divide
- Capabilities and Constraints
- City Performance



Future Networks Considerations

- Standards – Economies of Scope and Scale
- Technology Enablers, e.g. AI, position / location determination
- Equipment Availability
- Ease of Deployment

IEEE INGR Applications and Services WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-appssvcs@ieee.org

IEEE INGR Related Activities

Education and Conferences

- **Global Focus**: 5G World Forum 2021, WCNC 2022
- **Regional / Local Focus**: IEEE 5G Summits, SusTech 2021
- **Sponsored Workshops**: System Optimization WG, Security WG
- **Podcasts** featuring WGs
- **Monthly webinars** featuring each WG
- **Young Professionals** Summer & Winter Sessions
- **Courses** on Bridging the 4G/5G Gap: Telecommunications Roadmap for Implementation

Industry Engagement and Task Forces

- **Public Safety Task Force** (White Paper Released June 2021)
- **IEEE SA Industry Connections**:
  - Transforming the **Telehealth** Paradigm: Sustainable Connectivity, Accessibility, Privacy, and Security for All - https://standards.ieee.org/industry-connections/transforming-telehealth.html
  - **Transdisciplinary Framework** for 5G and Future Networks Applications and Services (new)
- **IEEE CTU Challenge**

Standards Development

- **P1950.1** (**Smart Cities Architecture** Initiative)
- Rapid Reaction Standardization Activities (**RRSAs**) under development for
  - **CTU**
  - **Massive MIMO**
  - **Energy Efficiency WGs**

Summary

Roadmaps

- Roadmaps help to address some of the technical and engineering risks associated with the new technologies.
- The IEEE INGR provides a high-level perspective and projection of how the industry could evolve, with highlights of common needs, the challenges to achieving those needs, and the potential solutions to those challenges as nine initial chapters.
- It is the purpose of the INGR roadmap to stimulate an industry-wide dialogue to synchronously address all the facets of the development and deployment of 5G in a well-coordinated manner, starting with the year 2020 and going beyond.

INGR First Edition and 2021 Edition (completed)

- This first edition roadmap lays the foundation for the next edition that will include a description and evaluation of 6G and other future enhancements.
- **INGR 2021 Edition Chapters are available at https://futurenetworks.ieee.org/roadmap**

INGR 2022 Edition (new)

- As work continues with the 2022 Edition, new experts are encouraged to participate, to evolve and strengthen this crucial document. Join us!
- **https://futurenetworks.ieee.org/roadmap#workingGroups**

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As work continues with the 2022 Edition, new experts are encouraged to participate, to evolve and strengthen this crucial document.

Join us !

INGR Access and Participation

International Network Generations Roadmap (INGR)

Future network technologies (5G, 6G, etc.) are expected to enable fundamentally new applications that will transform the way humanity lives, works, and engages with its environment. Be a part of this transformation today!

- The INGR is a semi-annual technical document highlighting network technology evolutions over 3-, 5- and 10-year horizons.
- Created by a group of 100+ international IEEE experts from industry, academia and prominent research labs, organized across 15 distinct working groups.
- Every 12-18 months, INGR will release a new multi-chapter document highlighting development needs, the challenges/roadblocks to achieving those needs, and potential solutions to those challenges.
- At least twice a year, INGR leadership will do outreach to industry and hold presentations highlighting the most crucial future technical roadblocks, to engage industry to solve or avoid those risks and roadblocks.
- **FREE with Future Networks membership – Join today!**

Contact us to get involved!
m.borst@ieee.org

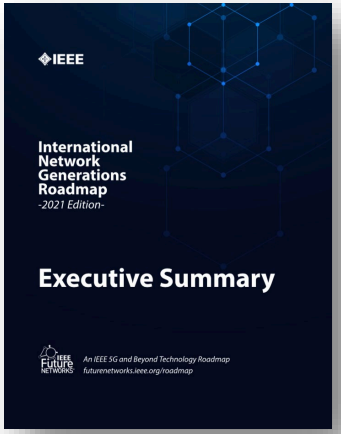
INGR 1st Edition Release

- Access the documents online at
  futurenetworks.ieee.org/roadmap

- INGR is a program of the **IEEE Future Networks Initiative**

Accessing INGR 2021 Chapters

1. Visit FutureNetworks.ieee.org/roadmap
2. Sign in as an FNI member (IEEE account)
3. Download all chapters



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