LAA as a Key Enabler in Slice-aware 5G RAN: Challenges and Opportunities

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Abstract—**The specification of the fifth generation (5G) mobile and wireless communications is progressing at a rapid pace, where the early drop non-standalone (NSA) version is already completed in December 2017 by third generation partnership project (3GPP). 5G does not only aim at a mere performance enhancement relative to previous generations but also being a key enabler for different services and business operations known as vertical industries. To this end, on one hand, 5G incorporates the framework of network slicing as a flexible and future-proof means to support verticals industries on a common infrastructure. On the other hand, 5G extends the notion of a conventional radio resource toward a native use of other available resources, namely, the unlicensed spectrum (varying from 1-100GHz) in a licensed-assisted access (LAA) way, to respond to stringent and diverse service requirements. This paper places the aforementioned key 5G features into the focus, and proposes a new framework, namely *LAA-as-a-Service* which aims to provide different LAA configurations to be used on-demand in a service-oriented manner. First, the 3GPP standardization roadmap is presented, focusing on the challenges that need to be taken into consideration in order to allow for opportunistic complementary unlicensed spectrum usage for 5G assuming, very demanding 5G services in terms of key performance indicators (KPIs), e.g., latency and reliability. The LAA configurations can be seen as different RAN Configuration Modes (RCMs), i.e., RAN part of the end-to-end (E2E) network slice. Furthermore, as a particular 5G case study, a very dynamic and interference-limited scenario, which is a 5G ultra dense network (UDN) scenario with un-planned/dynamic small cells, is exemplified to show that dynamic radio topology coupled with LAA-as-a-Service is a promising and complementary enhancement.**

Keywords—5G, Slicing, Licensed Assisted Access, NR, RRM, Small Cells

I. INTRODUCTION

The fifth generation (5G) mobile and wireless communications system is characterized by a wide-range of services grouped under three generic service types, namely, enhanced mobile broadband (eMBB), massive machine-type communications (mMTC) and ultra-reliable and low-latency communications (URLLC). The 5G services impose a diverse set of requirements that can change over time and space. Moreover, network slicing concept is a key enabler, which is introduced in 5G to address the various requirements from multiple vertical industries assuming a shared network infrastructure. A network slice can be customized according to the needs of the vertical industries and the services to be supported. Accordingly, the network operation efficiency can be increased, as well, compared to a case where each business operation is supported by a fully isolated sub-network. Network slicing is a key pillar in 5G networks, and the end-to-end (E2E) nature imposes domain-specific requirements which will span over multiple technical domains, i.e., radio access network (RAN), transport network, and core network (CN), in order to meet the service level agreements (SLAs). From RAN perspective, the slicing requirement can be mapped onto:

- **Spectrum Requirements**: Slices might require different chunks of radio resources (e.g., below 6 GHz and mm-Wave radio) to meet the slice performance needs. In order to meet the spectrum requirements from multiple slices, slice-tailored resource management might be required at RAN.
- **Functional Requirements**: Each slice may require different control plane/user plane functions and/or functional placements in order to provide optimized and agile performance at RAN. As stated in literature [1], network slices will allow for flexible functional placements and tailored network functions to meet the per-slice SLAs.
- **Isolation Requirements**: E2E slices shall be logically isolated. However, at RAN, the potential utilization of common infrastructure might provide a bottleneck towards complete isolation. In addition, given the slice criticality, each slice might have different requirement for isolation at RAN domain. Hence, the different isolation requirement per slice at the RAN domain might require sophisticated resource management to meet per-slice performance needs.

A paradigm change in RAN, which can be seen as good candidate for meeting the aforementioned slicing requirements, is the use of unlicensed band in assistance to the licensed band. On this basis, licensed-assisted access (LAA) is seen as a key candidate technology to boost long-term evolution (LTE) coverage using small cells in both licensed and unlicensed bands in a cost efficient manner. Here, the licensed channel remains the primary carrier, and the unlicensed band can be used for best-effort service upon availability. LAA is standardized by 3rd generation partnership project (3GPP) in Release 13 (Rel. 13) and can offer LTE downlink (DL) speeds up to 450 Mbps. In 5G, due to the wide range of unlicensed bands (from 1-100GHz) that are considered, LAA can have

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different characteristics, parameterizations and design choices given the spectrum considerations. Especially for the case of mm-Wave unlicensed bands, where the bandwidth that can be utilized is much higher and the interference can be eliminated due to high directivity of antennas, LAA can be seen as viable candidate for 5G services with tight requirements. Another factor which necessitates the *on-demand* operation of LAA in 5G RAN, is the multi-service support possibly with conflicting key performance indicators (KPIs).

In this paper, the aforementioned design paradigms are analyzed jointly, associated challenges are highlighted, and key design recommendations are provided for multi-service support. The proposed on-demand LAA configuration and operation aim to address tight and diverse 5G service requirements within the scope of E2E slicing. To do this, a set of different LAA configurations are proposed, which apply to different RAN characteristics (e.g., spectrum considerations, environment, and density) that can be mapped to different slices for complementary usage for meeting their requirements. In this direction, a test case is provided to improve the performance in 5G ultra-dense networks (UDNs) with dynamic small cell underlays, where it is shown that dynamic radio topology coupled with LAA-as-a-Service is a promising and complementary enhancement.

The rest of the paper is organized as follows. Section II introduces LAA and its role in 5G, focusing on the challenges which need to be considered, while Section III presents the novel LAA-as-a-Service concept. Section IV focuses on the use case of UDN where this framework is demonstrated along with system-level evaluations. Finally, conclusions are drawn in Section V.

II. 5G LAA Standardization Roadmap and Challenges

A. 5G Standardization Status

Licensed-assisted operations are beneficial for 5G new radio (NR) to offload the traffic to unlicensed band. The licensed spectrum can work as primary spectrum for high-priority traffic with strict QoS requirements, and unlicensed spectrum can be utilized as complementary spectrum opportunistically for traffic offloading purposes, as shown in Figure 1. Considering the joint operation, it would be beneficial for NR to share the common design across licensed and unlicensed bands as much as possible, e.g., similar physical layer (PHY) numerology, multiple access scheme, frame structure, and coding, which provides efficiency and flexibility in resource management and simplicity in implementation.

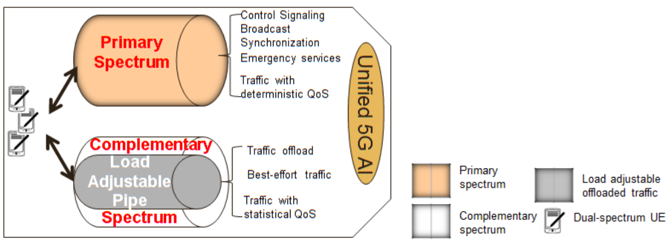

Figure 1 Joint operation of 5G NR on both licensed and unlicensed bands. Air interface is denoted by AI in the figure.

In 3GPP, it was approved to start the study item (SI) on "NR-based Access to Unlicensed Spectrum" in Release 15 [2]. The SI is expected to conclude in June 2018 and followed by a work item (WI) in Release 16. In RAN1, both below and above 6GHz unlicensed bands, e.g., 5GHz, 37GHz, and 60GHz, will be considered to maximize the applicability. Standalone operations, such as, initial access and mobility, as well as coexistence among different radio access technologies (RATs) are included in the objectives of the NR-based unlicensed access SI. The architectural scenarios will also be studied in RAN2, e.g., an NR-based LAA cell connects with an LTE or NR anchor cell operating in licensed spectrum; or on the other hand, an NR-based cell operating in standalone mode can operate in unlicensed spectrum, while connected to a 5G-CN network.

Considering the regulation of unlicensed spectrum, there are some restrictions on the NR-based unlicensed operations, for example, occupied channel bandwidth (OCB), maximum channel occupancy time (MCOT) and listen before talk (LBT), which might impact the waveform and signaling design. In 5GHz band [3], the OCB shall be between 80% and 100% of the declared nominal channel bandwidth. The channel occupancy time (COT) is related to the channel access priority. In 60GHz band [4], the OCB shall be between 70% and 100% of the declared nominal channel bandwidth. The COT shall be less than 9ms. LBT is a necessary and efficient coexistence mechanism among different RATs operating in the unlicensed band including 5GHz and 60GHz bands. It employs at least energy detection to determine the presence or absence of other signals. The regulation in 37GHz is still not finalized, although some report and order are issued by FCC [5].

In order to maintain fair coexistence with other systems using unlicensed spectrum, such as, WiFi IEEE 802.11ac/ax and LTE LAA/ eLAA/ FeLAA[1] devices in 5 GHz band, NR should maintain the similar mechanism and parameters of the LBT defined in LAA/eLAA, such as, Cat 2 and Cat 4 LBT. For 60 GHz band, LBT in NR should be defined based on the transmission characteristics on this band and could refer to the LBT in WiFi 802.11ad/ay.

As one of the objectives in the SI, physical channels inheriting the choices of duplex mode, waveform, carrier bandwidth, subcarrier spacing, frame structure, and PHY design would be part of the NR study to avoid unnecessary divergence from decisions made in the NR WI [2]. Inheriting these licensed access-related decisions will not only reduce the workload of NR-based unlicensed access system design but also keep good consistence of the NR system. On the other side, frame structure and some of physical procedure, e.g., initial access and random access should be considered together with the LBT and OCB requirements. Some physical channels should be adjusted considering the OCB requirement in unlicensed band, e.g., physical uplink (UL) control channel (PUCCH) and physical random access channel (PRACH).

[1] eLAA and FeLAA stand for enhanced LAA & further enhanced LAA, respectivey.

NR-based standalone unlicensed access is also in the scope of objectives of NR unlicensed SI.

B. Challenges

As also highlighted above, one of the key challenges in initial LTE LAA design is to ensure fair co-existence in unlicensed bands with other technologies like WiFi. To this end, mechanisms like LBT could effectively co-exist with WiFi and provide high spectral efficiencies. With LBT, the BS can more dynamically occupy the channel based on the detected medium status, which can both alleviate the delay issue and effectively balance the channel occupancy among co-existing transmitters. The key challenges regarding the implementation of LAA is the fact that interference in 5 GHz bands (e.g., weather radar and WiFi) can be very high and unpredictable. Also other challenges are the LAA-WiFi Hidden terminal problem and delays due to LBT in Heterogeneous Networks (HetNets). These challenges have prohibited the use of LAA for other than best effort traffic in LTE.

In 5G, some *additional* challenges are expected:

- One of the key enablers to provide additional capacity in UDNs, is the use of unlicensed spectrum. Nevertheless, due to the potentially "free" spectrum that can be assessed by different technologies, the use of unlicensed bands has been seen as very good capacity booster mainly for best effort services; but, for delay/reliability critical 5G services the utilization of LAA might be challenging.
- NR supports 400MHz maximum channel bandwidth per NR carrier in Release 15. Wideband operation could provide NR unlicensed access with lower latency, higher channel access opportunity, less implementation complexity and increased resource utilization. Considering wide unlicensed transmission bandwidth (i.e., 80MHz at 5GHz), the available transmission bandwidth may vary from time to time due to interference from other systems. It is essential to investigate how to adapt the transmission bandwidth dynamically according to the LBT result in order to ensure optimized utilization of unlicensed resources.
- In High Frequency (HF) band, high-gain beamforming is available for 5G system design, which may bring severe hidden node and exposed node problems for LBT. *Hidden node problem* is that transmitter of one link cannot hear the current link transmission but there will be interference when they transmit simultaneously. *Exposed node problem* is that transmitter of one link hears the current link transmission but actually there will not be interference when they transmit at the same time. The hidden node and exposed node issues become more severe in directional transmission with narrow transmit (Tx) and receive (Rx) beams especially for high frequency with high-gain beamforming. The key reason is that the channel availability sensed at transmitter side does not represent that at receiver in the case of directional transmission and reception. Figure 2 illustrates an example of the hidden and exposed node problems.

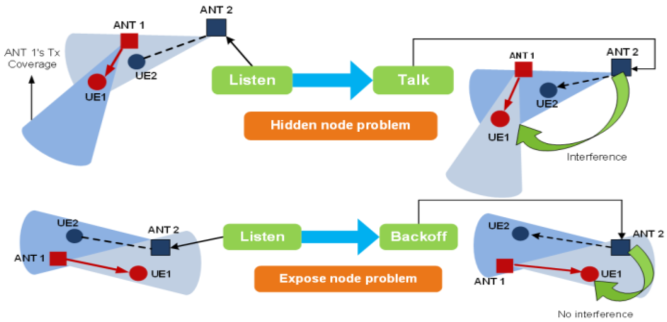

Figure 2 Example of hidden and exposed node problems in HF.

- In UDNs with dynamic radio nodes (i.e., un-planned small cells, moving relays, and nomadic nodes - NNs), utilizing 5G-LAA in un-coordinated manner will cause (and suffer from) high interference from multiple heterogeneous sources. So, LAA shall take changing radio topology conditions into account.
- In slice-aware RAN, where 5G LAA is also a key enabler, the availability of unlicensed bands and unpredictable interference will impact the per-slice/service KPIs differently. Fast coordination between multiple 5G nodes is required, to ensure that diverse and adaptive service requirements can be met. In such cases, LAA shall be dynamically adapted according to service Requirements. For example, LBT can be omitted for critical services in higher bands or isolated environments, e.g., factory.

III. LAA-AS-A SERVICE FRAMEWORK

Prior to 5G, a radio resource is typically considered as a part of the conventional notion of resource. It is characterized by time (duration of the transmission), frequency (carrier frequency and bandwidth), transmit power, and other system parameters including antenna configuration and modulation/coding schemes. In 5G, the notion of resource can be extended to cover different aspects such as, hard resources (e.g., number/type/configuration of antennas, existence of nomadic / unplanned access nodes or mobile terminals that can be used as relays) and soft resources (software capabilities of network nodes and user equipments - UEs). One particular extension, which is relevant to this work is the operation of access nodes in HFs (which can operate in both licensed and unlicensed spectrum) with much larger bandwidth and new challenges regarding the management and control, compared to low frequencies (LFs) [6].

In RAN, the limitation of resources may provide a bottleneck towards ensuring proper isolation, since multitude of slices will eventually use shared RAN resources. In this direction, RAN part of E2E slice or RAN configuration mode (RCM) has been proposed in literature [1] which is composition of RAN network functions, specific function settings and associated resources (i.e., hardware/software and network resources). These RCMs will multiplex the traffic to/from CN to ensure optimization across slices.

In this context, an LAA configuration can be seen as a unique functional parameterization to determine the LAA coverage, performance and availability of unlicensed resources. This may depend on the spectrum (e.g., in HF different LBT design might be required) or the environment (e.g., LBT can be omitted for an isolated enterprise network). So, the set of LAA configurations is an exemplary realization of RCMs, if we assume only unlicensed resources.

Each service type might have different KPIs (e.g., latency, reliability, and throughput); hence, the configuration of LAA should be decided to meet per SLA, from a set of LAA configurations, which are dependent on the resource types and RAN conditions. The performance requirements as identified by the SLAs can be different and conflicting from one service-type to another. Hence, a new criterion that will be required for 5G LAA is the fair co-existence in service-tailored RAN. Therefore, the objective of this study is to provide *LAA-as-a-Service* with different service-tailored configurations in order to meet KPIs for different services, assuming that each service might experience different performance degradation in licensed bands.

There can be two ways to provide LAA-as-a-Service solutions: 1) the on-demand activation of access nodes to operate in unlicensed carriers aggregately with the licensed carrier and 2) the service-tailored LAA configurations that can be dynamically mapped to different services taking into account the capacity, coverage and reliability requirements. The LAA configuration can have multiple parameters, like the preferred spectrum, the LBT design (e.g., directional vs omnidirectional), whether LBT can be omitted (e.g., for isolated environments) and service prioritization, if more than one service use the same LAA configuration.

In particular, the service-tailored LAA configuration may include:

- The selection of unlicensed bands which are more preferable to be used per service, given also the decision of whether to use LBT and which LBT type to be supported (e.g., selection among different LBT designs). As an example, for some critical services with good isolation (e.g., low WiFi access point density), LBT can be omitted to reduce latency.
- The configuration of LBT (i.e., timers, thresholds, and reservation signals), if supported, subject to the service type it belongs.
- The level of coordination of LAA operation on-demand subject to the resource situation (e.g., channel conditions, resource availability and traffic, level of complementary usage spectrum) and context changes, to minimize interference (i.e., centralized vs. distributed functionality for inter-cell resource allocation) and to optimize the performance.

Table 1 LAA Configurations for exemplary services

	LAA Config. 1 – HF, urban (e.g. eMBB)	**LAA Config. 2 – LF, urban (e.g. URLLC)**	**LAA Config. 3 – LF, isolated indoor (e.g. URLLC)**	**LAA Config. 4, LF, mIOT**
Contention Window Size (CWS)	Normal size	Small size (multiple attempts with small gaps)	No LBT	Small size (multiple attempts with small gaps)
Clear Channel Assessment (CCA) Threshold	High threshold (e.g. -40dB) for higher spectrum re-use	Low threshold (e.g. -70dB) for less interference		Low threshold (e.g. -70dB) for less interference
Burst Size	Maximum burst (depends on regulations)	Small burst (e.g. 1ms)	Small burst (e.g. 1ms)	Small burst (e.g. 1ms)
Reservation Signals	RRM/CSI/RLM information Directional/Beam-based LBT mode indication Slice priority	RRM/CSI/RLM information Multi-connectivity information (Cell IDs, pre-allocated RBs) Slice priority	Signalling through primary cell	Group-based RRM/CSI/RLM, Multi-connectivity information (Cell IDs, pre-allocated RBs)
Spectrum	High Frequencies (>5 GHZ)	Low frequencies (carrier aggregation using redundant links over multiple low freq. bands)	Low frequencies (carrier aggregation over multiple low freq. bands)	Ultra-low frequencies (e.g. 900MHZ or TV whitespace)
Other parameters	Per carrier LBT HARQ through the same cell	LBT for all carriers HARQ through primary cell	-	LBT for all carriers HARQ optimized for coverage

In Table 1, we present an example for four characteristic scenarios associated with different services (eMBB, URLLC 1 – urban, URLLC 2- isolated environment, e.g., an enterprise factory, massive Internet-Of-Things (mIOT)). In particular, in LAA Configuration 1, the main requirement is for beam-based LBT design, since it is expected to use unlicensed spectrum in HF. In LAA Configuration 2, parameterization for LF is used for urban environment, whereas the LAA Configuration 3 is tailored for isolated environments and can be mapped to URLLC, where LBT can be omitted. Finally LAA Configuration 4, parameterization for ultra-low frequencies (e.g., TV whitespaces) can be used and group-based measurements can be provided through the reservation signals. Furthermore, HARQ can be optimized for coverage [10] and further parameterization can be similar to Configuration 2.

IV. DEMONSTRATION OF LAA-AS-A-SERVICE IN 5G USE CASE: UDNS WITH UNPLANNED DYNAMIC SMALL CELLS

UDN with dynamic radio topologies is an emerging enabler for the 5G system to cope with the spatially and temporally varying traffic conditions. Compared to a fixed radio topology, dynamic radio topology offers on-demand activation and deactivation of the unplanned dynamic access nodes to respond to the variations in the network. In particular, dynamic small cells have the advantages of reduced capital expenditure (CAPEX), e.g., thanks to reduced need for deployment of additional wireless access nodes, and reduced operational expenditure (OPEX), e.g., thanks to avoiding site leasing.

Also, overall energy efficiency of the network can be improved, by offloading the macro-cells on a need basis [9]. Within the framework of dynamic radio topology, the network shall react quickly and dynamically to fulfill the increased service requirements in a certain time period and at a target service region.

Accordingly, it is envisioned that 5G RAN becomes increasingly dense with the introduction of new access node types. To ensure that network resources are efficiently used, a flexible RAN deployment becomes very important in order to adapt to traffic load. Unplanned dynamic small cell operation emerges as a means to enable the on-demand use of network resources, which can in turn minimize congestions and improve network energy efficiency. At the same time, total cost of ownership (TCO) can be reduced thanks to the activation/deactivation of the access nodes on a need basis.

One drawback of fixed small cells, for example, pico-cells, femtocells, and relay nodes, is that the full operation of such dense deployment is *not* needed anytime and anywhere due to the notion of the inhomogeneous distribution of traffic over time and space. Hence, fixed network deployment has the disadvantage of increased TCO. In addition, the need for searching a proper deployment site can further limit the achievable network topology.

A Nomadic Node (NN) is a movable dynamic small cell that can enable demand-driven service provisioning to increase the network capacity and/or to extend the cell coverage area. NNs can be mounted on vehicles, e.g., within a car-sharing fleet, which are rapidly spreading over other cities globally [7]. It is worth noting that the notion of a vehicle may be extended to any kind of mobile facility, such as, a truck, a bus, and other types of vessels, e.g., unmanned aerial vehicle (UAV). Figure 3.a depicts the NN operation along with several advantages and mode transition enabling on-demand activation/deactivation. Accordingly, the 5G infrastructure will not solely be based on the fixed access nodes but will integrate the access nodes on the move like the NNs. The activation and deactivation of such *unplanned* nodes on the move will depend on the requirements of the target service and requested demand in a confined region. NNs are seen as a complementary enhancement to the existing infrastructure of a mobile network operator, which may already operate other types of small cells. The utilization of different types of the access nodes will be based on the needs and conditions of the operator taking into account the TCO of the deployment.

An NN may be associated with some uncertainty with regards to its availability, i.e., an NN may or may not be available in the target service region, for instance, caused by driver behavior. In addition, to attain the aforementioned benefits of NNs, a flexible backhaul shall be employed, where the capacity of the backhaul link can play a crucial role in the E2E user performance. The backhaul of an NN can be realized via a wireless connection, e.g., in-band half-duplex operation, out-band operation, and full-duplex operation. An NN may serve out-vehicle users as well as in-vehicle users. The NNs may be parked along a road or in a parking lot. That is, there can be more than one NN available in a region.

In particular, NN activation and the corresponding process should be carried out in an autonomic manner without additional manual control in order to increase the operation efficiency, which is particularly important given that NNs may operate on vehicles' batteries. In order to increase the operational efficiency of NNs, different modes are described herein for the generic NN operation, see Figure 3.b. When an NN is not actively serving UEs, e.g., outside the target service region, the NN stays at the idle NN mode. During the idle NN mode, the NN may have an active UE mode, where it can communicate with the network and operate as a normal UE, e.g., for getting the target service region maps. When a new NN becomes available, and admitted by the base station (BS), the NN changes its mode from idle NN mode to potential NN mode. When the NN is selected as the serving NN, it will change its status from potential NN mode to active NN mode. Here, the active NN mode defines an NN, which is actively serving as an access node of the network, i.e., an active NN can serve or is serving UEs in its proximity. Similarly, when the NN is not the serving NN but a candidate NN, it will switch its mode from active NN mode to potential NN mode. The transitions may be between any of these modes, e.g., when a serving NN leaves the target service region, it can switch its mode from active NN mode to idle NN mode.

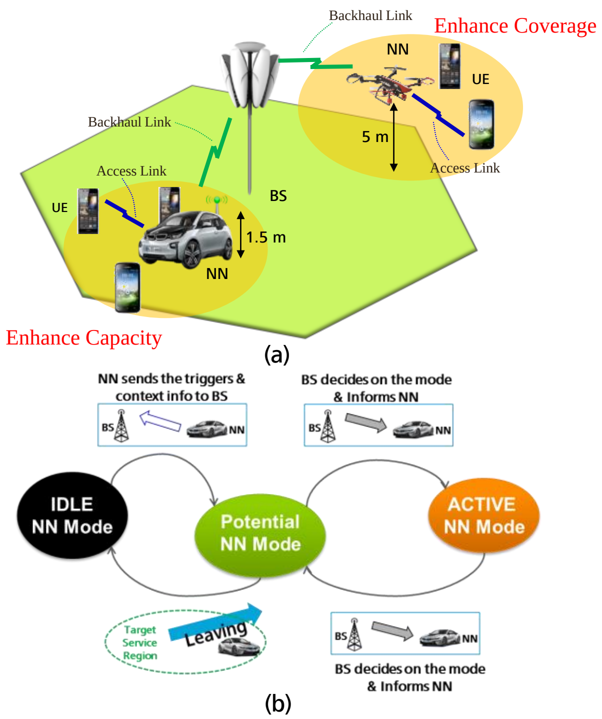

Figure 3 5G use case with unplanned dynamic small cells.

Two different case studies are shown where we have different KPIs (throughput in eMBB vs. reliability in URLLC), which reflect to the resource situation and user allocation in licensed bands. For the first case, the KPI is to enhance throughput; hence we perform Coordinated Scheduling by muting conflicting resources, taking into account a pre-defined energy detection threshold for WiFi-activated access points. The second case is when some users cannot achieve the target reliability in licensed bands (according to the service requirements) and need to enhance it by utilizing in parallel LAA (URLLC). For the latter, together with the NNs in licensed carriers, a set of LAA NNs provide multi-connectivity by parallel redundant links to the user at a reserved (but low) number of Resource Blocks, which can be changed subject to the number of users demanding unlicensed bandwidth for reliability improvement.

For the evaluation, system-level Monte Carlo simulations were performed to evaluate the performance in proposed scenario with different number of activated NNs (1-5) and 25 UEs were randomly dropped in a hotspot area at the edges of the macro BS umbrella. The NNs operate mainly in licensed carriers (3.5GHZ) with full frequency re-use, but they can also operate in unlicensed bands (5GHz band) subject to the access conditions and the activated Wi-Fi access points. Both access node types operate with 20 MHz bandwidth available. Ideal backhaul is assumed for the NN-macro BS links and round robin algorithm is used for scheduling. For the channel models in the simulation scenarios, 3GPP-compliant parameters were used (outdoor LAA scenario 4, in [12]).

For the eMBB case, as illustrated in Fig. 4, when more NNs appear in unlicensed band without coordination, the gains are limited. On the other hand, if coordination is performed (interference coordination by muting at cell edges or multi-connectivity) we can observe huge gains in terms of DL throughput. Here to mention that this figure mainly shows the trend of capacity gains when no interference from WiFi is assumed, within the given scheduling period. Since one of the limitations in LAA is the foreseeable delays due to HARQ, we assume that the re-transmissions are handled by the primary cell (e.g., macro or NN) in licensed carrier.

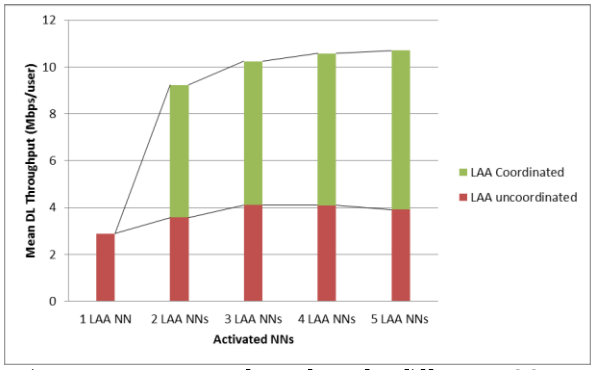

Figure 4 Mean User Throughput for different LAA NN Activations.

In Fig. 5, we also provide the satisfaction ratio (the proportional number of users which achieve 99.999% reliability) for the URLLC case study. Satisfaction in terms of reliability can be measured at the 10^{-5} percentile of cumulative distribution function (CDF) of signal-to-interference-plus-noise ratio (SINR) where the threshold of 0dB is assumed as exemplary target reliability. As can be seen from Fig. 5, when coordinating the LAA operation in a reliability-driven fashion, so to improve the worst case SINR (by allowing multi-connectivity with limited number of reserved resource blocks), the reliability requirement is met and the proportion of users with satisfied KPI increases from 80% to 100%. On the other hand, without coordinated operation, the satisfaction ratio decreases as the number of NNs increases, due to Inter-NN interference.

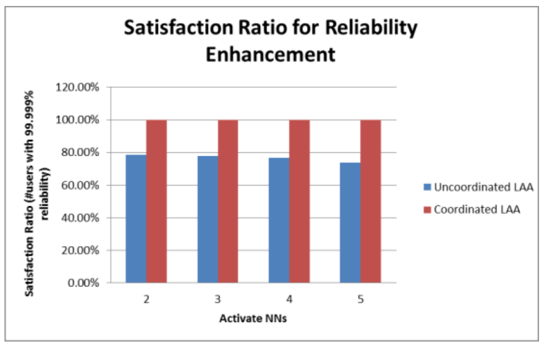

Figure 5 Satisfaction Ratio for Reliability enhancement.

V. CONCLUSIONS

This paper discussed the utilization of unlicensed spectrum as a key enabler for 5G RAN, where multiple services with diverse and conflicting KPIs require additional spectrum to meet their performance requirements. This paper initially presented the challenges and the standardization roadmap in

5G, focusing on the challenges that necessitate the proposal of novel solutions to support LAA in 5G. We proposed, in this direction, a solution to improve the performance in RAN across different slice types and introduced the concept of 5G LAA-as-a-service, which is the service-tailored on-demand operation and configuration of 5G LAA. It was shown that dynamic radio topology coupled with LAA-as-a-Service is a promising and complementary enhancement to 5G UDNs and can offer high performance gains, if coordinated.

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