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Scenarios for 5G Networks

The COHERENT Approach

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***Abstract*—Efficient coordination among network elements and optimal resource utilization in heterogeneous mobile networks (HMNs) is a key factor for the success of future 5G systems. The COHERENT project focuses on developing an innovative programmable control and coordination framework which is aware of the underlying network topology, radio environment and traffic conditions, and can efficiently coordinate available spectrum resources. In this paper, we provide a set of scenarios and use cases that the COHERENT project intends to address.**

Keywords— 5G scenarios; 5G use cases; software defined networking; COHERENT project

I. Introduction

Mobile networks have evolved towards heterogeneous networks, with multi-radio access technology (RAT), densified multi-layer cell deployment, flexible spectrum access, elastic capacity and high energy efficiency. The traditional cell concept in future mobile networks will disappear as wireless network resources have to be utilized harmonically in the same area by different network entities. Therefore, we need innovations to deal with the control and coordination problem in large-scale HMNs so we can release the full potential of 5G networks, to fulfil the 5G Key Performance Indicators (KPIs). The key enabler to achieve such goal lies in the careful separation of control and data plane in 5G radio access networks (RANs).

The COHERENT project [1] intends to build upon advanced network abstractions concepts in order to enable an efficient and scalable solution for network-wide coordination in HMNs. The main concept proposed by the project is illustrated in Fig. 1. In particular, it aims to design, develop and showcase a novel control framework for 5G heterogeneous radio networks, which leverages the proper abstraction of physical and MAC layer in the network and a novel programmable control framework, to offer operators a powerful means to dynamically and efficiently control wireless network resources, and thus significantly improve capacity, spectrum reuse efficiency, energy efficiency and user experience in their increasing complex HMNs.

In this paper, we present a set of scenarios[1] and use cases[2] that are of COHERENT's interest. Four scenarios are considered, namely 1) *network cooperation*, 2) *spectrum management*, 3) *critical communications* and 4) *network slicing*. We describe these scenarios in the following sections. Section II is about network cooperation. In particular, we focus on *RAN sharing and WiFi-based infrastructure sharing among HMN*. Section III is about spectrum management, where we present a use case for *flexible spectrum access*, as well as a use case for *distributed antenna system in small cell deployments*. Section IV focuses on critical communications, including use cases of *coordination within mesh networks*, *resource sharing for broadband private mobile radio (PMR) networks*, as well as *coverage extension and support of device-to-device (D2D) communications*. Section V is related to *network slicing*. In the network slicing scenario, we present four use cases related to *PMR services offered by a mobile virtual network operator (MVNO)*, *public safety applications using evolved Multimedia Broadcast Multicast Service (eMBMS)*, as well as *service differentiation* (in terms of user grouping and offering different service types). Finally, Section VI provides a brief overview of proposed scenarios and use cases for 5G so far.

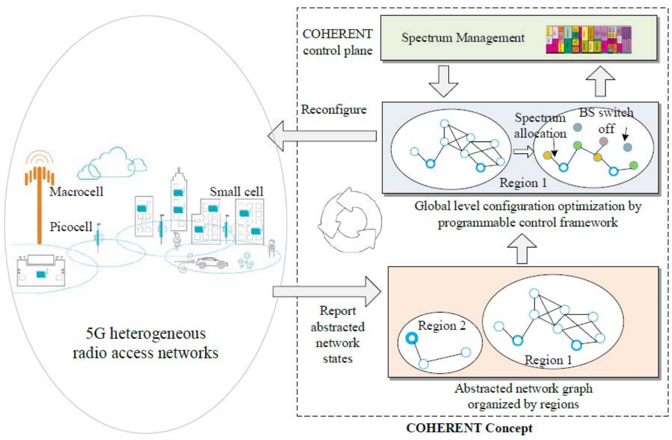

Fig. 1. Illustration of COHERENT concept

II. Network Cooperation and Interoperability

Commercial aspects of operations in heterogeneous environment drive the operators' need to look for solutions which allow them to share their resources. Sharing can be applied to various elements of network deployment and various

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[1] *Scenario* is a wide application area, which may include multiple use cases.

[2] *Use case* is referred to a specific application paradigm.

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technologies. The controller or coordinator, which can be located in the cloud, is responsible to coordinate all the available sharing schemes and provide control signaling for sharing in the HMN.

A. RAN sharing

The RAN sharing concept aims to allow the MVNOs to dynamically use available mobile radio resources or/and infrastructures in the network which belong to other Mobile Network Operators (MNOs). This sharing scheme can reduce the costs of the MNOs. These expenditure reductions result from the sharing of available infrastructures or/and radio resources among different MNOs. For the infrastructure sharing case, there are further two main types of sharing: *distributed RAN (D-RAN)* sharing and *cloud-RAN (C-RAN)* sharing. For D-RAN sharing case, the legacy RAN infrastructures or/and a part of the core network are shared among different operators, e.g., Multi-operator Core Network (MOCN) and Gateway Core Network (GWCN) architectures in 3GPP definition. As for C-RAN case, the shared eNodeB can be further reduced into simple Remote Radio Head (RRH) which only contains RF elements and the baseband functions, which are moved to general purpose processors (GPP) in the cloud, are shared among different operators. These shared GPP resources are also called the base band unit (BBU) pool. Then the statistical multiplexing and traffic load variation of all eNodeBs of different operators can be fully exploited, which further reduces the capital expenditure (CAPEX).

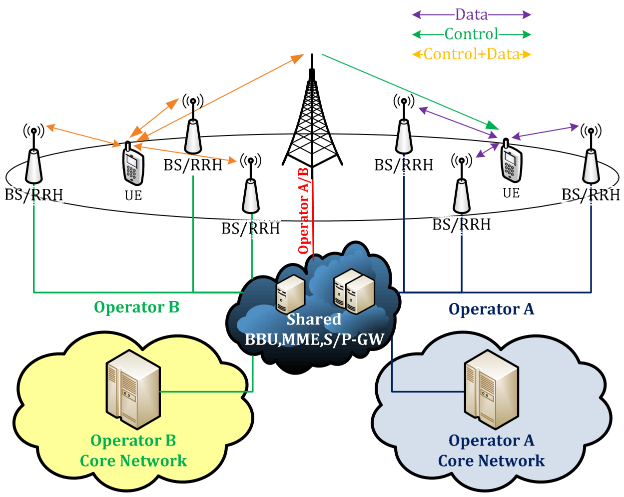

Fig. 2. RAN-sharing among HMN, including legacy cellular networks and C-RAN. Operator B adopts traditional RAN implementation, while Operator A employs SDN-enaled control scheme.

In Fig. 2, different infrastructure sharing schemes are depicted. First of all, in D-RAN infrastructure sharing, the macro base stations (BSs), Mobility Management Entity (MME), gateway (GW) are shared between two operators. Moreover, if the micro BSs are further replaced with simple RRHs, the BBU pool on the cloud can be shared among different operators so the C-RAN sharing is applied. Furthermore, software defined networking (SDN) concept can be applied to separate the control plane and data plane. In this case, operator B applies the classical implementation of RAN, while operator A allocates the data plane on micro BS/RRH and control plane signaling on the macro BS. The separation of control and data planes enables an easier control of the resources sharing. Efficient RAN sharing of both radio and infrastructure is able to guarantee performances and QoS.

B. RAT sharing

Technology sharing may be implemented in many forms ranging from passive sharing of BS sites and masts to sharing of core equipment. In general we consider supporting radio access technology (RAT) sharing as complementary concept to RAN sharing, since it is focused on sharing of supporting technologies which traditionally may even not belong to the network of an MNO. This use case focuses on sharing the core and access network of different RATs, e.g., WiFi. In Fig. 3, the cable operators can share the common core network entities with the legacy MNO using different RAT (e.g., cable modems equipped with WiFi transceivers). This sharing can reduce the cost on the core network entities for both MNO and cable modem operator. Besides, it can further extend the original MNO’s coverage via introducing extra WiFi hotspots.

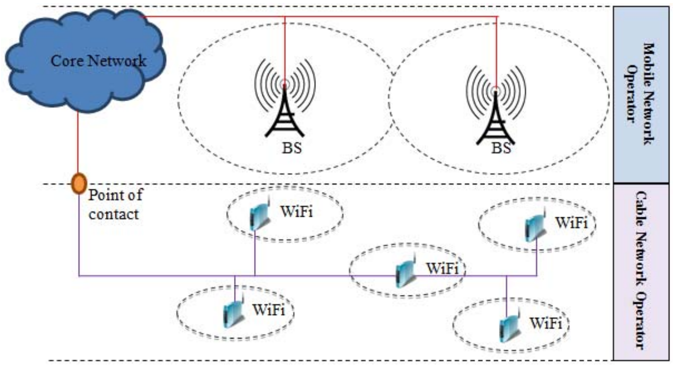

Fig. 3. RAT sharing (traditional cellular networks and WiFi networks) between MNOs and cable network operators.

III. Spectrum Management

Spectrum management in general is a process which aims to achieve efficient use of available frequencies. Traditionally this process has been regulated countrywide by a designated regulatory body, which allows for periodic resource allocation in a form of a license based on technical compatibility and formal aspects. However, such a periodic allocation is usually provided for several years and often does not assure optimal solution for general public interest. This section focuses on use cases that aim for more efficient operation over the scarce spectrum and undermine exclusive spectrum licensing, thus allowing for more efficient collaborative approach.

A. Flexible spectrum access

In dense urban areas, mobile traffic volume in a region may undergo dynamically changes during the day because of rush hours or some special events happen in that region. When the traffic demand in a region is extremely high so that more spectrum is required to provide extra capacity, the mobile broadband networks shall have the flexibility to temporarily provide more spectrum in the region, in order to guarantee users' quality of experience (QoE). The extra spectrum can be obtained through various means, e.g. utilization of higher frequency bands (such as mm-waves), intra-operator spectrum reallocation including flexible duplexing, inter-operator spectrum sharing, application of such solutions as Licensed Shared Access (LSA) from incumbent spectrum owners or Spectrum Access Systems (SAS).

Efficient application of such a scheme will be possible only when the MNO possesses enough spectrum opportunities to guarantee reliable backhaul and fronthaul connection, depending on the operator's network infrastructure. The ability of flexible, yet precise spectrum control and management also in the context of x-haul (combination of backhaul and fronthaul) is important to ensure realization of the Service Level Agreements (SLA) to the operator's clients.

Furthermore, although much research effort is and will be put on harmonization of spectrum usage, it is the national regulator who defines the detailed rules of spectrum usage in a given region. Moreover, special spectrum usage templates can be defined due to the realization of, e.g., specific mass event (such as visit of a VIP or organization of the mass sport contests), where many mobile users will request for high-quality up-link broadband services, which may be provided while using the downlink FDD frequency channel.

Finally, the operator can consider application of advanced utilization of unlicensed bands for, e.g., traffic offloading for non-3GPP networks in order to realize the committed SLAs. Clearly, such offloading can be done for either capacity or coverage, allowing user-centric service delivery. This opportunity can be observed in the so-called License Assisted Access (LAA) approaches.

The presence of the sophisticated spectrum management and control framework can be a good candidate for 5G networks supporting flexible and effective mobile broadband access schemes. The new schemes for flexible spectrum access, which support the ability to setup user-centric service delivery, are relevant to a number of vertical use cases.

B. Distributed antenna system in dense small cell deployments

The operators have started widely deployment of small cells at traffic hotspots to expand network capacity and align with exponentially growing traffic demand. It has resulted in high network densification in dense urban areas (e.g. shopping malls, airports, stadiums of urban networks), where inter-cell distances could be less than 100 meters. With decreasing cell sizes at traffic hotspots, the number of cell-edge areas increases dramatically. As the users move throughout hot-spot areas covered by multiple BSs, they will be always located at cell-edge at some moments and experience performance degradation due to high interference. Mobile operators are looking for efficient densification techniques while the users are looking for consistent service in hot spot areas.

IV. Critical Communications

Private Mobile Radio (PMR) systems cover a wide variety of applications for industrial companies, governmental institutions, transportation companies, security forces. A large part of Public Protection and Disaster Relief (PPDR) services are currently identified as emerging services for 5G [2]. 5G has the ambition of providing flexible systems in which different services with diverging requirements can be supported in its unique framework. This result is not obtained by a monolithic networking and radio access system performing everything, but by using an efficient management and coordination of the most adapted technical solutions to fulfill the requested performance. The integration of PMR systems in the 5G system should bring important advantages such as, for example, better interoperability and coordination with civilian networks and with the emerging services related to connected objects, but also reduced costs.

A. Coordination of rapidly deployable mesh networks

In case of natural disasters, civilian networks but also PMR networks or Essential Service Operator (ESO) networks for PPDR applications may be completely destroyed or severely damaged. 5G systems should be able to provide communications even in those cases [2], [3]. Consideration on critical services, minimal energy consumption, fast system / network recovery, fast solution deployment, and location of survivals are primordial. Another important point is the transition of the wireless communications services from the moment just after the disaster, up to the moment in which normal operation of the wireless communication systems is re-established. Beside satellite and ad-hoc communications established among user terminals, another way to re-establish a network on a damaged area is to deploy wireless PMR mesh networks. Since the deployment is not done according to a well-studied deployment plan and the network must support mobility of its nodes, the communication technology should work also on possibly unstable network topologies.

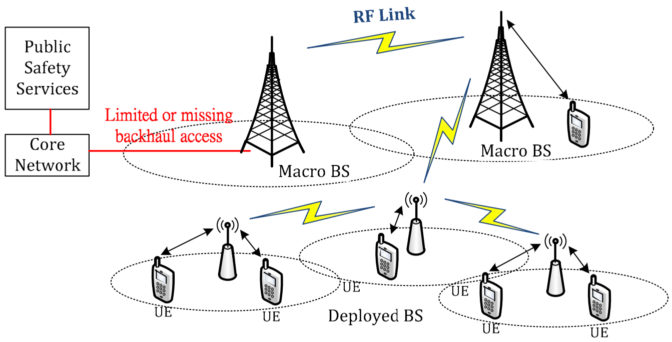

Fig. 4. Coordination with rapidly deployable mesh networks

Rapidly deployable wireless mesh networks will operate on the same spectrum as the pre-existing PMR systems which may be completely down, or which may have kept minimal capabilities in certain areas. For example, certain BSs with independent energy supply may see that the system is out of order or that there is a malfunction of any kind and may decide (according to predefined policies) to work as isolated cells and to, therefore, adapt network topology accordingly

(Fig. 4). The rapidly deployable wireless mesh network shall coexist or even coordinate with the rest of the system, if it is still partly operational. Moreover, the global management should allow smooth coordination during all the phases in which the previous communication system is reestablished to its full capacity.

Another use case similar to the natural disaster is when a backhaul link is in failure due to a faulty equipment or power outage or physical damages on the backhaul, etc. In that case the core network may not be fully accessible to the BSs and hence they can try to establish a wireless backhaul. In this case, in order to keep on the service running, network resiliency is fundamental.

B. Flexible resource sharing for broadband PMR networks

Several institutions, such as National police and fire fighters, have their own PMR networks (e.g. legacy PMR networks and/or broadband PMR networks based on LTE). These PMR networks will probably work at least on dedicated spectrum. Besides public safety forces, Essential Service Operators (ESO) play a fundamental role in a country. They consist in transportation companies (railways, airports, metros, etc.), energy production plants, energy distribution companies, water production and distribution companies, etc. Therefore, providing secure communications to ESO is important as for classic PMR network systems.

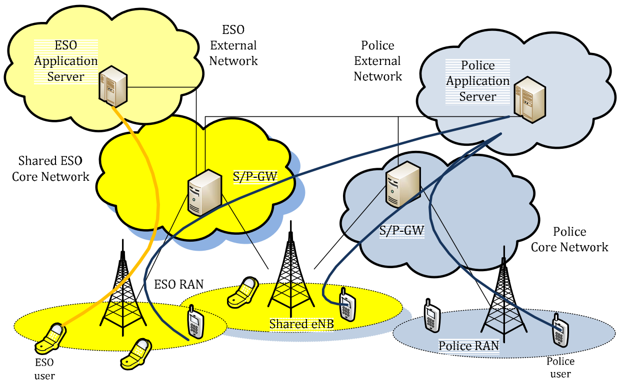

Fig. 5. Flexible resource sharing in PMR networks

A possible use case could be a crisis scenario in which there is a terrorist attack or other major threat in a metro station or near an energy plant (Fig. 5). A large number of police officers, medical staff, and fire fighters converge to the location. Communication needs of police officers and fire fighters in the area increase quickly, as a result of the high number of users and of the services required, e.g., detailed real-time video transmission. In order to cover those needs, additional communication resources are required by the PMR police network because, for instance, it has no coverage in the requested area (e.g. underground or metro station), or because there is a coverage but with a limited number of frequency channels (e.g. rural area for energy plant). In those cases the 5G PMR network can redistribute resources to police forces in a minimum required time, while preserving the requested QoS and priority policies of the legacy communications. The result is that policemen transparently use the resources of the ESO PMR network and a higher number of services can be supported with the right level of security and QoS.

C. Coverage extension for supporting D2D communications

Legacy PMR standards like TETRA allow communications out of coverage of the fixed cell-based infrastructure. This feature is currently not completely supported by current 4G systems, even if Proximity Services (ProSe) has been introduced in Rel-13 of [5], standardization efforts have already been initiated for Rel-12.

There are mainly two ways in which legacy PMR systems achieve communications out of coverage of fixed infrastructure. The first one is to support direct communications between mobile users, which is called Direct Mode Operation (DMO) in TETRA. In LTE, D2D communication, called also sidelink communications in the standard, out-of-coverage can support this mode, at least for data transmission. The second way to extend coverage is to use a user equipment (UE) as a relay. Both options are at least in part standardized in 3GPP, but are far to be deployed.

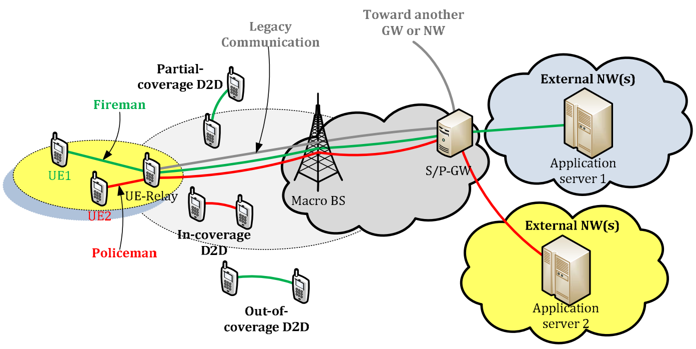

Fig. 6. Coverage extension and support of communications without coverage

For civilian use, out-of-coverage D2D communications or UE relay mode face some barriers, related to the difficulty for the operator to control the data flows in order to charge the spectrum use and to control QoS (Fig. 6). Of course, privacy and security issues also exist. For PMR use, the barriers to the adoption of out-of-coverage D2D communications are completely different. The LTE standard is introducing the good features, but the support from manufacturer is not guaranteed in short time since the PMR market is smaller than the one for consumer services. Hence it is expected that voice services will still be supported by legacy PMR systems, while data communications will progressively switch to LTE based broadband PMR systems. The management of the two systems will be a challenge.

V. NETWORK SLICING

A network slice is composed of a collection of logical network functions that support a particular network service. It enables parallel networks to be set dynamically lowering the entrance barrier for new MVNOs and OTTs while at the same time ensuring minimal disruption to subscribers. Moreover, traditional operators can tap into new revenue streams by providing value added services such as content caching directly in the RAN or location based services.

A. Enhanced MVNO for PMR services

A PMR network (e.g. the one of an ESO or other actors like police, fire brigade, etc.) could be operated by an MVNO over the network of a traditional civilian MNO (Fig. 7). The PMR network should be deployed over one or many network slices. The PMR network shall be isolated from the rest of the mobile network not only in terms of network services, but also from the security perspective (resistance to cyber-attacks included) and network performance. PMR specific services, such as Push-To-Talk (PTT) group call applications, dispatcher operation etc. shall be provided to the user or there must be the possibility to jointly manage already existing legacy PMR systems (for instance based on TETRA) and new PMR systems. In other words, an MNO should be able to provide to the PMR network operated by MVNO the same services as for a legacy PMR system. The PMR network may have different needs according to the geographical area and the operational situation. For instance, in case of crisis, resources shall be allocated in order to satisfy the requested services according to their priorities. The system shall be able to dynamically manage resource allocation policies among different services of the PMR network.

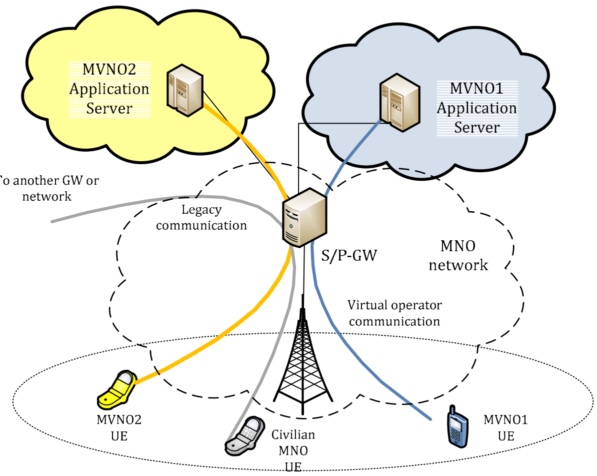

Fig. 7. Enhanced MVNO for PMR services

B. Dynamic eMBMS for public safety applications

3GPP LTE supports multimedia broadcast / multicast services thanks to the enhanced Multimedia Broadcast Multicast Service (eMBMS) introduced since LTE Rel-10 [4]. eMBMS was designed for the delivery of video streaming and download of multimedia content mainly. Hence, it is not adapted to services with stringent latency requirements, like group calls for public safety. The aim is to support group calls for PMR systems, satisfying PMR requirements, with LTE eMBMS (Fig. 8).

C. Service differentiation

Network applications have different performance requirements. Therefore, it is beneficial to separate them using logical "network slices". In general, MNOs' RAN may operate on a set of various frequency bands. Each frequency band may feature different parameters such as capacity, latency, or jitter associated with its configuration, implementation and utilization. Moreover, each of the customer applications may have different QoS requirements.

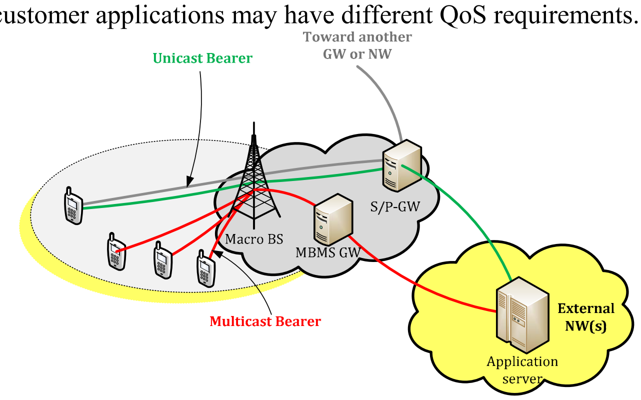

Fig. 8. Dynamic eMBMS for public safety applications

Therefore, we need application-aware bandwidth/client steering capabilities, which allow high bandwidth-consuming users to be directed towards a spectrum band which provides sufficient capacity, while latency sensitive applications should be steered towards low latency bands. Fig. 9 presents a use case, where an MNO offers two different types of services (a bouquet of IPTV channels provided in standard quality, and a video on demand (VoD) service for premium customers).

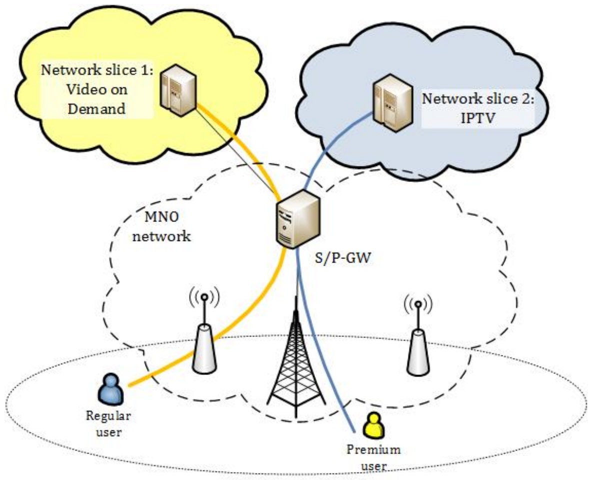

Fig. 9. Differentiation for multimedia service provisioning

VI. Related Work on Scenarios for 5G Networks

Several scenarios and use cases have been presented for 5G networks so far. ITU-R has defined three usage scenarios for 5G [6]. They include *enhanced mobile broadband*, *ultra-reliable and low latency communications*, and *massive machine type communications*. Similarly 5G PPP has defined three 5G service capabilities that include *user experience continuity*, *mission critical services*, and *Internet of Things (IoT)*, which roughly correspond to the ITU-R usage scenarios. Each service capability is emphasizing different KPIs [7]. In NGMN, operators have defined eight use case families [3]. Each of them can be mapped onto the ITU-R use case families. Enhanced mobile broadband includes *broadband access in dense areas*, *broadband access* *everywhere*, *high user mobility*, and *broadcast-like services*. Ultra-reliable and low latency communications includes *extreme real-time communications*, *lifeline communications*, and *ultra-reliable communications*. Massive machine-type communications includes *massive Internet of Things*. We may conclude that the ITU-R usage scenarios form a good starting point for classification of different use cases and if a more detailed classification is needed, the operators' view in [3] is a good reference.

The METIS project has defined five scenarios which include *amazingly fast*, *great service in a crowd*, *ubiquitous things communicating*, *best experience follows you*, and *super real-time and reliable connections* [8, 9]. In addition, METIS has defined 12 test cases, including virtual reality office, dense urban information society, shopping mall, stadium, teleprotection in smart grid network, traffic jam, blind spots, real-time remote computing for mobile terminals, open air festival, emergency communications, massive deployment of sensors and actuators, and traffic efficiency and safety. Latest results are summarized in the METIS-II white paper [10]. Again, the classification is rather similar to [6].

3GPP has a draft document TR 22.891 [2], which contains already more than 70 use cases which are classified into five use case categories, including *enhanced Mobile Broadband (eMBB)*, *Critical Communications (CriC)*, *Massive Internet of Things (MIoT)*, *Network Operation (NEO)*, and *enhanced Vehicle-to-X Communications (eV2X)*.

VII. CONCLUSION

In this paper, we have presented scenarios for 5G networks in order to introduce research issues that have to be considered as we develop COHERENT architecture. We highlighted the main concepts in terms of abstraction and control in 5G radio access networks so that we can orchestrate HMN to a ubiquitous and unified service platform. Our expectation is that the research agenda is evolving, since many topics arise during our development process.

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