IEEE Future NETWORKS

Enabling 5G and Beyond

International Network Generations Roadmap (INGR) Virtual Workshop

Testbed Working Group

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IEEE

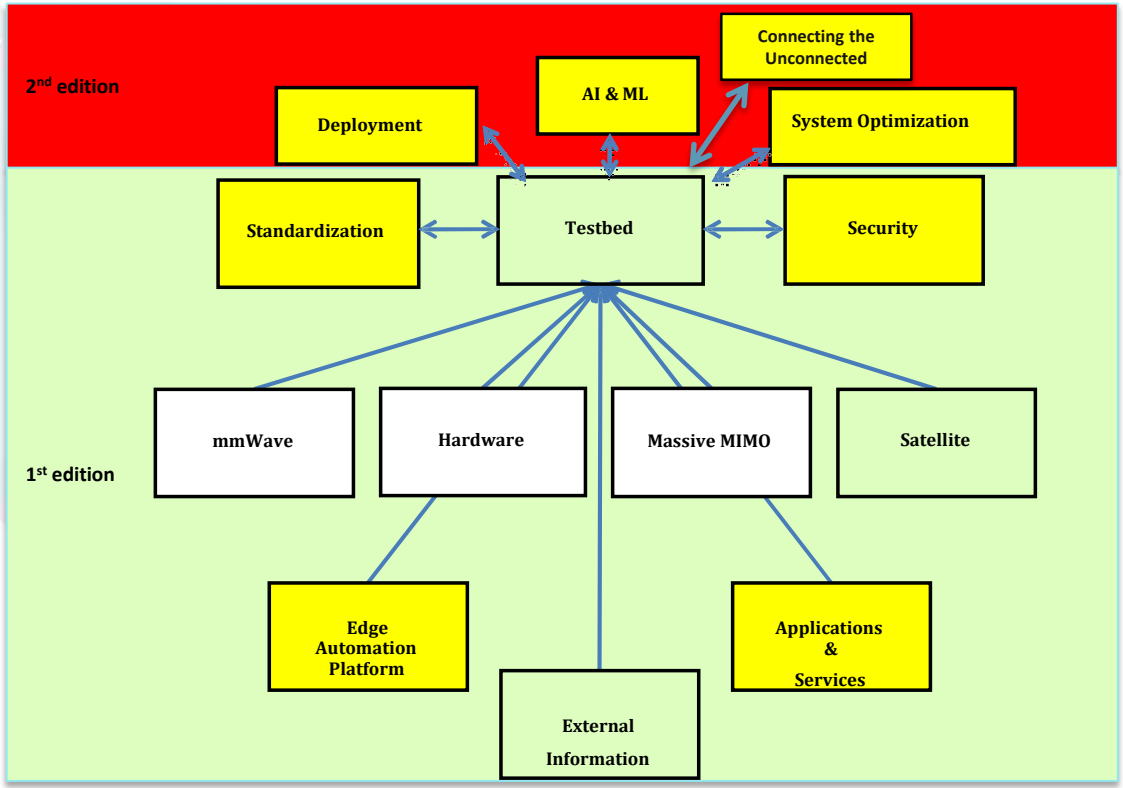
Objective of the working group

- Leverage IEEE community's strong **simulation, measurement and calibration capabilities** for testbeds to develop best practices, calibration methods and (ultimately) testing standards
- Propose and drive development of **future testbed requirements**
- Collaborate with the **vendor and research community** to expand existing testbeds with next generation of technologies (as they become available).
- **Inventory types of testbeds** that are available, serve as facilitator for setting up a testbed federations and make them available to IEEE community
- Organize workshops related to future networks experimental aspects (including **use case scenarios, trials and proof-of-concept deployments**).
- **Create the IEEE Federation of Future Networks Testbeds covering all aspects of new technology research, experimentation and evaluation**

10-year Vision

- Short Term (3 years):
  - Develop a bank of data sets from each of the participating testbed and pilot roll-out programs regarding technical challenges and relevant statistics and provide access to R&D community to this data, in order to support:
    - establishing a global federation of testbeds
    - propagation data from private/public networks (if available) as well as connectivity demand patterns,
    - innovative use case validation, and
    - influencing application-specific performance characteristic range definition for the technical (researcher, innovator or industry) communities.
  - Identify a set of testbed building components that are technology independent
  - Initiate legacy testbed federation creation through ad-hoc proxy services
- Medium Term (5 years):
  - Work closely with the other WGs on defining requirements for the next generation of tesbeds and build up expected performance benchmarks or key performance indicators (KPIs) for beyond 5G/6G networks.
  - Propose new network architecture for 6G and beyond, exploiting the learning from the federation of testbeds.
- Long Term (10 years):
  - Establish testbed building standards along multiple technology axes with the aim of facilitating efficient engagement with experimental platforms for both academic and industrial researchers
  - Develop novel testbeds federations to generalize use cases beyond 5G or 6G with the aim of influencing development of next generation of network architectures

Scope


2nd edition
Connecting the Unconnected
AI & ML
Deployment
System Optimization
Standardization
Testbed
Security
1st edition
mmWave
Hardware
Massive MIMO
Satellite
Edge Automation Platform
Applications & Services
External Information

External Stakeholder

- **Equipment Vendors—**one of the main objectives for equipment vendors to participate in testbed construction and operations is to satisfy the requirement to show interoperability at the neutral “playgrounds,” especially before the formal standardization. Another objective is to enable collaboration of testbed operators with the equipment vendors and supplier community especially with regards to donations/contributions of space, equipment and other resources.
- **Network Operators** —Agile development cycles drive the need for scaled experimentation in order to evaluate technologies (quite often testbeds are operated by network operators).
- **Standardization Bodies** —Need a place to evaluate and compare proposals.
- **Academia** —Due to ever-increasing complexity, researchers are increasingly relying on experimentation for technology development and performance evaluation.
- **Innovators** —Cannot afford to build their own playgrounds
- **Local/National Governments** —Evaluation of societal benefits (that impact regulatory decisions).
- **Military** —Requires platform for dual-use technology evaluation.
- **Open-source Communities** —Have a significant interest to increase the participation base by adoption of common development grounds. Given the nature of this community, they also have significant interest to develop features and capabilities

Today's Landscape

- **Today's Landscape**
  - Large number of (announced) 5G testbeds and trials
    - Fully disconnected/independent (even unaware of each other) collection
  - Three main, mostly disconnected, stakeholder groups: industrial, academic and standards/alliance compliance bodies
  - Lack of testbed deployment standards
  - Lack of testbed interoperability events
  - Lack of cooperation/federation between testbeds
  - Lack of common planning for testbed development
  - Small number of (fully public) testbeds
  - Selected players with closed nature of interfaces
  - Lack of collaboration among government, public sector and educational institutions

Driver Metrics Chart (Edition 1)

DRIVER NAME	METRIC (CURRENT STATE)	PROJECTED METRIC 3-YEAR	PROJECTED METRIC 5-YEAR	PROJECTED METRIC 10-YEAR (2029)
Technology development – low latency (e2e)	5 ms	1 ms	100 µs	10 µs
Technology development – reliability	99.999%	99.9999%	-	99.99999%
Technology development – data rate	1 Gbps	2 Gbps	10 Gbps	20 Gbps
Technology development – scaling	1000 devices	10000 devices	20000 devices	100000 devices
Use cases	MBB	eMBB	mMTC	URLLC
Data Sharing platform (User, application, network)	Heterogeneous	Universal – by translation (creating guideline, coalition)	Universal – by design (architecture)	By default (AI powered, fully automated)
Data monetization	Sparse	Data as a commodity/ spontaneous data demand	Data harvesting as business	Data economy eco-system (Block-chain/ML & AI Powered)

Driver Metrics Chart (Edition 2)

DRIVER NAME	METRIC (CURRENT STATE)	PROJECTED METRIC 3-YEAR	PROJECTED METRIC 5-YEAR	PROJECTED METRIC 10-YEAR
Data labeling	Ad-hoc	Common standards for experiment (and testbed performance) data collection and labeling	~~Global experimental data sets archive creation~~	Fully autonomous reference data sets creation (ML/AI)
Security framework	NIST	Development of KPIs and metrics	~~Standardization of security assessment and mitigation building blocks~~	Fully autonomous security evaluation (ML/AI)
Risk assessment & management (RA&M)	Ad-hoc	Development of KPIs and risk assessment metrics	~~Development of RA&M standards~~	Fully autonomous alerting and reporting evaluation (ML/AI)
Federation interface standard	Ad-hoc / p2p proxy	Develop reference architecture (module-based architecture definition)	~~Consensus development (documented best practices development)~~	Common practice standards
Holistic approach to resource management (slice, spectrum, bandwidth, latency, reliability, etc.)	Individual metric optimization	Incremental expansion of ML/AI use for resource management; benchmark standardization	~~Fully autonomous major resources management benchmarking framework development (ML/AI)~~	Fully autonomous arbitrary resources management evaluation at scale (ML/AI)
Resilience	Ad-hoc	Development of KPIs and evaluation scenarios; benchmark standardization and local scale evaluation support	~~Development of KPI evaluation building blocks and global scale evaluation support~~	Fully autonomous resilience evaluation at scale (ML/AI)

Top Needs for 10-year Vision

Name	*Current State (2020)*	*3 years (2023)*	*5 years (2025)*	*Future State 10-years (2030)*
Need 1	**Testbed Clearing- House**	**A semantic-based testbed inventory with overview of capabilities**	**Automated testbed crawler**	**–**
Challenge(s) for Need #1	**Mechanisms for collecting information**	**Semantic description of (existing and) upcoming technologies**	**Testbed registration mechanisms**	**–**
Possible Solution for Challenge #1	**WG members input** **Portal for testbed self-registration**	**Semantic tools research**	**Policy development and harmonization**	**–**

Top Needs for 10-year Vision

Name	*Current State (2020)*	*3 years (2023)*	*5 years (2025)*	*Future State 10-years (2030)*
Need #2	**Lack of testbed harmonization**	**Testbeds component and operation harmonization**	**Federation of testbeds (including common AAA and tools sharing)**	**Common testbed platform development and integration**
Challenge(s) for Need #2	**Multiple disjointed testbeds serving particular verticals with domain specific implementations**	**Diversity of testbeds and usage models**	**Standardization of common elements enabling federation and tools sharing.**	**Support for large number of technologies and applications**
Possible Solution for Challenge #2	**Conferences, workshops and other (face-to-face and online) meetings**	**Identify common elements, develop guidelines, policies and pre- standardization documents**	**Development of services that are pluggable to allow customization for particular verticals and new technologies.**	**Standard testbed core services are used for most emerging testbed deployments; existing testbeds are retrofitted to common core.**

The ultimate need is for a testbed framework to link together all these elements (e.g. link: a.) testbed configuration, b.) fw/sw of the DUT, c.) data collection, d.) performance evaluation software/scripts and e.) publication)

Top Challenges

- Technology development support
  - "From simulation to deployment"
- Verticals support
  - "Highly Specialized" vs. "Universal"
- Testbed certification
  - Establishment of the certification criteria
- Operations (and Standard) harmonization
  - Steep learning curve (reducing impediments for experimenters)
  - Creating joint ecosystem for multiple stakeholders
- Diversity of needed operator skillsets
  - Virtualization
  - Network automation
  - Etc.
- Accessibility:
  - Open source (ONAP, ORAN, OSM (5GPPP))
    - Security alliance, Single sign-on, ect.
  - Agile development (federated development & testing facility)
- Use cases
- Infrastructure sharing (Learning based sharing)
- Distributed security
- Hardware/software (innovation, edge/open source compatibility)
- Harmonization/Management of testbed complexity

Standardization
(roadmap – short, Med & long)

- Vision/Evolution & revolution –(problem statement)
- Scenario (testbed, consortium)
- Distributed/ global (context/ thresholding)
- Compliance testing
- Interoperability/co-existence/inter-programmability
- Standard/pre-standard (ONF/ORAN) testbed models
- Extendable architecture
- Accessibility/ multi-operatability

- Domain specific KPI mapping
- Interface/protocol
- Technology agnostics
- Performance measurement is a block
- Reliability assessment
- Plug & play
- PoC
- Recommended practice
- (methods can be define for KPI cannot be define)

Conclusion & recommendation

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). Well defined external facing APIs for vendor provided implementation/testbed management tools
Lack of inter-testbed cooperation	Introduction of certification on testbed vertical compliance and interoperability to promote cooperation and component reuse. Standardization of testbed building blocks
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 translation)
Lack of skills	Establish dedicated testbed for skill enhancement. IEEE to provide online webinar to facilitate live event, if possible from a testbed site.

Next Steps

- Periodic Working Groups Meetings
- Work on the second edition of the Working Group document
- Testbed Workshop, Webinars, Podcast
- Testbed Catalogue
- Collaboration with other Working groups

Get involved!

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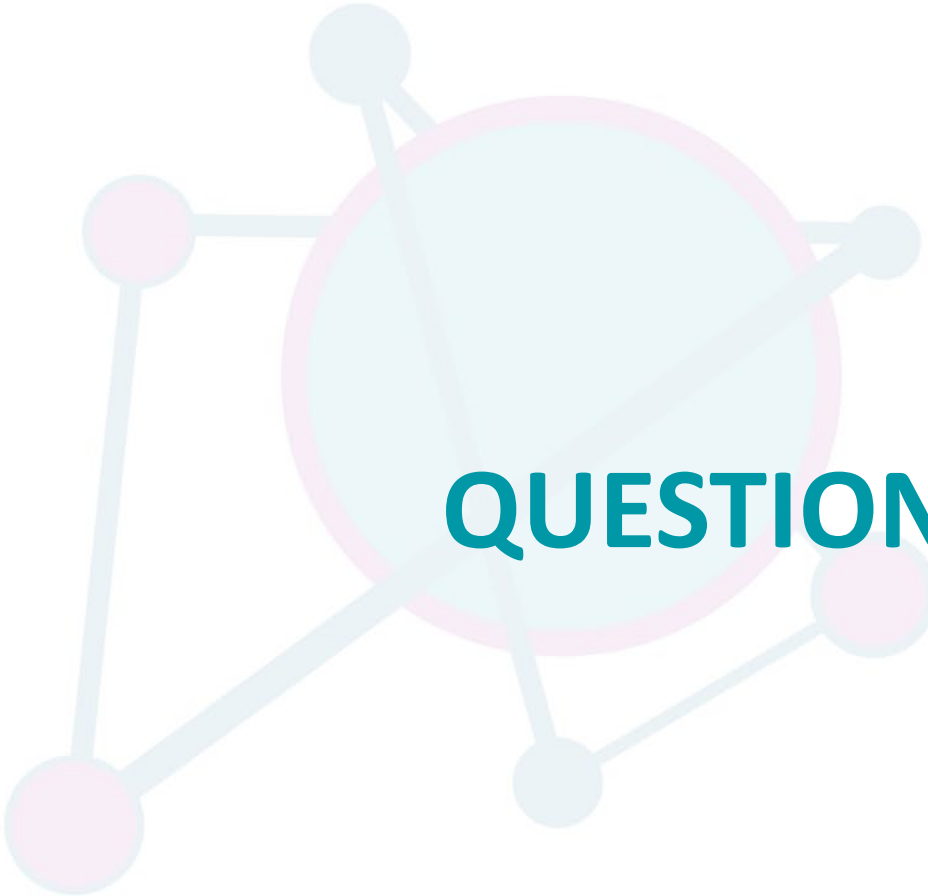

QUESTIONS?