5G NR Uplink Enhancements

Better Cell Coverage & User Experience

White Paper

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Introduction

As the industry approaches global, commercial 5G deployment, some intrinsic challenges are carried over from one generation to another. One such challenge is providing uplink coverage and throughput; this link imbalance between downlink and uplink in legacy cellular technologies is due to factors such as differences in transmit power and the number of antennas deployed in base stations versus user devices. Carriers worldwide have always focused on achieving high spectral efficiency along with capacity, coverage and performance. TDD come with many benefits over FDD, but operators have always shown interest in features that target uplink efficiency and coverage because of the frame structure, and the nature of the spectrum unutilized for TDD being deployed in high bands.

5G opens up new spectrum by the introduction of Sub-6GHz and mmWave, which can also be deployed as non-standalone with LTE, thus, creating new challenges for carriers to deliver a ubiquitous user experience, especially at cell-edge radio conditions. Efficient spectrum usage and utilization is becoming an important consideration for future cellular network deployments, due to increased data rate and capacity demands from different types of user applications. This increases the need for supporting new features and methods for spectrum management, resource and connection latency improvement, in order to enhance the system performance and user experience. The exponential increase in the demand for data connectivity can put disproportionate pressure on either uplink or downlink performance, depending on the usage of the smartphones or other cellular applications.

There are several different techniques and features available now in 3GPP that can be used to improve areas of throughput (both uplink and downlink), latencies, and capacity, especially for users at the cell-edge. In addition, as 5G NR will offer different types of deployment including dual connectivity with LTE, it is quite often that the uplink becomes a bottleneck in cases such as file uploading, video streaming, etc. Therefore, 5G NR can utilize some existing features from already deployed LTE-TDD networks, in addition to new features targeting uplink enhancements. In this paper we evaluate High Power(/Performance) User Equipment (HPUE), which is perceived as one of the key features inherited from LTE and can be considered a baseline for 5G deployment. This paper also discusses new features, Dynamic Power Sharing (DPS) and Single Uplink Operation (SUO), which have been added for Dual Connectivity between LTE and NR.

High Power User Equipment (HPUE)

In LTE, UEs are specified to operate with a maximum uplink transmit power to 23dBm +/-2, called Power Class 3 (PC3). The uplink is typically the limiting factor in LTE and the gap between downlink and uplink can reach ~5-7dB, mainly due to differences of the transmit power, the TDD carrier frequency link budget and number of antennas deployed in eNB versus UEs. In the higher band deployments it becomes crucial for carriers to offer a better user experience at the cell-edge, as increasing the uplink transmit power on high frequency bands could help utilize the capabilities of TDD bands. With this objective, 3GPP introduced a new Power Class that allows the device to operate with a maximum transmit power of up to 31dBm, based on the carrier frequency. The concept of High Power was initially introduced in Release 11 to operate with FDD band-14 (700 PS) for public safety applications. For FDD B14, Power Class 1 (PC1) was introduced with max uplink transmit power of 31dBm. Band-41 (TD 2500) HPUE was later introduced in 3GPP Release 14 with Power Class 2 (PC2) allowing the UE to transmit with up to 26dBm. PC2 with Band-41 can also be applicable to Release 10 UE capability as well. Typically, any device capable of uplink transmit power higher than 23dBm is referred to as High Power(/Performance) UE (HPUE). In 3GPP Release 14, HPUE was also extended to LTE-TDD band 40 (TD 2300). The increase in UE output power compensates the propagation losses, enabling carriers to have reasonable coverage without adding to expansions of infrastructure.

HPUE consideration for 5G in Sub-6GHz FR1 spectrum will provide significant advantages for users and carriers. Minimum changes to UE modem design are expected. Power Class 2 UEs would be implemented using the same architecture as Power Class 3 UEs, but with modified PA (Power Amplifiers) and filters, leading to more cost effective solutions without necessarily increasing the power consumption. The main objectives of Power Class 2 are:

- Increase device uplink transmit power to afford significant uplink coverage extension, thus reducing the performance gap between DL and UL in LTE-TDD networks.
- Improve the TDD competitiveness with respect to FDD deployment, as HPUE will provide a 3dB power increase which will lead to similar performance versus the use of FDD deployed in mid-frequency bands.
- Improve the cell-edge spectral efficiency by using higher order modulation and transport block size, due to additional power headroom available with the higher uplink transmit power.
- Enhance the overall cell-edge performance, especially where the downlink performance is limited by the speed of acknowledgements in uplink.

So far, 3GPP RAN4 has completed the PC2 HPUE feature to improve uplink coverage for 5G Standalone (SA) deployments on NR bands. The following NR bands were approved to support PC2 HPUE for 5G NR SA in Release 15:

- Band n41 (2496-2690 MHz): UL-MIMO (2Tx 23+23dBm) and 1Tx (26dBm) are supported for NR Band n41.
- Band n77 (3.3-4.2 GHz): UL-MIMO (2Tx 23+23dBm) and 1Tx (26dBm) are supported for NR Band n77.
- Band n78 (3.3-3.8 GHz): UL-MIMO (2Tx 23+23dBm) and 1Tx (26dBm) are supported for NR Band n78.
- Band n79 (4.4-5 GHz): UL-MIMO (2Tx 23+23dBm) and 1Tx (26dBm) are supported for NR Band n79.

Considering that the link imbalance will remain during 5G Non-standalone (NSA) deployments, Power Class 2 (+26dBm) for Dual Connectivity UE should be the most practical and suitable choice to improve the uplink coverage for 5G NR NSA deployment.

Power Class 2 UE for Dual Connectivity (one LTE band + one NR band) supporting +26 dBm has been proposed for TDD-TDD band combinations in RP-182877 work item. The proposed (1 LTE band + 1 NR band) uplink Dual Connectivity (DC) within FR1 to be added in Release 16 are: DC_39A-n41A, DC_(n)41AA, DC_41A-n41A, DC_39A-n79A and DC_41A-n79A

HPUE Performance Evaluation from Field Trials

In this section, MediaTek studied the performance aspects of HPUE in field trials performed over the live cellular network with LTE B41. With HPUE functionality, the UE shall support different Power Classes on different bands. Specifically, in this trial the UE shall support Power Class 2 on Band-41 and Power Class 3 on other bands. Once the UE acquires the serving cell and reads the SystemInformationBlocks, it becomes aware of the cell HPUE capability by reading the subframe configuration and P-MAX value. The eNB becomes aware of the HPUE capability as soon as it receives the UE capability message. After this point, both the UE and eNB can operate in either idle or connected modes at a supported Power Class, based on the common understanding of the UE and serving cell capabilities.

To verify the uplink coverage gains of HPUE compared to the legacy devices, uplink throughput tests were conducted in mobility and far cell conditions. The objectives of this trial are to assess the uplink throughput in different RF conditions, and evaluate the RSRP levels at which the UE uplink transmit power reaches the maximum for both PC2 and PC3. In the trial, both PC2 and PC3 devices are set side-by-side and experience the same radio conditions on the same band-41 channel and PCI (Physical Cell ID) to provide equal test conditions.

Figure 1 demonstrates the uplink performance comparison between HPUE and non-HPUE. In this test condition, the uplink throughput was evaluated at the RSRP levels in which both PC2 and PC3 start observing different uplink transmit power (UE Tx Power). It is observed that HPUE outperforms the legacy device and with coverage gain of 3dB. If we look at the results in some details we can see that the HPUE is consistently transmitting with 25dBm between RSRP -112dBm and -115dBm and achieving better throughput than legacy UE with more than 500 Kbps gain. It is observed that at this RSRP ranges, PC2 uplink throughput performance is consistently better than PC3 with an increased gain as RSRP degrades towards the edge coverage of the cell. At very low RSRP of levels < -115dBm, PC3 starts to hit zero uplink throughput, and hence the gain of the uplink throughput for HPUE becomes very obvious, due to the clear coverage enhancements.

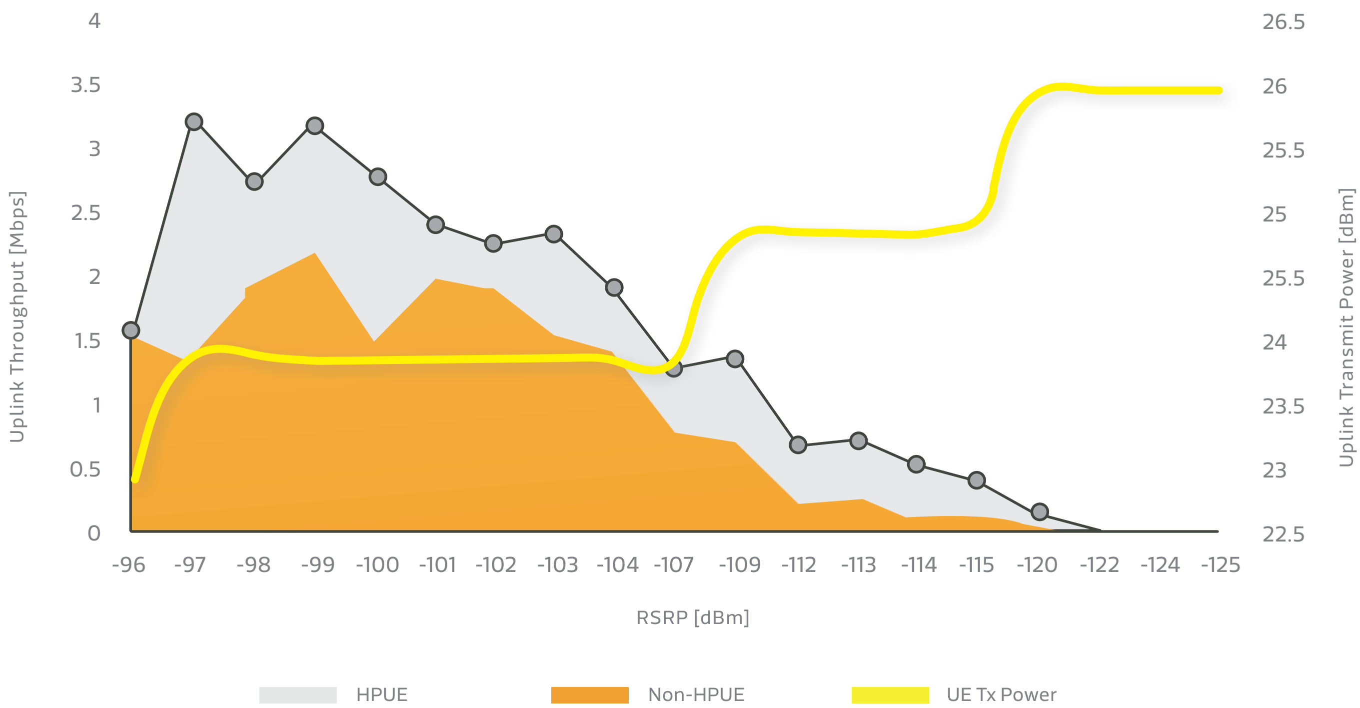

Figure 1- HPUE vs. non-HPUE Uplink Throughput Performance in Mobility

On the other hand, the coverage improvements of PC2 allows the scheduler to assign more resources, especially at cell-edge. It is observed that the HPUE is always assigned by the eNB scheduler with higher MCS (Modulation and Coding Scheme) values compared to non-HPUE. These higher uplink MCS allocations clearly indicate better uplink throughput opportunities for the HPUE. As a result of assigned higher uplink MCS, there is also a visible improvement in modulation used by HPUE compared to the legacy device. More instances of UL 64QAM were observed for HPUE in below -95dBm conditions enabling it for better throughput and spectral efficiency. The modulation distribution is shown in figure 2 in mobility conditions.

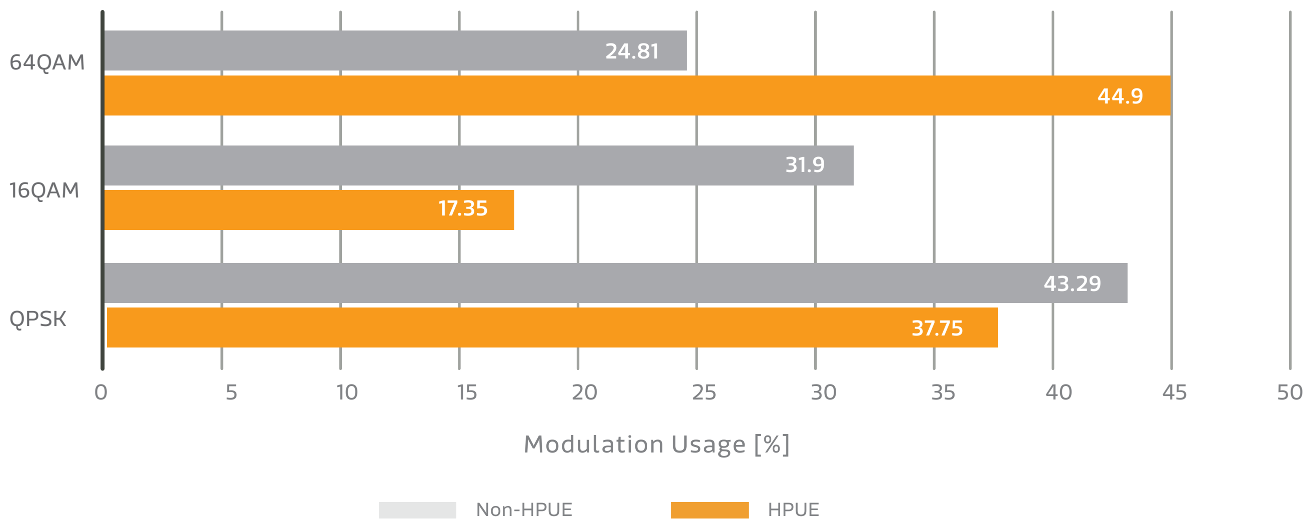

Figure 2 HPUE vs. non-HPUE Uplink Modulation Utilization in Mobility

The test results shown in these trials prove the significant gains in the uplink coverage and throughput for the HPUE provided by higher uplink transmit power, better MCS and higher modulation scheduled to PC2 UEs. As a result, HPUE is proven to provide better spectral efficiency, especially at cell-edge.

Another expected improvement derived by coverage enhancement is the impact to the call drop and paging success rate KPIs. With extended coverage, it is expected that Out of Service (OoS) and Radio Link Failures (RLF) are also significantly improved in HPUE compared to the legacy devices. Mobility test in idle and connected modes were conducted where both PC2 and PC3 devices were locked on band-41 (i.e. no re-selection/handover to other bands is possible due to UE capability locked to band-41 only). In idle mode, the OoS was observed at RSRP -126 dBm on legacy UE, whereas HPUE went out of service at RSRP -131 dBm.

This indicates that the coverage gain helping UE to stay in LTE for longer time rather than IRAT reselection to 3G/2G, which can help KPIs such as reachability and paging success rate. In connected mode, it was observed that the PC3 device hit the RLF at RSRP -121dBm while the HPUE hits the call drop due to RLF at no earlier than -126dBm. These tests clearly indicate that the coverage gain can be beneficial to several LTE services and KPIs like VoLTE voice quality, paging success rate, call drop rate KPIs, and RACH channel performance (accessibility performance). Additionally, this also indicate that TDD coverage at higher bands can perform similar to FDD in mid bands.

One of the main concerns in deploying HPUE support in the network is of course the UE power consumption. Table 1 summarizes the tests performed in both near cell coverage in stationary conditions (RSRP of -70dBm) and poor cell coverage (RSRP of -115dBm).

The battery capacity on the UE used was 1000mAh. The results demonstrate that practically there is no significant impact on the power consumption of the devices, comparing PC2 to PC3 UEs.

Table 1 HPUE vs. Non-HPUE Power Consumption Evaluation

Parameters	Current Consumption Comparison of HPUE to Non-HPUE				
	File Download		File Upload		Overall User Experience
	Good RSRP	Poor RSRP	Good RSRP	Poor RSRP	All Radio Conditions
RF Conditions	-70dBm	-115dBm	-70dBm	-115dBm	
% Current Consumption relative impact	0.6%	-2.3%	0.4%	-12.1%	-2.8%

Generally, averaging the near and far cell conditions for current consumption (to reflect actual user experience that typically active in LTE cells in different RF with a mix of file upload and download), the overall impact to the current consumption is negligible. Therefore, deploying HPUE feature in a network is not expected to introduce significant impact to the end user experience in terms of battery standby time. The RF part of the modem activity can be important to the overall power consumption and as observed in this testing, the Tx power consumption is much higher than Rx power consumption. Therefore, uplink enhancements can bring reasonable improvements to the user experience and coverage, without additional negative impact to the battery lifetime.

Dynamic Power Sharing (DPS)

EN-DC (EUTRA-NR Dual Connectivity) architecture was introduced in 3GPP Release 15, in which data can be sent on both eNB (LTE) and gNB (NR) where the UE is connected simultaneously to both technologies. Different from Carrier Aggregation, Dual Connectivity can offer similar benefits but for non-co-sited deployments – this is a very important aspect for 5G NR deployments.

In EN-DC architecture, both NR and LTE are allowed to transmit and receive data at the same time to boost downlink and uplink throughput. However, the challenge is the total sum of combined transmit power of NR and LTE shall still be limited by a configured maximum power, which is dependent on UE capability. It means even LTE and NR scheduling is separated are splitting bearer, transmission power calculation may need to be considered jointly between different radios to fulfill limitation and optimize performance. In this section, we compare performance of two different EN-DC power control schemes, one is Equal Power Sharing (EPS) between LTE and NR and the other is Dynamic Power Sharing (DPS). Another scheme is also compared in later section which is Single Uplink operation (SUO).

Comparison between Equal and Dynamic Power Sharing

For Power Class 3 UE as example, maximum output power of both LTE and NR are limited to 20 dBm to constraint maximum total output power of ≤ 23 dBm for equally power sharing UE. The drawback of equally power sharing is even if LTE power is less than 20 dBm, transmission power of NR is still limited to maximum 20 dBm which causes power headroom of NR becomes lower. Therefore, the performance of throughput may not be optimal. Besides, the uplink coverage can be a concern if the LTE transmit power is limited to 20 dBm.

Dynamic power sharing allows UE in dual transmission scenario to operate in a manner that after allocating the required transmission power of MCG (Master Cell Group), the remainder of uplink power can be allocated to SCG (Secondary Cell Group). For dynamic power sharing, MCG has higher priority than SCG for power allocation. The reason is that the control plane signaling will go through MCG mainly, thus the uplink coverage of MCG shall be guaranteed.

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With the aid of dynamic power sharing for Power Class 3 UE, both LTE and NR uplink transmission do not need a maximum power limit of 20 dBm as dual uplink can share power headroom dynamically. This scheme offers the potential of an optimum power allocation between LTE and NR in a UE specific manner based on different coverage scenarios, as demonstrated in figure 3.

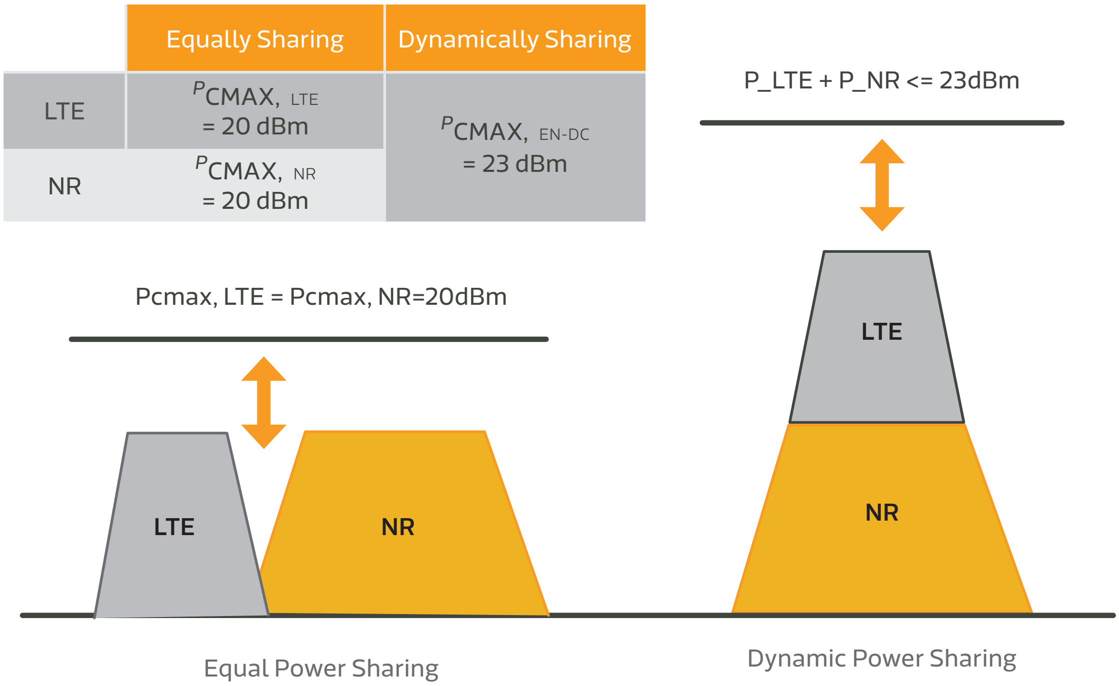
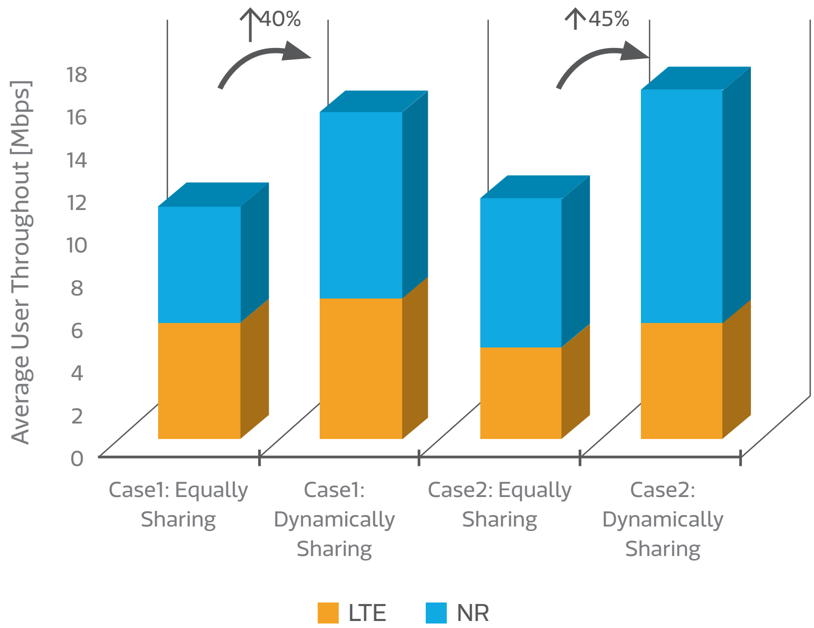


Figure 3 Power consumption for variable video data rates

Simulation results in figure 4 shows how dynamic power sharing brings a significant gain to the average user uplink throughput in both high LTE and high NR traffic cases. The inter-site distance between e/gNBs is 500 meters in this simulation. It is observed that equal power sharing has higher percentage of maximum output power being used versus dynamic power sharing, which implies equally power sharing suffered more frequent severe cases of insufficient transmission power, thus, performance of the throughput suffered. Dynamic power sharing technique is significantly better than equal power sharing for uplink power control, with a gain in uplink throughput of ≥ 40%, depending on the traffic pattern ratio split between LTE and NR.



Parameters	LTE	NR
Band	2.5 GHz	4 GHz
Bandwidth	20 MHz	20 MHz
SCS	15 kHz	15 kHz
Modulation	64QAM	256QAM
Power Class	23 dBm	

Case 1: Traffic arrival rate (LTE : NR) = (3:2)

Case 2: Traffic arrival rate (LTE : NR) = (2:3)

Figure 4 EPS vs. DPS, Average User Throughput Comparison

Comparison between Dynamic Power Sharing and Single Uplink Operation

EN-DC architecture brings challenges to power consumption, while NR/LTE co-existence has issues such as intermodulation distortion (IMD). Therefore, single uplink operation (SUO) for EN-DC was proposed and 3GPP has already agreed that NSA mode UE can declare the capability of only single uplink support by switching between LTE and NR carriers. Based on the requirement of SUO and the improved performance of dynamic power sharing, 3GPP RAN1 defined two EN-DC uplink power sharing modes:

- Semi-static time division between NR and LTE for single uplink operation.
- Dynamic power sharing between NR and LTE for dual uplink configuration.

The definition of SUO is only a single uplink allowed at a time instance in non-standalone scenarios. The motivation of introducing SUO includes the following two main considerations:

- In NSA mode, simultaneous uplink transmission impacts LTE downlink for some difficult band combinations (e.g., B3+B42) where IMD products fall into B3 downlink.
- Cell-edge UEs may not have enough power to do simultaneous uplink transmission.

The main idea of SUO operation is to restrict LTE uplink transmission to some specific subframes and apply NR uplink transmission in the remaining subframes. There are three possible solutions, listed in table 2, to implement SUO in the network. UE implementation will be transparent in most of these options.

Table 2 Solutions of SUO Implementation

Options	Description	UE Impact
1	NW implementation to generate the gap	None
2	DL-reference UL/DL configuration for TDD Pcell	None
3	DL-reference UL/DL configuration defined for FDD-SCell in TDD-FDD CA with TDD-Pcell	TDD-like HARQ feedback timing is applied to LTE-FDD carrier

The illustration of SUO is shown in figure 5. The UE is mandated to support uplink-switch timing at least less than 20us if SUO is supported by the UE.

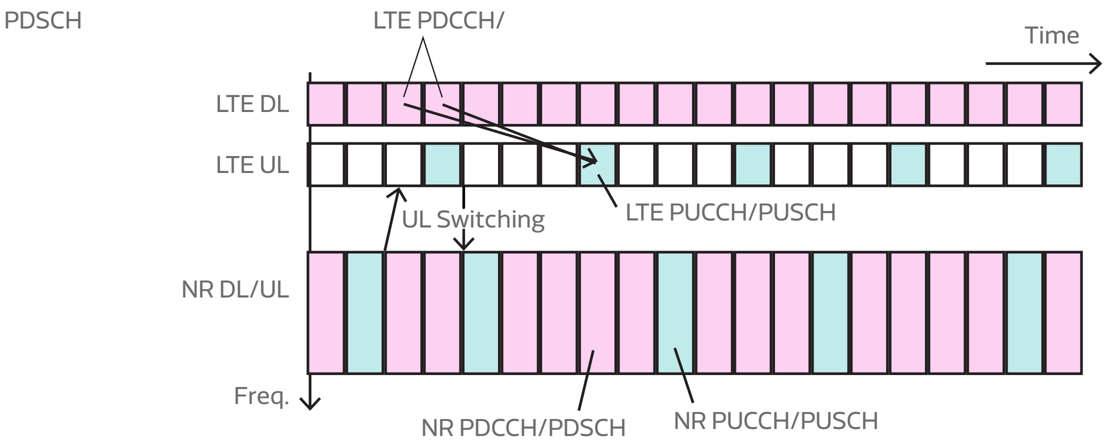


Figure 5 SUO Operation and Concept

There are two methods of SUO being defined in 3GPP:

- SUO Method #1: cell specific SUO configuration.

- SUO Method #2: UE specific SUO configuration.

For SUO method #1, all UEs can apply the same DL/UL configuration as shown in table 3. The subframe number with "U" means subframes are reserved for LTE uplink transmission. NR uplink transmission can only use other subframes with "D" or "S". For SUO method #2, each UE has specific DL/UL configuration. The rule of uplink transmission timing is the same as SUO method #1.

Table 3 TDD DL/UL Configuration

Uplink-Downlink Configuration	Downlink-to-Uplink Switch-point periodicity	Subframe Number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

Before showing the performance comparison between SUO and dynamic power sharing, we define power-limited UE as one that may encounter insufficient transmission power. The criteria of a power-limited UE is defined as maximum power of PUSCH > 20 dBm, where maximum power of PUSCH is minimum value between maximum output power of UE and calculated PUSCH power assuming all RB resource is allocated to the UE. To prevent the aggregated transmission power exceeding the UE's Power Class limitation, we then assume that for all power-limited UEs without dynamic power sharing capability, it will fall back to single uplink operation.

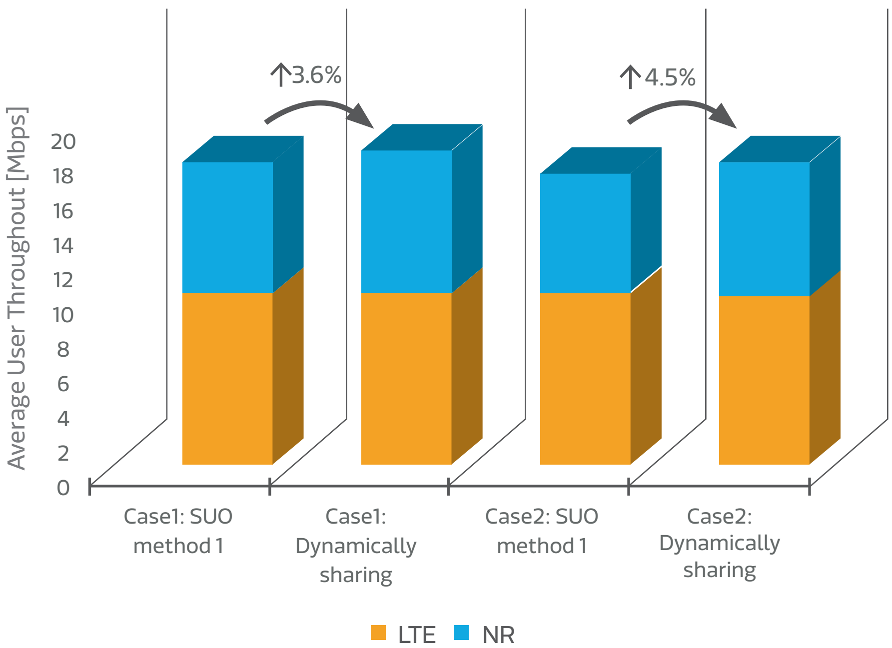


Figure 6 SUO vs. DPS, Average User Throughout of all UE

The simulation results in figure 6 show the average user throughput of all users for different power sharing schemes. Dynamic power sharing has around 5% average throughput increase compared to SUO Case-1 (Traffic arrival rate [LTE : NR] = [3 : 2]) and Case-2 (Traffic arrival rate [LTE : NR] = [2 : 3]).

The gain of dynamic power sharing is not obvious because the above result is the average for all users. For those UEs which are close to the cell, throughput should be similar in each case.

The other observation is average user throughput of SUO Case-1 will be slightly better than SUO Case-2. The reason being that a UE in good radio conditions will have more chance to be scheduled in cell specific SUO configuration, so it will achieve better system performance. However, in comparison, the average delay of cell-edge UE will become longer.

On the other hand, a UE which reaches its power-limits is defined as SUO UE. If we only consider the performance of SUO UE, SUO method #2, as illustrated in figure 7, will have better performance than SUO method #1 (shown in the previous figure) because a cell-edge UE will have more chance to achieve scheduled uplink transmission.

Another key observation is that the dynamic power sharing can boost throughput performance of SUO UEs; a simulation result shows over 50% throughput increase on SUO UEs.

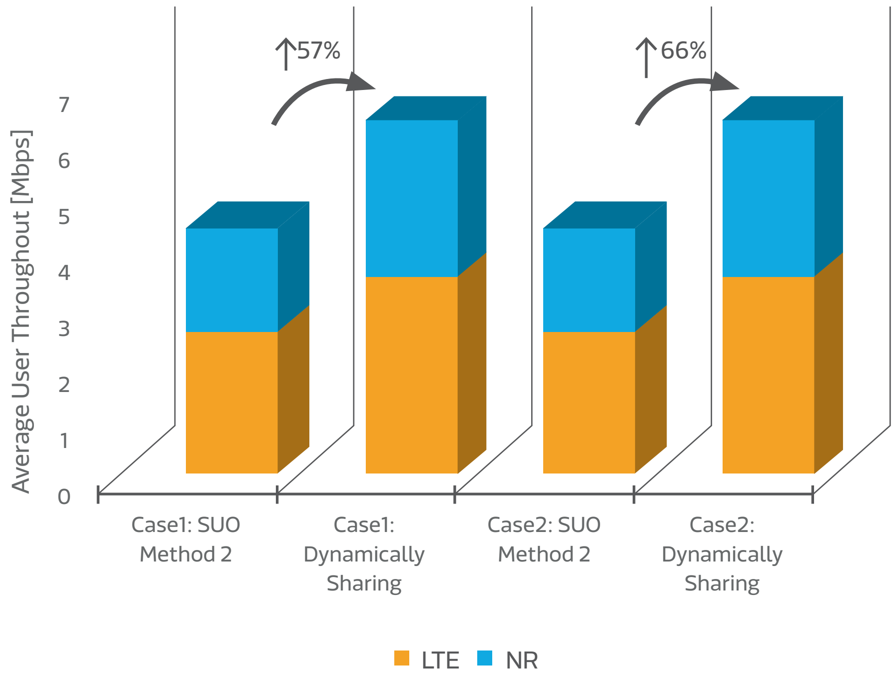


Figure 7 Average User Throughout of SUO UE

The conclusion from the simulation results in figures 6 and 7 indicate that dynamic power sharing (DPS) is significantly better than SUO for cell-edge UEs, with 57% better average uplink throughput than SUO UEs.

In addition, the cell-specific SUO configuration (SUO method #1) is better than the UE-specific configuration (SUO method #2).

3GPP Specifications for SUO and DPS

3GPP TS 38.331 specifies UE capability related to support of SUO and dynamic power sharing. The UE capability bits are included in MRDC Parameters (Multi-RAT Dual Connectivity) listed in table 4. It was agreed during 3GPP RAN Plenary #80 that the UE should support SUO-based power control if dynamic power sharing is not supported.

Table 4 MRDC Parameters within UE Capability Message

MRDC-Parameters	
singleUL-Transmission	Indicates that the UE does not support simultaneous UL transmissions as defined in TS 38.101-3. The UE may only set this bit for certain band combinations defined in TS 38.101-3
dynamicPowerSharing	Indicates whether the UE supports dynamic EN-DC power sharing or not. If the UE supports this capability it will dynamically share the power between NR and LTE if P_LTE + P_NR > Pcmax.
tdm-Pattern	Indicates whether the UE supports the tdm-Pattern for single UL-transmission associated functionality. Support is conditionally mandatory for UEs that do not support dynamic power sharing and for UEs that indicate single UL for any BC, and optional otherwise.
ul-SharingEUTRA-NR	Indicates whether the UE supports EN-DC with EUTRA-NR coexistence in UL sharing via TDM only, FDM only, or both TDM and FDM from UE perspective.
ul-SwitchingTimeEUTRA-NR	Indicates support of switching type between LTE UL and NR UL for EN-DC with LTE-NR coexistence in UL sharing from UE perspective. Type1 indicates UE supports switching within less than 0 us and type2 indicates UE supports switching within less than 20us. It is mandatory to report switching time type 1 or type 2 if UE supports LTE and NR UL Transmission in the shared carrier via TDM only or LTE and NR UL transmission in the shared carrier via FDM or TDM.

The TDM-pattern configuration is included in the NR configuration of LTE RRCConnectionReconfiguration message because it defines UL/DL reference configuration that indicates the time during which a UE configured with EN-DC is allowed to transmit. 3GPP TS 38.213 specifies the EN-DC power control mechanism as follows. For the EN-DC deployment option 3/3a/3x, MCG means LTE anchor carrier and SCG represents NR carriers.

- Maximum allowed power values for LTE (p-MaxEUTRA) and NR (P-NR) are configured separately
- If a UE is configured P_LTE + P_NR > Pcmax
    - If the UE is configured with TDM pattern for single uplink operation
        - If the UE does not indicate a capability for dynamic power sharing between LTE and NR, the UE is not expected to transmit in a slot on the SCG when a corresponding subframe on the MCG is an UL subframe in TDM pattern.
    - If the UE indicated a capability for dynamic power sharing between LTE and NR and if the UE transmission in subframe of MCG overlap in time with UE transmission in slot of SCG

- The UE shall reduce transmission power in any portion of transmission slot of SCG so that P_LTE + P_NR_adjust ≤ Pcmax in any portion of slot of SCG.

From the procedures defined by 3GPP, the UE needs to fall back to 1Tx mode (SUO) once reaching its power limitation threshold, providing dynamic power sharing is not supported by UE. The UE behavior with and without dynamic power sharing is illustrated in figure 8. LTE uplink is unavailable sometimes due to TDM pattern if the UE is on single uplink mode. The UE may also be unable to react to quick changes in radio conditions, due to the large control plane signaling latencies.

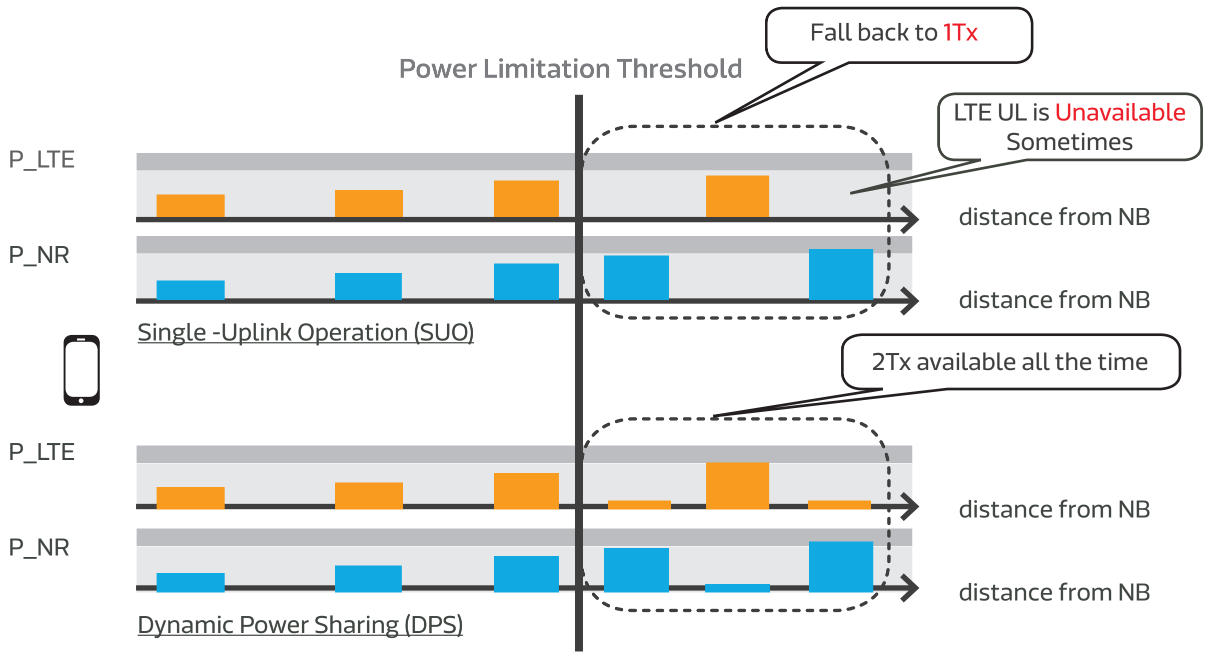


Figure 8 SUO and DPS Operation

Conclusion

5G creates new deployment challenges for carriers trying to deliver a ubiquitous user experience with both standalone and non-standalone, especially at the cell-edge. Efficient spectrum usage and utilization for different types of user applications is becoming important for the future cellular network deployments, in order to cope with increased data rate and capacity demands. As 5G NR will offer different types of deployment including dual connectivity with LTE, the uplink is likely to become a bottleneck due to coverage difference with the downlink in higher bands. Additionally, cell-edge performance and power consumption are two challenging topics to 5G NR design. Therefore, 5G NR can utilize some existing features from deployed LTE-TDD networks, in addition to new features targeting uplink enhancements. In this paper, we evaluated High Power(/Performance) User Equipment (HPUE) and are also discussing new features added for Dual Connectivity between LTE and NR; Dynamic Power Sharing (DPS) and Single Uplink Operation (SUO).

The HPUE feature offers a compelling value add to carriers and users and is realized as a prominent feature in 5G as well. Practically, the HPUE outperforms the legacy UE with a gain of 3dB in uplink coverage. This coverage enhancement increases the uplink throughput and improves with higher order modulation utilization (e.g. 64QAM); all at minimal impact to battery consumption. Similar gains will be extended in 5G NR deployments with several bands such as n41, n77, n78 and n79, having already added HPUE capability.

EN-DC architecture is already being evaluated by most global operators for their initial 5G deployment and commercial network, which is expected as the first wave of non-standalone deployment. In EN-DC architecture, both NR and LTE can transmit and receive data at the same time to boost downlink and uplink throughput. However, the challenge is the total sum of combined transmit power of NR and LTE shall still be limited by a configured maximum power. Dynamic power sharing (DPS) technique is significantly better than equally power sharing for uplink power control, with a gain in uplink user throughput of ≥ 40%.

EN-DC architecture brings challenges to power consumption, while NR/LTE co-existence has issues such as intermodulation distortion (IMD). Therefore, the single uplink operation (SUO) agreed by 3GPP allows NSA mode UE the capability of only single uplink support by switching between LTE and NR carriers in difficult band combinations. DPS is significantly better than SUO for cell-edge UEs with 57% better average uplink throughput, but with very similar performance in near-cell conditions. Based on the evaluation results done by MediaTek, DPS is a better power control scheme to achieve good cell-edge performance in EN-DC deployment scenarios. SUO is expected to be only applied to the difficult band combinations where IMD issue degrades LTE downlink severely.

MediaTek maintains its active role working with the whole ecosystem to enhance the user experience and ensure efficient 5G NR system deployment. MediaTek continues to bring innovate features to its 5G modems for uplink coverage, performance and power consumption enhancements in order to accelerate successful 5G NR system for standalone and non-standalone deployments.

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