# Conclusions

The study focused on the following objectives: (1) confirm XR and Cloud Gaming (CG) applications of interest, (2) identify the traffic models for the applications of interest taking outcome of SA WG4 work as input, (3) identify evaluation methodology and KPIs to assess XR and CG performance for relevant deployment scenarios, (4) evaluate XR and CG performance towards characterization of identified KPIs.

Diverse AR, VR, and CG applications were identified and confirmed as the applications of interest in the study. These applications include, but not limited to: VR1 (Viewport dependent streaming), VR2 (Split Rendering: Viewport rendering with Time Warp in device), AR1 (XR Distributed Computing), AR2 (XR Conversational), and CG.

Traffic models and characteristics of AR, VR, and CG applications were developed taking into account NR RAN performance evaluations. The traffic models include single stream downlink (DL) traffic model for VR/AR/CG, optional multi-stream DL traffic model for VR/AR/CG, single stream uplink (UL) traffic models for VR/AR/CG, and multi-stream UL traffic model for AR, as described in Clause 5. A baseline per UE KPI which considers PER and PDB is identified and used for subsequent evaluations.

The AR, VR, and CG performance for NR was evaluated using the traffic models for FR1 and FR2 in various deployment scenarios (indoor hotspot, dense urban, and urban macro) in terms of capacity, UE power consumption, coverage and mobility.

XR capacity

The capacity for AR, VR, and CG applications was evaluated and the results are summarized as follows:

* The baseline capacity for AR, VR, and CG in FR1 DL/UL and FR2 DL/UL were evaluated based on the agreed traffic models, evaluation methodology, and KPIs, with the results collected in Clause 8.3.1. The evaluation results show that 5G NR can support AR, VR, and CG for the evaluated cases and scenarios, where the capacity in urban macro scenario is generally lower than that in dense urban and indoor hotspot scenarios.
* The capacity impact of different data-rates, different PDB/PER (packet delay budget/packet error rate) values, jitter, dual-eye buffer staggering, different TDD frame formats, different bandwidths, or FDM/SDM and mini-slot operations have been evaluated. The results and observations are given in Clause 8.3.2. Based on the evaluation results, the following is observed:
  + The NR system capacity in support of AR, VR, and CG applications is smaller for applications requiring higher data rate.
  + The NR system capacity in support of AR, VR, and CG applications is higher with larger PDB value and/or relaxed PER requirement (i.e., higher PER values).
  + The AR, VR, and CG capacity is higher with larger system bandwidth.
* Various potential NR capacity enhancement schemes in support of XR services were proposed and evaluated by different companies. Their results are collected in Clause 8.3.3.

XR UE power consumption

The UE power consumption for AR, VR, and CG applications was evaluated and the results are summarized as follows:

* The power saving gain from Release 15, 16, and 17 power saving schemes including CDRX, PDCCH monitoring adaptation, cross slot scheduling, MIMO layer adaptation was evaluated with respect to the case when UE is always on, i.e., UE is available for gNB scheduling for all slots. Corresponding results and observations are given in Clause 9.3.1.
* The UE power consumption was evaluated for different parameters. The results are collected in Clause 9.3.2. The following is observed from the results:
  + There is a trade-off between UE power saving gain and capacity.
  + UE power consumption is affected by the choice of the CDRX configuration.
* The potential enhancement schemes for UE power saving were proposed and evaluated by different companies. Their results and observations are given in Clause 9.3.3.

XR coverage

The AR, VR, and CG coverage was evaluated based on the agreed traffic model and two methodologies for coverage evaluation. Note that these two methodologies are different from the traditional methodology based on link budget for coverage evaluation. The results are collected in Clause 10.3.

According to the evaluation results, it is observed that for deployment scenarios of dense urban and urban macro, UL coverage is worse than DL coverage.

XR mobility

The performance of mobility for AR, VR, and CG applications was studied. The study considers two mobility KPIs given in Clause 11.2: number of consecutive XR packets lost due to a handover event and minimum target time between handover events. The evaluation methodology of mobility performance is a simplified analytical approach given in Clause A.4, and the evaluation results are collected in Clause 11.3. The following is observed from the results:

* + Higher PDB leads to lower (better) mobility KPIs.
  + Higher frame rate leads to higher (worse) number of consecutive XR packets lost.
  + When varying the handover interruption time, the lower (better) mobility KPIs are achieved when handover interruption time is lower than PDB.
  + ~~Both selected KPIs are better when the handover interruption time is lower than PDB.~~

Higher handover interruption time leads to higher (worse) mobility KPIs.

Based on the study, it is recommended to further study and enhance the capacity and UE power consumption performance of 5G NR for XR and CG applications.