GTI Proof of Concept of 5G System White Paper

GTI

White Paper of Proof of Concept of 5G System

V 1.0

Version	V1.0
Deliverable Type	☐Procedural Document √Working Document
Confidential Level	☐ Open to GTI Operator Members ☐Open to GTI Partners √Open to Public
Program Name	5G eMBB
Working Group	Network WG, Terminal WG
Project Name	Sub 6GHz Project: Task-N-PM2-PJ1-2: PoC and Trials & commercialization Task-T-PM2-PJ1-5: PoC Device and Trials
Source members	CMCC, Huawei, ZTE, Ericsson, MediaTek, Qualcomm
Support members	CMCC, Huawei, ZTE, Ericsson, MediaTek, Qualcomm
Editor	CMCC, Huawei, ZTE, Ericsson, MediaTek, Qualcomm
Last Edit Date	27-07-2017
Approval Date	DD-08-2017

Confidentiality: The GTI documents may contain information that is confidential and access to the documents is restricted to the persons listed in the Confidential Level. This document may not be used, disclosed or reproduced, in whole or in part, without the prior written authorisation of GTI, and those so authorised may only use this document for the purpose consistent with the authorisation. GTI disclaims any liability for the accuracy or completeness or timeliness of the information contained in this document. The information contained in this document may be subject to change without prior notice.

Document History

Date	Meeting #	Revision Contents	Old	New
06-07-2017		First Draft		
27-07-2017		First Release		

Table of Contents

1 Introduction

Following the large-scale commercialization of 4G, the fifth generation of mobile communications (5G), which is expected to be commercialized towards year 2020 and beyond, has become the focus of global interests. It is no doubt that 5G will certainly become one of the most important engines of economy development and social informatization of human society by realizing demands of ultimate experience and stimulating innovative services.

The joint effort of the global mobile industry has made the 5G visions and key requirements unified and consolidated in ITU-R after years of research on 5G by various promotion groups and forums around the world, such as IMT-2020 Promotion Group, 5GIA, 5G Forum , 5GMF, 5G Americas, 5GPPP, NGMN and etc. Three most representing deployment scenarios for the requirements were identified: enhanced mobile broadband (eMBB), ultra-reliable low latency communications (URLLC) and massive machine type communications (mMTC). Performance metrics were also agreed, which include, for example, peak data rates, control and user plane latency, reliability and others as in the Recommendation ITU-R M.2083.

In the light of what was identified in ITU-R, 3GPP, the most influential standard development body on cellular communications in the world commenced 5G standardization in 2016.   A set of Study items of 5G including study on New Services Enabling, New Architecture and New Radio was completed at early 2017 in 3GPP with intention to define and describe the potential evolutional technologies under consideration, along with the complexity evaluation of each technique. A corresponding Work Item of 5G NR for forging highly competitive and globally harmonized standards was approved in March, 2017 to specify features that enable new NR system to work successfully in commercial deployments.

As a continuous effort to prompt global wireless ecosystem, GTI has set a plan for the roadmap of 5G trial and commercialization (as shown in Figure 1), and believes it is right time to publish white paper of PoC to voice the views and conduct activities by collaborating with industrial partners to ensure time to market of 5G in near future in terms of:

- Advancing highly competitive and globally harmonized standards of 5G
- Conducting PoC work in compliant with 3GPP standards to demonstrate the capability of 5G NR

    technologies and identify issues may possibly hurdle the commercialization e.g hardware platform

Figure 1 Timeline for 5G PoC Trial and Commercialization of GTI

This white paper addresses outstanding aspects which are seen fundamental to corresponding work carried out for PoC with inclusion of three subclasses.

- Key performance indexes need to be identified in PoC task

- Substantial features enabling the competence of 5G NR

- Verification configurations and cases of PoC

2 Key Capacities

5G related forums and groups summarize tens of requirements and key capacities for different scenarios and inputs ITU for 5G requirements discussion. Consolidated the input, ITU-R M.2083 summarizes the system key capacities as follows. Furthermore, ITU-R M.2083 provides comparison on key capacities between 4G (IMT-Advanced) and 5G (IMT-2020) in Figure .

- Peak data rate: Maximum achievable data rate under ideal conditions per user/device (in Gbit/s).

- User experienced data rate: achievable data rate that is available ubiquitously[1] across the coverage area to a mobile user/device (in Mbit/s or Gbit/s).

- Latency: the contribution by the radio network to the time from when the source sends a packet to when the destination receives it (in ms).

- Mobility: maximum speed at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/-RAT) can be achieved (in km/h).

- Connection density: total number of connected and/or accessible devices per unit area (per km2).

- Energy efficiency which has two aspects:

   o On the network side, energy efficiency refers to the quantity of information bits transmitted to/ received from users, per unit of energy consumption of the radio access network (RAN) (in bit/Joule);

   o On the device side, energy efficiency refers to quantity of information bits per unit of energy consumption of the communication module (in bit/Joule).

- Spectrum efficiency: Average data throughput per unit of spectrum resource and per cell2 (bit/s/Hz).

- Area traffic capacity: Total traffic throughput served per geographic area (in Mbit/s/m2).

---

[1] The term "ubiquitous" is related to the considered target coverage area and is not intended to relate to an entire region or country.

[2] The radio coverage area over which a mobile terminal can maintain a connection with one or more units of radio equipment located within that area. For an individual base station, this is the radio coverage area of the base station or of a subsystem (e.g. sector antenna).
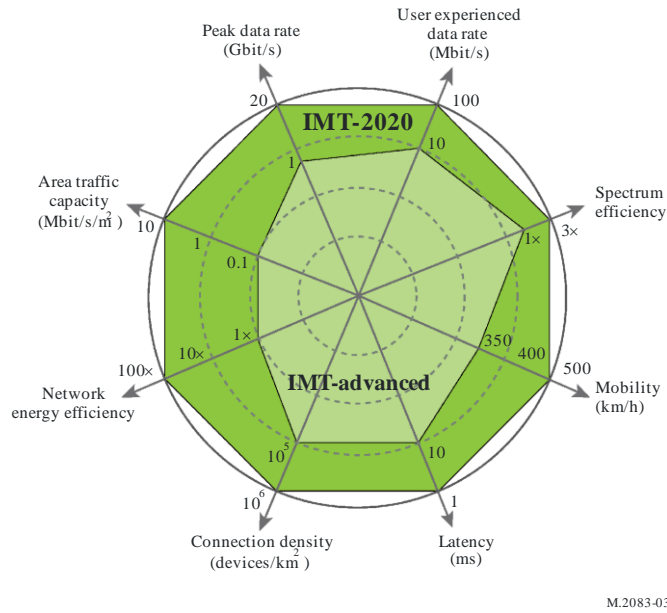
Figure 2 Key capacities comparison between 4G and 5G in ITU-R M.2083

Among all the 3 scenarios, eMBB poses high requirements only for parts of the key capacities: high peak data rate, low latency, user experienced data rate, area traffic capacity, and related capacities like wideband operation. As the PoC is expected to demonstrate the single system capabilities with limited number of users, the high peak data rate and low latency should be of high priorities.

Peak data rate is the most well-known capacity since 3G when the industry realized the phone and other user terminal should be with internet access and data connection for other services. For every generation, the data rate boosts to a new level and it's expected to be around multiple Giga bits per seconds or even larger for 5G. Latency reduction is another hot issue since 4G and several latency sensitive applications (e.g. V2V) were enabled by E-UTRAN. Though we can't get the full picture of 5G applications, VR and AR are reported with high frequency when people talking 5G. To enable applications like VR, AR and etc, 5G system needs "low latency gene" from day 1. In 3GPP requirements [2], following latency requirements are highlighted for eMBB.

Table 1 Latency requirements identified by 3GPP [2]

	Latency requirements
Control plane	10ms
User plane	4ms

Beyond the capacities listed before, wide band operation is another key capacity that needs to be identified. To maintain the flexibility, E-UTRAN defines a set of system bandwidth from 1.4MHz to 20MHz

and introduces carrier aggregation enable larger bandwidth utilization. Carrier aggregation provides wideband operation but needs to introduce some complexity and overhead when aggregating multiple component carriers. When the number of aggregated component carriers becomes large (e.g. more than 100MHz), the system overhead of control signaling increases dramatically and system efficiency drops rapidly. In 5G, industries conduct mmWave (a.k.a. above 6GHz) to achieve more than 100MHz to 1GHz contiguous spectrum. Therefore, larger system bandwidth (e.g. more than 100MHz or even larger) is necessary instead of aggregating a large number of small bandwidth. During standardization discussion, 3GPP makes several assumptions for different frequencies, while 100MHz is the basic assumptions for sub6GHz.

To summarize, this PoC whitepaper at least focuses on following key capacities:

- Peak data rate: multi Giga bits per seconds

- Latency: 4 ms for user plane and 10ms for control plane

- Wide band operation: 100MHz or above

3 NR Features

To achieve the 5G NR key performance requirements of 5G PoC which has been identified and defined in part2, major challenges should be addressed for the design of flexible 5G new air interface and features.

Therefore, in this section, the NR Features are explored with respect to 3GPP standard. They are key enablers for 5G PoC key capacities and recommended to be verified in 5G PoC.

3.1 General scheme

3.1.1 Numerologies and frame structure

OFDM numerology is basic parameters for OFDM based system design, which basically include subcarrier spacing, cyclic prefix length, TTI length. For numerology design, attributes, such as service types, carrier frequency, channel characteristics, inter-site distance, UE speeds and possible transmission schemes should be taken into account.

- Subcarrier spacing: Scalable numerology should allow at least from 15kHz to 480kHz subcarrier spacing. All numerologies with 15 kHz and larger subcarrier spacing, regardless of CP overhead, align on symbol boundaries every 1ms in NR carrier.
- CP length:

- o Normal CP is supported for all numerology and procedures.

- o Extended CP will be only supported for 60kHz subcarrier spacing in Rel-15. It could be enabled through RRC configuration for some procedures and numerology.

- TTI length: The TTI length should be designed to meet the latency requirement.

Multiple subcarrier spacings can be derived by scaling a basic subcarrier spacing by an integer N (N $=2^n$). Scalable numerology should allow at least from 15kHz to 480kHz subcarrier spacing. The numerology used can be selected independently of the frequency band although it is assumed not to use a very low subcarrier spacing at very high carrier frequencies. Flexible network and UE channel bandwidth is supported.

Based on the above discussions, the observation is that one numerology may not be able to support wide range of service efficiently, and the 5G new radio framework should be configurable to different sets of OFDM numerologies (subcarrier spacing, cyclic prefix length, TTI length). If it is required to multiplex multiple numerologies for multiple services in one carrier, both FDM and TDM manner can be considered.

A slot can contain all downlink, all uplink, or {at least one downlink part and at least one uplink part}. Slot aggregation is supported, i.e., data transmission can be scheduled to span one or multiple slots. Regarding to the frame structure, a subframe duration is fixed to 1ms and frame length is 10ms. NR supports both semi-statically and dynamically assigned DL/UL transmission direction.

3.2 Basic transmission scheme

3.2.1 Modulation

QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported. BPSK and 0.5 pi-BPSK are also supported in UL where 0.5 pi-BPSK is only for DFT-s-OFDM.

3.2.2 Channel coding

The channel coding candidates supported for NR should be considered many factors such as: decoding throughput, latency, error correction, flexibility and complexity.

Both LDPC and polar code compared to other coding candidates such as TBCC, Turbo, etc. in all aspects of outstanding performance. In particular, they can satisfy NR's Key capacities that peak date rate is 20Gbps DL and 10Gbps UL. In addition, LDPC decoder is based on the parallel internal structure, which means that the decoding can be parallel processing at the same time, not only can handle a large amount

of data, but also reduce the processing delay. Finally, the channel coding scheme for transport blocks in NR is quasi-cyclic LDPC codes with 2 base graphs and 8 sets of parity check matrices for each base graph, respectively. One base graph is used for code blocks larger than a certain size or with initial transmission code rate higher than a threshold; otherwise, the other base graph is used. Before the LDPC coding for large transport blocks, the transport block is segmented into multiple code blocks. The channel coding scheme for broadcast channel and control information is Polar coding based on nested sequences. Puncturing, shortening and repetition are used for rate matching.

The main channel coding structure is depicted in below Figure . Channel coding techniques for NR should support info block size K flexibility and codeword size flexibility where basic code design with rate matching (i.e., puncturing, shortening or repetition) supports 1-bit granularity in codeword size. Channel coding technique(s) designed for data channels of NR support both Incremental Redundancy (IR) (or similar) and Chase Combining (CC) HARQ.
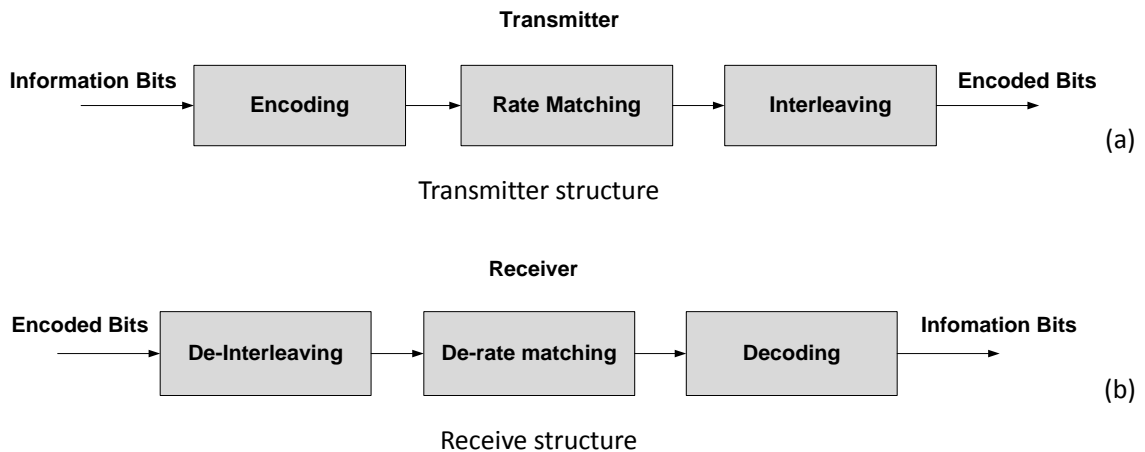

Figure 3 channel coding structure

3.2.3 Multi-antenna

The massive MIMO is considered as one of the most important solutions in 5G technology to achieve 1000x data rate compared to the LTE. For this purpose, the antenna ports for data transmission need to be increased to maximize the network's potential in spatial multiplexing. In NR, 8 orthogonal DMRS ports for SU and up to 12 orthogonal DMRS ports for MU data transmission has been agreed, and further work is focused on detail design of signaling and pattern. On the other hand, CSI acquisition and interference measurement should be enhanced as well to support the high-order SU/MU data transmission. To improve CSI measurement and reporting, a high-resolution codebook design and an enhanced SRS design (i.e. increased SRS ports) for reciprocity based transmission are necessary in NR. Currently, type I codebook up to rank 8 and type II codebook for rank 1&2 has been supported. Codebook for Beamformed CSI-RS can be used for linear combination of multiple beams. Moreover, the ZP&NZP CSI-RS for IM has been agreed in NR

to enhance interference measurement. In addition, it is expected that the UE should at least has the Tx/Rx capability of 2T4R in NR. Antenna switching on SRS is supported.

The multi-TRP coordinated transmission is another important topic for MIMO in NR. The coordination between TRPs can be more flexible in NR as both single and multiple PDCCH transmission are supported, which can adapt to both idea and non-idea backhaul scenarios. With the enhanced multi-TRP coordinated transmission, e.g. non-coherent joint transmission (NCJT), the serving experience for the cell-edge users can be significantly improved.

The beam management is a new feature in NR. As the frequency bands are expanded to above 6GHz, the beamforming is necessary to compensate the increased path attenuation. From the perspective of initial access, the cell coverage in HF bands is the first priority to consider as the synchronization, random access and broadcast signals are all beam-based. For data transmission, effective beam tracking and pairing mechanism should be carefully designed for both robustness and throughput, which combat possible rotation and blockage in HF bands. The beam sweeping procedure is used to find a most accurate beam pair between the gNB and the UE to maximize the beamforming gain. Group based beam reporting is supported to obtain multiple beam group information corresponding to multiple channel clusters. For data transmission, indication of quasi-co-location information between RS ports is performed to derive spatial receive channel properties. Then, the beam recovery procedure is performed to provide a chance to quickly recover from the beam failure before the RLF.

3.3 Physical layer procedure

3.3.1 Scheduling

NR supports at least same-slot and cross-slot scheduling for both DL and UL. Timing between DL assignment and corresponding DL data transmission can be indicated by a field in the DCI from a set of values and the set of values is configured by higher layer. In addition, it is also possible to allow the timing between DL assignment and corresponding DL data transmission be configured by higher layer. The timings are defined at least for the case where the timings are unknown to the UE. Both contiguous and non-contiguous resource allocation for data with CP-OFDM is supported.

To achieve power saving at UE side, RF bandwidth adaptation is supported in NR. UE could operate on a smaller bandwidth to reduce power consumption and be switched to a larger bandwidth to transmit/receive signals. As illustrated in Figure, NR allows a UE to operate in a way where it receives at least downlink control information in a first RF bandwidth and where the UE is not expected to receive in a second RF bandwidth that is larger than the first RF bandwidth within less than X μs
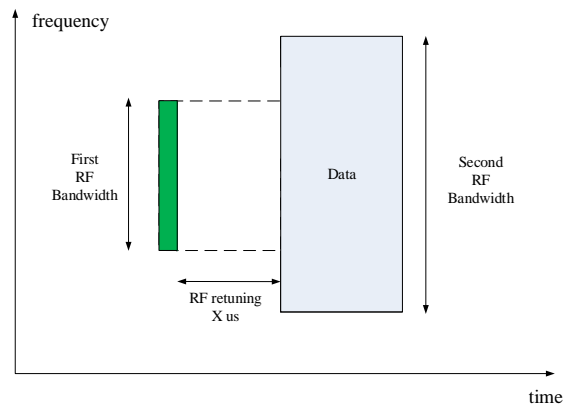
Figure 4 RF bandwidth adaptation

3.3.2 HARQ

HARQ-ACK feedback with one bit per TB is supported. Operation of more than one DL HARQ processes is supported for a given UE while operation of one DL HARQ process is supported for some UEs. UE supports a set of minimum HARQ processing time. NR also supports different minimum HARQ processing time at least for across UEs. The HARQ processing time at least includes delay between DL data reception timing to the corresponding HARQ-ACK transmission timing and delay between UL grant reception timing to the corresponding UL data transmission timing. UE is required to indicate its capability of minimum HARQ processing time to gNB.

Code Block Group (CBG)-based transmission with single/multi-bit HARQ-ACK feedback is supported, which shall have the following characteristics:

- Only allow CBG based (re)-transmission for the same TB of a HARQ process

- CBG can include all CB of a TB regardless of the size of the TB. In such case, UE reports single HARQ ACK bit for the TB

- CBG can include one CB

- CBG granularity is configurable

3.3.3 Initial access and mobility

Multi-beam-based or single beam repetition based transmission/reception of synchronous and broadcast signals is a key feature of NR that differentiates from LTE. To facilitate multi-beam-based or single beam repetition based transmission, a synchronous signal (SS) burst set composed of multiple SS blocks is transmitted within 5ms window, which can perform a complete beam sweeping, as shown in Figure.

Non-contiguous SS burst set structure is adopted in NR. The maximum number of SS blocks within an SS burst set depends on the corresponding frequency range (4 for sub3GHz, 8 for 3~6GHz and 64 for 6~52.6GHz). The SS burst set is transmitted periodically.

One SS block consists of one NR-PSS symbol, one NR-SSS symbol and two NR-PBCH symbols, which are multiplexed in time division manner, i.e. PSS+PBCH+SSS+PBCH.   The transmission BW of NR-PBCH occupies 288 subcarriers while NR-PSS/SSS just occupy 127 subcarriers which is aligned with center frequency of NR-PBCH.   Note that for each SS block, the TRP/beam is transparent to the UE since NR-PSS, NR-SSS and NR-PBCH in each SS block have the same single antenna port.
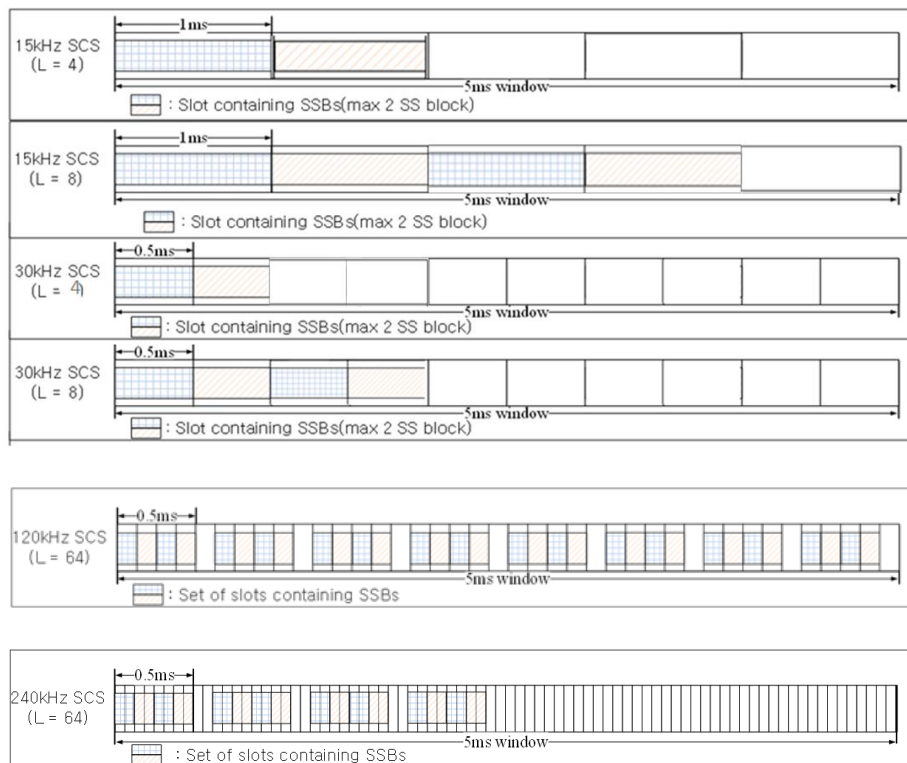

Figure 5 An SS burst set composition

NR physical cell ID is extended to 1008 to facilitate flexible deployment, which is jointly carried by NR-PSS and NR-SSS, where NR-PSS is frequency domain-based pure BPSK M sequence and NR-SSS is Gold sequence.   One default of four types subcarrier spacing (15kHz, 30kHz, 120kHz and 240kHz) associated with SS block transmission is defined for each frequency band to facilitate fast initial access in mixed numerology.

For the minimum system information delivery, part of minimum system information is transmitted in NR-PBCH. The remaining minimum system information (RMSI) is transmitted in shared downlink (DL) channel via NR-PDSCH.

NR supports 4 types of PRACH preamble formats with sequence length of 839 and 5/1.25kHz subcarrier spacing (SCS), where the formats with 5kHz SCS are defined for high speed (up to 500km/h) and

medium cell radius (up to 14km).　NR also support some PRACH preamble formats with shorter sequence length and 1, 2, 4, 6 and 12 OFDM symbols for 15/30/60/120kHz SCS.　The PRACH preambles with shorter sequences are designed to support gNB Rx beam sweeping within a RACH occasion which are useful for small cell, high speed and high frequency cases. A 4-step RACH procedure is supported in NR and an association between SS block and a subset of RACH resources and/or preambles can be configured to facilitate the DL beam identification of the subsequent messages.

For RRM measurement in NR, DL measurement is supported based on different signals. IDLE mode UE measures cells using cell-specific SS block to derive cell level quality, without identifying multiple beams or multiple TRPs.　CONNECTED mode UE can use UE-specific CSI-RS for L3 mobility, in addition to SS block. Up to two measurement window periodicities can be configured for intra-frequency CONNECTED mode measurement, providing the flexibility to UE to measure different cells.

3.3.4 Power control

For NR-PUSCH at least targeting eMBB, both open-loop and closed-loop power controls are supported. Open-loop based on pathloss estimate is supported where pathloss measurement for UL power control is to be based on at least one type of DL RS for beam measurement. Note that beam measurement RS includes CSI-RS, RS defined for mobility purpose. The same gNB antenna port can be used for pathloss measurement for multiple processes.

Fractional power control is supported. Closed-loop power control is based on NW signaling. Dynamic UL-power adjustment is considered.

Separate power control process can be supported for transmission of different channel/RS (i.e., PUSCH, PUCCH, SRS).

NR supports beam specific power control as baseline. Power control for UE side multiple panel transmission is supported.

3.4 Other scheme

3.4.1 HPUE

One of the most interested frequency bands in sub-6GHz range for initial NR deployment is C-band. Comparing to lower frequency bands as deployed in 2G, 3G or LTE, propagation loss is expected to be larger, which could be offset by advanced spatial processing technologies, such as massive MIMO array at the BS and multiple Tx at the UE. TDD systems have been deployed in many parts of the world. In many

scenarios, low frequency band is used for coverage and high frequency band is used for capacity increase. Since high frequency TDD bands have shorter signal propagation properties, increasing the UL Tx power on high frequency bands could help utilizing the capabilities of TDD bands to improve overall user experience. With the introduction of power class 2 UE with max transmit power of 26dBm which can be implemented by a single UL path, or two 23dBm UL streams combination, the high frequency TDD bands can enhance coverage and overall user experience both indoors and outdoors. While HPUE has been successfully adopted in LTE Band 41, and HPUE to be adopted on 3.5GHz band for NR has also been agreed as 3GPP REL-15 WID scope.

4 Verification for 5G PoC

In order to verify 5G NR key features and corresponding performance for typical use cases, basic configuration of POC system and verification cases are defined in this section.

4.1 POC system configuration

5G POC system mainly include 5G NR base station and device. The capabilities of both base station and device should align with 3GPP Rel-14 NR SI framework. The key configurations of POC system are specified below. Besides the configurations, other basic procedures should be supported to enable POC system operating, which is left to implementation.

The key configurations of POC system:

Frequency band: 3400 MHz ~ 3600 MHz

System bandwidth: >= 100 MHz

Output power: ~200W for macro cells deployment

Numerology and frame structure should match definition in 3GPP Rel-14 SI framework

Modulation scheme: QPSK, 16QAM, 64QAM, 256QAM are supported for DL transmissions; and QPSK, 16QAM, 64QAM are supported for UL transmissions.

Antenna ports: up to 64T/64R; Antenna elements >=128 (for BS)

Antenna ports: 2T/4R or 4T/8R (for UE)

Multi-antenna scheme:

DL: The maximum number of layers for SU-MIMO is recommended to be based on UE capability (e.g. 8 for CPE, 4 for Smart phone); the maximum number of layers for MU-MIMO is recommended not less than 16.

UL: The maximum number of layers for SU-MIMO is recommended to be based on UE capability (e.g. 4 for CPE, 2 for Smart phone); the maximum number of layers for MU-MIMO is recommended not less than 8.

4.2 Verification Cases

In the Verification, throughput, latency, and coverage are much more important performance metrics.

Verification cases are listed below:

Peak data rate

a)   UL/DL single user peak data rate (or spectral efficiency):

Evaluate the UL/DL peak data rate (or SE) of a single user located at the "best" location within the cell.

b)   UL/DL peak cell throughput (or cell SE)

Evaluate the UL/DL peak cell throughput (or cell SE) when multiple users are deployed at the "best" locations within the cell.

Average throughput

a)   SU-MIMO: average UL/DL cell throughput

Evaluate the average UL/DL cell throughput under different levels of interference in SU-MIMO mode. The ratio of the "good", "general", "bad" users is 1:2:1.

b)   MU-MIMO: average UL/DL cell throughput

Evaluate the average UL/DL cell throughput under different levels of interference in MU-MIMO mode. The ratio of the "good", "general" and "bad" users is 1:2:1.

Coverage range

Single cell coverage

To measure the UL/DL maximum distance for both inside and outside buildings under various levels of interference, in order to observe and study single cell coverage.

Latency

a) Control plane latency

The time it takes for a UE (at "good", "general" and "bad" locations respectively) to transit from a battery efficient state (e.g., IDLE or INACTIVE, as discussed in 3GPP) to the start of continuous application-layer data transfer (e.g., ACTIVE).

b) User plane latency

The Ping delays for a UE (at "good", "general" and "bad" locations respectively) with various packet sizes.

Mobility

Handover success rate

The success rate of inter-cell handover between neighboring cells.

Reference

[1] ITU recommendation M.2083 IMT Vision - "Framework and overall objectives of the future development of IMT for 2020 and beyond", Sep., 2015

[2] 3GPP TR38.913 v 14.0, Study on Scenarios and Requirements for Next Generation Access Technologies, Sep., 2016

[3] 3GPP TR38.802 V14.1.0, Study on new radio access technology -Physical Layer Aspects, Jun.,2017