5G IA - Spectrum Working Group

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<u>Spectrum WG Response to the 5G IA Board on the RSPG 2nd Opinion</u>

1. Introduction

The present document has been developed with the purpose of providing views on the observation in the RSPG's "2nd Opinion on 5G networks" (RSPG 2nd Opinion in what follows) that the 5G PPP should investigate features related to new ways of sharing spectrum[1].

In this context, the WG Spectrum carried out a survey among all 5G PPP projects to collect information on the work that is being done within 5G PPP on such "new ways of sharing" and associated technologies.

The following 5G PPP projects responded to the survey: 5GCITY, 5G-PHOS, 5G-PICTURE, blueSPACE, IoRL, METRO-HAUL, ONE5G, and SaT5G.

Of those, four projects (5G-PHOS, 5G-PICTURE, blueSPACE, and ONE5G) turned out to be developing studies on relevant technologies in the 5G radio access networks – in particular, antenna beamforming technologies. Subsequently, the information collected during the first survey was supplemented by a second round of questions to these four projects, focussing more on 5G beamforming for interference avoidance towards stations of other services.

During the survey period, relevant information was also received about the H2020 SANSA project, as summarised later in this document.

The survey focussed on the following four main elements:

1) the most likely 5G deployments in the mmWave bands will be small cell and, at least initially, such deployments will be in urban and suburban areas;
2) beamforming techniques can be effectively applied to provide operators with the capability of defining the radiation in given directions and with different beamforming capabilities;
3) antenna beamforming technologies, as studied to date, can be implemented to explicitly minimize radiation in specific directions (i.e., towards receiving stations of other services);

[1] Section A2.1.2 ("New ways of sharing"), 3rd bullet

4) coupling of antenna beamforming and other technical approaches (e.g., database/geolocation technologies) improves effectiveness in mitigating interference to other services.

The survey results are summarised in the following section.

An outline of considerations for future work within 5G PPP is provided in the conclusions.

2. <u>"New ways of sharing" technical enablers</u>

Two main 5G features are considered as possible technical enablers of "new ways of sharing":

- mmWave bands radio access;
- antenna beamforming technologies.

2.1 mmWave bands radio access

mmWave bands are specifically considered in several applications under study within 5G PPP, e.g., for backhaul/fronthaul (XHaul) links in small cell deployments (5G-PICTURE), for Spatial Division Multiplexing (SDM) based networks (blueSPACE), and for access to mobile clients either directly or through high capacity mmWave small cells (5G-PHOS).

In other projects, e.g., ONE5G and SaT5G (with respect to the satellite-based backhaul aspects), mmWave bands are considered more as a suitable frequency range within a wider set of applicable ones.

The <u>first of the surveyed elements</u> concerned the RSPG opinion that the most likely deployments implemented in the mmWave bands would be small cell and that, at least initially, such deployments would be in urban and suburban areas.

In this respect, the majority of the 5G PPP projects surveyed are indeed considering dense urban/suburban small cell deployments.

In fact, while signals at lower frequency bands can propagate for many kilometres and penetrate quite easily through buildings, mmWave signal propagation is limited to only a few kilometres or less and does not penetrate through buildings as easily. Due to these radio propagation characteristics, the use of mmWave bands can more easily permit small cell deployments in dense radio access scenarios.

In addition, when considering possible 5G mmWave spectrum sharing, mmWave band small cell deployments offer, on the one hand, the possibility of 5G station deployment closer to the existing stations to be protected, due to the mmWave radio propagation peculiarities previously mentioned, and, on the other hand, less problematic coexistence scenarios where aggregated User Equipment (UEs) are the main interference source to be considered, due to UE signal ranges closer to the Base Station (BS) than would otherwise be the case.

2.2 Antenna beamforming technologies

The <u>second surveyed element</u> concerned the RSPG opinion that beamforming techniques can be effectively applied to provide operators with the capability of defining the radiation in given directions and with different beamforming capabilities.

According to the survey results, this opinion is widely confirmed, as outlined in the following.

Antenna beamforming technologies are a major topic under study in four of the surveyed 5G PPP projects. In particular, antenna beamforming technologies:

a. are being studied in 5G PPP projects using various array types with various beam-steering options in the space domain with different beam-steering criteria and methodologies used;
b. are mainly studied to maximize 5G system performance enhancements, using information (e.g., system parameters, channel and traffic information) made properly available in the network according to technical standards as necessary;
c. can be effectively applied to provide operators with the capability of defining the radiation in given directions and with different beamforming capabilities, as suggested by the RSPG 2nd Opinion.

The main information that WG Spectrum collected during its first survey can be summarized as follows:

5G-PHOS: both optical and RF beamforming capabilities to steer the mmWave antenna to the desired angle are studied within this project. The studied antenna is a rectangular array of mmWave antennas (up to 64x64 elements) with analog beamforming performed through phase and amplitude variations (both in the RF and optical domains). Radiation patterns of variable beam-width are obtained to cover a wide angular domain, while also supporting a large scanning angle, to determine the relative location of the receiver with respect to the antenna.

5G-PICTURE: antenna and beamforming technologies, efficient beam training and beam tracking mechanisms are major topics within this project. Current studies are being carried out in the 60 GHz frequency range with Uniform Linear Arrays (ULAs) allowing beam-steering in a horizontal direction. Uniform rectangular arrays (URAs) are also under development with more beam-steering options for more complex scenarios.

blueSPACE: Optical Beam Forming Network (OBFN) techniques are being studied within this project with the emphasis on the underlying optical technologies, like the integrated optical chips and the spatially multiplexed delivery network. In the system under consideration, the multiple optical signals are converted to the electrical domain and feed the antenna array. The optical signals are processed in such a way that the emitted RF signal forms the narrow beam in the chosen direction. The beam shape and direction can be adjusted by optical signal processing.

ONE5G: massive MIMO is a major topic within this project; studies are focused on analog/digital beamforming, efficient channel state information, flexible HW architecture, and antenna array shapes. Sector and beam management techniques are being studied using Uniform Planar Arrays (UPAs), where static beamforming gain distributions are only allowed, and Uniform Cylindrical Arrays (UCAs), where dynamic beamforming gain distributions are allowed with beam directions adapted to traffic demand evolution geographically throughout the day. UCAs developed in Massive MIMO are also deployed in a Proof-of-Concept testbed.

The third surveyed element concerned the possibility that antenna beamforming technologies, as studied to date, could be implemented to explicitly minimize radiation in specific directions (i.e., towards receiving stations of other services).

Unfortunately, the information collected in WG Spectrum's first survey was not sufficient to evaluate this suggestion, as the surveyed 5GPPP projects did not offer any indication in this regard.

As previously mentioned, antenna beamforming technologies can effectively be applied to provide operators with the capability of defining the signal radiation in given directions and with different beamforming capabilities, eventually enabling new ways of sharing. In that event, antenna beamforming would be basically purposed to minimize radiation in given directions, based on criteria such as regulatory coexistence parameters and location of stations external to the 5G service.

Finally, the fourth surveyed element concerned the RSPG 2nd Opinion suggestion that the coupling of antenna beamforming and other technical approaches (e.g., database/geolocation technologies) could potentially improve the effectiveness in mitigating interference to other services. Also in this case, the survey information collected was unfortunately insufficient to permit an evaluation of this suggestion, indicating that this was generally not a major topic in the surveyed 5GPPP projects.

Based on these results, WG Spectrum further addressed the four interested 5G PPP projects with a second round of questions.

The second survey round (answered only by 5G PPP project blueSPACE) also confirmed that currently none of the technical issues which could enable new ways of sharing through antenna beamforming technologies are being studied by the 5G PPP projects, and that significant extensions to the system architectures currently under study would be required for this purpose.

As mentioned earlier, within the context of the SANSA project, interference-aware beamforming technologies were applied to terrestrial transmitters with the aim of protecting non-intended satellite or terrestrial receivers. Investigated beamforming technologies include analog, digital, and hybrid analog-digital arrays as well as low-complexity alternatives, such as holographic or reflectarray antennas. Database information usage for dynamic carrier allocation solutions was studied as well. While the results appear promising, it must be noted that in most cases considered within SANSA it was assumed that the transmitter knew the spatial responses (wireless channel) to the non-intended receivers. How to estimate these spatial responses remains to be solved, as this was not part of the project.

3. Conclusions

Based on the collected information among 5G PPP projects, WG Spectrum analysis was finally devoted to identifying possible directions for future work within 5G PPP.

Several technical elements could be envisaged for future studies on the usage of beamforming technologies at mmW frequency bands to improve spectrum sharing.

In this regard, novel functionalities would need to be added to the baseline architectures and systems currently under study, e.g.,

- the possibility to deploy a dedicated processing unit at the interfering system base station, aimed at implementing interference avoidance functionalities;
- the availability at the above-mentioned processing unit of static system data, such as geographical locations of base stations, used frequencies, nominal emitted powers, etc., of both interfering and interfered system;
- the capability of dynamically measuring (i.e., sensing) at the interfering system base station the state of the radio environment, including spectral occupancy, actual signal level and arrival directions of the received signals of the interfered system, and accuracy requirements (note that this would not be applicable in the case that the interfered system either is a receiving-only system or transmits in a different frequency band and that feedback would need be established differently);
- the possibility of a distributed processing unit operating at local level or a centralized one operating for the whole network; by means of the static data and dynamic measures mentioned above, the

processing unit would execute specific actions/algorithms at the base station of the interfering system aimed at avoiding or limiting the interference towards the interfered system;

- consideration of cases where the interfered system is harmed either by the signal transmitted by an interfering base station or by the user equipment served by the interfering base station;
- coupling of the processing unit with (or even integration into) the radio resources management system, possibly providing service level assurance (e.g., high priority services should have guaranteed operation even though causing interference, while low priority services or services with high immunity to distortions can operate with lower quality or even not operate at all).

ANNEX - List of WG Spectrum questions to the 5G PPP projects

1st survey

1) Is accessing mmWave frequency bands a technical must for the Project 5G solutions to be developed?
2) Is/are there specific mmWave frequency range/ranges under study in the Project and what?
3) What are the 5G network deployment types (macro, small cell, micro, …) under consideration and what deployment priority if multiple possible?
4) In case of small cell deployments where and with what geographical concentration can such deployments be mainly envisaged (e.g., mainly concentrated in urban/suburban areas, in localized hot spots, for indoor/outdoor, …)?
5) Have radio propagation models and simulations been performed in the Project? Can you provide information on how such results could help assess coexistence issues?
6) Are antenna beamforming technologies studied in the Project?
7) Are antenna beamforming technologies fundamental element of the studied 5G technology/system/application?
8) Can you provide a technical description of the antenna beamforming technology under study with respect to the possibility to explicitly minimize the radiation in specific directions, i.e. towards receiving stations of other services?
9) Are such antenna beamforming technologies compliant with 5G performance requirements (e.g., end-to-end latency, NR frame structure, …)?
10) Are technical approaches such as database / geolocation technologies studied in the Project and what the scope? What are the novelty elements of the studied approaches? Please add relevant information.
11) Please provide any other relevant information concerning the enablers of "new ways of sharing" mentioned in Section A2.1.2 ("New ways of sharing") of the referenced Opinion, if not already implied in the above questions.

2nd survey

1) Can the studied antenna beamforming technologies directly/easily deal with different beam-steering criteria – i.e., change the focus from *maximizing* overall radiation to *minimizing* radiation in certain directions, and with which degree of freedom?
2) When system and channel parameters involved in the beam-forming and -steering process are relevant to a system that is a station of another service (e.g., Fixed Satellite Service), are the required parameters already available? If not, then to what extent would new research studies be necessary to make them available? What standardisation actions would be needed?
3) The RSPG 2nd Opinion mentions the possible coupling of antenna beamforming and other technical approaches (e.g., database/geolocation technologies) as a means to potentially improve effectiveness in mitigating interference to other services. Our Spectrum WG survey results indicate that this is not currently a major topic in the 5G PPP projects. To what extent would new research studies be necessary in order to address also these approaches? What standardisation actions would be needed?