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5G DYNAMIC SPECTRUM SHARING (DSS) TO SHARE RESOURCES DYNAMICALLY BETWEEN 4G AND 5G

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Abstract-Dynamic Spectrum Sharing (DSS)facilitates Communication Service Providers (CPSs) to utilise their spectrums and hardware resources dynamically in both LTE 4G and in 5G, in the both time and frequency domains as Shown in fig 1. Implementation of DSS idea need to study in details frame structures, control, synchronizations and traffic channels of 4G-LTE and 5G-NR.The physical layer of 5G designed as 4G of 3GPP where DSS is feasible and has equal subcarrier spacing of time domain. DSS design is backward compatible of all LTE equipment. Telecom service providers (TSPs) thus want to maintain reference signal of LTE cell reference of signal (CSR) transmission. Design of 5G transmission hardware keep similar to LTE CSR, it is called CSR matching of rate. In 5G Demodulation Reference Signal (DMRS), along with Phase tracking Reference Signal (PTRs),Sounding Reference Signal (SRS) and Channel State Information Reference Signal (CSI-RS) is used.
And in LTE-4G Transmission Mode (TM 09) is used to overcome interference between base stations (NodeB) and to maximise signal stability and to improve performance.
Keywords: Dynamic Spectrum Sharing (DSS), Long Term Evolution (LTE), Cell Reference Signal (CRS), 4G, 5G, New Radio (NR), 3GPP.

I. INTRODUCTION

The mobile wireless communication was introduced with the first generation – 1G. It was the voice-only system, initiated in the 1980. However, it has been replaced by the second generation – 2G, when the analog radio signals used by 1G were replaced by digital in the 1990. The main feature of 2G was to provide delivering of the multimedia messages (text and picture messages) at low speed. In the recent time, people started to use the mobile phones in their daily lives and the demand for data services such as internet was increasing. So, there occurred a need for the technology to offer high speed data, which resulted in wireless communication evolving toward the third generation – 3G. Beside the hide speed data transmission, the main characteristics of the 3G were more security, video conferencing, 3D gaming, TV streaming, high bandwidth requirements, and large capabilities and so on. With the technology advancements, the smart devices popularity increasing and wireless communication were evolved toward fourth generation – 4G[1]. This, current generation, offers the same feature as 3G, but also additional such: multimedia newspapers, watching TV programs and faster data transmission.

Dynamic Spectrum Sharing (DSS)now becomes a major part of all mobile telecom service providers of 5G - NR technology. Now cellular base station (eNodeB) of DSS feature will come to the very low total cost of ownership (TCO) to rollout 5G services over spectrum allocated for 4G technology which can enable nationwide coverage of 5G services in very short time span soon after launch. After a simple up gradation of software only, Dynamic Spectrum Sharing (DSS) can be implemented over existing LTE spectrum, and it can operate both 5G New radio and LTE together on same time. The innovation of intelligent scheduler algorithm is solution which is based on optimum result after missing of 4G and 5G hardware in the access networks vary over time span. The developer of 5G develop this 5G NR keeping in mind that it could used to map for 4G LTE transmissions. So we can use available 4G LTE transmission spectrum band for rollout of 5G services without closing 4G LTE. It means that we have option to run 4G and 5G services on available resources making them DSS compatible, makes it easy for operator for transition from 4G to 5G in near future.

II. LITERATUE SURVEY

In this part, we will mention the ideas of the three articles that contain discussion about the next generation of the wireless communication. For instance, Ning Zhang and others, state in their 'Cloud Assisted HetNets Toward 5G Wireless Networks' article that growth in mobile data traffic volume, almost doubles every year from 2010 by now[2]. So, such venture leads forward to requirement for the next, more improved fifth generation in network communication. Also, according to Mamta Agiwal et al, one of the main role of the next generation 5G wireless is right to provide very high data rates. However, they also claim that its role is to provide high capacity, low latency and quality of service (QoS) improvement, compared to today's 4G. In their article 'Next Generation 5G Wireless Networks: A Comprehensive Survey', they offer very detailed discussion about 5G emerging reasons, vision and challenges [3]. 5G technologies and emerging applications are very well explained by Tondare S.M et al, in their journal 'Future of Mobile Communication 5G: Perspectives, Challenges and Services' [4].

III. 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 derive/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[5].

The 5G as well as LTE co-existence to come using DSS technology. 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[6].

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.Shared/unlicensed spectrum is important for 5G and is valuable for wide range of deployments from extreme bandwidth by aggregating spectrum, enhanced local broadband to Internet of Things verticals. 5G New Radio (NR) will nativelysupport all different spectrum types and is designed to take advantage of new sharing paradigms.

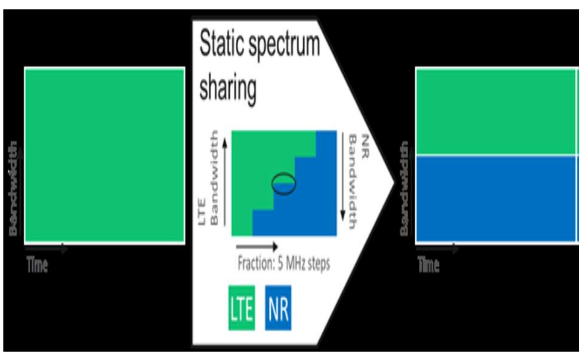

Fig.1: Static Spectrum Sharing
Picture credit – Nokia

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. Existing 4G network and infrastructure will be utilized in first phase of Non-Standalone (NSA) 5G NR rollout. Initially 4G-LTR and 5G NR co-exist using DSS technology. Radio Access Network (RAN) of 4G & 5G connect to existing 4G-LTE core network in NSA. Frequency division duplex (FDD) frequency band of 3.5GHz, will be utilized under TDD in 5G NR network. 5G network will combine all multiple carrier of 4G-LTE as one 5G-NR carrier[7].

What is Proposed 5G spectrum bands?

Dynamic spectrum sharing (DSS) allows operators to use the same spectrum bands for different radio access technologies. In recent quarters, vendors have positioned it primarily as a way to help operators evolve their 4G networks to support 5G in the face of finite spectrum resources. Dynamic Spectrum Sharing (DSS) enables the quick and cost-effective build-out of robust 5G services with broad coverage areas, using existing spectrum in mid- and low-band frequencies. Wireless Service Providers can tap spectrum currently used for 4G to launch nationwide 5G coverage with a simple network software upgrade, and deploy a “5G Ready” network to operate on 4G today, with easy upgrade to 5G without disruption[8].

Actually, the 5G spectrum bands have been categorized in three segments:

(1) Sub-1 GHz frequency (Low-band)

(2) Between 1 to 6 GHz (Mid-Band)

(3) Above 6 GHz (High-Band or millimetre bands).

As per the TRAI, the following frequency bands have been proposed in India:

In October 2016, the TRAI auctioned a 700 MHz, 800 MHz, 900 MHz, 1,800 MHz, 2,100 MHz, 2300 MHz and 2,500 MHz bands. In August 2018, the TRAI proposed a new frequency band ranging 3.3-3.6 GHz (275 MHz spectrum) below mid-band 6 GHz. The presently ISRO used 3.4-3.425 GHz (25 MHz) band as per report of TRAI.

Further, the Govt. may be recommended in future, the following frequency bands which can be used in India about 2020.

(1) 24.25 - 27.5 GHz band

(2) 31.8-33.4 GHz, and

(3) 37-43.5 GHz.

Concerning the frequency bands, they will be same bands as for 4G in addition to the bands in mm-wave. Frequency allocations are determined by the international telecommunication union ITU[9].

Antenna requirement we need to specify the centre frequency and the bandwidth. As the data rate is high about 10GHz and the bandwidth efficiency is 6 assuming 256 QAM. Then the bandwidth required will be about 2GHz. This transmission bandwidth can be realized by a single wide band antenna or multiple smaller bandwidth antennas dividing the bandwidth on them. As the number of antennas increases the bandwidth assigned to every antenna decreases. So, it seems that there are two possible solutions:Ultra wideband antennas with band width greater than 500 MHz or wide band antennas with bandwidth smaller than the above limit.The challenging task is to increase the increase the band width of RF front end feeding the antenna. Dynamic Spectrum Sharing (DSS), it enables mobile telecom operators to share resources of spectrum dynamically to all other technology like 4G and 5G[10]..It depends on mobile service provider’s resource of Spectrum and also main functions can faster rollout of new features of

5G services. Mobile telecom operators can use all types of Radio Access networks to induct new hardware and can use old type access network as well.

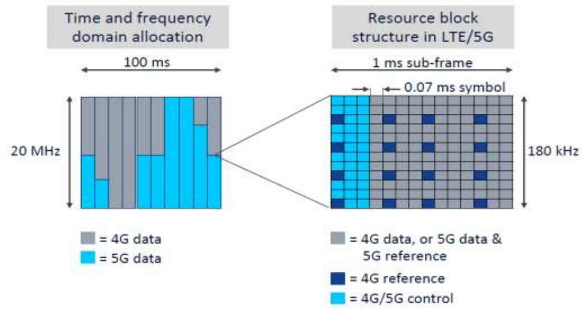

Figure 2: Dynamic Spectrum Sharing in 4G & 5G
Diagram credit – Nokia

It means Dynamic Spectrum Sharing (DSS) can extend life of ongoing access networks hardware. Dynamic Spectrum Sharing (DSS) is more important for Frequency Division Duplex (FDD) bands to start 5G services after transition from 4G technology. 5G Frequency Division Duplex (FDD) supporting devices using Dynamic Spectrum Sharing (DSS). Benefits for implementation of Dynamic Spectrum Sharing (DSS) depends among telecom service operators to operators because of they hold different amount and types of radio resources. Dynamic Spectrum Sharing (DSS) is flexible enough and can be implemented in both higher and lower frequency bands of 3.5 GHz to provide services of 5G[11].. And 5G technology is best suitable to provide services in dense urban area. So Dynamic Spectrum Sharing (DSS) is capable to add capacity in existing 4G services and implement 5G services over 4G resources and networks.

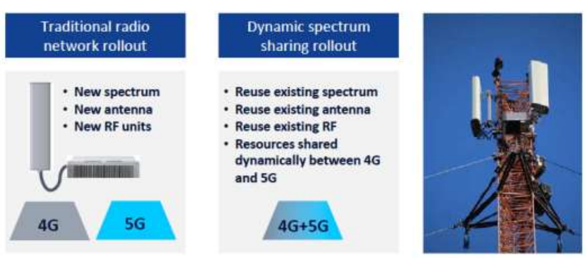

Fig3: Traditional Radio network rollout vs DSS rollout
Picture credit – Nokia

A. 5G Technology Explanation

5G – A Paradigm Shift

It is predicted that the architecture of the new network will be changed. There will be added new technologies to form faster network, which could deliver the rich traffic of multimedia and other data. 5G architecture requirements include advances in Radio Network, Air Interface, Smart Antenna, Cloud RAN and HetNets[12].

1. Radio Network Evolution

The researchers are working on the design of the device centric networking which will move the current Base Station centric network. The 5G network also go forwards using of the higher frequency communication through mm-W signals. However, the propagation of this kind of signal has some limitations for the signal outdoor environment. For example, for high data rate, a line of sight (LOS) communication has better performance over non-line of sight (NLOS). DSS function is based on reference framework of functionalities of 5G as a part of 5G standalone (SA) and 5G Non-Standalone architecture (NSA).The solution is dual-mode modem which will provide the user to switch between more networks. So, mm-wave can be used for data communication, but control and system information can be transmitted using 4G. The narrow beams will improve link quality between BS grids and big number of users, so the 5G radio networking will be different a lot from the legacy networks. Its evolution will also affect the air interface.
Following phased for a smooth 5G rollout[13].

Fig4: 4G/5G Non Stand Alone & Stand Alone with DSS
Picture credit - Qualcomm products

2. Advanced Air Interface

5G network communication provides the change from omni-directional to a directional antenna topology. Frequency reuse for **beamforming** antennas at both transmitter and receiver will be improved by using Spatial Division Multiple access (SDMA). However, there could be a problem to connect every antenna to high rate (A/D) and (D/A). Some possible solutions are the hybrid architecture and integrating analog and digital **beamforming**. Separation of the BS into different areas additionally relaxes the hardware, but it brings other difficulties in synchronization and information transmission. Optimal antenna configurations for various **beamforming** procedures improve execution. Huge BS arrangement and requirement for LOS communication can be facilitated by the partition of uplink and downlink.
Future 5G networks will transmit data through targeted beams and advanced signal processing that could speed up data rates and boost bandwidth[14].

3. Smart Antenna

One of the key successes in 5G network development is an effective antenna array design. It relies on the progress of the air interface change. Smart antenna's role is to help in interference reduction, while in the same time maintain certain area and transmit power reduction of mobile handset and BS. Also, it obtains location information on all subscribers and increases the system capacity. The use of the narrow beams results in more energy transmission at higher frequency. Among other advantages of smart antenna is also that same channel can be used by different beams. It reduces co-interference problem[15]. Even weaker antennas can provide significant capacity gains. That is why the design of the smart antenna is significant for 5G wireless communication. Smart antenna includes subarrays, which are important for beam steering. Those subarrays can be arranged in three different ways: (i) circular, (ii) planar and (iii) segmented. Circular subarray is meaningful for wireless communication, while curvature provides wider beam steering and better directivity of linear configuration. Segmented configurations can also achieve the required dimension of directivity and scan range. The horn antennas have the highest gains among all other antennas since its array provide high power output at BS[16].

4. Centralized Architecture—Cloud RAN

Cloud Radio Access Network (C-RAN) refers to the mobile network architecture that can address a various difficulties the operators face while try to support rising end-user's requirements. Actually, it tries to advance network architecture, mobility, performance, but also to reduce network costs. The significance of the C-RAN lies in solution of the problems related to increasing demands for high data rates. Network industries are focused on network capacity improvements by more cells addition, designing MIMO techniques, adding more complex heterogeneous network structure. Nevertheless, these efforts are interrupted by Capital Expenditure and Operating Expenditure. The important characteristic of C-RAN is that it is based on centralization and virtualization. For example, it is intended for pooling the Baseband Units from more BS into the centralized one for multiplexing purpose. Remote Radio Heads (RRH) is contained from transreciever parts, amplifiers, duplexer digital process, A/D conversions power amplification and filtering. RRH is connected to BBU pool only with single mode fibre of data rate larger than 1 Gbps. Therefore, cloud computing ability can easily manage more complex control processes[17]. Moving the RF to BBUs, results in radio frequencies to be generated in the BBU by itself. All transmissions are done by a mutual cloud-radio over fiber framework. It allows the use of analog RF, which further helps to services and operators to coexist with no major interference. Researchers suggest SDN based virtual networks with the cloud in the role of the backone. It allows the connection of cloud applications with wireless networks through programmable interfaces. Heterogeneous backhaul equipment which integrating the fixed broadband as well as wireless LOS backhaul is suitable as an infrastructure. Therefore, a standardized interface is used for both, designing and optimizing RAN along with backhaul network. RAN as a service (RANs), refers to the centralized cloud platform with both, packaging and delivering options. C-RAN enables shared pool of resources increasing deployment, management and operational efforts[18].

5. Heterogeneous Approach—HetNets

Heterogeneous Networks is composed of large number of small cells with varying transmission power. It refers to the big and vast network with different base stations (BS): macro, pico and femto using those smaller cells with low transmission power. By the setting of low power small BSs, network capacity is advanced and coverage is extended to cover indoor and outdoor. Radio Access Technology can be used to generate unnecessary signalling overhead, suggesting the use of an efficient multi-RAT handover. A large number of frequency algorithms and reuse options improve heterogeneous network performance. Spectral resource arrangement is a potential solution for interference problem. It is proposed that the architecture of the 5G will replace the base station centric and import device centric networks, from small to femto cells which will formthe heterogeneous network[19]. It is believed that heterogeneous connectivity of small cells is the main building block for 5G architecture.

B. PHYSICAL LAYER DESIGN ISSUES

In order to apply 5G architecture over existing wireless systems we need a proper understanding for the physical layer and some of it is concepts like understanding how mm-wave channel works, adaptive Beamforming and Massive MIMO system

1. Understanding mm-wave Wireless Channel

The raise of the mm-wave brings new challenges in the communication systems. The first challenge we face is un-availability of any standard channel model beside that we need to care about the effects and biological safety of this waves. For the technical part we need to do channel characterization looking at 4 different aspects/characteristics which are propagation loss, signal penetration, doppler and multipath[20]. Propagation loss of higher frequencies means prominent loss, where shorter wavelengths and directional transmission of narrow beams makes a higher and better performance of spatial multiplexing and reduces the interference Also, in order to have effective and good system design we need to study mm-wave propagation in different environments.

2. Adaptive Beamforming

In this section we are going to discuss the importance of smart antennas for mm-waves and generally for the integration of 5G networks. Creating and Controlling the Beam: we need a good understanding of mm-waves if we want to focus the energy to wanted direction. We can apply Beamforming in digital, analog or RF forms. comparing digital and analog beamforming we can see that digital preforms better with and higher complexity and cost on the other side we see the analog as an effective and simple method but as not flexible as digital one. Antenna training protocols: it is obvious that the directional antennas are the future of 5G networks and as far as it is good it also brings new problem with it is design, beams are either good aligned and have a connection or beams are not aligned at all and accordantly not connected.

3. Massive MIMO System

Base station is provided by with a very large number of antennas with the help MIMO systems and linear signal processing methods, these antennas are able to send both vertical and horizontal beams. Massive MIMO increases both spectral and energy efficiency. Each antenna is arranged in a way to achieve directivity during transmission. 2D grid configuration and deployment of antenna arrays in massive MIMO systems are suggested. Also, 3D and distributed array structures could be candidate for 5G system[21].

5G Application

5G technologies will make a great impact on future industries of all kinds, such as education, transportation, healthcare, entertainment, etc. In fact, it will make a great global effect to the whole world society that will use benefits from it in every way. But it will also make us more dependable on our mobiles, too. Mobility will become an essential part of our lives without us even noticing, but it will bring us, says predictions, trillions of worth revenues in coming years. These are following:

- D2D Communications
- Internet of Things
- Internet of Vehicles
- Health Care and Wearable
- M2M Communication

Conclusion:

Dual connectivity between LTE-4G and 5G-NR can be realized by Dynamic Spectrum Sharing (DSS) technology. It must support non standalone (NSA) and standalone (SA) 5G-NR which combine spectrum of both LTE-4G and 5G-NR. Low band spectrum which is used by LTE-4G, must be compatible with 5G-NR to get coverage in less dense area. Utilization of DSS will significantly reduce cost of spectrums as well as hardware. And it reduces time to rollout 5G by sharing infrastructure of 4G. And transition from 4G to 5G will be in very smooth manner. All these depends on mobile communication service providers deployment strategy and planning to implement 5G services using 4G infrastructures.Next generation 5G network connection is promising a manifold growing up in data rate, connectivity and QoS. New applications, such are IoT, smart grids and IoV are predicted to be supported by 5G architecture. In this paper, 5G system is summarized. We began the discussion with 5G architecture, which refers to the design of radio network layout, smart antenna air interfaces and cloud and heterogeneous system. Also, we discussed about both, Physical and MAC layers and their improvements. Finally, we explained 5G architecture in details. We hope that this article will be useful as a guideline for the future works in 5G wireless communications.

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