RADIO ACCESS CHALLENGES FOR NEW ACCESS TECHNOLOGY IN 5G MOBILE SYSTEMS

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Abstract: In this paper main focus is placed on the challenges in front of 5G network from radio access perspective that are defining the shape of the new 5G access technology. In order to define the 5G radio access it is crucial to understand the needs from the users and business and to understand the use cases needed to be served by the new 5G mobile system. In the paper we describe the potential use cases that are driving force behind the need for redesign of the access technology for new 5G architecture. New access ecosystem needs to be modular and to be able to introduce state of the art radio techniques that are being developed but also needs to be wide enough by its capabilities to incorporate existing radio interfaces. In this manner we present the view of the 5G radio ecosystem that needs to cover current and future demands. New access technology needs to enable easy interworking between mobile/mobile (between generations) and mobile/fix networks and will have to be open towards new radio interfaces in order to enable addition of new use cases to cover certain user or business demands. According to all presented above, we give view of the 5G access network candidates as well as view of the complete 5G access ecosystem that should be part of the new 5G network design.
Keywords: 5G architecture, Radio Interface, 5G Access, fix/mobile interworking, 5G identities.

1. INTRODUCTION

Previous new generations of mobile systems have been largely defined by a new radio interface (RI). Second generation of mobile systems, 2G was the first digital mobile system in the radio interface with FDMA/TDMA GMSK implementation that offered global roaming and wide radio standardization, 3G brought CDMA access in the radio interface while 4G/LTE implemented OFDM radio interface. 5G access will be different. The already-high spectral efficiency of LTE means there should be no compelling reason to replace LTE soon after 2020. Certain use cases will require new radio access capabilities, but implementing a single radio interface to realize the broad range of use cases and the diversity of their requirements will be challenging and inefficient in many ways. That's why it is widely spread view, in the industry, that 5G will consist of a family of radio interfaces (RIs), with an evolution of the LTE RI complemented by more specialized 5G RIs, e.g. for high frequency mm-wave spectrum. In that manner 5G needs to allow an introduction of new RIs during lifetime of the system, so that a new RI is no longer bound to a new mobile generation. In this way industry will escape from the unwritten law on change of mobile generations each 10 years, and can react more flexibly and cost efficiently to market demands. This postulate should also cover the cases where a new 5G radio interface technology that emerges from 5G which does not offer sufficient gain within the existing spectrum bands to justify a replacement of LTE, can also be accommodated in the new access ecosystem. One of the biggest challenges in 5G will be the massive increase of traffic demand that need to be addressed by densification of the access network. That's why 5G needs to support densification. As fiber connectivity will be common for base stations after 2020, it should be possible to move the Baseband processing to centralized Digital Unit (DU) pools, known as C-RAN architecture. These pools will typically still be near the network edge, but will provide centralized use of DUs for multiple base stations located in the vicinity. Besides C-RAN being targeted as the dominant deployment, standard base station architecture known as Distributed RAN (D-RAN) that locate the baseband radio functions at the radio site will still be needed, e.g. for a home router. The centralized DUs in the pool will be part of the distributed network cloud. In general, RUs and DUs shall be technology neutral with an open interface between them, supporting the loading of new SW-defined RIs from different vendors. This concept is presented on the figure1.

5G radio technologies will be deployed not only in licensed spectrum, but also in unlicensed spectrum, in order to use all available options for providing coverage and capacity. It is expected that in the long run, 5G will also play a role in the home residential market, challenging WiFi as the dominant technology in this area by developing a harmonized family of 3GPP-based RIs. However, WiFi and its future evolution are unlikely to be quickly displaced, and it is expected that 5G should support a tight integration of WiFi at the radio level, keeping the 5G CN RAT-agnostic. [1], [2], [3], [4]

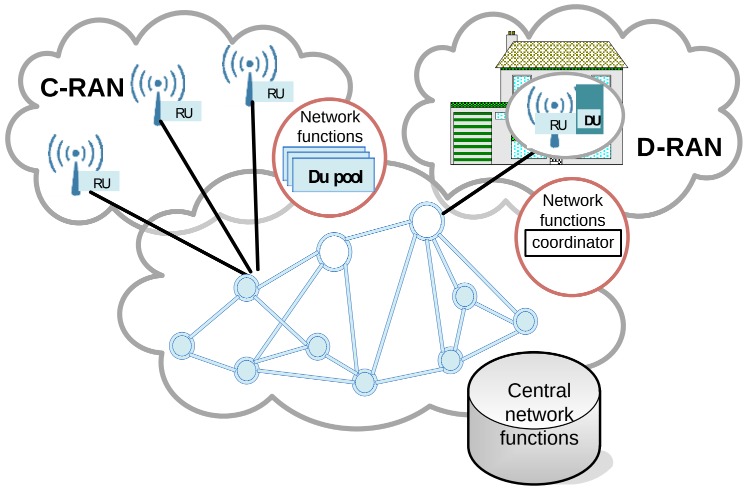

Fig 1. 5G radio architecture

2. NEW RADIO TECHNOLOGIES CANDIDATES FOR 5G ACCESS

While 5G is not expected to be defined by a new RI in the same way as previous generations, it is almost certain that new radio technologies will be developed and deployed while we see the first 5G viable developments. The most promising new technologies that are candidates to complement the 5G access radio interfaces are following:

- **Higher Frequencies - Millimeter Wave (mmWave) band:** The support of higher channel bandwidths of 100 MHz or more will be needed within the 5G access system in order to offer higher capacity and higher user data rates without increasing aggregation complexity of the carriers. Such large spectrum bandwidth are not available in the existing frequency bands below 6 GHz, that by itself imposes using of high frequency spectrum to support a continuing growth in user data rates. Unfortunately the propagation of higher bands is a limiting factor for offering wide area coverage, and in particular, penetration into building is limited.
- **Reduced scheduling period:** Considering the fact that round trip time (RTT) or e2e latency plays major role in applications performance, 5G target of 1 ms or smaller RTT requires a reduction in the scheduling time period to substantially smaller than the 1ms transmission interval used for LTE. However, wide area support of such low latencies will be challenged by the achievable coverage and payload overhead. This will restrict the service area only for very low latency use cases like areas with mmWave deployments supporting wider channel bandwidth.
- **New waveforms:** Several new waveforms are being developed that can been used for 5G radio interfaces that adapt OFDM to cope with some of the constraints imposed by multiple access in LTE. Non-orthogonal access methods can increase resource utilization beyond orthogonal limits, but this comes whit certain price that needs to be paid by increased intra-carrier interference (ICI) that in other hands can be managed by advanced interference cancellation methods. New techniques like Filter-bank Multi-carrier (FBMC) and Universal Filtered Multi-carrier (UFMC) can improve the spectral characteristics, by reducing guard band requirements, and relaxing synchronization requirements.
- **Full duplex:** Full duplex is proposed as a technology that could double spectrum efficiency by using a frequency band simultaneously for both uplink and downlink, relying on interference cancellation at the transceiver. It is not yet clear whether a sufficiently good isolation between link directions is achievable in commercial terminals to support this as a mainstream access technology.
- **Massive MIMO:** Evolution of advanced antenna systems to support much higher order spatial multiplexing through narrower beam forming can be used in order to increase capacity. Application of Massive MIMO in the lower bands can be constrained by the physical antenna size, however, the use of higher frequency bands enables a greater number of antenna elements to be realized on same physical area.
- **Densification:** 5G is expected to be accompanied or preceded by a substantial densification of the network through the deployment of small cells. Network densification is enabler of higher frequency deployments, which in turn also support advanced antenna development. Small cell deployment is likely to play a key role in cost effective densification.

- **UE-centric network:** LTE radio interface is cell-centric, in other words terminals are connect to serving cell that also controls their mobility. In LTE-A this is evolving to a more User Centric approach where the terminal can be connected to multiple cells simultaneously using carrier aggregation. C-RAN implementation of inter-site carrier aggregation would allow user data to be carried over small cells with limited coverage, while control signaling is carrier over more reliable macro cellular carriers. New access technologies will extend this principle so that UEs can be served by collection of resources from multiple cells. [5], [6], [7], [8], [9]

3. INTERWORKING OF MOBILE GENERATIONS AS WELL AS FIX NETWORKS IN UNIFIED NETWORK ENVIRONMENT

In current mobile networks operators support a variety of user equipment, from 2G-only legacy phones or M2M modules, up to LTE enabled smart phones. These devices connect to the 2G/3G/4G Core, and there is an ensured backwards compatibility of services. For 5G a new clean approach will be chosen that would exploit 5G Network Cloud implementation, without need for backward compatibility to 2G/3G. 5G devices can connect via new RI's to this network cloud, as well as via a modified LTE RI. The modification is needed to allow LTE base stations to continue connecting legacy devices to the legacy EPC core, that will allow connecting of 5G devices to the simplified core functions within the 5G Network Cloud, so that the evolved LTE radio interface can benefit from the improved flexibilities.

It should be noted that 5G smart phones may still support legacy RIs such as GSM, in order to provide access when there is no LTE network available, however handover from 5G to 2G/3G will not be supported as LTE should provide sufficient coverage. Minimal interworking between 5G cloud and 2G/3G/4G core may still be required, like share of identities in order to recognize a user across both worlds, and share parts of user profile. However more complex interworking like seamless mobility or service continuity between 5G and 2G/3G will not be considered. This concept is presented on the figure 2.

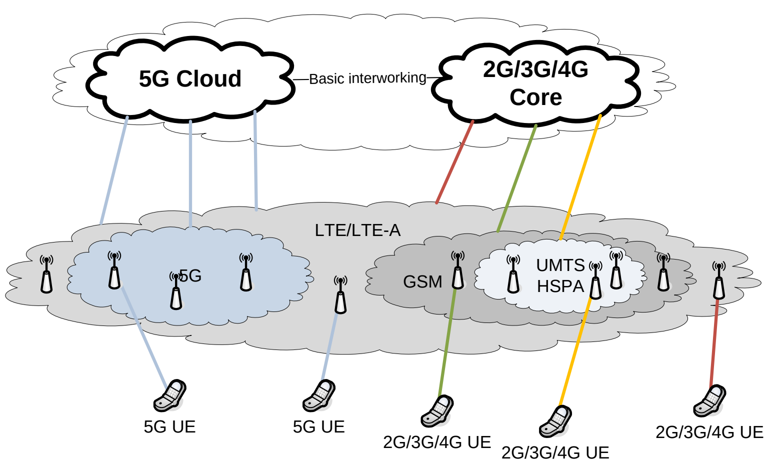

Fig 2. Interworking between different mobile generation

A key conceptual difference between fixed and mobile networks is the connection endpoint, in mobile networks this is typically mobile device (generally we speak of SIM card placed in the device), where in fixed network this is a household with multiple devices behind (generally termination endpoint is called network termination device). The difference can be easily seen when a mobile device attaches on fixed access via WLAN. From fixed network perspective, this device is just an anonymous device behind the defined network termination for fixed access. In case of convergent scenario, this mobile device should be addressed from the fixed network in the same manner as network termination point in the household. In order to address this convergent scenario a different approach for determination of the role of devices in the network is needed where different termination identities from network perspective are defined.

In IP addressing, even today there is an option to address both an endpoint (network address) and a device behind (sub-network address). In line with this, a new termination identity, called "network identity", can be used to identify a network endpoint (fixed or mobile), but which also connects further devices "endpoint identity" from potentially different operators. However, we should consider a network endpoint as "network identity" only in case further 5G devices are connected behind. In case where behind this device (network endpoint) we connect devices that are connected to 5G device via non-5G technologies (like Bluetooth), then the 5G connecting device would be regarded as "endpoint identity" rather than as "network identity".

4. CONCLUSION

In this paper we have managed to present the basic requirements that need to be fulfilled by 5G radio interfaces for new next generation systems that give the shape of the new access technology. In this view it is clear that 5G needs to be designed and build for Diversity, Flexibility and efficiency. Presented radio interface additions as well marked new radio techniques will bring new access possibilities that should be able to respond to the user requirements in the times to come. It is clear that 5G radio access should be designed for highly cost efficient deployment and operation through automation and self-healing capabilities. In new radio access network cost efficient densification of will be essential, supporting simple customer & third party deployment. 5G architecture should target a radically simplified access agnostic core network based on cloud technologies that should support the addition of new radio and fixed access interfaces quickly and seamlessly.

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