On the Introduction of 5G Networks in Romania

A novel architecture for spectrum occupancy evaluation

Alexandru Martian, Calin Vladeanu, Mahmood Jalal Ahmad Al Sammarraie
Telecommunications Department
University Politehnica of Bucharest
Bucharest, Romania
E-mail: martian@radio.pub.ro, calin@comm.pub.ro, mahmood.alsammarraie@gmail.com

***Abstract*—In the context of the upcoming 5G networks, the current paper reviews several aspects regarding the New Radio (NR) physical layer: the radio technologies that were proposed for the implementation of the air interface, the frequency bands foreseen to be used and access in unlicensed spectrum areas. The current situation regarding the introduction of 5G networks in Romania is also discussed. Finally, we propose, in the framework of an ongoing research project, a preliminary architecture for a spectrum occupancy evaluation system.**

Keywords-5G; NR interface; frequency allocation; software defined radio; spectrum occupancy.

I. INTRODUCTION

As the requirements in terms of data rate are ever increasing along with the expansion of the multimedia and wireless communications markets, the forthcoming fifth generation of mobile communication networks (5G) will have to provide significantly higher values for capacity, data rate and number of connected devices as compared to the current generation (4G). Moreover, several major user scenarios are defined for 5G, including enhanced Mobile Broadband (eMBB), Ultra-Reliable and Low Latency Communications (URLLC) and massive Machine Type Communications (mMTC) [1].

However, several challenges will have to be faced in order to obtain the above-mentioned performance goals. A key problem that must be solved is related to the limited frequency resources that are currently available, because of the fixed allocation policy and the large number of wireless communication standards that require spectrum resources.

The current state of 5G New Radio (NR) standardization includes a first version of the standard developed by 3GPP (Rel. 15), both in terms of non-standalone network operation (specifications were concluded in December 2017) [2], and in the case of standalone network operation (the specifications in this case were concluded in June 2018) [3]. The development of a new release (Rel. 16) already started and is expected to be concluded before the end of 2019.

The current paper focuses on the physical layer of the forthcoming generation of mobile communication networks. The main contributions of the article are a review of the unlicensed spectrum access elements in case of mobile communication networks and a proposal of a spectrum occupancy evaluation system. The proposed system is based on the use of Software Defined Radio (SDR) platforms and brings novelties over state-of-the-art by combining SDR platforms with different characteristics and by using optimized spectrum sensing algorithms.

The rest of this paper is organized as follows. Section II contains a review of the various radio technologies that were considered for the implementation of the radio interface in 5G networks. Section III discusses the frequency bands that are foreseen to be used for 5G networks. In Section IV, several aspects regarding the use of unlicensed spectrum resources in the context of 5G networks are presented. A preliminary architecture of a spectrum occupancy evaluation system is proposed in Section V. Section VI concludes the paper and contains future research directions.

II. RADIO TECHNOLOGIES CONSIDERED FOR THE RADIO INTERFACE IN 5G NETWORKS

As with all the other generations of mobile networks, the requirements imposed for 5G networks are ever increasing. In Table I, a comparison between the performances that can be obtained using the current 4G networks and the ones that are expected for the upcoming 5G networks.

As it can be noticed, the requirements in case of the upcoming 5G networks are significantly higher compared to the ones for the existing 4G networks.

TABLE I. PERFORMANCE COMPARISON BETWEEN 4G AND 5G NETWORKS [14]

Indicator	Significance	4G	5G
Peak data rate (Gbit/s)	Total traffic for a single device in a cell	1	20
User experience date rate (Mbit/s)	Total traffic constantly perceived by the user	10	100
Spectral efficiency (bit/s/Hz/site)	Data rate per unit of bandwidth	10	15-30
Mobility speed (km/h)	Maximum speed for which certain quality parameters can be maintained	350	500
Latency (ms)	Time in which the data packet travels through the network	10	1
Density of connection (per km^2)	Number of connections in an area for which certain quality parameters can be maintained	100000	1000000
Area traffic capacity ($Mbit/s/m^2$)	Total traffic for a certain area	0.1	10

 ISBN: 978-1-61208-693-4

Several radio technologies are considered for the implementation of the air interface within the future 5G networks. These technologies, which are seen as appropriate in order to achieve the performances specified in the 3GPP standard (see Table I), can be grouped into several categories as follows:

• Multi-carrier technologies such as CP-OFDM [4], Windowed OFDM (WOFDM) [5], Unique-Word OFDM (UW-OFDM) [6], Discrete Fourier Transform-Spread OFDM [7];

• Single carrier technologies such as Continuous Phase Modulation - Single Carrier - FDMA (CPM-SC-FDMA) [8] [9], Differential Quadrature Amplitude Modulation (DQAM) [10];

• other technologies such as Bi-Orthogonal Frequency Division Multiplexing (B-OFDM) [11], Filter Bank Multi-carrier (FBMC) [12], Generalized Frequency Division Multiplexing (GFDM) [13], Universal Filtered Multicarrier (UFMC) [14].

III. Frequency Bands Forseen to be Used in 5G Networks

The current allocation of frequency resources for the existing mobile communication networks (2G, 3G, 4G) comprises of various frequency bands, all of them being located below 4 GHz. In Figure 1, the allocation of spectrum resources for the case of Romania is presented, as given in [15] by the National Authority for Management and Regulation in Communications of Romania (ANCOM).

In terms of frequency bands expected to be used in future 5G networks, two main categories are defined as follows:

- Frequency bands below 6 GHz (FR1);
- Frequency bands between 24.25 GHz and 52.6 GHz (FR2).

For the particular case of Romania, the same national strategy for 5G [15] also mentions the frequency bands to be used in future 5G networks for which a call for tender will be held in the second half of 2019:

• The 3.4-3.8 GHz frequency band, which is considered by the RSPG (public consultation group on radio spectrum allocation policy at European Commission level) to be the most suitable for immediate use by 5G networks [16] [17];

• The frequencies in the 700 MHz band, which are suitable for the development of 5G network coverage over extended areas, due to lower radio frequency attenuation. For this band the existing infrastructure is expected to be used;

• The 24.25-27.5 GHz frequency band, which can offer bandwidths of the hundreds of MHz required to achieve the performance specified in [2] and [3] (speeds up to 20 Gbps under stable conditions for mobile users).

IV. Aspects Regarding Access in Unlicensed Frequency Bands in 5G Networks

Considering the fact that several wireless communication systems appeared in the last decades and they all required frequency resources, spectrum allocation became a critical aspect in recent years. However, several measurement campaigns that were conducted worldwide [18] clearly shown that most of the spectrum is currently used in a very inefficient way. We also conducted measurement campaigns in Romania [19] and obtained spectrum occupancy values going all the way down to less than 15% in rural areas. One possible approach for improving the efficiency of spectrum usage would be to allow the access of different wireless communication systems in unlicensed bands or in bands licensed to other systems, as long as the licensed (Primary) system/User (PU) is not active.

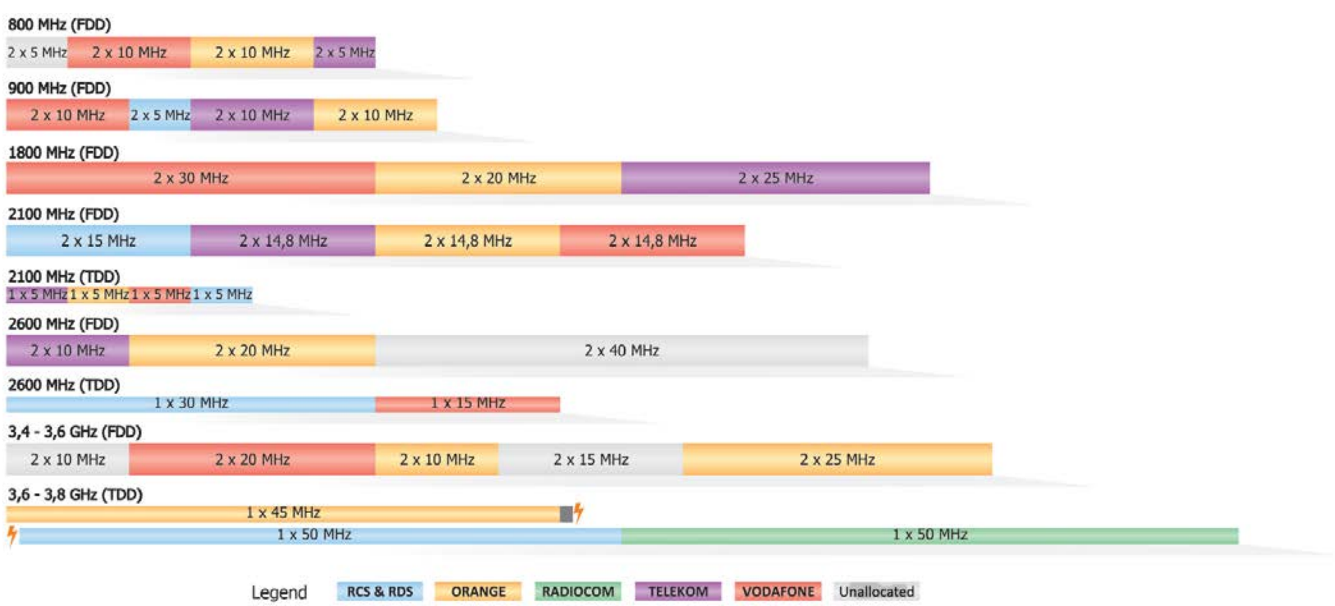

Figure 1. Allocation of spectrum resources for 2G, 3G and 4G in Romania [15]

 ISBN: 978-1-61208-693-4

Such an approach, known as Dynamic Spectrum Access (DSA) or Dynamic Spectrum Sharing (DSS) requires that each equipment that accesses such a frequency band continuously scans the spectrum, process known as Spectrum Sensing (SS), in order to detect a possible activity of the PU. As soon as such an activity is detected, the unlicensed (Secondary) User (SU) should immediately cease its activity in that frequency band, in order to avoid any interference with the PU.

Starting with the fourth generation of mobile communication networks (4G), standardization efforts focused on the possibility of allowing users to access both licensed and unlicensed spectrum under a unified network infrastructure. The LTE-Unlicensed (LTE-U) technology was initiated as part of LTE Release 13 in order to obtain the above-mentioned goal [20].

Another LTE-based technology which operates standalone in unlicensed and shared spectrum is MulteFire [21]. The MulteFire specification was developed by the MulteFire Alliance, an independent, diverse and international member-driven consortium. Based on 3GPP Release 13 and 14, MulteFire technology supports Listen-Before-Talk for fair co-existence with Wi-Fi and other technologies operating in the same spectrum. It supports private LTE and neutral host deployment models and targets industrial IoT, enterprise, cable, and various other vertical markets.

A study regarding NR-based access to unlicensed spectrum was started by 3GPPP in 2018 [22] and has as goal the development of a single global solution for NR-based access to unlicensed spectrum, which should be compatible with the NR concepts.

Several regulatory requirements for the 5GHz frequency band are being mentioned for all the different ITU Regions, including Dynamic Frequency Selection (DFS). DFS is a spectrum-sharing mechanism that allows the coexistence of wireless LANs with radar systems by automatically selecting a frequency that does not interfere with certain radar systems while operating in the 5 GHz band. The DFS concept was first introduced in 2001 and is a feature that is present in the ETSI BRAN HIPERLAN/2 and IEEE Standard 802.11h.

For the case of the upcoming NR-Unlicensed (NR-U) standard, it appears that a DFS conformance testing would only have to be performed for the Base Station (BS), as full DFS functionality doesn't have to be implemented in all devices, but only in those controlling the transmission.

Different unlicensed bands or shared bands have been discussed for the NR-U, such as 2.4 GHz band, 3.5 GHz band, 5 GHz band, and 6 GHz band. Some of these frequency bands are available globally, whereas some of the bands are only available in some specific regions.

Although in [22] only the case of the 5GHz band is discussed in detail, the same principles will be applicable to a set of frequency ranges to be further defined, without any prioritization for any particular unlicensed band. However, unlicensed bands below 1GHz are not targeted, due to the lack of spectrum in that range, which would make an efficient NR-U operation impossible.

V. Preliminary Architecture of a Spectrum Occupancy Evaluation System

In the following year, in the framework of the Spectrum-5G research project, our research team intends to conduct several measurement campaigns in order to evaluate the spectrum occupancy in urban and rural areas of Romania. We intend to collect RF data for a frequency range up to 6 GHz and for long time periods, in order to obtain a relevant picture of the current spectrum occupancy status. A preliminary architecture of the system that we intend to design and use for performing the measurements is presented in Figure 2.

As it can be noticed, the system is based on the use of several SDR platforms as capture devices. The radio frequency signal is captured by means of a broadband antenna (frequency range of at least up to 6 GHz), which is then distributed to multiple SDR platforms via a broadband radiofrequency power splitter. The SDR platforms will monitor different frequency bands, selected through filtering circuits.

For higher frequency bands, Low Noise Amplifiers (LNA) will be added to increase the level of detected signals in order to obtain improved performance in the spectrum sensing process. As it can be seen in Figure 2, the SDR platforms targeted for the system implementation will be:

- USRP X310 (with UBX-160 RF daughterboard) – Frequency range 10-6000 MHz; Maximum instantaneous bandwidth 160 MHz; Host interface – 10 Gbit ethernet;
- USRP N210 (with WBX RF daughterboard) – Frequency range 50-2200 MHz; Maximum instantaneous bandwidth 40 MHz; Host interface – 1 Gbit ethernet;
- USRP B200mini – Frequency range 70-6000 MHz; Maximum instantaneous bandwidth 56 MHz; Host interface – USB 3.0;
- HackRF One – Frequency range 1-6000 MHz; Maximum instantaneous bandwidth 20 MHz; Host interface – USB 2.0.

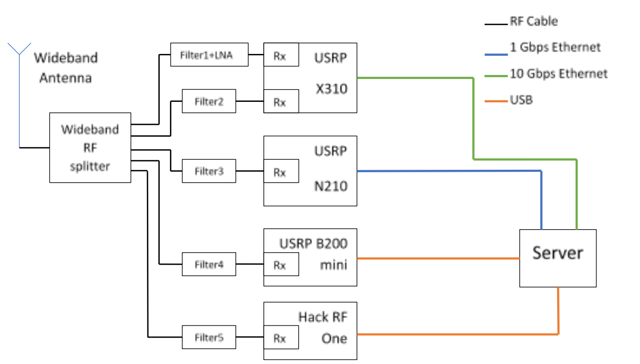

Figure 2. Preliminary architecture of the proposed spectrum occupancy evaluation system.

The information from the SDR platforms will then be centralized using a high-performance server, this approach enabling the simultaneous acquirement of data from different frequency bands. From a software point of view, we intend to use the GNU Radio environment to control and capture the data from SDR platforms, and the MATLAB environment for estimating the degree of occupancy of the spectrum based on collected data using different spectrum sensing algorithms. We already developed several algorithms based on energy detection [23], which will be used alongside classical algorithms like [24]. Although in the current paper the case of Romania is discussed in detail, the flexibility of the proposed system will allow its use for analyzing the spectrum occupancy for any other country.

VI. Conclusion and Future Work

The paper presented several aspects regarding the physical layer of the upcoming fifth generation of mobile communication networks. The candidate radio technologies that are considered for the implementation of the air interface were mentioned, together with the frequency bands that are foreseen to be used for covering all the different use scenarios covered by 5G networks. A review of the different aspects related to the access in unlicensed frequency band is also performed. A preliminary architecture of a spectrum occupancy evaluation system, based on several software defined radio platform, is finally proposed. As future work, we intend to implement, in the framework of the Spectrum-5G research project, the previously described architecture and we intend to use it for performing measurement campaigns in several urban and rural areas in Romania.

Acknowledgment

This work was supported by a grant of Ministry of Research and Innovation, CNCS - UEFISCDI, project number PN-III-P1-1.1-PD-2016-1696, within PNCDI III.

References

[1] M. Shafi et al., "5G: A Tutorial Overview of Standards, Trials, Challenges, Deployment, and Practice," in IEEE Journal on Selected Areas in Communications, vol. 35, no. 6, pp. 1201-1221, Jun. 2017.

[2] 3GPP First 5G NR Standard Approved, available at: http://www.3gpp.org/news-events/3gpp-news/1929-nsa_nr_5g, retrieved: Jan. 2019.

[3] 3GPP Release 15, available at: http://www.3gpp.org/release-15 , retrieved: Jan. 2019.

[4] H. Steendam and M. Moeneclaey, “Different guard interval techniques for OFDM: Performance comparison,” in Multi-Carrier Spread Spectrum, vol.1, pp.11–24, 2007.

[5] B. Muquet, Z. Wang, G. Giannakis, M. de Courville, and P. Duhamel, “Cyclic Prefixing or Zero Padding for Wireless Multicarrier Transmissions” in IEEE Transactions on Communications, vol. 50, no. 12, pp.2136–2148, Dec. 2002.

[6] M. Huemer, C. Hofbauer, A. Onic, and J. B. Huber, “Design and analysis of UW-OFDM signals,” in International Journal of Electronics and Communications, vol. 68, no. 10, pp. 958 – 968, 2014.

[7] T. Svensson et al., “Block interleaved frequency division multiple access for power efficiency, robustness, flexibility, and scalability,” in EURASIP Journal on Wireless Communications and Networking, pp.13, Sep. 2009.

[8] G. Huang, A. Nix, and S. Armour, “Impact of radio resource allocation and pulse shaping on PAPR of SC-FDMA signals,” in Proc. IEEE 18th Int. Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), pp. 1–5, Sep. 2007.

[9] M. Wylie-Green, E. Perrins, and T. Svensson, “Introduction to CPM-SCFDMA: A novel multiple-access power-efficient transmission scheme,” in IEEE Transactions on Communications, vol. 59, no. 7, pp. 1904–1915, Jul. 2011

[10] N. Svensson, “On differentially encoded star 16QAM with differential detection and diversity,” in IEEE Transactions on Vehicular Technology, vol. 44, no. 3, pp. 586–593, Aug. 1995.

[11] M. Kasparick, G. Wunder, P. Jung, and D. Maryopi, “Bi-Orthogonal Waveforms for 5G Random Access with Short Message Support,” in Proc. European Wireless Conference (EW’14),Barcelona, Spain, pp.1-6, Jun. 2014.

[12] J.-B. Dore, V. Berg, and D. Ktenas, “Channel estimation techniques for 5G cellular networks: FBMC and multiuser asynchronous fragmented spectrum scenario,” in Transactions on Emerging Telecommunications Technologies, vol. 26, no. 1, pp. 15–30, Nov 2014.

[13] G. Fettweis, “GFDM - Generalized Frequency Division Multiplexing", VTC Spring - IEEE 69th Vehicular Technology Conference, pp. 1 - 4, Jun. 2009.

[14] V. Vakilian, T. Wild, F. Schaich,, S. ten Brink, and J. F. Frigon, “Universal Filtered Multi-Carrier Technique for Wireless Systems Beyond LTE,” in Proc. 9th Int. Workshop on Broadband Wireless Access @ IEEE Globecom’13, Atlanta, pp. 223-228, Dec. 2013.

[15] 5G Strategy for Romania, available at: http://www.ancom.org.ro/uploads/links_files/Strategia_5G_pentru_Romania.pdf, retrieved: Jan. 2019.

[16] Strategic Roadmap Towards 5G for Europe – Opinion on spectrum related aspects for next-generation wireless systems (5G), available at: http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf, retrieved: Jan. 2019.

[17] Strategic Roadmap Towards 5G for Europe – RSPG Second Opinion on 5G Networks, available at: https://circabc.europa.eu/sd/a/fe1a3338-b751-43e3-9ed8-a5632f051d1f/RSPG18-005final-2nd_opinion_on_5G.pdf, retrieved: Jan. 2019.

[18] D. Das and S. Das, “A Survey on Spectrum Occupancy Measurement for Cognitive Radio”, in Wireless Personal Communications, vol. 85, issue 4, pp. 2581-2598, Dec. 2015.

[19] A. Marțian, R. Crăciunescu, A. Vulpe, G. Suciu, and O. Fratu “Access to RF White Spaces in Romania: Present and Future”, in Wireless Personal Communications, vol. 86, issue 3, pp. 693-702, Apr. 2016.

[20] R. Zhang, et al., "LTE-unlicensed: the future of spectrum aggregation for cellular networks," in IEEE Wireless Communications, vol. 22, no. 3, pp. 150-159, Jun. 2015.

[21] MulteFire Release 1.0, available at: https://www.multefire.org/wp-content/uploads/MulteFire-Release-1.0-whitepaper_FINAL.pdf, retrieved: Jan. 2019.

[22] 3GPP Study on NR-based Access to Unlicensed Spectrum, available at: http://www.3gpp.org/DynaReport/38889.htm, retrieved: Jan. 2019.

[23] C. Vlădeanu, C. V. Năstase, and A. Marţian, “Energy Detection Algorithm for Spectrum Sensing Using Three Consecutive Sensing Events,” in IEEE Wireless Communications Letters, vol. 5, pp. 284-287, Jun. 2016.

[24] H. Urkowitz, “Energy detection of unknown deterministic signals,” in Proceedings of the IEEE, vol.55, no.4, pp. 523-531, Apr. 1967.