NGMN Radio Performance Assessment Framework

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NGMN RADIO PERFORMANCE ASSESSMENT FRAMEWORK

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01 OVERARCHING STATEMENT

The NGMN Position Statement [1] outlined that 6G should be a graceful evolution of communications networks into the 2030s building on the existing 5G ecosystem and legacy access technologies. For a new 6G radio interface (i.e., new RAT) to truly add value, when compared with the most advanced capabilities of 5G, improvements that make a meaningful difference in reducing network costs while also improving customer experience and generating revenue growth opportunities for mobile network operators (MNOs) should be demonstrated. The Position Statement seeks to evolve our existing 5G/5G-Advanced ecosystem to foster new innovations which deliver value to customers and simplify network operation [1].

The telecoms industry has reached an inflection point such that it can no longer be automatically assumed that a new Radio Access Technology (RAT) would inherently add value in a 6G system. A different approach is needed. As new innovations emerge, and proposals for radio interfaces materialise, NGMN strongly believes that candidates for radio enhancements should be assessed to ensure alignment with the guiding principles of the Position Statement [1].

The Statement outlined that 6G must not inherently trigger a hardware refresh of 5G RAN infrastructure, and the decision to refresh 5G RAN hardware must be an individual operator driven choice for operational reasons such as end-of-life, energy consumption or new capabilities, and independent of supporting 6G [1]. 6G introduction must also allow certain scenarios to be realised through software-based feature upgrades of existing network elements to meet 6G requirements [1].

This publication proposes a new NGMN Radio Performance Assessment Framework (RPAF) for radio candidates to ensure future proposals for new RATs can be compared against the best-performing version of the New Radio (NR) feature set that is implemented in state-of-the-art 5G/5G-Advanced networks around the time 6G is first deployed. This RPAF is primarily intended as a guideline to 3GPP so that their evaluation process ensures a new 6G RAT deployed provides tangible benefit over an equivalent 5G-Advanced evolution, especially considering new RAT deployment within already deployed bands.

While the RPAF emphasises a new baseline for comparing potential 6G RATs with 5G-Advanced, beyond-radio-domain enhancements may be needed and a broader set of improvements reflecting new capabilities considered holistically, for 6G deployment to be encouraged in the 2030s.

02 KEY ATTRIBUTES OF THE NGMN RADIO PERFORMANCE ASSESSMENT FRAMEWORK (RPAF)

The core ingredients of the proposed NGMN Radio Performance Assessment Framework to reflect MNO priorities are listed as follows:

1) Retention and utilisation of performance thresholds contained within the specifications of terrestrial radio interfaces in the IMT-2020 submission(s)[2].

    a. A subset of performance metrics should be selected as a comparison benchmark. The definition of these metrics might be revised as discussed later in the document.

    b. Only metrics whose enhancements would add significant value to customers should be part of this chosen subset of performance metrics. These should include measures to contain network costs (e.g. energy consumption) so costs are not transferred to customers.

2) A new 6G RAT should demonstrate significant benefits over and above a 5G-Advanced evolution , at least in the following key metrics:

    a. Spectral Efficiency – The radio improvements from a new RAT must demonstrate significant benefits in average spectral efficiency and the 5th percentile user spectral efficiency, aligned with the ITU-R definitions [2], across a variety of eMBB test scenarios for both the Downlink (DL) and the Uplink (UL) channels. The 5th percentile spectrum efficiency from full buffer simulation is not a reliable indicator of user experienced data rate, but it is nonetheless useful to ensure that improvements in average spectral efficiency are not at the expense of cell edge performance. In case the spectrum band does not offer full coverage for the deployment scenario considered, use of multi-band simulations that include also lower frequency spectrum should be considered.

    b. User Experienced Data Rates - At the 6G introduction, the actual 6G user data rates must be at least as good as legacy 5G-Advanced values at 6G introduction, especially at the 5th percentile point. Substantial improvement should only be sought where feasible assuming deployment representative of current mobile networks. More work is required on determining the appropriate metrics needed to ensure this. Consideration should be given to evaluating user experienced data rate using non-full buffer methods as spectrum-bandwidth scaling is not valid for UL as the UL is typically constrained by UE power, not spectrum. Evaluation of user experienced data rate where non-full buffer evaluation methods are used should be done both for a common set of traffic levels across the candidate technologies, defined by loading of 5G-Advanced capacity, and for a certain fractional loading of the capacity defined by the spectral efficiency for that candidate technology. Consideration should also be given to improving the representativeness of the simulations by modelling multi-band networks with diverse spectrum bands.

c. Total Radiated Sensitivity/Total Radiated Power (TRS/TRP) – The radio performance benchmark should consider Over-The-Air (OTA) Total Radiated Sensitivity/Total Radiated Power (TRS/TRP) so that proposed radio enhancements do not degrade OTA performance of the UE [3].

d. Total Energy Consumption – End-to-end (E2E) system-level energy consumption of the complete stack of access technologies must be considered in the radio performance benchmark. This analysis should factor in the Life Cycle Assessments, as well as Scope 1, 2 & 3 Greenhouse Gas (GHG) emissions of each respective radio network component. The 6G RAT energy consumption should not be studied in isolation but the energy footprint of the whole stack, including the 6G RAT plus the preceding access technologies should be calculated in aggregate and compared against the energy footprint of the whole stack of access technologies with a 5G-Advanced being used as an alternative to 6G RAT where possible. Total energy consumption should be reported for a variety of different loading levels, enabling calculation of energy consumption for traffic variation over one day, but also considering that during low traffic periods many cells could be turned off and traffic moved to other cells. The evaluation might also consider user data rate experience benefits associated with keeping cells active but with minimal energy consumption at low traffic levels.

e. Network Simplicity – Proposals for radio enhancements should demonstrate network simplification, a reduction in the operational cost of deployment, and total cost of ownership. In a fashion analogous to calculating energy consumption, the combination of legacy access technologies with the addition of a 6G layer should be compared with the same combination of legacy access technologies without the 6G layer to see which configuration offers greater network simplification.

3) Benchmark radio performance shall be against 3GPP Release 18 as a minimum, but also recognizing the best-performing characteristics of 5G Advanced Stand-Alone (5G-A SA) that will materialise from the continued evolution of this technology in subsequent releases, and which could be deployed around the time of 6G deployment and include these in the radio performance benchmark.

4) The evaluation should at a minimum be carried out for deployments representative of today's typical macro cellular networks with a representative site density, along with optional additional cases that illustrate the benefits of densification.

5) It is up to each MNO to decide if the total cost of ownership associated with any enhancements would yield profitable returns.

The key attributes of the Radio Performance Assessment Framework provide a basis for benchmarking the performance of radio enhancements relative to state-of-the-art existing technologies. However, the ingredients of the benchmark should also be simultaneously viewed as a testament to the vast potential yet to be exploited by 5G/5G-Advanced.

03 ITU-R IMT-2020 TERRESTRIAL RADIO SPECIFICATIONS: HOW TO SELECT THE APPROPRIATE SUBSET OF METRICS FOR THE 6G RADIO PERFORMANCE ASSESSMENT FRAMEWORK?

New Radio (NR) as a component Radio Interface Technology (RIT) within the Set of IMT-2020 Radio Interface Technologies (SRITs) can, if its potential is fully exploited, achieve peak data rates of 140 Gbit/s in the downlink and 65 Gbit/s in the uplink if channel bandwidths up to 400 MHz and Carrier Aggregation over 16 component carriers are supported. The historical tendency to use peak data rates as a comparison metric is outdated since the best that 5G/5G-Advanced can offer already exceeds customer demand, independent of supporting 6G, and does not reflect the need for network (or per-user) capacity and that the customer experience is dominated by "worst case", e.g., cell edge, performance. Also, peak data rates can be artificially inflated without any improvements to spectral efficiency simply by assuming migration to higher frequency bands and greater corresponding channel bandwidths. This should not be used for benchmarking. It is recommended that the RPAF does not include the peak data rate metric as a justification for a new 6G RAT, and instead focusses on metrics that customers value.

A similar argument can be made for not using latency reduction beyond the sub-1ms order of magnitude to claim 6G gains since at this threshold, the server latency at the application layer dominates in shaping the user experience.

The following subset of performance metrics should be included in the Radio Performance Assessment Framework to better reflect MNO priorities in the spirit of the Position Statement [1]:

1) For a given carrier frequency and channel bandwidth, evaluation of the average spectral efficiency and user experienced data rate should be a key basis for comparing different technology candidates; all comparisons should be done on a peer-to-peer configuration basis.

2) User experienced data rate evaluation should become more representative of actual network performance. See previous chapter for more details.

3) The baseline framework to assess radio performance simulation gains should contain numerical values in the respective 3GPP-aligned compliance matrix, link budget template and characteristics table that reflect the best-performing configurations of today's state-of-the-art 5G/5G Advanced networks with periodic updates as 5G capabilities continue to evolve.

4) Direct comparison of RAN Energy Consumption – For each proposed radio feature enhancement, the baseline framework should include measurement of the difference in RAN energy consumption associated with that feature as a percentage change in total energy consumption relative to the total energy consumed in a 5G system without that feature. This is particularly relevant when considering new AI features where the energy consumption is likely to be impacted by changes in processing requirements (including the energy used for model development and training).

04 3GPP STANDARDS RELEASES – BUILDING A DYNAMICALLY EVOLVING PERFORMANCE BENCHMARK

Incorporating 3GPP Standards releases and their corresponding feature sets into this Radio Performance Assessment Framework should be grounded in the principle of comparing against an iteratively moving benchmark. This is a dynamic process rather than a static one. The dynamic approach is better placed to reflect the reality that even the most advanced capabilities of 5G/5G-Advanced are constantly evolving with each successive 3GPP release. Think of an Olympic athlete setting ever-higher performance thresholds: a competing athlete would have to surpass these ever-higher thresholds just to remain in the competition.

1) 3GPP releases prior to this RPAF benchmark, e.g., NR Rel-15 to Rel-17, should no longer be used to compare radio enhancement candidates to avoid artificially inflating 6G gains. All comparison shall be on a peer-to-peer configuration basis with any difference explicitly documented (e.g. difference in CBW, Tx Powers, Transmitter/receiver characteristics or MIMO configurations).

2) 3GPP Rel-18 is the first 5G-Advanced standard. As a minimum, radio enhancement candidates should demonstrate significant benefits above and beyond 3GPP Rel-18 5G-Advanced. In addition, the benchmark might consider appropriate performance improvement from features in subsequent releases (Rel-19 to Rel-21) when it would be reasonable to expect 5G-Advanced to support such features around the time 6G is introduced.

   a. This is to ensure that any proposed radio enhancements are compared against a benchmark that tracks the evolution of 5G Standards from Rel-18 into later releases as appropriate.

3) Key features of the assessment framework should include at least the following:

   a. Rel-18 MU-MIMO baseline (e.g., 128Tx128Rx antenna configuration, up to 24 orthogonal DMRS ports)

   b. An assumption that the BS is already using AI/ML for many functions including e.g., Positioning, CSI feedback, beam management, including neural networks to understand channel conditions and the existence of AI models to predict beam trajectory. Enhancements related to AI-RAN should exceed the performance of AI features to be enabled in forthcoming Rel-19 specifications.

   c. A simulation of 3GPP Rel-18 Dynamic TDD compliant with relevant regulations. In case Sub-band Full Duplex technology (SBFD) is proposed for a 6G RAT, the 5G-Advanced implementation of SBFD should be used as the benchmark.

   d. Proposed Dynamic Spectrum Sharing (DSS) schemes should be compared against a 5G system with no spectrum sharing. An example of this would be to compare a system with 6G in the upper 6 GHz band and 5G-6G DSS in low bands (e.g., sub-

GHz) against a system without any DSS e.g., with 5G in the upper 6 GHz band and all other legacy bands. Additional evaluations of 6G with no DSS should be done as an additional case, as DSS implementation on all existing spectrum bands maybe costly and 5G-6G dual connectivity can be an alternative means of ensuring competitive user data rates at 6G introduction.

e. Radio enhancement candidates should compare against a feature set which includes the most advanced uplink enhancements e.g., delivered by dynamic transmission switching. The radio performance baseline should account for enhanced uplink coverage achievable via power limit increases for devices performing Carrier Aggregation (CA)/Dual Connectivity (DC) and reduced PAPR through spectrum shaping without spectrum extension.

f. The radio performance baseline should include the most advanced CA features e.g., supporting SSB-less SCell for inter-band CA in FR1 bands.

g. The performance framework baseline should include the latest state-of-the-art UE battery saving techniques specifically related to the usage of low-power wake up receivers to be enabled in Rel-19.

h. The performance baseline should include the more advanced mobility features in 5G-Advanced, e.g. 5G LTM (lower layer triggered mobility) or DAPS since these reflect the improved handover performance also possible with 5G-Advanced.

i. When using upper 6GHz as a reference, the comparison should be between expanding 5G NR into the upper 6GHz band vs using the band for 6G. DSS need not be assumed for 6G in this band.

j. For low bands below 1 GHz a 20 MHz CBW and a 4x4 MIMO configuration shall be used as the comparison baseline.

k. Equivalent base station antenna dimensions as for the benchmark 5G-Advanced deployment should be assumed for the 6G RAT. These should reflect the increasing challenges (including EMF) for deployment of extra or larger antennas in macro sites.

05 COMPLEXITY AND ARCHITECTURE CONSIDERATIONS

Discussing the number of architecture options in 6G is premature while fundamental issues such as the need for a new RAT remain uncertain.

The following attributes related to network operation and architecture must be taken into consideration in the RPAF:

a. The deployment of a new 6G RAT on top of existing 5G Stand-Alone (5G SA) adds significant complexity in managing more RATs, potential adaptions to the 5G Core, and support of dual connectivity and/or DSS to ensure competitive data rates. New innovations should minimise the operational and technical complexity in this case.

b. The extra complexity arising from introducing a new RAT must be matched by performance improvement. In case 6G RAT introduction requires a more difficult migration (e.g. lacking dual connectivity with a costly DSS implementation), a corresponding increase in the performance benefits from the new RAT should be targeted.

06 REFERENCES

[1] NGMN Position Statement on 6G, September 2023, https://www.ngmn.org/wp-content/uploads/NGMN_6G_Position_Statement.pdf

[2] ITU-R Report, "Minimum Requirements Related to Technical Performance for IMT-2020 Radio Interface(s), November 2017, https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2410-2017-PDF-E.pdf

[3] 3GPP Technical Specification, 38.161, NR; User Equipment (UE) TRP (Total Radiated Power) and TRS (Total Radiated Sensitivity) requirements; Range 1 Standalone and Range 1 Interworking operation with other radios (Release 18)

NEXT GENERATION MOBILE NETWORKS ALLIANCE

NGMN is a forum established in 2006 by world-leading Mobile Network Operators. NGMN is a global operator-led alliance, comprising over 80 companies and organisations across operators, manufacturers, consultancies and academia.

Its objective is to guarantee that next generation network infrastructure, service platforms, and devices will fulfil the requirements of operators and, ultimately, meet end-user demands and expectations.

VISION

The vision of NGMN is to provide impactful industry guidance to achieve innovative, sustainable and affordable mobile telecommunication services for the end user with a particular focus on Mastering the Route to Disaggregation, Green Future Networks and 6G, whilst continuing to support 5G's full implementation.

MISSION

The mission of NGMN is:

- To evaluate and drive technology evolution towards the three **Strategic Focus Topics:**
    - **Mastering to the Route to Disaggregation:** Leading in the development of open, disaggregated, virtualised and cloud native solutions with a focus on the E2E Operating Model
    - **Green Future Networks:** Developing sustainable and environmentally conscious solutions
    - **6G:** Anticipating the emergence of 6G by highlighting key technological trends and societal requirements, as well as outlining use cases, requirements, and design considerations to address them.
- To define precise functional and non-functional requirements for the next generation of mobile networks
- To provide guidance to equipment developers, standardisation bodies, and collaborative partners, leading to the implementation of a cost-effective network evolution
- To serve as a platform for information exchange within the industry, addressing urgent concerns, sharing experiences, and learning from technological challenges
- To identify and eliminate obstacles hindering the successful implementation of appealing mobile services.