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Utilization of Technology of 5G NR and 4G LTE in Frequency Spectrum

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***Abstract*: This paper presents an overview on utilization of technology of 5G NR and 4G LTE in frequency spectrum.**

***Keywords*: 5G, 4G, LTE, Frequency spectrum.**

1. Introduction

5G NR (New Radio) is a new radio access technology (RAT) developed by 3GPP for the 5G (fifth generation) mobile network. [1] It was designed to be the global standard for the air interface of 5G networks. [2]

The 3GPP specification 38 series [3] provides the technical details behind NR, the RAT beyond LTE.

Study of NR within 3GPP started in 2015, and the first specification was made available by the end of 2017. While the 3GPP standardization process was ongoing, industry had already begun efforts to implement infrastructure compliant with the draft standard, with the expectation that the first large-scale commercial launch of 5G NR would occur in 2019. In telecommunication, Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements. [1][2] The standard is developed by the 3GPP (3rd Generation Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9. LTE is the upgrade path for carriers with both GSM/UMTS networks and CDMA2000 networks. The different LTE frequencies and bands used in different countries mean that only multi-band phones are able to use LTE in all countries where it is supported.

LTE is commonly marketed as "4G LTE and Advance 4G", but it does not meet the technical criteria of a 4G wireless service, as specified in the 3GPP Release 8 and 9 document series for LTE Advanced. LTE is also commonly known as 3.95G. The requirements were originally set forth by the ITU-R organization in the IMT Advanced specification. However, due to marketing pressures and the significant advancements that WiMAX, Evolved High Speed Packet Access and LTE bring to the original 3G technologies, ITU later decided that LTE together with the aforementioned technologies can be called 4G technologies. [3] The LTE Advanced standard formally satisfies the ITU-R requirements to be considered IMT-Advanced. [4] To differentiate LTE Advanced and WiMAX-Advanced from current 4G technologies, ITU has defined them as "True 4G" [5][6].

2. Frequency range

Numerology (sub-carrier spacing) for New Radio
NR supports five sub-carrier spacings

Sub-Carrier Spacing	Slot Duration	Comment	Frequency Bands
15 kHz	1 millisecond	same as LTE	Available in FR1
30 kHz	0.5 millisecond		Available in FR1
60 kHz	0.25 millisecond	Both normal Cyclic Prefix (CP) and extended CP may be used with 60 kHz sub-carrier spacing	Available in both FR1 and FR2
120 kHz	0.125 millisecond	This is the highest sub-carrier spacing for data the path	Available in FR2
240 kHz	0.0625 millisecond	This is only possible for search and measurement purposes, using the Synchronization Signal Block (SSB)	Available in FR2

The LTE standard covers a range of many different bands, each of which is designated by both a frequency and a band number:

- North America – 600, 700, 750, 800 850, 1900, 2100(AWS), 2300 (WCS), 2500, 2600 MHz (bands 2, 4, 5, 7, 12, 13, 17, 25, 26, 29, 30, 41, 66, 71).
- Latin America and Caribbean – 750, 850, 900, 1700, 1800, 1900, 2100, 2600 MHz (bands 1, 2, 3, 4, 5, 7, 8, 13, 17, 28).
- Europe – 450, 700, 800, 900, 1500, 1800, 2100, 2300, 2600, 3500, 3700 MHz (bands 1, 3, 7, 8, 20, 22, 28, 31, 32, 38, 40, 42, 43).
- Asia – 450, 700, 800, 850, 900, 1500, 1800, 1900, 2100, 2300, 2500, 2600, 3500 MHz (bands 1, 3, 5, 7, 8, 11, 18, 19,

21, 26, 21, 31, 38, 39, 40, 41, 42).

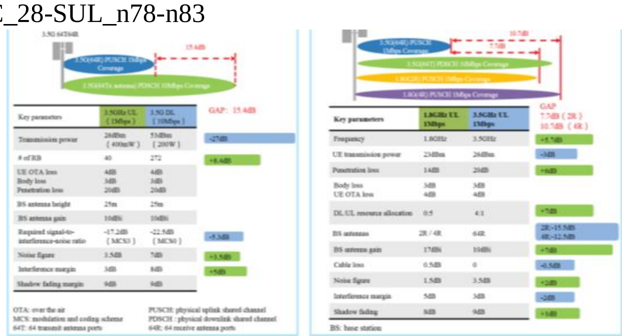
- Africa – 700, 800, 850, 900, 1800, 2100, 2500, 2600 MHz (bands 1, 3, 5, 7, 8, 20, 28, 41)
- Oceania (incl. Australia and New Zealand) – 700, 800, 850, 1800, 2100, 2300, 2600 MHz (bands 1, 3, 7, 12, 20, 28, 40).

As a result, phones from one country may not work in other countries. Users will need a multi-band capable phone for roaming internationally.

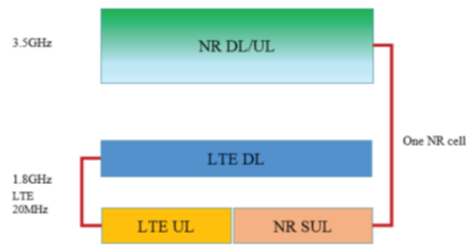
UL Spectrum Sharing: UL/DL Decoupling:

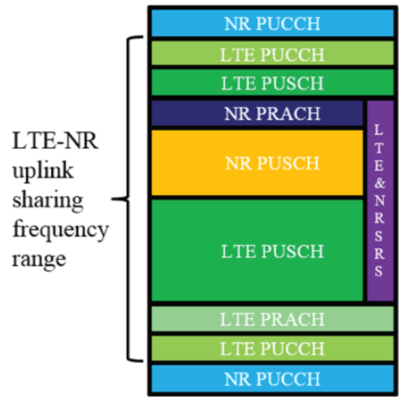
Currently, the most likely spectrum below 6 GHz for 5G-NR deployment is C-Band (3.2~5 GHz), where one operator could obtain 100 MHz or more spectrum, and time-division duplex (TDD) is used to facilitate the use of advanced massive multiple-input multiple-output (MIMO) technologies. Compared with the 2 GHz or lower frequency bands that are widely used for LTE systems, C-band suffers larger path loss and penetration loss. This issue is even more severe for the UL due to the higher frequency and smaller portion of UL resource allocation, and the coverage is up to 15.4 dB smaller than that of the DL, as shown. This UL-DL coverage gap will largely limit the cell coverage and hence increase the number of base station (BS) sites in order to cover the same geographical area, which will translate into higher deployment costs for operators. To enable operators to reuse their existing LTE BS sites and at the same time address the issue of UL-DL coverage gap, the rate.

SUL frequency band and band combination definition [5].
5G-NR bands
5G-NR band combinations
Standalone (SA)
Non-standalone (NSA)
Band no.
Frequency Duplex Band combination number
n77 3.3–4.2 GHz TDD SUL_n78-n80 DC_1-SUL_n78-n84
n78 3.3–3.8 GHz TDD SUL_n78-n81 DC_3-SUL_n78-n80
n79 4.4–5.0 GHz TDD SUL_n78-n82 DC_3-SUL_n78-n82
n80 1710–1785 MHz SUL SUL_n78-n83 DC_8-SUL_n78-n81
n81 880–915 MHz SUL SUL_n78-n84 DC_20-SUL_n78-82
n82 832–862 MHz SUL
DC: dual connectivity
DC_28-SUL_n78-n83



UL sharing from the UE perspective (spectrum combination for one UE).





Subcarrier alignment and resource sharing between LTE and 5G-NR. concept of UL/DL decoupling is introduced in 5G-NR design. Unlike a traditional cell, where there is only one UL carrier and one DL carrier, UL/DL decoupling for 5G-NR proposes to use an additional 5G-NR UL carrier to supplement a 5G-NR TDD carrier. Note that this additional UL carrier and the TDD carrier are in different frequency bands; say the additional UL carrier is in 1.8 GHz band and the TDD carrier is in 3.5 GHz band. As such, there will be one DL carrier and two UL carriers in the same cell where either of the UL carriers can be used with the DL carrier. When a user equipment (UE) is at the cell center where there is good channel quality, the normal TDD carrier can be used, and when the UE is at the cell edge where UL coverage is not guaranteed, the additional UL, which is called supplementary UL(SUL) in 3GPP specifications, can be used. In this way, the UL/ DL decoupling can enhance the UL coverage of a 5G-NR cell. Besides the coverage improvement, latency performance of 5G-NR in C-Band is also improved. The reason is that TDD is used for C-Band, and a smaller portion of the resources are allocated to UL because normally DL traffic (e.g., MBB traffic) is dominant. Therefore, the UL traffic or the acknowledgment (ACK)/negative ACK (NACK) for DL data packets will have to wait until there are available UL slots, and this will result in larger traffic latency as compared to frequency-division duplex (FDD). On the other hand, if more UL-DL switching points are introduced to reduce latency, spectrum efficiency will be degraded. As shown in Fig. 2, to achieve similar latency performance (option 1: 1.5 ms, option 2: 2.6 ms), option 2 has 14.3 percent guard period (GP) overhead compared with the 2.8 percent GP overhead of option 1 [4]. To enable the UL/DL decoupling and UL sharing between LTE and 5G-NR SUL, several important aspects mentioned below were standardized. SUL frequency band defi nition: SUL frequency bands and related standalone (SA) and non-standalone (NSA) band combinations are defined in Table 1 As seen from Table 1, an SA SUL band combination consists of an SUL band and a TDD band, and an NSA band combination consists of an LTE frequency band and an SUL band combination where the LTE UL carrier frequency is the same as the 5G-NR SUL carrier frequency. One example is DC_3-SUL_n78-n80. In this case, it is called UL sharing from UE perspective (ULSUP) in 3GPP, as shown in Fig. 3. To facilitate the description, in one cell with SUL configuration, the UL carrier other than the SUL is called normal UL (NUL). 100 kHz channel raster and 7.5 kHz frequency shifts for SUL: Since LTE and 5G-NR are both based on orthogonal frequency-division multiplexing (OFDM) technology and the same numerologies for OFDM, an SUL carrier can share the currently deployed LTE FDD UL carrier efficiently when orthogonality between the two can be ensured [6]. This is achieved by aligning the RF channels with the same 100 Hz channel raster when a 7.5 kHz frequency shifts to the SUL carrier. Note that this frequency shift is configurable. Besides the subcarrier alignment, the uplink resource blocks (RBs) of LTE and 5G-NR SUL are aligned so that the RBs to LTE and 5G-NR can be adjacent to each other without interference to each other, as shown. UL/SUL selection for random access: NUL and SUL in one cell can be selected by an idle UE for random access based on its channel quality to increase the random access success probability for the UE at the cell edge. Dynamic/semi-static switching between SUL and NUL: When a UE is configured with both SUL and NUL, the UE can be dynamically or semi-statically scheduled on the NUL or SUL to fully utilize the UL resource in the cell. For dynamic scheduling, different traffic can be scheduled on NUL or SUL. One example is that the traffic with low latency requirement can be scheduled on SUL due to its always available UL resources. To avoid signal transmission overlap between the SUL and NUL, the timing adjustment is unified (i.e., the NUL and SUL share the same timing advance adjustment command from the network).

Single TX between LTE UL and SUL: For a UE in NSA mode with SUL, the LTE UL and SUL carriers are both supposed to carry uplink signals. However due to total power limitation of the UE, the power has to be shared between LTE UL, 5G-NR SUL, and NUL. To guarantee the uplink performance, the LTE UL and SUL/NUL ability to be transmitted by the same UE based on a TDM pattern is supported, so the LTE UL and SUL/ UL signal will not overlap in the time domain, and full UE power can be used by either 5G-NR NUL, SUL, or LTE UL. The UE also supports dynamic switching between LTE UL and SUL without switching time to avoid the switching time overhead. Other enablers of the UL/DL decoupling are also supported, including the UL power control, UL feedback on SUL, and so on.

A. DL Spectrum Sharing

LTE and 5G-NR can also share the same DL frequency. This DL sharing is also useful for operators that have no additional lower frequency for 5G-NR deployment. For DL sharing, the challenge is that the LTE is transmitting cell-specific reference signal (CRS) in 4 or 6 OFDM non-continuous symbols of each subframe. The 5G-NR DL signal has to be designed to not collide with CRS to avoid performance degradation to LTE users. SSB pattern: The 4 OFDM symbol 5G-NR synchronization signal block (SSB) using 30 kHz subcarrier spacing can be placed on the OFDM symbols between two LTE CRS symbols. This special SSB time pattern is called case C in 3GPP specification. Initial COREST position: The starting OFDM symbol of the 5G-NR control resource set in a subframe can be indicated by the SSB so that it can also be placed on the OFDM symbols not occupied by LTE CRS. LTE CRS rate matching: When 5G-NR physical downlink shared channel (PDSCH) is using 15 kHz subcarrier spacing, the subcarrier of LTE and 5G-NR are also orthogonal. To avoid the LTE CRS subcarriers, a 5G-NR user is configured with the LTE CRS frequency information so that the 5G-NR user can calculate the LTE CRS positions as reserved resources, and the 5G-NR

PDSCH will rate match around those reserved resources. By rate matching, 5G-NR PDSCH can also be scheduled on the OFDM symbols with CRS, but on the subcarriers not occupied by CRS. LTE NB-IoT and LTE-M coexistence with 5G-NR: The LTE narrowband Internet of Things (NB-IoT) and LTE-M [7] are expected to continue in service even after the LTE spectrum is re-farmed to 5G-NR. One of the options is to deploy the LTE IoT systems within a 5G-NR carrier. 5G-NR introduced a symbol- RB level reserved resource to accommodate the existing LTE IoT systems deployed in the same carrier. It is worth nothing that to provide the random access functionalities on a 5G-NR DL carrier shared with an LTE DL carrier, UL sharing is also needed to share with an LTE UL carrier.

B. Adjacent Carrier Coexistence

To deploy 5G-NR and LTE on the same frequency band, the interference between the two systems should be guaranteed. The most critical coexistence challenge happens in a TDD frequency band, where the transmission direction (UL or DL) should be aligned between LTE and 5G-NR to avoid UL/DL interference. LTE defined seven TDD configurations for different UL/ DL traffic ratios. In 5G-NR the UL/DL transmission direction is flexibly designed and can be fully aligned with LTE TDD UL/DL transmission direction. One example is that for LTE TDD configuration 2 and special subframe configuration 1, 5G-NR can configure its cell as 5 ms periodicity with 51 DL OFDM symbols in the front of the 5-subframe period and 16 UL OFDM symbols (subcarrier spacing is 15 kHz) in the rear of the period. Furthermore, since 5G-NR starts with DL symbols and ends with UL symbols in UL-DL periodicity, there will be two subframe shifts between the subframe number of LTE and 5G-NR.

3. Conclusion

This article introduces the efficient coexistence between LTE and 5G-NR. Through the UL only sharing known as UL/DL decoupling, 5G-NR provides a tool to extend its coverage with C-Band deployment, and makes it possible to deploy a C-Band 5G-NR network using existing LTE sites for seamless coverage. Moreover, the co-site deployment of 5G-NR and LTE greatly reduces the 5G-NR network cost and speeds up the 5G-NR commercialization. The UL sharing between LTE and 5G-NR also provides a powerful tool to strike a good balance between spectrum efficiency and low latency, and between coverage and channel bandwidth. The simultaneous 5G-NR DL/UL sharing with an LTE DL/UL carrier provides the possibility of early and low load 5G-NR deployment since the FDD LTE DL may have such high traffic load that only a shared low traffic load on 5G-NR DL can be accommodated. The 5G-NR is also designed to coexist with a TD-LTE system in the same TDD band to align the UL/DL transmission direction. Overall, 5G-NR is designed to allow efficient coexistence with 4G LTE for very flexible deployments and use cases.

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