Using Spectrum Sharing to Deploy 4G/5G Capable Wireless Networks

A Technical Paper prepared for SCTE•ISBE by

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Introduction

The deployment of mobile service should be viewed as an evolution that builds on all spectrum assets, either licensed or unlicensed. Multiple-Systems Operators (MSOs) need to be able to make the best use of the performance characteristics of both 4G LTE and 5G NR technologies across all available spectrum to support their business strategies while maintaining coexistence between all the technologies deployed in the network.

In addition, the MSOs that deploy 4G LTE will need a seamless way to migrate their networks to 5G with minimum disruption to their day-to-day operations and customer experience. Spectrum sharing is one key aspect that must be considered as part of the evolution of mobile networks from LTE to 5G NR, allowing the combination of technologies and spectrum assets, as well as handling both legacy device fleet while 5G NR devices are on the rise.

The key design principles of spectrum sharing are (a) avoid inefficient spectrum utilization when there is low penetration of 5G NR devices (b) maximize LTE and 5G NR downlink peak rates (c) best possible user experience everywhere (d) largest possible 5G NR footprint as well as smooth introduction of 5G NR in an existing 4G network.

This paper shall consider the fact that each spectrum band has different physical properties, meaning there are trade-offs between capacity, coverage, and latency, as well as reliability and spectral efficiency. These trade-offs need to be taken into consideration when planning 5G NR deployments, especially with regards to the MSOs service focus, whether this is enhanced Mobile Broadband, Massive IoT, Critical IoT or Fixed Wireless Access.

Today standards offer a framework of functionalities, for example, dual connectivity between LTE and 5G NR and inter-band carrier aggregation. However, there are additional opportunities for innovation when it comes to mobile spectrum and technology generations which will be examined in this paper.

Understanding Spectrum Trade-off

Each spectrum band has different physical properties, meaning there are trade-offs between capacity, coverage and latency, as well as reliability and spectral efficiency, as illustrated in Figure 1. If the network is optimized for one metric, there could be a trade-off and, in some cases, even degradation of another metric.

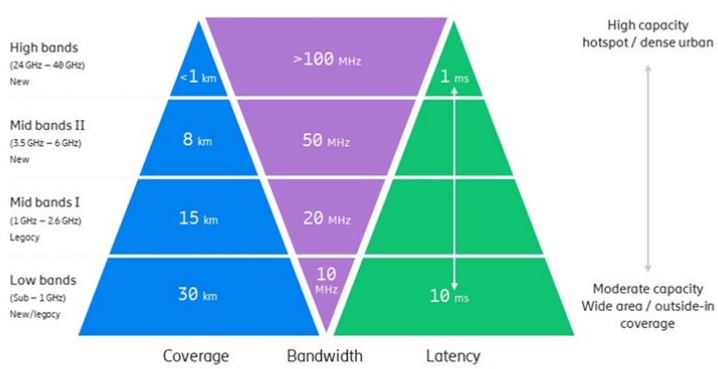

Figure 1: Spectrum trade-offs [1]

Low-band spectrum (below 1 GHz) has historically been used to secure coverage. The licensed bandwidth available is typically between 10 MHz to 30 MHz in United States. This type of spectrum is the most suitable for wide-area and outside-in coverage from macro base stations.

In case of low band spectrum, spectrum sharing will be crucial because of the limited bandwidth available and a must-have wide-area for 5G NR coverage. This approach will be better served during 5G NR sunrise as well as years to come while sustaining LTE legacy coverage and capacity.

There is a first tier of mid-band spectrum below 2.6 GHz. It is currently used for 2G, 3G and 4G services. The licensed bandwidth available is larger than sub 1 GHz, so it is well suited as a capacity layer, network densification – tighter cell site grid.

The next tier of mid-band spectrum has typically been allocated between 3.5 GHz and 6 GHz spectrum bands, e.g. CBRS, LAA. It is likely to see larger bandwidths (50–100 MHz) and considers different arrangements of unlicensed spectrum allocation.

Both mid and high-band spectrum offers an attractive in-building opportunity. Because of the antenna/radio equipment sizing -possible because of the frequency range and impacting size, weight and power considerations- as well as the capacity that it can bring. The leakage of signal (inside-out) could be easier to handle – in comparison to low band.

The latency span - presented in Figure 1 - is indicative and provided for comparison reason. In case of wider frequency bands, one highlight to bring into consideration is that radio networks have a better relationship between latency and performance, i.e. available in high bands. Besides, This is reflected as well by the selection of numerology/sub-carrier spacing - what could be more suitable to the different spectrum options and cell-range.

These trade-offs need to be taken into consideration when planning any network deployment, especially with regard to the MSO's service focus, whether this is Fixed Wireless Access, Enhanced Mobile Broadband, massive IoT and/or critical IoT.

Spectrum Sharing Design Principles

Today's standards offer a reference framework of functionalities as part of 5G Standalone (SA) and Non-Standalone architecture (NSA), for example:

- Dual Connectivity between LTE and NR, in which user plane data can be exchanged between a mobile device and a 5G NR gNB along with the LTE connectivity as an anchor. It offers the lowest time to market as it builds on top of LTE Radio Access and Packet Core.

- NR Carrier Aggregation, enables higher data throughput by aggregating bandwidth of separate carriers to a single devive/user equipment.

- 3GPP Release 16 functionality, like 5G NR Unlicensed, additional NR Inter-band carrier aggregation scenarios.

However, there are additional opportunities for innovation when it comes to mobile spectrum and technology generations, how those interact and how to maximize a scarce resource as in the case of spectrum, either licensed, or unlicensed.

As depicted in

Figure *2* [7], technology adoption and coexistence between LTE and 5G NR is a reality today and is expected to last for the years to come. There could be enablers that can trigger a faster adoption, but even in the best case, LTE and 5G NR coexistence will be expected to last for years to come in both low and mid-band spectrum.

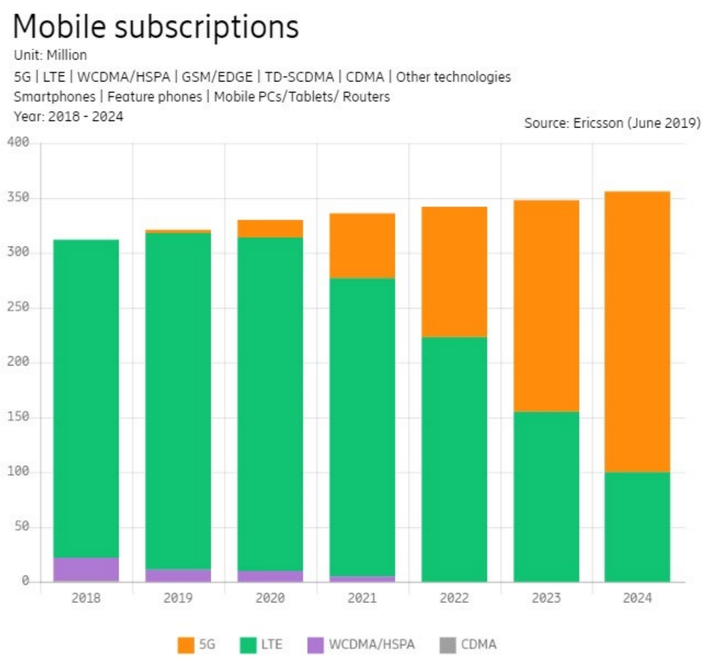

Figure 2: North America mobile subscriptions forecast per technology[7]

This is the preamble to a set of key design principles of spectrum sharing, where both efficiency and ease of deployment will need to be considered, in particular, crucial during the sun-rise of 5G as well as LTE co-existence in years to come. Those key principles are listed below:

(a) Avoid inefficient spectrum utilization when there is low penetration of 5G NR devices.

(b) Maximize LTE and 5G NR downlink peak rates

(c) Best possible user experience everywhere, gather for both legacy LTE and new 5G NR devices

(d) Gain largest possible NR footprint as well as smooth introduction of 5G NR in an existing 4G network

Spectrum re-farming, also known as static allocation, refers to the process of repurposing spectrum from one technology to another, typically governed by specific minimum requirements of a given technology allocation, which requires coordination and planning.

The nature of the static allocation makes it less efficient because it is difficult to size on the early ramp-up of 5G and at the same time service current legacy 4G/LTE user demand. Also, this approach struggles to suit the current needs of both user and new services development when considering a smooth and scalable approach.

Let's assume that it is possible to split the spectrum as per Figure *3*. There will be an impact on both capacity and user peak throughput – losing half of the capabilities at best. All users, both 4G and 5G, will be impacted in terms of capacity and peak user throughput.

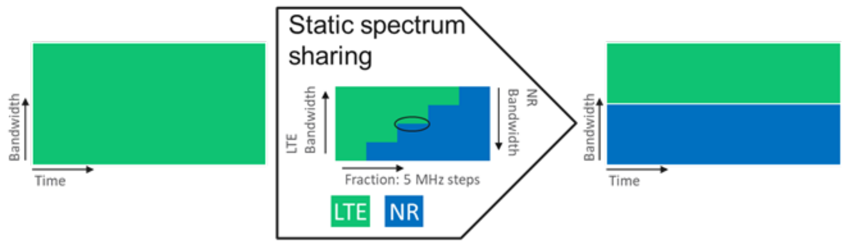

Figure 3: Static Spectrum Sharing Case

Notice that there a limited granularity to how spectrum can be split, i.e. there is likely to be a minimum spectrum allocation per technology and a static set of steps to slice and dice. Therefore, it is possible to change allocation over time, but still, there is a significant trade-off because of the minimum size of granularity that could be allowed.

The side effect of such static allocation will be a compromise over peak rates. It is clear that it is not possible to maximize both LTE and NR rates at the same time. Therefore, it is considered, as a guiding principle, to seek the maximization of the peak rates on both technologies.

Opportunities to Innovate

As outlined by 5G Americas [[5], one opportunity to innovate is from a top-down approach via database-driven dynamic spectrum sharing approach. It will allow flexibility on the assignment across operators – as exemplified by Spectrum Access System (SAS) under CBRS architecture [[6].

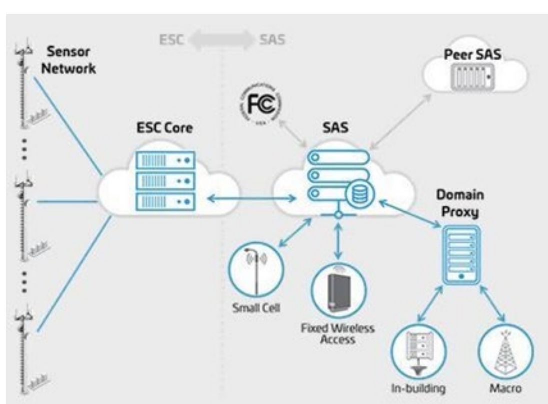

Figure 4: SAS Database-driven top-down approach (Graphic: Business Wire)

There are additional opportunities based on the flexibility of 5G NR, i.e. self-contained transmissions, flexible allocation, blank subcarriers, blank slots; those are some of the building blocks of a bottom-up approach. The idea will be to embed NR signals within the LTE physical layer framework, e.g. resource borrowing in time and spectrum domain. It will open new opportunities for a more dynamic spectrum sharing scheme that can be used instead of a static split of the spectrum; and can fulfil the design principles outlined before.

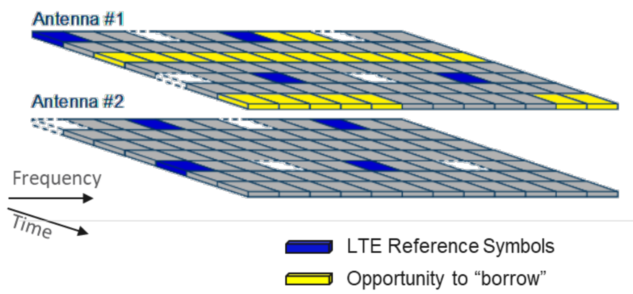

Figure 5: Example of opportunities to borrow resources

In addition, LTE scheduler implementation and efficiency could be equipped to enable a dynamic spectrum sharing schema in sync with NR scheduler. This is illustrated in Figure 5. But it must be noted that those opportunities can increase because of the bursty traffic behavior of mobile networks [[8]. Therefore, it is possible to take advantage of such opportunities to borrow and shared time and domain resources between 5G NR and LTE sharing the same spectrum.

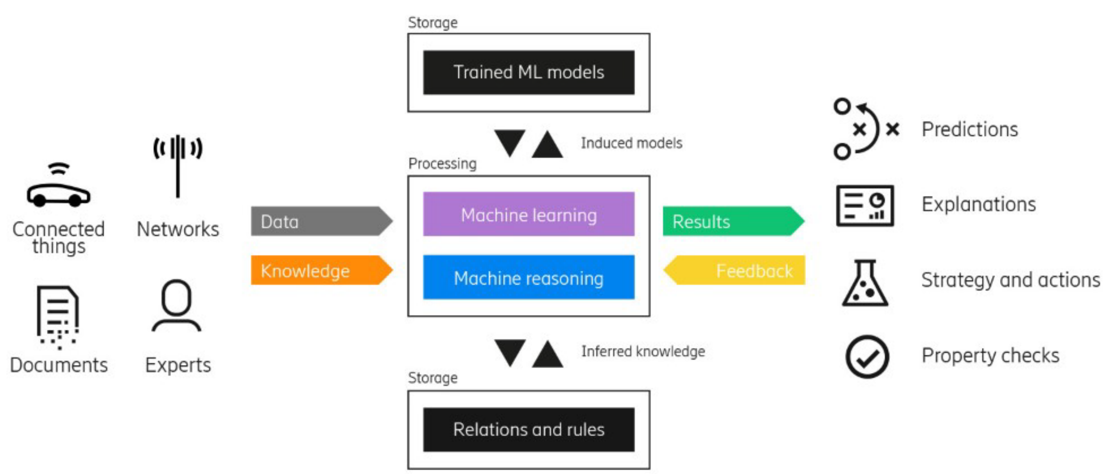

Figure 6: Interplay of machine learning and reasoning procedures in intelligent systems [9]

The logical next step is to utilize Machine Learning (ML) for spectrum sharing to deploy 4G/5G capable wireless networks, as illustrated in Figure 6. This will open the possibilities of making predictions based on trained ML models. Machine learning can help to better define policies on how to handle variety of services and connected devices.

Besides, it will open the door to more complex and adaptable time/frequency domain resource sharing schema between technologies. It can extend to include variability of traffic across a more diverse type of devices/connected things against network resources – well beyond radio resources, e.g. incorporating transport awareness, traffic changes due to unforeseen events.

MSO Deployment Story

Let's take as reference any MSO or Cable operator deploying a LTE network today. This company will benefit from having a tool such as Dynamic Spectrum Sharing that allows using the same spectrum simultaneously between LTE and new 5G NR service.

Figure 7 presents a possible MSO deployment strategy. The introduction of 5G NR may start using Dual Connectivity (EN-DC) and dynamic spectrum sharing in the low band, and later evolved towards Standalone Mode (SA) and leveraging even further NR Carrier Aggregation. In both steps, dynamic spectrum sharing will be a critical function to make sure spectrum usage is maximized given device penetration on each technology.

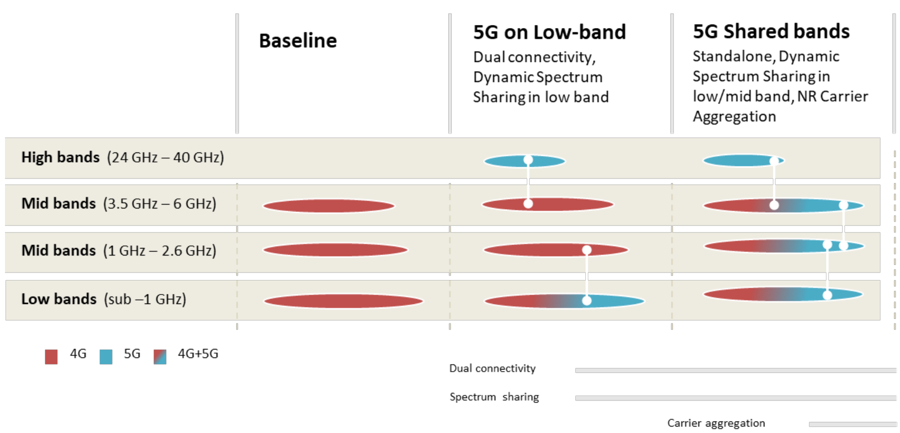

Figure 7: MSO deployment strategy example

Conclusion

Dual Connectivity between 4G and 5G NR will be enhanced by a dynamic spectrum sharing solution. The spectrum sharing solution must evolve to support both NR inter-band carrier aggregation, as well as the future introduction of 5G Standalone (SA) Architecture.

In case of low band spectrum, spectrum sharing will be crucial because of the limited bandwidth, and a must-have wide-area for 5G NR coverage during 5G NR sunrise while sustaining LTE legacy coverage and capacity in the years to come.

Besides, availability and cost of implementing new spectrum bands have a significant impact on where, when and how service providers deploy 5G. However, solutions that enable service providers to start rolling out 5G coverage in the widely available mid and low bands mean they can start offering a 5G experience to as many users as possible, reducing time-to-market of 5G new use cases, and sustain legacy LTE devices.

Abbreviations

3GPP	3rd Generation Partnership Project
4G	Fourth generation cellular network technology
5G	Fifth generation cellular network technology
CBRS	Citizens Broadband Radio Service
EN-DC	E-UTRAN New Radio – Dual Connectivity
IoT	Internet of Things
LTE	Long Term Evolution
ML	Machine Learning
MSOs	Multiple-Systems Operators
NR	New Radio
NSA	Non-Standalone Architecture
SA	Standalone Architecture
SAS	Spectrum Access System

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