Research and Innovation Action

5G-Enhance

5G Enhanced Mobile Broadband Access Networks in Crowded Environments

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Executive Summary

One of 5G Enhance main objectives is the advanced Spectrum and Network sharing for eMBB in dense areas. The objective of this deliverable is to define the technological roadmap of WP4, which focuses on the development of advanced spectrum and network sharing techniques to be used in dense areas. This document presents the state of the art in sharing technologires as defined by the 3GPP and how this can be enhanced to further advance the sharing technologies for eMBB and in conjunction with micro operators.

Table of Contents

List of Acronyms and Abbreviations

Term	Description
5G	Fifth Generation
ASNRM	Advanced Spectrum and Network Resouce Managemen
LSA	licensed shared access
SAS	spectrum access system
eMBB	Enhanced Mobile Broad Band

List of Definitions

Spectrum and Network Sharing - a technology that enables multiple operators to share same set of radio resources (spectrum) and/or some parts of a network including RAN and/or CN.

1.Introduction

This is the first deliverable of the 5G Enhance WP4: Advanced Spectrum and Network Resouce Management (ASNRM) which handles the mechanisms and technologies required for the sharing of the different resouces between different use cases, including the sharing of the spectrum, base stations and core network.

The role of this deliverable is to define a network sharing architecture, able to provide the basis for the further developments as well as to determine the general technical direction of the research and innovation work within the work package.

As being the first deliverable of the work package, it includes the preliminary work required from the partners in order to bring together the prior knowledge within a common understanding and system. For this, a comprehensive and condensed state of the art in spectrum and network sharing was performed (Section 2). As basis of the 5G-Enhance, the network sharing is considered as the best alternative of deploying parallel use cases on top of high-end equipment to address the stringent requirements of enhanced Mobile Broadband (eMBB) use cases. Three levels of sharing were identified: at spectrum level, at radio access network (RAN) level and at Core Network (CN) / Architectural level. The RAN and the core network sharing are made possible by the sharing of underlying hardware resouces represented by compute, storage and network.

Ads part of the initial state of the art, a comprehensive architecture of spectrum and resource sharing is defined, following the 3GPP 5G architecture (Section 3). This architecture has the role to concentrate the developments within the project towards a common understanding of the partners. Additionally, by comparing it to the standards, it gives the opportunity to underline the missing critical technology elements towards which the rest of this work package will be directed to.

Following the proposed architecture, a set of considerations are made towards its proper deployment within the main use case of this work package: the micro-operator providing eMBB communication (Section 4). These considerations further the architecture on the direction of the interaction with the User Equipment (UE) required as well as on the split of the functionality between the local micro-operator and the central locations.

A new set of requirements derived from the developed architecture are arising, specifically oriented towards handling the split between the local and the remote location and the spectrum allocation (Section 5).

This deliverable concludes with a section which underlines the specific architectural enhancements towars which this work package will work (Section 6), enabling the focusing of the work towards a meaningful direction.

2. State of the art in spectrum and network sharing

This section describes the state of the art in spectrum and network sharing in relation to the 5G system, the eMBB use case and the dense communication environments.

2.1 Motivation for sharing

Spectrum and network sharing are representing a set of technologies that allows several operators to share same spectrum, RAN or CN. In one form or another this technology has been present in 3G and 4G systems since Release 6 of 3GPP specifications [TS 23.251].

The key motivation for network sharing by conventional operators has been reduction of deployment and maintenance cost. Various sharing scenarios are described in [TR 22.951], for example:

- Different CNs share same RAN elements without spectrum sharing, i.e., using different frequencies
- Different CNs share RAN of a third-party operator, where spectrum resources used but different CNs are not separated
- Different operators share same spectrum without sharing RAN or CN
- Different RANs share same CN or some part of it.

Above scenarios could be implemented based on operator needs and available radio regulations.

Compared to 3G and 4G, where one system was designed to enable all intended use cases, 5G system enables diversified deployments, where some parts of the system are designed for specific use cases. Furthermore, due to the specific spectrum and usage regulations, in some regions of the world (e.g. Germany) there is the possibility to deploy private 5G networks within the specific use case location and to share these networks with other private or public operators.

ITU has developed requirements and roadmap towards IMT-2020. These requirements are the result of analyzing various current and potential future applications. It is important to note that not all requirements shall be satisfied simultaneously. Instead, three key groups of use cases could be identified:

- Enhanced mobile broadband (eMBB): focused on supporting high data rate users [TR 22.863]
- Massive machine type communication (mMTC): focused on supporting large number of low data rate users and on energy efficiency of communication [TR 22.861]
- Ultra reliable low latency communication (URLLC): focused on providing high reliability and low delay [TR 22.862].

Especially towards addressing eMBB and URLLC, there is a strong need to have high-end technologies being deployed close to the location of the subscribers in order to be able to provide the extra capacity required as well as the low latency and the reliability of the communication. This extends the current centralized network model, where a uniform operator is deployed across a country, towards a more granular set of deployments, where local micro-operators (which could also be part of a wide area operator) provide enhanced services in a specific location for the specific use case need.

As a result, there could be deployments, including RAN and CN, tailored to a specific group of use cases or even a subgroup within, for example, eMBB and URLLC group of use cases and addressing the specific deployment requirements for example enterprise networks within buildings or public networks in airports or train stations.

In such situation, where there is a need to deploy multiple RANs and/or CNs for different users even at the same geographical area the importance of spectrum and network sharing grows considerably. This is multiplied by the need of high end of the 5G technologies to be able to supply the response to the specific capacity, delay and reliability requirments, ultimately resulting in very high costs. Because of these reasons, network sharing was included in the baseline Release 15 of 5GS System Architecture [TS 23.501].

This also brings the concept of micro operator in play. In this concept a third-party could deploy a system within a localized area tailored to the users in this area. While system could be 5G-based or non-5G-based, it could allow users of public 5G networks to access some services to help realize some of the 5G use cases subject to service agreements between a micro operator and public 5G operators.

For example, instead of deploying dedicated parts of each of several public operators in a specific geographic location (e.g. train station) and inquiring high costs for such deployment and maintainance, private operator network could be deployed and some part of its capacity could be shared with these public operators.

To summarize, motivation for spectrum and network sharing is as follows:
- Reduction of deployment and maintenance cost for public operators by using RAN and CN resources of shared networks
- Creating new business models and opportunities for competition and service level improvements by enabling micro-operator deployment scenarios
- Improving spectrum utilization efficiency by using various spectrum sharing technologies.

2.2 Sharing architectures

Which resources are shared depends on sharing scenarios, operator agreements, and available radio regulations.

In 3G and 4G two basic spectrum and network sharing architectures have been standardized [TS 23.251]:
- Gateway Core Network (GWCN)
- Multi-Operator Core Network (MOCN).

GWCN is shown in Figure 1. In this configuration not only RAN but also some elements of CN are shared.

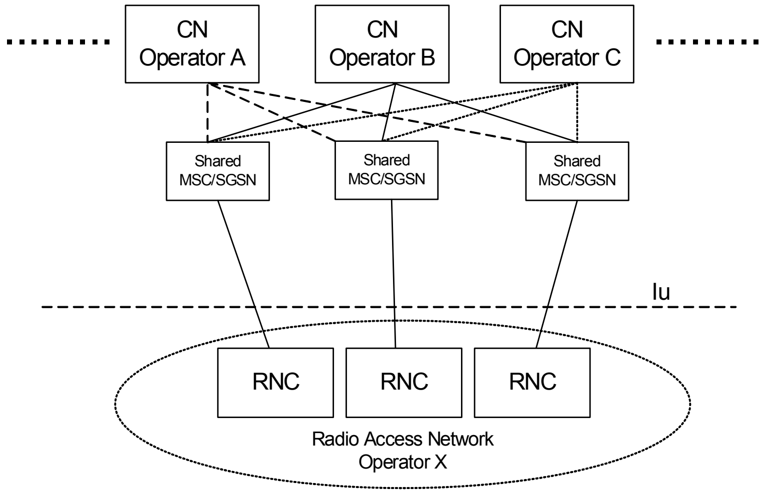

Figure 1 GWCN network sharing configuration [TS 23.251]

MOCN is shown in Figure 2. In this configuration multiple CNs are connected to shared RAN.

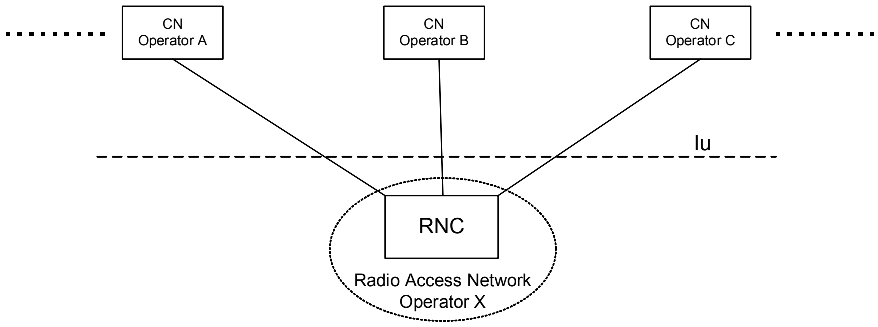

Figure 2 MOCN network sharing configuration [TS 23.251]

In both configurations spectrum could be shared or not depending on how RAN allocates radio resources.

In Release 15 of 5GS only 5G MOCN configuration is specified as shown in Figure 3. In this configuration multiple 5G CNs are connected to the same NG-RAN.

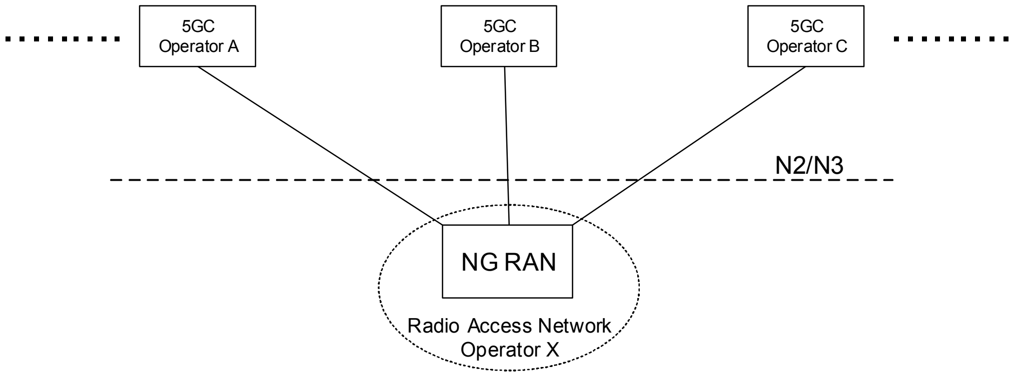

Figure 3 5G MOCN network sharing configuration [TS 23.501]

In all these network sharing architectures PLMN IDs of participating operators are broadcasted within the service area of the shared RAN and an UE can select any of these PLMNs if it has corresponding subscription.

In 5G wireless network, as in any wireless system, spectrum resource is limited and technologies to improve spectrum utilization are important. Spectrum sharing is one of such technologies. Several spectrum sharing approaches, such as LSA (licensed shared access) and SAS (spectrum access system) have been proposed in [Tehrani et al. 2016].
In LSA, spectrum is shared by an incumbent wireless system and another wireless system that is allowed to use this spectrum on a non-interference basis under the specific radio regulations. LSA provides mechanisms for protecting the incumbent spectrum users and introduces additional licensed users in the given band resulting in quality guarantees for both entrant and incumbent systems. It does not currently define how the additional licenses are defined and awarded as this is a national matter decided by the national regulators. The three-tier model for Citizens Broadband Radio Service (CBRS) allows MNOs and other new small scale entrants to operate on local spectrum licenses called Priority Access Licenses (PAL) in specific areas called census tracts where the license holder defines a protection area where its operation has guaranteed quality. Spectrum sharing in the model id implemented via Spectrum Access System (SAS) which is defined by FCC and three tires of spectrum users are specified:

- the first tier is incumbent user,
- the second tier is priority access license (PAL) user and
- the third tier is general authoriezed access (GAA) user which has lower access guarantees than the PAL.

Local spectrum availability is critical for the establishment of micro operator networks which can be accomplished through spectrum sharing. Figure 4 illustrates the high-level architecture from [Matinmikko-Blue et al. 2018] for micro licensing where the regulator defines the sharing rules for local spectrum micro licenses. If there are incumbent spectrum users, they are protected from harmful interference from the micro operators. The micro operator has a network management system with spectrum manager that controls its spectrum access according to spectrum availability information through spectrum repository and co-existence manager. The co-existence manager is a new entity to coordinate between different license holders including incumbents and micro licensees with different levels of spectrum access rights.

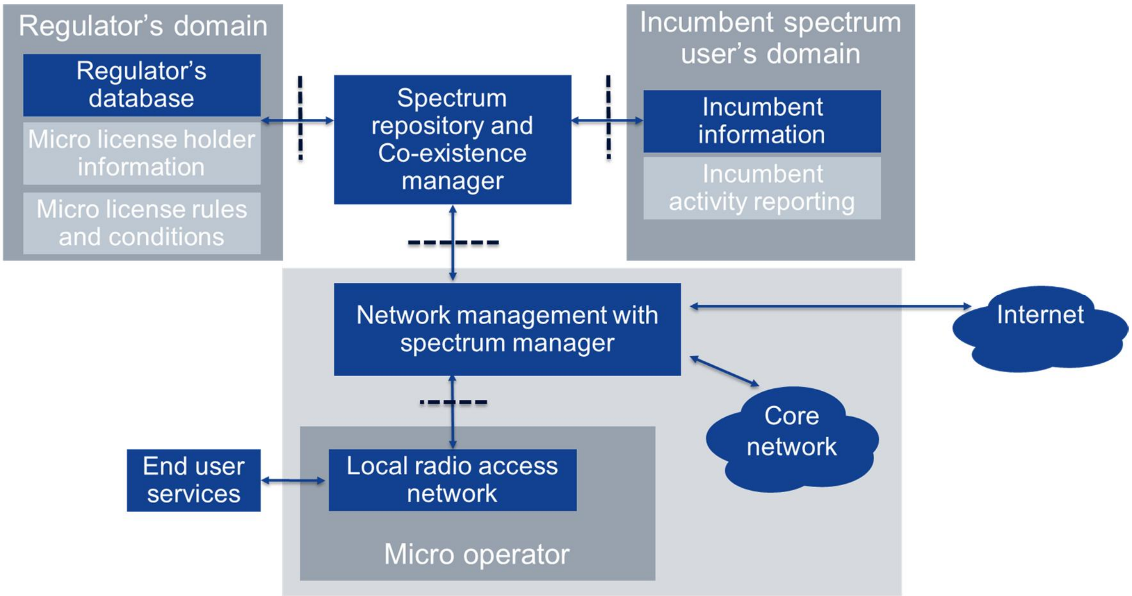

Figure 4 High-level architecture for micro operator concept with micro licensing (modified from [Matinmikko-Blue et al. 2018]).

3.5G system architecture

This section will describe 5G system architecture based on a set of TSs. Description will include Architecture and Functions. Also, new technologies and concepts compared to 4G system will be briefly described here. This is also state of the art as in Section 2. Compared to Section 2, where CN was one block, in Section 3 details of 5G System Architecture are provided. The description will be based on 5G Release 15 that will serve as a baseline to add new features to be developed during this project.

3.1 Architecture and functions

Baseline 5G architecture has been defined by 3GPP in Release 15 and described in [TS 23.501], including procedure description [TS 23.502] and policy framework [TS 23.503]. This 5G System Architecture is shown in Figure 5.

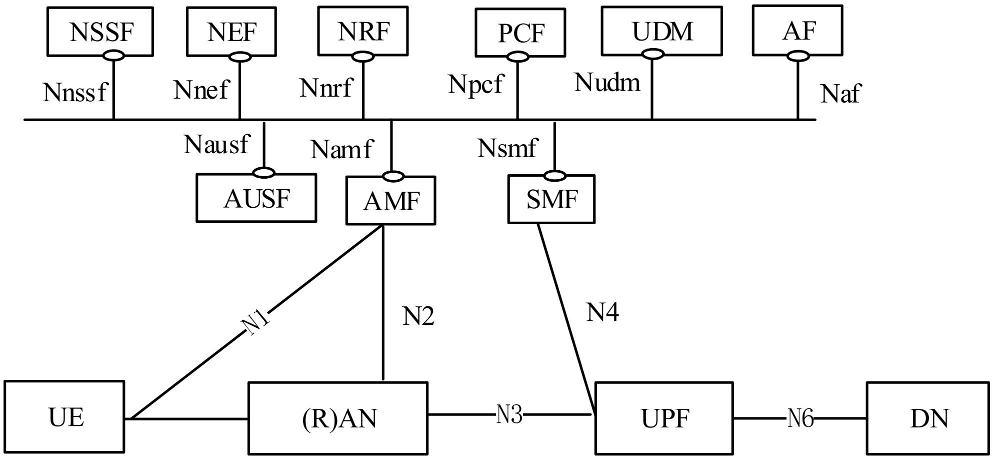

Figure 5 5G System Architecture [TS 23.501]

The 5G System Architecture consists of the following network functions (NF), which are briefly described in this section (for the full information please check the 3GPP specification [TS23.501]

- User Equipment (UE) – an end user terminal able to obtain services from 5G system using RAN.
- (Radio) Access Network ((R)AN) – an access network in a 5G system, typically directly associated with the 5G radio base stations.
- Authentication Server Function (AUSF) – a network function that handles the authentication of UEs.
- Access and Mobility Management Function (AMF) – a network functionthat handles access control and mobility management of the UEs.
- Session Management Function (SMF) – a network function that handles session management.
- Unified Data Management (UDM) – a structured data base including the subscription profile for the UEs.
- NF Repository Function (NRF) – the NRF enables the discovery and the dynamic notifications on the status of the communicating network functions.
- Network Exposure Function (NEF) – a generic exposure function which includes all the control plane APIs available towards the applications.

- Network Slice Selection Function (NSSF) – a network function which enables the selection of a slice of network functions for a particular data flow from an application.
- Policy Control Function (PCF) – a network function making decisions on QoS and charging policies for specific applications.
- Application Function (AF) – a network functions that enables an application to influence how its traffic will be handled (e.g. routed).
- Data Network (DN) – a generic name for the system towards and from which the packet core receives the data from (e.g. the Internet).

Figure 5 shows baseline 5G System Architecture. [TS 23.501] also describes how this system architecture is applied to non-roaming scenario with single and multi-PDU connections, home-routed and local-breakout roaming scenatios, support of non-3GPP access and interworking with EPC.

Detailed description of 5G System Architecture NFs is presented in [TS 23.501], interactions between NFs are described in [TS 23.502] and will be defined is further detailes by 3GPP CT groups, policy and charging framework is defined in [TS 23.503]. Instead of repeating all this information in this deliverable, we highlight what new technologies and concepts are included in 5G System.

3.2 5G technologies and concepts

5G System Architecture enables deployment of such new technologies as Network Function Virtualization and Software Defined Networking. In this section, the new key concepts considered are described.

Some of the key concept used in 5G System Architecture design are:

- Separate the user plane functions from the control plane functions for scalability and flexible deployments, especially towards the data plane
- Modularized function desing to enable customized network functiosn to be designed for the use cases, flexible network function sharing and end-to-end network slicing
- Service-oriented procedures and direct interactions between NFs – based on the web services protocols, enabling the easy scalability of network functions as well as the easy extension of the control plane with new functions
- Minimize dependencies between the access network and the core network – still the base stations need to be bound to an AMF for control plane operations, albeit not anymore requiring a data path binding.
- Support a unified authentication framework – a single authentication framework is included in the AUSF as a separate new network function instead of multiple ones, separated per access technology type, as in the case of 4G
- Support "stateless" NFs, where the "compute" resource is decoupled from the "storage" resource – an unstructured data repository is added to the system, enabling the network functions to store their data in their specific format in a shared environment, thus making them stateless and easy to remove from the system when needed.
- Support capability exposure – through the NEF, the different capabilities of the packet core are grouped and exposed to the applications.
- Support concurrent access to local and centralized services, e. g. edge computing – with the control-data plane separation, a very easy solution for offloading was integrated. Through this, a dedicated data path may be terminated at local Service Hosting nodes which are placed at the edge of the network

Some new features supported by 5G System include:

- Service based architecture – the 5G core network system is based within the control plane on micro-services protocols and services such as HTTP/2, JSON and OpenAPI and follow a REST based communication
- E2E network slicing – multiple core networks can be deployed in parallel and be customized for the different services
- Data storage architecture enabling compute and storage separation – a new data plane was created enabling the distribution of information independent of the core network functions.
- Architectural enablers for virtualized deployment – the network functions were highly reduced in complexity to easy fit to single servers. Additional load balancing mechanisms were added as to enable a very easy deployment and scaling.
- Common N1/N2 for 3GPP and non-3GPP access – a new level of convergence was reached for the non-3GPP accesses which will use the same control plane interfaces for authentication and authorization as well as for mobility management
- Application influence on traffic routing – routing information can be send by the applications to the SMF, through the PCF to enable the routing of the data traffic towards the appropriate Service Hosting Nodes.

4. Micro operator scenario in dense environments providing eMBB

5G is expected to open new roles in the future mobile business ecosystem through the introduction of local 5G operators such as the recent micro operator concept [Matinmikko et al. 2017], [Matinmikko et al. 2018], [Ishizu et al], [Filin et al]. The concept of micro operators aims at boosting local service delivery in 5G through locally deployed small cell networks in specific locations for tailored service delivery. The three basic elements of the micro operator concept include 1) planning and building of local small cell infrastructure; 2) operation and maintenance of the network infrastructure; and 3) provisioning of tailored services within the specific location (Matinmikko et al. 2017). The concept aims to respond to the trends of change in the 5G deployments where location specific vertical services, indoor networks and sharing of infrastructure become increasingly important. Micro operators aim at complementing the traditional mobile network operators' (MNO) offerings in these locations. Regarding its customers, the micro operator can operate a closed network to serve its own human or machine type of customers that are not served by MNOs such as in a factory setting. Alternatively, the micro operator can act as a neutral host for other MNOs by serving their customers in specific high-demand locations. A hybrid is also possible where the micro operator serves both MNOs' customers and its own customers.

Micro operators are built on top of the technical features of dense indoor small cell networks, operation in higher carrier frequencies (such as >3Ghz or even mmWave for increasing the capacity as there is no need for a large coverage), and the opening of network architecture to support multi-tenancy and network slicing for serving multiple serviced providers customers [Matinmikko-Blue et al. 2017]. The deployment of local 5G networks by micro operators requires local spectrum availability which can be achieved through e.g. locally issued spectrum access rights [Matinmikko et al. 2018]. This development would allow the establishment of a large number of local small cell radio access network deployments by different stakeholders such as facility owners to meet the versatile needs of vertical sectors in specific places with quality guarantees. This requires development of techniques for interference coordination between micro operators as well as potential incumbent spectrum users by combining the ideas from both individual and general authorization regimes to allow dynamic adaptation to changing interference conditions and different levels of interference protection.

eMBB is one of the three major usage scenarios for 5G defined by the ITU-R [ITU-R 2015]. eMBB presents new application areas and requirements in addition to existing Mobile Broadband for improved performance and an increasingly seamless user experience. The eMBB usage scenario covers both wide-area coverage and hotspot cases, which have different requirements and deployment models. The hotspot case typically includes high user densities and calls for very high traffic capacity and user data rates, while the requirement for mobility is low. For the wide area coverage case, seamless coverage and medium to high mobility are desired, with much improved user data rate compared to existing data rates but not as high as in the hotspot case [ITU-R 2015]. The minimum technical performance requirements for the eMBB usage scenario defined by the ITU-R in [ITU-R 2017] are considerably higher than for previous generations of mobile communications networks. Considering the KPIs for specifically the eMBB in indoor hotspot case, the minimum requirements for peak data rate are 20 Gb/s in downlink and 10 Gb/s in uplink, peak spectral efficiency 30 bit/s/Hz in downlink and 15 bit/s/Hz in uplink, average spectral efficiency 9 bit/s/Hz in downlink 9 and 6.75 bit/s/Hs in uplink, and area traffic capacity in downlink 10 Mbit/s/m2 [ITU-R 2017]. Meeting these requirements calls for the development of new eMBB techniques as well as new operator models to address the eMBB usage scenario in hotspot case.

3GPP standardization related to micro operator scenario is ongoing within two study items in Release 16:

- FS_ATSSS: Study on Access Traffic Steering, Switch and Splitting support in the 5G system architecture [TR 23.793]
- FS_Vertical_LAN: 5GS Enhanced support of Vertical and LAN Services [TR 23.734].

FS_ATSSS study is considering scenario where micro operator is using non-3GPP RAT, for example: WiFi.
FS_Vertical_LAN considers various deployment scenarios where micro operator is using 5G NR RAT.

Figure 6 shows a micro operator scenario that may benefit from network sharing. Operator A is large area network operator, operator X is local area network operator (for example, inside residential, commercial, or industrial property). F1 is lower frequency allocation, F2 is new higher frequency allocation used for micro cells.
Micro cells of local area operator X may have better coverage inside this specific local area than micro cells of large area operator A. Also, micro cells of local area operator X are capable of supporting one or several sets of QoS requirements tailored for specific classes of applications compared to micro cells of large area operator A (for example, tailored for high data rate or low latency applications).
There are several options to provide a connection to an application for the scenario shown in Figure 6.

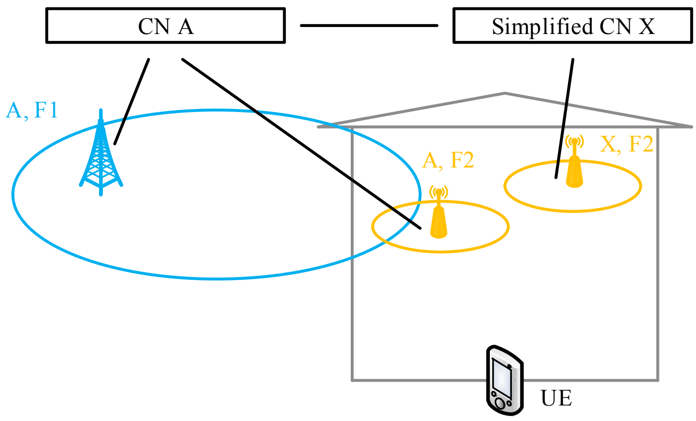

Figure 6 Small cell sharing scenario

One of the options is shown in Figure 7. Solid lines correspond to data, dashed lines correspond to control information. Here, large area operator A macro cell is used for control information. Large area operator A micro cell or local area operator X micro cell is used for data (selection is based, for example, on coverage, required QoS requirements, etc).

Figure 7 Option 1 to provide a connection to an application.

Another option is shown in Figure 8. Solid lines correspond to data, dashed lines correspond to control information. Here, local area operator X micro cell is used for data. Large area operator A macro cell or local area operator X micro cell is used for control information (selection is based, for example, on required CN functionality).

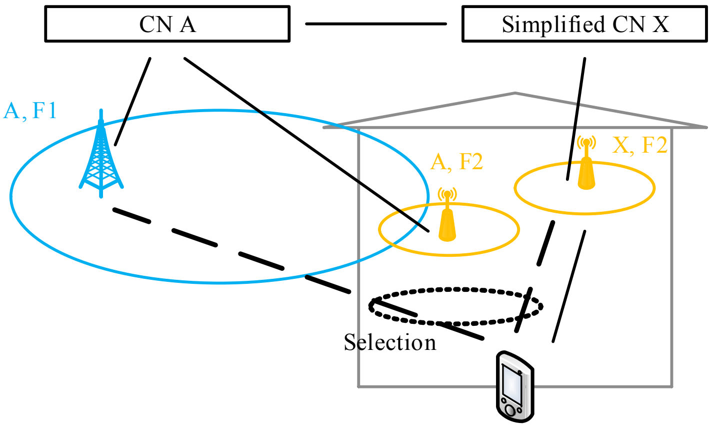

Figure 8 Option 2 to provide a connection to an application.

Also, network sharing technology is one of the ways to increase flexibility and efficiency of spectrum usage. For example, some dedicated spectrum may be assigned to each of the conventional network operators while some part of the spectrum may be assigned to a shared network.

A shared network operator may allocate shared resources to the participating operators based on their planned and current needs and according to service level agreements. This will help to take into account varying spectrum needs of conventional operators.

5. New requirements to realize micro operator scenario (for eMBB)

5.1 Network Sharing (CN) requirements

This section lists requirements to 5G CN in order to realize micro-operator scenario for eMBB in dense environments. It is largerly based on [TR 22.804] and [TR23.734]. These requirements are trying to identify what new features are needed on top of Release 15 5G CN. Requirements in [TR 22.804] and key issues in [TR23.734] are extended in order to better serve the goals of the 5G-Enhance project.

Network service requirements are as follows:

- The 5G system shall support micro-operator networks, as defined in the previous section
- The 5G system shall support micro-operator networks that provide coverage within a specific geographical area.
- The 5G system shall support unique network identifiers for micro-operator networks.
- The 5G system shall support micro-operator networks as tenant-centric network slices with traffic, QoS, and service separation between tenants, e.g., communication services of one tenant do not interfere with communication services from another tenant.
- The 5G system shall support multi-tenancy in a micro-operator network such that there may be restrictions on which resources an individual tenant is allowed to access.
- The 5G system shall support capability to deploy micro-operator network in either licensed or unlicensed bands.

- Subject to an agreement between the operators/service providers, operator policies and the regional or national regulatory requirements, the 5G system shall support mobility between a micro-operator network and a public PLMN.

- The 5G system shall be able to expose a suitable API to provide the information regarding the geographic location of coverage area (e.g radio cell sector coverage) to an authorised 3rd party.
- The 5G system shall be able to expose a suitable API to provide the information about the allocated and free network service resources in the network to an authorised user.
- The 5G system shall be able to expose a suitable API for monitoring the resource utilisation of the network service in a micro-operator network (radio access point and the transport network (front, backhaul) by an authorised 3rd party.
- A micro-operator network shall be able to expose a suitable API to allow an authorised 3rd party to define and reconfigure the properties of offered 5G communication services.
- The 5G system shall be able expose a suitable API for an authorised 3rd party application to negotiate communication service requirements.
- The 3GPP system shall support a suitable API for an authorised 3rd party to provide information about the required transmission QoS desired for different granularity of data transmitted of the 3rd application.
- The 5G system shall be able to expose a suitable API to provide the connectivity status and geographic position of all UEs and their radio access points to an authorised user.

- The 5G system shall support a mechanism for a UE to identify a micro-operator network.
- The 5G system shall support a mechanism to allow a UE to select a micro-operator network that it is authorised to access.

- A UE shall be able to detect the availability of a micro-operator network before attempting to access a cell of this network.

5.2 Spectrum sharing requirements

The main new feature of 5G-Enhance system model is that it supports local micro operator deployments indicating that different stakeholders can deploy local 5G-Enhance networks. The local micro operator may need to share the spectrum with an incumbents, or with between the potentially a large number of other local micro operators. In the following, we present the spectrum sharing related requirements for the 5G-Enhance system:

- The 5G Enhance system shall support both different levels of spectrum access rights ranging from exclusively licensed to unlicensed spectrum bands.
- The 5G Enhance system shall support sub 6GHz band and mm-wave spectrum band for sharing the spectrum among the micro-operator networks.
- The 5G Enhance system shall have the capability of supporting dynamic spectrum demand over a period of time for micro-operator networks.
- The 5G Enhance system shall have the capability to mitigate interference from incumbent's to micro-operator networks (operating both indoor and outdoor).
- The 5G Enhance system shall have the capability to protect incumbents while sharing its spectrum band with the micro-operator networks as defined by the regulators.
- The 5G Enhance system shall support flexible spectrum sharing schemes among micro-operators and incumbents depending on the various parameters gathered by the operators.
- The 5G Enhance system shall allow an intense reuse of the sharing spectrum in dense areas, in order to increase the spectrum utilization.

5.3 Possible technologies/directions to satisfy requirements

Based on the network service requirements listed im Section 5.1 in order to realize network sharing it might be interested to study the following topics within this project.
Network identification for micro-operator networks:

- What information elements are included in the micro-operator network identification, e.g., network operator identifier, type of the network, location information?
- What are the assumption on the uniqueness of the micro-operator network identification?

Network discovery, selection and access control for micro-operator networks:

- Subscription to micro-operator networks.
- How is micro-operator network ID provided to the UE for network discovery and selection?
- Which criteria are used by the UE for selection of micro-operator network?
- What supporting information is provided to the UE for selection of micro-operator network?
- How to perform access control?

Access to PLMN services via micro-operator network:

- How to access public PLMN services via micro-operator network?

- How to access selected micro-operator network services via public PLMN?

For an efficient spectrum sharing, smart spectrum is a key concept. In the spectrum sharing among multiple wireless networks, such as micor operator network, macro operator network, and different type of wireless networks, the spectrum sharing requirements have to be satisfied. In smart spectrum access, there are four key functional technologoies: measurement, database, learning, and spectrum management and they can enhance efficiency of the spectrum sharing.

A spectrum measurement system in smart spectrum is required to be able to perform wide-band, long-term, and wide area spectrum measurement. Implementation cost of the spectrum measurement system is an issue. For this issue, low cost of sensor is desirable. The sensing accuracy is low due to individual sensing ability and physical orientation of each sensor. Therefore a calibration method has to be established. In the measurement based spectrum database, it is required a large numbers of measurement data sets for improving the accuracy of the data in wide support area. Crowd sensing by using mobile terminals like smart phones is one of the solutions for gathering the datasets.

The observed data is stored in spectrum database/data server through the internet and learning algorithms are employed to undertand aspects and characteristics of spectrum usage and extract useful information for efficient spectrum management and spectrum sharing. Multidimensional (time-space-frequency) learning algorithm for spectrum usage modeling and prediction can provide several benefits in the spectrum sharing to achieve the requirements in 5G Enhance. For example, time domain measurement and learning can provie statistical information of spectrum utilization and it is useful to design a proper access scheme for interference mitigation in the spectrum sharing. In addition, this information may be useful to satisfy the dynamic spectrum demand. In addition, multidimensional spectrum usage model can enhance the flexible spectrum sharing schemes.

The smart spectrum management considering spectrum efficiency with satisfying the user demands are the important issue. In this project, the smart spectrum utilization with reliability according to the user demand and with improving the spectrum sharing efficiency among multiple operators by using the extracted information through measurenet, database, and learning process.

- Considering the database architecture for smart spectrum management
- Design of the database based on the spectrum measurement results and spectrum usage models
- Development of spectrum resource management for efficient spectrum sharing and guaranteeing communication reliability

  Development of spectrum management server for allocating and sharing the spectrum for multi-operator scenario

We plan to develop a spectrum manager for spectral management and coexistence of micro operators. Development of various management and coexistence mechanisms tailored to enable high-spectral efficiency and to avoid energy-wasteful interference between operators, will be addressed.

6. 5G Architecture and functional enhancements for micro operator support of eMBB

This Section presents the primelary architecture of the 5G Enahnce stem that will be refined later in the project if needed.

6.1 Spectrum Sharing

Figure 9 illustrate an architecture of spectrum sharing based on the smart spectrum concept. Efficiency, flexibility, and scalability of the spectrum sharing can be enhanced by the four key technologies of the smart spectrum concept and the four key technologies are measurement, database, learning, and spectrum management. Wireless networks A, B can be either macro operator based wireless network or micro operator based wireless network. The learning can provide useful information based on the measurement results to spectrum resounce manager and the network performances can be enhanced to achieve the requirements.

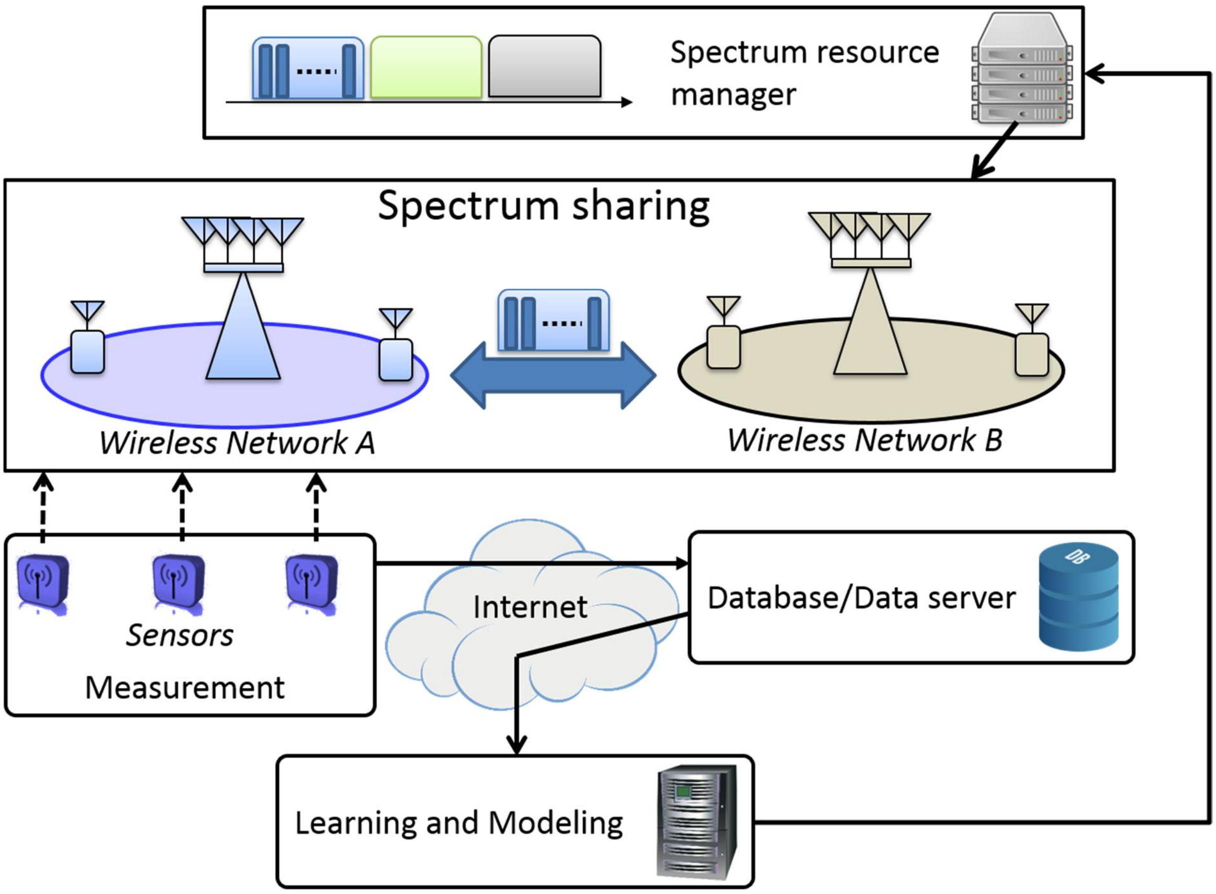

Figure 9: Architecture of spectrum sharing based on the smart spectrum concept

6.2 Network Sharing

Figure 10 illustrates new functional enhancements that would be enabled by micro operator scenario to realize eMBB use cases.

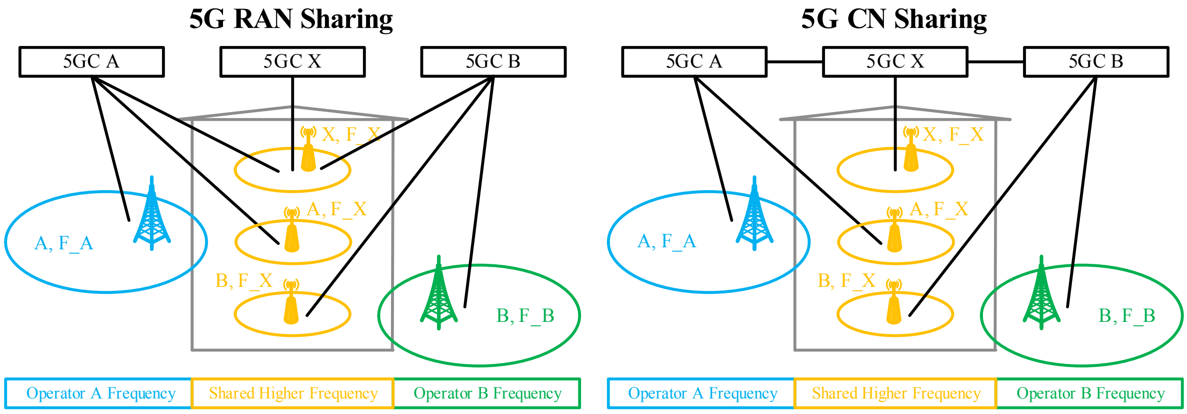

Figure 10 Function enhancements for micro operator support for eMBB.

Using RAN sharing and/or CN sharing users from public PLMNs could have access to services provided by a micro-operator network in localized geographic areas. In addition to network sharing, spectrum sharing between public PLMNs and micro-operator network could be possible in specific frequency bands subject to national and international radio regulations.

Figure 11 shows an example system architecture to implement micro-operator scenario using network sharing technology.

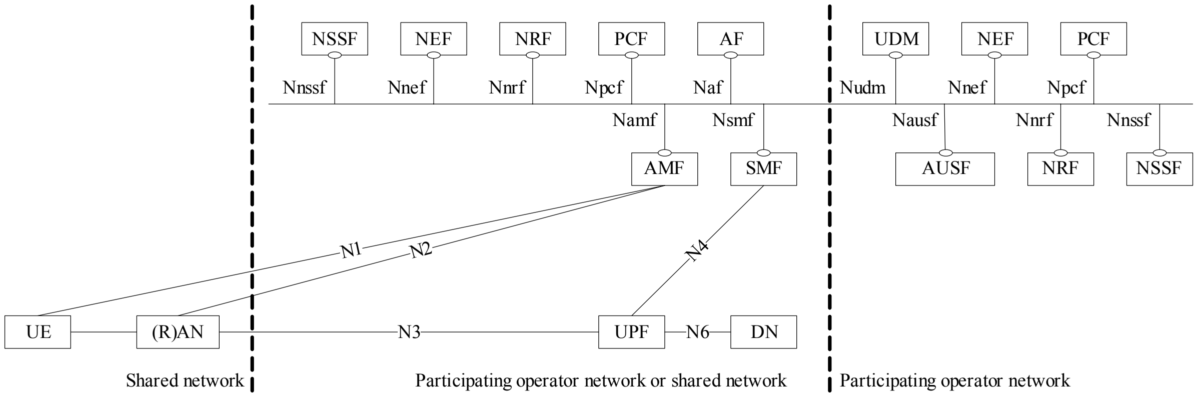

Figure 11 System architecture to implement micro-operator scenario using network sharing technology.

The left side of Figure 11 shows the minimum set of functions provided by a shared network. If only this set of functions is shared, this corresponds to RAN sharing. The right side of Figure 11 shows the minimum set of functions provided by a public PLMN. The middle part corresponds to CN sharing. How they are split between a public PLMN and a shared micro-operator network is flexible and depends on particular deployment.

How the architecture in Figure 11 could be enhanced and how it may need to be modified to support vertical service and access traffic steering, switch and splitting would be studied within this project.

7. Summary

In this deliverable, the basis for the further development of the Advanced Spectrum and Network Resouce Management (ASNRM) solution addressing the needs of dense urban areas. In particular a micro-opertor scenario based on spectrum and network sharing technologies is considered within 5G Enhance project.

Motivation for sharing could be briefly summarized as follows:

- Reduction of deployment and maintenance cost for public operators by using RAN and CN resources of shared networks
- Creating new business models and opportunities for competition and service level improvements by enabling micro-operator deployment scenarios
- Improving spectrum utilization efficiency by using various spectrum sharing technologies.

In this project the current 4G and Release 15 5G systems are taken as the baseline. On top of them new service and functional requirements are formulated to realize spectrum sharing and micro-operator scenario.

Based on the requirements several directions and technologies are selected that will be focus for R&D within 5G Enhance project leading to other deliverables and demonstrations.
Also, draft system architecture is proposed that will be futher improved within the duration of the project.

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