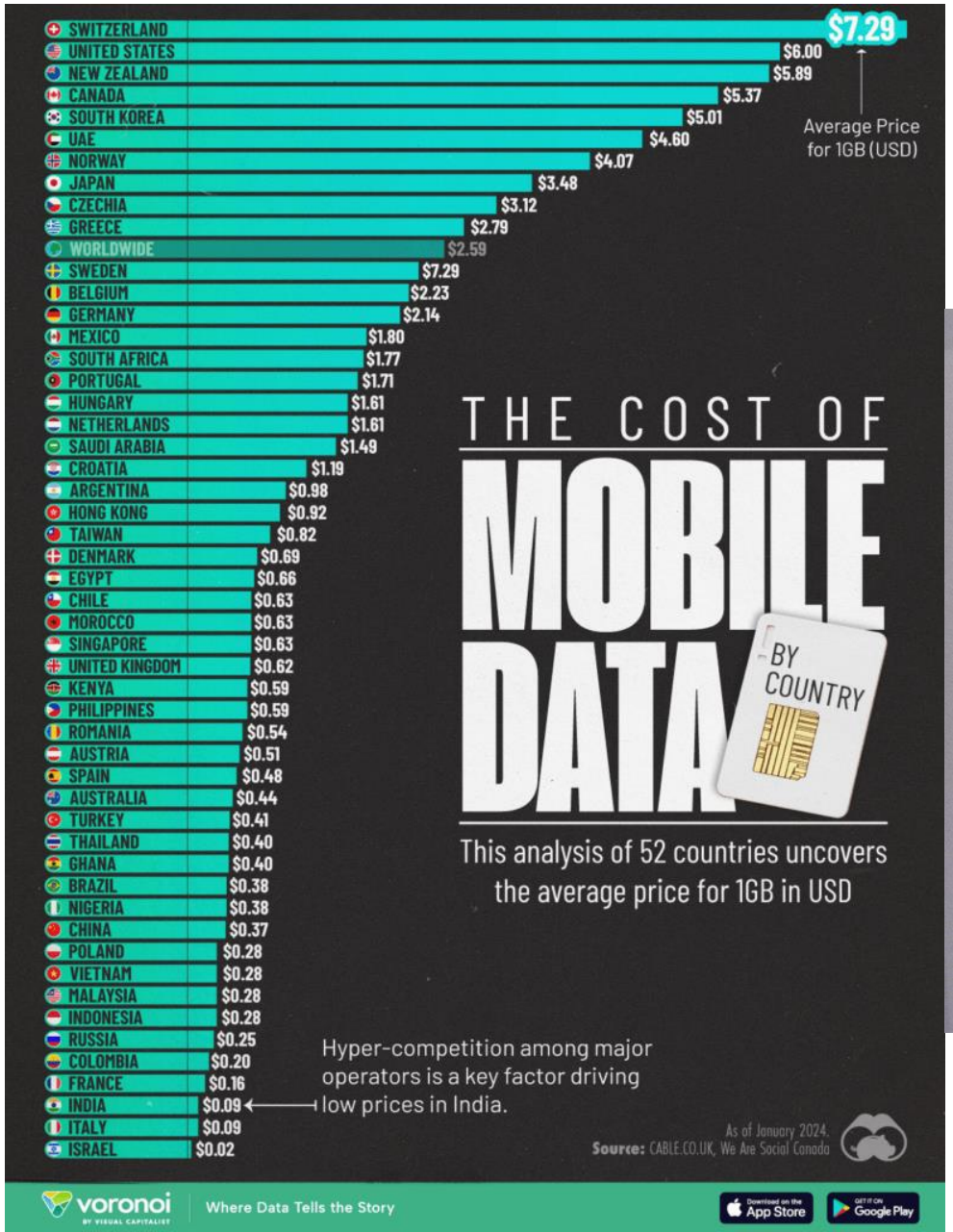
6G Roadmap & Status in 3GPP RAN

One 6G summit, Bologna, 18 SEPT. 2025

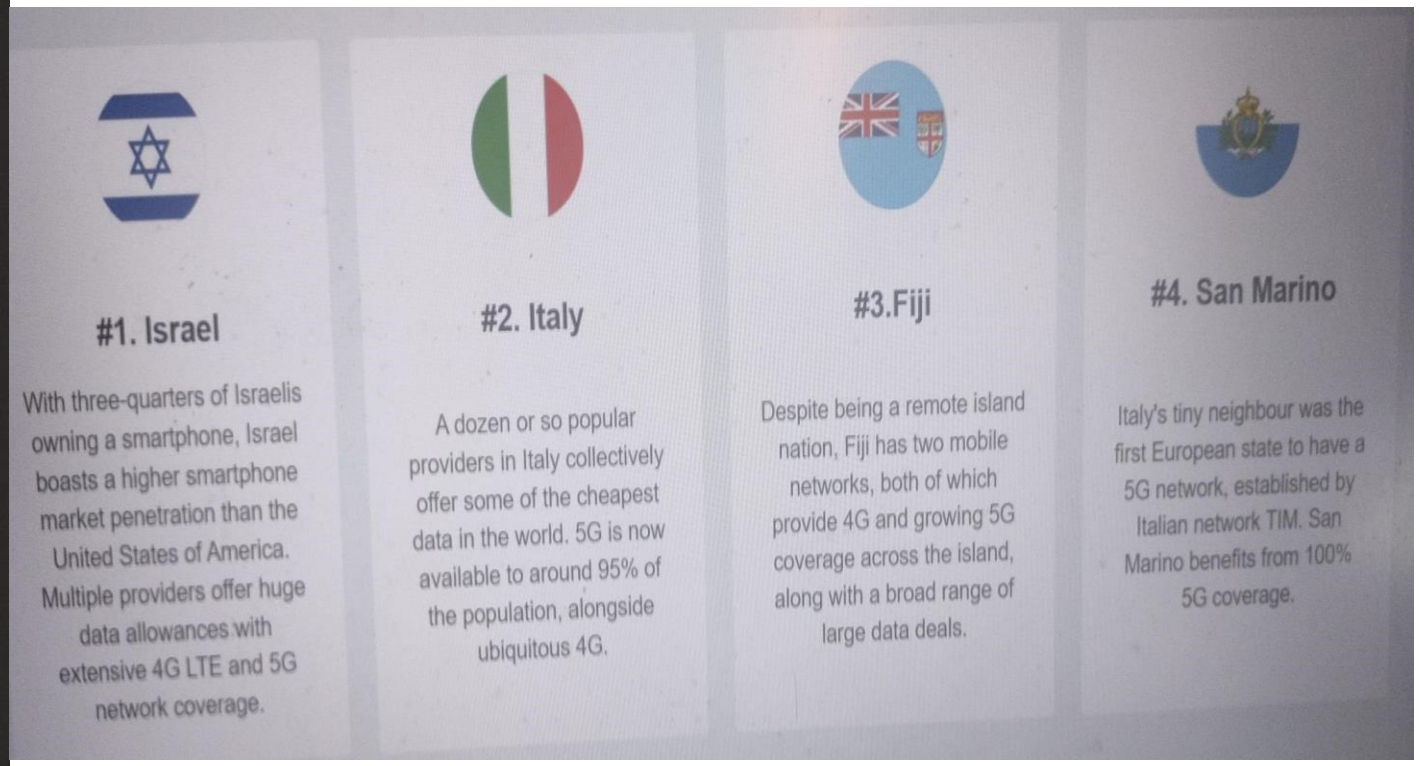
Enrico Buracchini
RAN Plenary Vice Chairman

TIM
LA FORZA DELLE CONNESSIONI

Business sustainaibilty: extreme competition at least in some EUs/ITALY + OTT pressure



SOURCE
The Cost of 1 GB of Mobile Data Worldwide – Visual Capitalist Licensing (end of JAN2024)



Worldwide Mobile Data Pricing 2023 | 1GB Cost in 237 Countries (End of 2023)

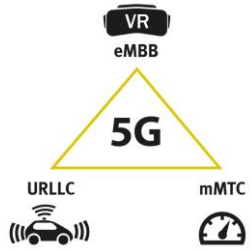
5G Releases

Release 15

Enhanced Mobile Broadband

Release 16

Massive & Industrial IoT, Private Networks, V2X



Release 17

En. IIoT, Drones, Satellites, Multicast/Broadcast, Public Safety

Rel.18 & onwards

5.5G

5G Phase 1 (Q3 2018)

- Enhanced Mobile Broadband (**eMBB**)
- Basic URLLC

5G Phase 2 (Q2 2020)

- Capacity enhancements
- Operational efficiency
- Expansion to **new vertical markets**

5G expansion (1H 2022)

- Even **more vertical markets**
- Continuous enhancements

5G Advanced (2H 2023)

- **AI/ML introduction**
- **JSAC**
- Continuous enhancements

Categorization of topics based on WS contributions

- AI/ML Air Interface
- MIMO Evolution
- Ambient IoT
- AI/ML mobility
- IoT NTN
- AI/ML for NG-RAN

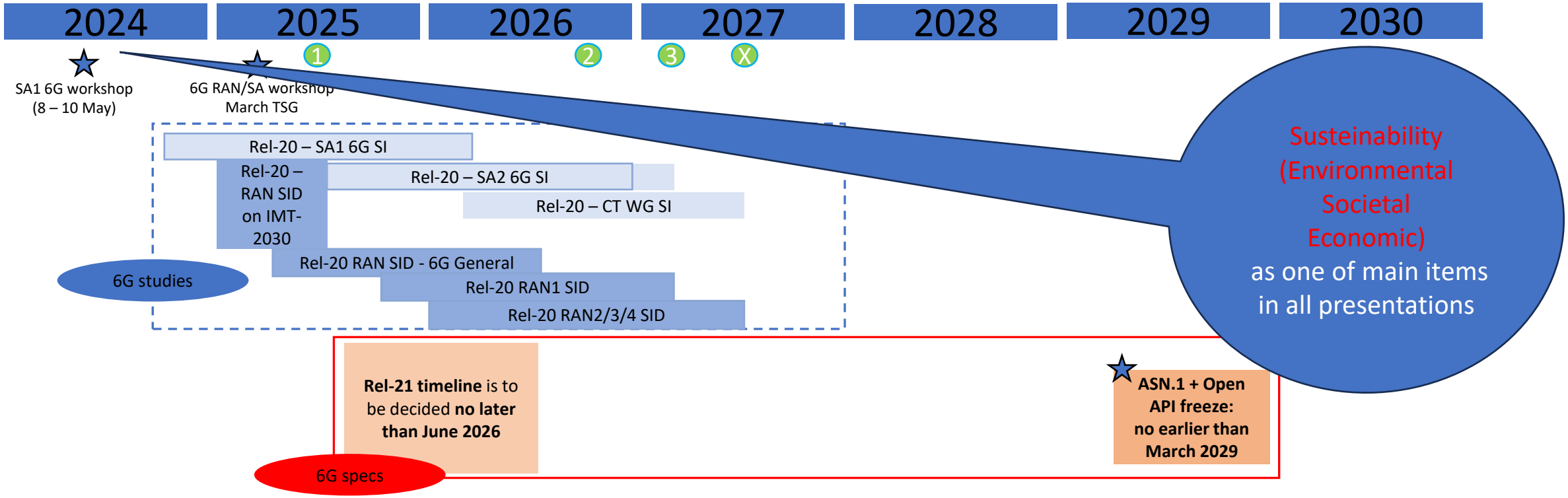
- Additional RAN1-led Candidate Topics
  - Coverage enh. (incl. FR2)
  - NES
- Additional RAN2-led Candidate Topics
  - Mobility Enh.
  - XR
  - UAV/UAM Enh.
  - NR NTN
- Additional RAN3-led Candidate Topics
  - Sensing/ISAC
  - SON/MDTEnh.

- Another candidate topic: Develop channel bandwidth 200MHz considering n104

- Others
  - SBFD
  - UE aggregation
  - CA enhancement (incl. faster scell activation)
  - RRC_inactive enh.
  - UE energy saving (incl. LP-WUS)
  - Sidelink enh. (incl. SL relay)
  - QoE enh.
  - RIS
  - Positioning
  - Topological enh. (NCR, femto, WAB)
  - UE Tx switching enh.
  - Packet priority based access control
  - Xn failure handling enh.
  - Digital twin
  - Ray tracing model
  - Other UL enh. (e.g., PA non-linearity, scheduling)
  - Others

Timeline agreed in March 2024 PLENARIES

- ✓ **Rel-20 (5G-Advanced + 6G studies)**
  - ✓ 5G-Advanced stage 1/2/3 Open API freeze dates → see << 🟢 >> below
  - ✓ SA1/SA2 6G study may continue beyond Stage-1/Stage-2 freeze dates for 5G-Advanced
- ✓ **Rel-21 (5G-Advanced + 6G specs)**
  - ✓ Timeline to be decided no later than June 2026
  - ✓ However, ASN.1/OpenAPI freeze date is no earlier than March 2029



3GPP 6G timeline is endorsed in RP-233985 (TSG#102) and RP-240823 (TSG#103):

- Studies for 6G in 3GPP start **from Release 20**
- Plenary study on 6G: **RAN plenary work split**
  - IMT-2030 discussion in RAN from 09/24 to 12/24
  - **RP SI Rel-20 focusing on ITU–IMT-2030: approval 12/24 until 06/25**
    RP SI Rel-20 focusing on 6G General: approval 03/25 (after WS), until 06/26
- IMT-2030 submission and normative work for 6G in 3GPP are expected to start from Release 21
  - **Release 21 is expected to produce the 1st set of 3GPP 6G technical specifications,** and will be the release for IMT-2030 submission before 2030
  - Release 21 is expected to be **delivered with a single drop** (i.e., a single code freeze)
  - Release 21 timeline ***is to be decided no later than June 2026***
    - However, ASN.1/OpenAPIfreeze date **is no earlier than March 2029**

6G workshop @Ran107 (March 2025, Seoul, SK)

6GWS-250243

- Opportunity for 3GPP members to present their **vision & priorities for next generation radio technology, system architecture, core network and protocols.**
- **1,676 registrations, 748 in-person registrants**
- **219 input contributions from operators, vendors, academia, and MRPs**
- Discussions covering **radio, core network, protocols, and more**

NOT BINDING WORKSHOP

.....does not imply any prioritization or ranking of 6G technical areas.

The scope of work within 3GPP is determined by its established working procedures, and there is no assurance that all the potential technical areas mentioned will be pursued as part of 3GPP studies in Release 20.

6G Motivation (Why 6G?)

Support for New Services and Use Cases

- Enabling new services and use cases beyond traditional communication, such as integrated sensing and communication (ISAC), XR/immersive communication, and AI-based services – Compute.

Revenue Growth and Monetization

- Creating new revenue streams by monetizing network capabilities and supporting diverse applications across industries.

AI and Automation

- Implementing AI-native networks for automation, optimization, and improved efficiency in network management and resource allocation.

Energy Efficiency and Sustainability

- Reducing energy consumption and promoting environmental sustainability through energy-saving features in network design and AI-driven power management.

Spectrum Efficiency

- Utilizing spectrum efficiently, including dynamic spectrum sharing and exploring new spectrum bands.

Ubiquitous Coverage

- Seamlessly integrating terrestrial and non-terrestrial networks (NTN) for ubiquitous coverage and resilient services.

Total Cost of Ownership (TCO) Reduction

- Reducing capital expenditure (CAPEX) and operational expenditure (OPEX) through simplified network operations and improved energy efficiency.

Improved Service Reliability and Customer Experience

- Enhancing service reliability, resiliency, and insights for improved customer experience.

Network Simplification

- Simplifying network architecture, reducing complexity, and improving operational efficiency.

6G Goals

Sustainability

- Focus on environmental, social, and economic sustainability. This includes energy efficiency, reduced resource consumption, and contributing to global emissions targets.

Resilience

- Designing networks that are robust and can withstand various events, including operational errors, heavy traffic, and disasters.

Security

- Increased security, integrity, and privacy are required from day one, incorporating zero trust principles and post-quantum security measures.

Customer Experience

- Improved end-user/customer experience through seamless, ubiquitous connectivity, ensuring reliable, high-quality services delivery. Optimized Quality of Experience (QoE) across diverse devices and network conditions.

Efficiency

- Cost reduction via simplified systems and operations, with AI-driven automation and optimization.

Interoperability

- Promoting open/interoperable interfaces and collaboration to foster innovation and avoid market fragmentation.

Lessons Learned from 5G

Challenges in Migration

- The transition from 5G Non-Standalone (NSA) to Standalone (SA) proved complex and difficult.

Architectural Complexity

- An excessive number of architectural options, features, and configurations led to high system complexity, impacting UE capabilities and deployment efficiency.

Slow Adoption of Key Capabilities

- Certain 5G features, such as network slicing, experienced slow adoption—necessitating an analysis of underlying causes and potential simplifications in 6G.

Deployment Inefficiencies

- Issues identified during 5G rollouts, including NRF profile inefficiencies and protocol challenges (e.g., HTTP/2 over TCP), should be addressed in 6G.

Optimized Network Functions

- Ensuring efficient Network Function (NF) sizing with clear decoupling, while further exploring stateless architectures.

Functionality Optimization

- 6G should focus on a well-dimensioned set of functionalities, minimizing redundant options and excessive configurations to reduce complexity.

Potential Technical Areas for 6G Study

6G System Design Considerations

Focus and Simplicity

- Lean and streamlined standards for 6G, e.g., by dimensioning an appropriate set of functionalities, minimizing the adoption of multiple options for the same functionality, avoiding excessive configurations, etc.

Cloud-Native Architecture

- Designing networks to be cloud-native to enable flexibility, agility, and innovation.

AI-Native Design

- Integrating AI and ML frameworks natively into the network for intelligent automation, optimization, and improved efficiency.

Scalability and Modular Design

- Implementing a scalable and modular design that allows a wide range of features, device types, services, and spectrum bands to be developed and deployed as needed.

Software-Driven Deployment

- Software-driven deployment with needs-based hardware refresh to allow for continuous innovation and agility.

Interoperability

- Designing components with interoperable interfaces and a unified management framework to ensure interoperability and avoid fragmentation.

Enhanced Security

- Ensuring the 6G system is secure by design to provide enhanced security and privacy.

IoT Support

- Designing 6G to support diverse IoT device types and use cases from day one, with a focus on long-term commitments and multi-generational solutions.

Service-Aware

- Enabling a service-aware intelligent network powered by AI-native, programmable, and service-aware 6G RAN.

Ubiquitous Connectivity

- Providing ubiquitous coverage through seamless integration of terrestrial and non-terrestrial networks.

Radio Access Network for 6G design considerations

- 6G Radio interface: Non-backwards compatible (from a UE perspective) to exploit full potential, with certain characteristics (e.g., waveform, modulation and channel coding) based on 5G NR with possible enhancements.
- Study needs to show **significant gains** to justify 6G Radio.
- Lean and Streamlined 6G, dimension appropriate set of functionalities, minimize adoption of multiple options for the same functionality, avoid excessive configurations
- **Superior coverage** for 6G radio from Day-1
- **Diverse device types** with scalable design from Day-1 based on, for example: Bandwidth/data rate, form factor, energy consumption
- Harmonized TN and NTN design
- AI/ML: **Extensible AI/ML framework** built on 5G-A as appropriate, with native support for AI/ML lifecycle management, (e.g., configuration, performance monitoring, deactivation, and seamless transition to conventional algorithms). And exploring new use cases.

Core Network for 6G design considerations

- A preference for a single 6G Standalone Architecture is noted, with SA mode as a baseline
- Core Network for 6G to be designed to cover new 6G requirements regarding AI, connectivity, Security/Privacy/ Resilience with possible reuse of the 5G SBA/SBI framework and investigate enhancement 5G SBA/SBI architecture
- Simplification of architecture and streamlining of NFs definitions and interactions/interfaces/protocols
- Investigation of new functions based on the SBA architecture to support new 6G Services
- Designed to integrate and interoperate with various access technologies, including FWA and Wi-Fi access
- A unified network exposure framework for simplifying the 3GPP-wide exposure framework to foster an API economy of scale

Migration/Architecture Options

- 6G SA standalone as the primary architecture option. Based on lesson learned from 5G, avoid 6G Non-Standalone (NSA) options if possible.
- MRSS (5G+6G spectrum sharing) and 6G-6G carrier aggregation
- Other aggregation means were proposed as possible additional migration path, for example -
  - 5G-6G Dual Connectivity
  - 5G-6G Dual-stack

What is under discussion almost now….

- Several technical aspects, e.g.
  - Waveforms/carrier spacing/modulations
  - Spectrum
  - Different device Types and their characteristics (eg number of TX/RX, form factors, etc…)
  - Services (AI/ML, JSAC, eMBB, NTN, IoT…)
  - Architecture and migration strategies
  - Simulation assumptions
- WGs activities: WG1 started in August, WG2 and Wg3 are upcoming, to start in October

THANKS!!! ☺
Q&A