IEEE Future Networks Organization Structure

- **Education Working Group**: F. Behmann, A. Dutta
- **Publications Working Group**: C. I, R. Waterhouse, Meng Lu
- **Roadmap Working Group**: R. Hu, N. Mangra
- **Conferences & Events Working Group**: L. Ladid, A. Dutta
- **Standards Working Group**: M. Ulema, A. Gelman, R. Schrage
- **Content & Community Development Working Group**: J. Irvine, A. Wyglinski
- **Testbed Working Group**: I. Seskar, M. Patwary
- **Industry Engagement Working Group**: M. Lu, S. Dixit

A. Dutta
T. Lee

Steering Committee Chair and Co-Chair

Staff Program Director

Craig Polk

14 sub-groups; 100+ volunteers
## IEEE INGR Structure and Working Groups

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>DESCRIPTION</th>
<th>INGR WORKING GROUP CHAPTERS</th>
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</thead>
</table>
| 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  
• 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) |

[https://futurenetworks.ieee.org/roadmap](https://futurenetworks.ieee.org/roadmap)
Call for Papers and Proposals

IMAGINING THE NETWORK OF THE FUTURE Submission Deadline: 25 September (FINAL)

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IEEE Electronics Packaging Society
IEEE Transportation Systems Society
IEEE Microwave Theory & Technology Society
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REGISTRATION

https://fnwf2023.ieee.org/registration
Prof Mischa Dohler

Mischa Dohler is VP Emerging Technologies at Ericsson Inc. in Silicon Valley, working on cutting-edge topics of 6G, Metaverse, XR, Quantum and Blockchain. He serves on the Technical Advisory Committee of the FCC and on the Spectrum Advisory Board of Ofcom.

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); 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.
Supercharge 6G with AAA

Prof Mischa Dohler
Fellow IEEE, Fellow Royal Academy of Engineering, Fellow Royal Society of the Arts

VP Emerging Tech, Ericsson Inc, Silicon Valley
Advisory Board, FCC (TAC) & Ofcom (Spectrum)
Visiting Professor, King’s College London

Sept 2023
Let’s Get The Roadmap Right!

- Fixed Internet
- Mobile Internet
- Things Internet
  "Internet of Things"
- Immersive Internet
  "Metaverse"
- Human-Centric Internet
  "Internet of Skills"
- Machine-Centric Internet
  "Singularity"
Where Do We Want To Be In 2030?

Possible 6G Use-Cases:

- “Holographic Society” and Merged Realities
- Massive Digital Twinning and JCAS
- Situational Awareness and Reprogramming of Cyber-Physical Worlds
- Efficient and Pervasive Mobile Broadband
- Sustainability and e-Health
Supercharge 6G With «AAA»

AI
Availability, Effectiveness & Efficiency

API
Monetization, Innovation & Scale

AR
New Use-Case; “iPhone Moment”

AI in 6G Networks

An overview of Artificial Intelligence in 6G Networks, across OSI Layers and operations.
Roadmap Towards Native-AI 6G Networks

“AI moves fast, which means incumbents don’t have a big advantage over new-joiners,” Jason W., 2023.

- Automated Networks
- Self-Organizing Networks
- AI-Native Networks

Manual Configuration → Applied Intelligence → Robust and Explainable Network → AI-Native Networks

- AI agents for network functions
- Continuous operation optimization
- Data driven infrastructure

- Automatic conflict resolution
- Predictive control
- Knowledge LCM

- Fully intent-driven networks
- Zero-touch, Automated LCM
- Self-designing networks

Customer experience / quality / efficiency

Manual & reactive → Fully automated & pro-active
Towards Native-AI 6G Protocol Stack

Today
Domain A
Layer z
AI/ML model
Layer ...
Layer 2
AI/ML model
Layer 1
AI/ML model

Evolution

Data-driven infrastructure (cross-domain)

Layer ...
Layer 2
AI/ML model
Layer 1
AI/ML model

Target
Domain A
Layer z
AI/ML model
Layer ...
Layer 2
AI/ML model
Layer 1
AI/ML model
Model life-cycle management (cross-domain)

Data-driven infrastructure (cross-domain)
Generative AI In 6G Systems


Generative AI Taxonomy:
- Explicit Density Function (RNN)
- Implicit Density Function (GAN)
- No Density Fct / Attention (LLM)

Beyond Communication Functions
- Generative AI for Positioning/JCAS
- Coding & DevOps
● Linear Model U-Tree (LMUT) distills a decision model from a trained agent by transferring the neural network (NN) to a linear decision tree

● No performance loss, transparent but less than drQDN

- Reinforcement Learning (RL) -> Q-Learning -> Deep Q-Networks (DQN) -> decomposed reward DQN (drDQN)

- No performance loss, transparent, user-interpretable and thus trustworthy

- [Diagram of Q-values, RSRP, SINR, Tput, Tilt relationships]
02

API in Future Networks

An overview of APIs in 5G SA & Beyond Networks and their value towards monetization in telecoms.
Opening Up Telco Networks To App Devs

Vonage Communications Platform

Gaming Video Banking

Easy to consume service APIs

Vonage Communications Platform

Advanced Network APIs exposed by CSPs

- Making it easy for developers to use and bundle API services in 5G SA & Beyond
- Exposing communication services and new advanced network functionality through easy-to-use APIs
- Enable native monetization in telco networks
Communication & Network APIs

Communications APIs
- Voice
- SMS
- Video
- Auth
- IP Chat

Network APIs
- QoS
- Silent Auth
- Location
- Device Data
- More to come...

Worldwide 5G and future 6G networks

High speed & Low latency
Reliability
Wireless edge solutions
Security
Network slicing
Enabling Native Monetization In Telecoms

Future innovation

Current adjacencies

Basic existing API

Enterprise

Consumer

Future innovation

Current adjacencies

Basic existing API

Customer interaction

Precise Location

Number insights

SMS 2FA

SMS APIs

Enhanced Verification

QoS Experience

Number masking

Voice APIs

AR/XR extended reality

Driving assistance and monitoring

Edge computing services

Real-time Cloud Gaming

Device connection management

Drone mgt. control

Gaming

IoT device related services

XR

XR Gaming

Device connection management

Customer interaction

Device connection management

AR/XR extended reality

Customer interaction

Driving assistance and monitoring

QoS Experience

IoT device related services

XR Gaming
AR in Future Networks

An overview of AR in 5G SA & Beyond Networks and their value as a unique 6G use-case.
Our AR Predictions In The 5G & 6G Era

VR to AR
2023 - 2025

AR takes lead
2025 - 2027

All day XR
2027 - 2030

Blended information

Spatial anchoring

Fully immersive

Likely scenario development:
- VR/MR, simple AR
- Static, on device, tethered
- Starts with local deployments

- 5G-native AR takes lead
- Local → wide area networks
- >1m users per AR app

- Global adoption with >1bn users
- Stand-alone, cloud, multi-user
- Privacy will be key
## Tech Innovation: Edge-Cloud Rendered AR

### Device-Rendered Quality
- VR/AR HMD
  - >4K-8K (!)

### HMD (+phone)

### Edgecloud-Rendered Quality

---

### Table: Device-Rendered Content vs. MEC-Rendered Content

<table>
<thead>
<tr>
<th></th>
<th>Device-Rendered Content</th>
<th>MEC-Rendered Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU</td>
<td>&lt;1 W processing power</td>
<td>350 W</td>
</tr>
<tr>
<td>Memory</td>
<td>Limited</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Battery</td>
<td>Significant Drain</td>
<td>2x-7x Saving</td>
</tr>
<tr>
<td>Connectivity</td>
<td>MBB 10kbps-1MBps</td>
<td>TCC 0.1-10s Mbps &amp; 10-40ms RTT &amp; 3ms jitter</td>
</tr>
</tbody>
</table>
Native “E2E System Low Latency” In 6G

- VoLTE latency statistics are globally roughly the same.
- MBB latencies are typically slightly better than VoLTE.
- Aim is to get same homogeneous latency as for VoLTE but for XR, but of course much lower.

Based on data from CellRevel measurements.
An overview of underpinning 6G technologies and architecture approach.
Ericsson’s 6G Technology Focus

Nov 2022 Blog: Why it’s a great time to start talking 6G – Ericsson
Feb 2023 Blog: Nine takeaways from early 6G research - Ericsson

- Limitless connectivity
  - Make dev & app centric for strong business case.
  - Ensure that 6G use-cases can be supported!

- Cognitive network
  - Ensure that system & AI “behave properly”.
  - Ensure that 6G system can be scaled.

- Network compute fabric

- Trustworthy Systems
Multi-Layer Spectrum In 6G

Sub-Terahertz (90…300 GHz): Complimentary spectrum for extreme performance in very local areas

mmWave (24…47 GHz): High-speed, very low latency in local areas

Centimeter (7…15GHz): Essential spectrum for 6G, good coverage and capacity (the lower, the better)

Midband TDD (2.3…7 GHz): The “Sweetspot” – Wide area coverage and good capacity

FDD (1.. 2.7 GHz): Nationwide coverage and indoor penetration

FDD (<1 GHz): Nationwide coverage and deep indoor penetration

Fully coordinated multi-layer network
6G possible to run on any layer
Spectrum aggregation and technology co-existence for spectrum already in use
6G Coverage & Capacity Comparison

Essential centimeter wave

Complementary sub-THz

[Color scale: 25 15 10 5 1 0.1 [Gbps]]
6G Zero-Energy Devices

- Devices harvesting ambient energy
- Solar panel
- Vibration (trains, heavy machinery)
- Small turbines
- Small thermoelectric generator
- Indoor light
- Wireless charger (a few meters)
- Acoustic noise
- Radio energy
Every peak channel impulse response is a function of distance and angle.

- Frequency: 60 GHz
- Bandwidth: 2 GHz
- Number of antennas: $25 \times 25 = 625$
- Antenna spacing: $0.4 \lambda$
- Distance between Tx and Rx: 1.5m
Overall 6G Architecture Approach

- Alignment within industry on **key migration path** prior to start of standardization
- Enable fast deployment of SA 6G by avoiding unnecessary deployment options

- Aim to **simplify the 6G architecture**, by aligning industry on key interfaces for standardization
- Reuse investment in 5GC, allowing smoother 6G introduction, and alignment of migration paths
Network Horizontalization Central To 6G

- Native separation of NFs from underlying platform, and overlaying management and exposure
- Beneficial to the continuous evolution of underlying platform technologies (from IT eco-system)

Applications

- End-to-end management/automation, service and analytics exposure

5G/6G CN

6G RAN

5G RAN

Data networks

Cloud infrastructure, transport, data pipeline, common platform functions, etc

6G UE

D/E

A

B

C

H
6G Testbed Proof-Points

Sub-THz 6G Communications

6G Digital Twin

Zero-Energy Joint Sensing-Comms

Centimetric 6G Communications
A non-exhaustive summary of key findings towards a successful implementation of 6G.
Summary of (Some) Gaps Towards 6G

6G Architecture & Overall Approach:
* Embrace new capabilities yet simplify 6G architecture & deployment options
* Supercharge 6G with AAA, i.e. AI, API and AR

AI – Artificial Intelligence:
* Develop methodologies & standards towards interoperable AI
* Significantly expand R&D and standards on Trustworthy AI

API – Application Protocol Interface:
* Expand Beyond-5G architecture work to natively include horizontal architecture
* Natively embed monetization capabilities into 6G via APIs

AR – Augmented Reality:
* Make a big bet on a next “iPhone moment”; ensure e2e design on all what this use-case needs
* Ensure consistent QoE, through consistent RAN, CN and E2E MECs
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