

LTE-NR tight-interworking and the first steps to 5G

For 5G systems to start delivering value immediately, initial components of the New Radio (NR) technology need to satisfy both urgent market needs - by assisting LTE radio – and the longer-term requirements of 5G. In this context, LTE-NR tight-interworking is one of the most important technology components.

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In this blog post, we will explain the concept and describe the key features now being standardized by the 3GPP.

This will make key benefits of 5G technologies available to users much earlier than expected and allow mobile operators to leverage their existing LTE deployments with on-demand NR aggregation while preparing full-scale roll out of NR stand-alone deployments. Furthermore, thanks to LTE-NR tight-interworking, we can channel the standardization efforts into specifying the initially needed NR features in 3GPP Release-15, as there will be no need to define all the anticipated NR functionalities for enabling LTE-NR tight-interworking.

LTE – NR dual connectivity

The main scenario for LTE-NR tight-interworking is widely considered LTE-NR dual connectivity (DC), in which user data can be exchanged between a mobile device (referred to as UE in the figures below) and an NR base station along with the LTE connectivity.

The DC concept as such is not new in cellular networks. In its simplest form, it allows two base stations to simultaneously deliver user data to a mobile device. DC between LTE base stations was introduced in 3GPP Release-12, completed in March 2015, and DC-like aggregation of LTE and WLAN was introduced in 3GPP Release-13, completed in March 2016. However, this is the first time when a DC scenario is being enabled for two different generations of 3GPP radio access technologies.

Since the underlying technology components and capabilities are not the same for LTE and NR, there have been a number of challenges to resolve before completing the first NR release in 3GPP

Release-15. The first solution to be standardized is Evolved - Universal Terrestrial Radio Access – New Radio dual connectivity - EN-DC.

In EN-DC, the master node (MN in figures below) is LTE, and the secondary, or aggregated, node (SN in figures below) is NR. Please note that “node” here simply refers to a base station. Both nodes have a direct interface with the existing core network, Evolved Packet Core (EPC), in the user plane that carries the user data, but only the master node has the direct interface towards EPC in the control plane that carries the signaling traffic between the mobile device and the core network. Thus, the LTE node is responsible for maintaining the connection state transitions, handling the connection setup/release, and initiating the first-time secondary node addition, that is, the EN-DC setup.

In EN-DC, a mobile device has a second Radio Resource Control (RRC) termination at the secondary node, unlike LTE DC where there is only one RRC termination point – at the master node. The separation of LTE and NR RRC termination points enables the secondary node, depending on network configuration, to trigger the intra-NR mobility, that is, initiating secondary node change/release/modification. In LTE DC, only the master node was able to do this.

Control plane

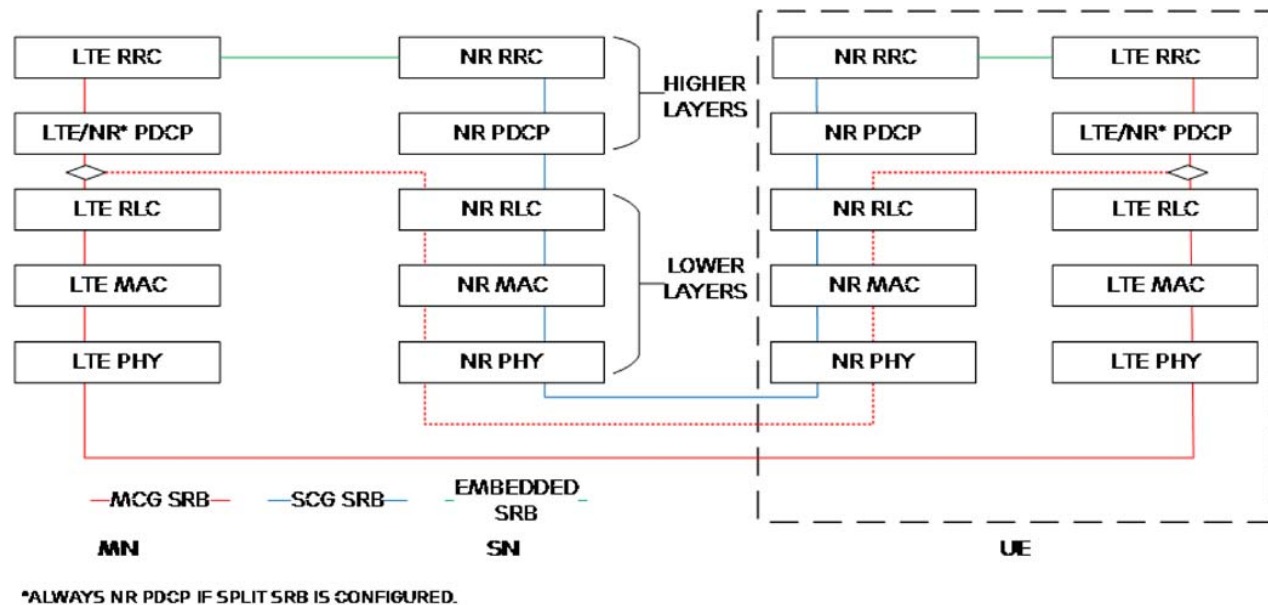
RRC refers to the signaling language spoken and associated behaviors undertaken between the network and a mobile device. This encompasses the connection reconfiguration and measurement reporting, which in turn enables effective data communication and seamless mobility. To set up and modify the EN-DC operation, a mobile device must comprehend both the LTE and NR RRC control signaling.

To transport these RRC messages between the network and a mobile device, a set of signaling radio bearers (SRBs) are used:

- **Master Cell Group (MCG) SRB (SRB1, SRB2):** Direct SRB between the master node and the mobile device that can be used for conveying master node RRC messages which can also embed secondary node RRC configurations.
- **Split SRB (SRB1+SRB1S, SRB2+SRB2S):** SRB that is split between the master node and the secondary node (at a higher layer, PDCP) towards the mobile device, allowing a master node RRC message to be sent via the lower layers (RLC, MAC and PHY) of either the master node or secondary node; or to be sent via the lower layers of both the master and secondary nodes. Here, the master node RRC message can also embed secondary node RRC configurations.

- **Secondary Cell Group (SCG) SRB (SRB3):** Direct SRB between the secondary node and the mobile device by which secondary node RRC messages are sent.

Figure 1 illustrates these SRBs.



As can be seen from the figure, the MCG SRBs (SRB1, SRB2) can be split to use both the master node and secondary node lower layers, and NR RRC messages can be sent embedded in the LTE RRC messages via the MCG SRB or directly via the SCG SRB. In LTE DC, there is no RRC termination at the secondary node and the only available SRBs for DC are MCG SRBs, that is, there is no split SRB, SCG SRB, or embedded RRC via the MCG SRB.

Thanks to the newly introduced split SRB, mobility robustness can be greatly improved, especially for NR high-frequency deployments. This is because the RRC messages can be exchanged both via the LTE and NR lower layers – either by duplicating the messages or selecting the better radio path as illustrated in Figure 1. Since the network could also configure the SCG SRB, direct and fast control plane communication between the mobile device and the secondary node in both downlink and uplink has become possible. An example of downlink communication is SCG reconfiguration and an example of uplink is measurement reporting. However, for the RRC configurations requiring co-ordination between the master node and the secondary node, for example, in case of adding new carriers, the embedded RRC message via the MCG SRB has to be employed even if SCG SRB is configured. That is because we want to avoid potential race

conditions between inter-dependent LTE and NR reconfigurations that may happen simultaneously.

User plane

When it comes to the user plane, where the user data is transported between the network and a mobile device, data radio bearers (DRBs) are used. Both LTE DC and EN-DC support:

- MCG DRBs – bearers terminated at the master node and using only the master node lower layers.
- MCG split DRBs – bearers terminated at the master node but that can use the lower layers of either the master node or secondary node; or can use the lower layers of both the master and secondary nodes.
- SCG DRBs – bearers terminated at the SN and using only the secondary node lower layers.

An additional data radio bearer has been introduced in EN-DC:

- SCG split DRBs – bearers terminated at the secondary node but that can use the lower layers of either the master node or secondary node, or can use the lower layers of both the master and secondary nodes.

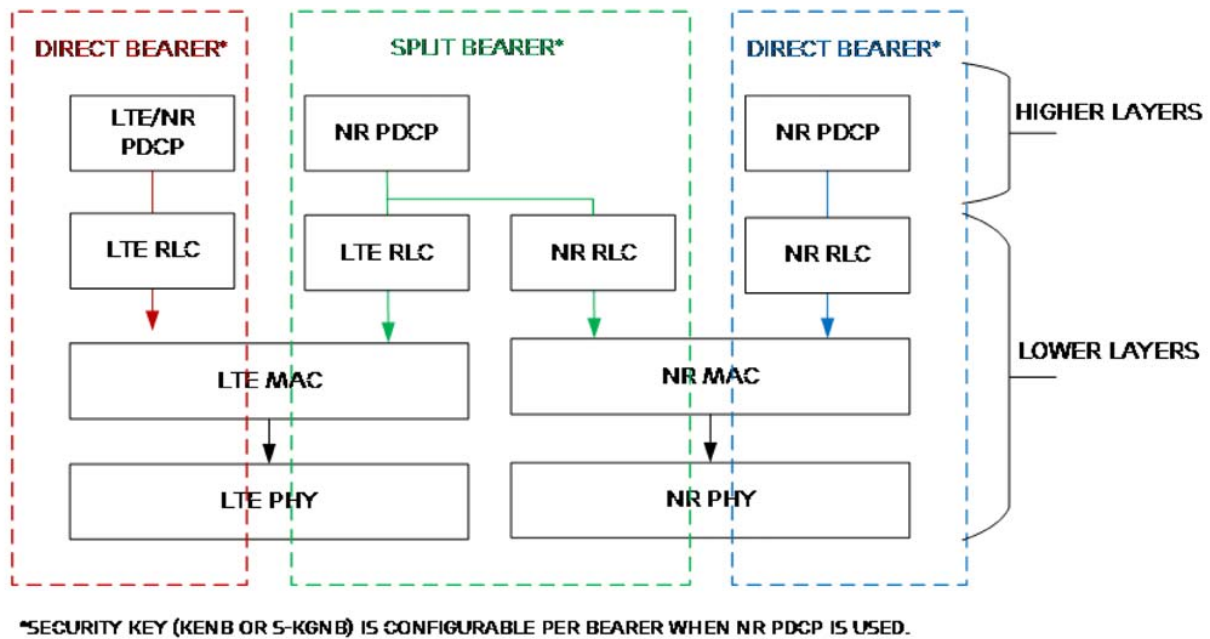
Adopting current LTE DC procedures for the introduction of the SCG split DRB entails that every bearer type change will require a re-establishment in the PDCP layer, as well as in some cases signaling towards the core network to switch the path from the core network to the radio access network. To minimize the impact of such bearer type changes, and minimize implementation and testing efforts on mobile devices, 3GPP has agreed to harmonize the bearer definitions. With the harmonized bearer concept, there will be only two kinds of bearers from the mobile device perspective:

- **Direct DRBs:** DRBs with only one lower layer configuration, either corresponding to LTE or NR lower layers. If the LTE lower layers are configured, either the NR or the LTE version of the higher layer can be used by the bearer. If the NR lower layers are configured, the NR version of the higher layer will be used.
- **Split DRBs:** DRBs with two lower layer configurations, corresponding to LTE and NR lower layers. It will always use the NR version of the higher layer. In case of split DRBs, packet duplication, when it is finalized as a new functionality in Release 15, could be used for additional reliability.

Furthermore, each bearer using NR PDCP, be it direct or split, will be assigned a security context (i.e., master node key - KeNB - or the secondary node key - S-KgNB) out of two possible contexts associated to different termination points at the network (for example, the master or secondary node), which are then used for encryption of the user plane data. These changes addressed in the

harmonized bearer concept make it very efficient to change bearer types without any major impact on the mobile device or the network.

Figure 2 illustrates the harmonized bearer concept in EN-DC.



To sum up, the highlights of LTE-NR tight-interworking with respect to LTE DC are given in the table below.

Features	LTE DC	EN-DC
RRC termination	Only at the master node	Both at the master node and the secondary node
Control plane termination towards the core network	Only at the master node	Only at the master node
Supported DRBs	MCG, MCG split, SCG	Direct, Split
Supported SRBs	MCG SRB	MCG SRB (optionally including NR RRC), split SRB (optionally including NR RRC), SCG SRB (including only NR RRC)
Packet duplication ¹ /Path switching ² for split DRBs/SRBs	Only path switching for MCG split DRBs	Path switching support as well as packet duplication feature (at least in downlink) for both split DRBs and split SRBs
Mobility	Master node controls mobility (both the master node and/or the secondary node)	Master node controls mobility in LTE, while either the master node or the secondary node can control mobility in NR (depending on network configuration)

1. Packet duplication refers to sending the same data packet over both MCG and SCG lower layers.

2. Path switching refers to the use of MCG or SCG lower layers for sending a data packet associated with a split DRB or split SRB.

Since LTE and NR are specified under the same standardization body – unlike the case for LTE and WLAN – there are high expectations for the tight-interworking capabilities. For instance, it is possible that both the LTE and NR nodes can be linked to the same core network and share a common set of radio protocol functionalities in case of LTE-NR tight-interworking. Therefore, it will be feasible for mobile operators to provide various services to the end-users in a more seamless and more reliable fashion.

We should also note that the standardization for EN-DC is not completed yet, so make sure to follow us and stay tuned!

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