“Tools and techniques for spectrum sharing for research and regulatory support”

Claudia Carciofi
Fondazione Ugo Bordoni, Italy

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Workshop “Spectrum sharing for the digital ecosystem towards 6G”

Outline

- Introduction: looking for efficient use of spectrum
- Sharing and coexistence methodologies
- Description of FUB sharing tool
- Coexistence studies in different scenarios:
  - Regulatory support: pioneer bands 700 MHz, 3500 MHz, 26 GHz
  - Research activity: 6 GHz band which has been identified among future candidate bands for IMT at next WRC23
- Conclusions and further work

Introduction: looking for efficient use of spectrum

- Sharing and coexistence of different services in the same bands is a key enabler for efficient use of spectrum for current 5G and next generation 6G systems.
- RSPG Opinion Spectrum Sharing: spectrum sharing in the Union is so far implemented in a rather static and conservative manner and needs to be developed, in particular for its potential to achieve more efficient use of radio spectrum, and to give incentives for innovation.
- RSPG Work Programme: improve spectrum sharing, implement innovative sharing solutions, promoting trials (sandboxes), pioneer scenarios/bands, new forms of licensing and a strategic focus on take-up of methods using databases and Licensed Shared Access.
- The shared use of spectrum should facilitate the adoption of 5G and 6G systems for vertical applications including the support of local geographical networks.
- Different spectrum sharing methods (e.g. cognitive radio, Licenced Shared Access LSA, Citizens Broadband Radio Service (CBRS), novel regulatory approaches (e.g. local licence, light licensing) to manage spectrum usage while avoiding interference and optimising 5G and future 6G network spectrum efficiency.

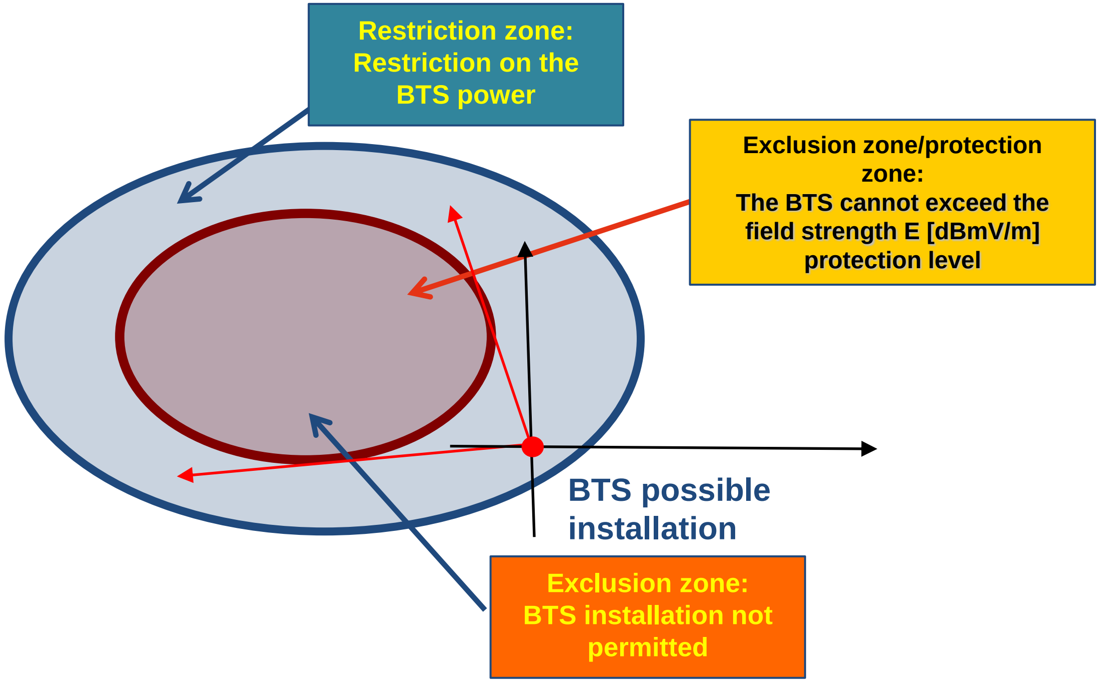
Sharing and coexistence methodologies (I)

- To tackle the huge problems arising from spectrum sharing by different services and technologies and for a number of different applications, many aspects have to be considered:
  - definition of criteria for equitable use
  - technical conditions relevant for preserving quality of service among stakeholders
  - supporting tools for the analysis of different options and case studies

- Technical analysis for sharing:
  - Identification of the scenario: 5G and incumbent services technical parameters, outodoor/indoor, co-channel, adjacent channel, synchronized or unsynchronized operation
  - Definition of the protection criteria (e.g. based on I/N, C(N+I))
  - Identification of sharing/coexistence conditions which maximize spectrum usage efficiency while protecting both incumbent and new 5G services

Sharing and coexistence methodologies (II)

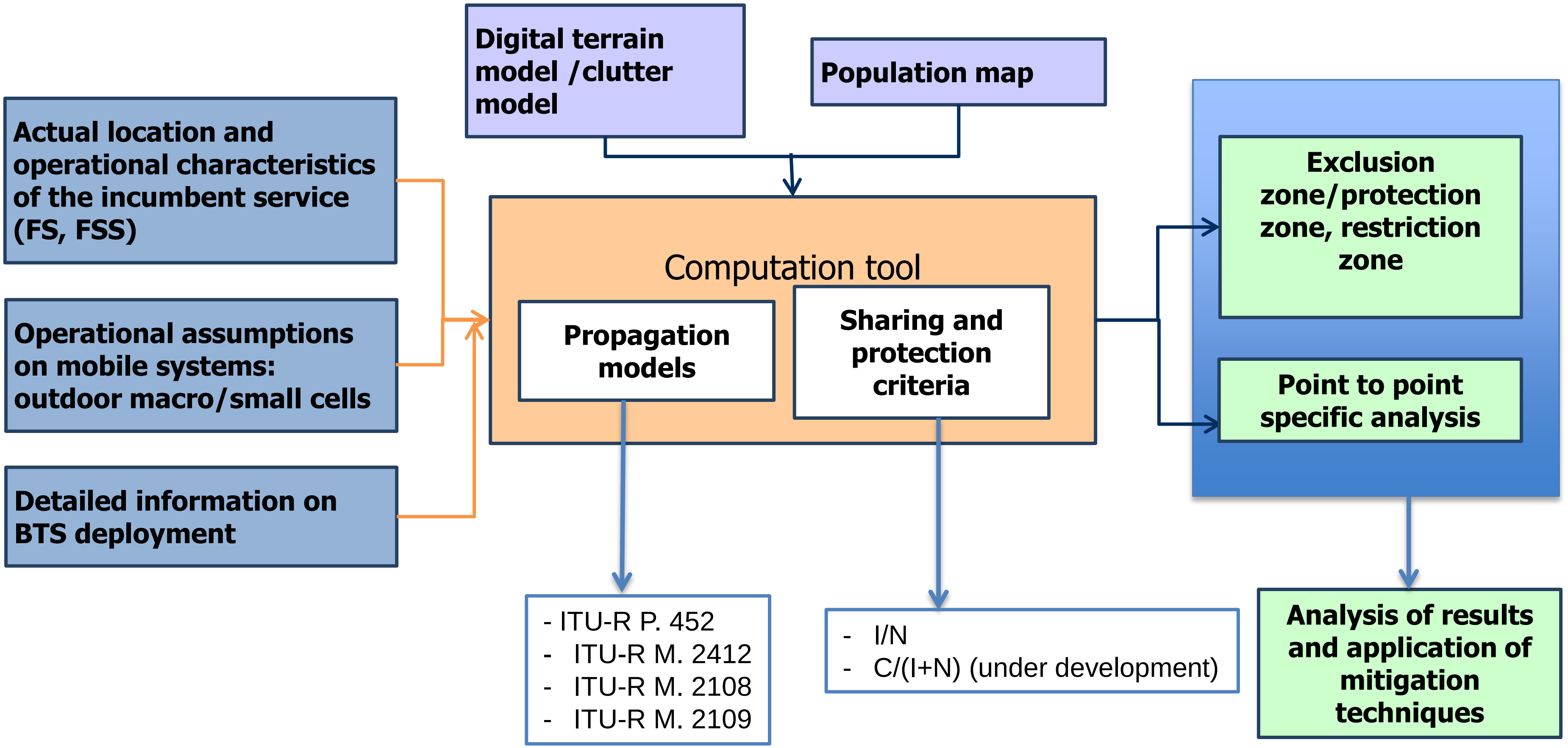
- First step: preliminary identification of sharing conditions based on geographical separation: Exclusion/Restriction/Protection zones (ECC Report 254)
- Second step: analysis of mitigation techniques: angular separation, AAS optimization, …
- Third step: point to point site specific coexistence analysis



Description of FUB sharing tool (I)

- FUB has developed a software sharing tool which has been largely used for regulatory support of the Ministry of Economic Development and the Italian Communications Regulatory Authority (AGCOM) in order to perform coexistence and compatibility studies in real 5G scenarios:
  - different frequency bands (e.g. 700 MHz, 2.3-2.4 GHz, 3.4-3.8 GHz, 26 GHz)
  - identifies sharing conditions between 4G and 5G systems and different incumbent users (e.g. Fixed Service - FS, Fixed Satellite Service - FSS, Programme Making and Special Events - PMSE, Telemetry).
- The tool is adopted for research activities to study different spectrum sharing methods (e.g. cognitive radio, LSA)
- The tool embeds rigorous propagation models based on ITU-R Recommendations and suitable procedures to assess co-channel and adjacent-channel coexistence.
- Protection requirements of the incumbent services are taken into account to identify coexistence conditions in terms of geographical, frequency, angular separation combined with mitigation techniques such as power restriction or antenna pattern optimization of the interferer service

Description of FUB sharing tool (II)



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Computation method and key parameters (I)

- The computation is performed with the **Minimum Coupling Loss (MCL)** method. We determine the **Interference to Noise Ratio (I/N)** as

$$I/N(\Delta f, d, \Theta 1, \Theta 2) = Pt + Att(\Delta f) + Gt(\Theta 1) + Gr(\Theta 2) - FsAtt(d) - N$$

Interferer Tx power (dBm)

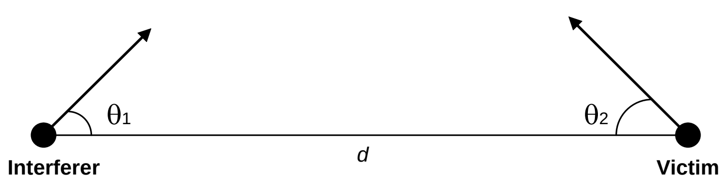
Loss due to receiver selectivity in dB, function of Δf (MHz)

Gain (dBi) of the interferer antenna at angle Θ1

Gain (dBi) of the victim antenna at angle Θ2

Path loss attenuation at distance d (Km)

Noise level of the victim Rx (dBm)



- The value of I/N is compared with the threshold at the victim receiver

Computation method and key parameters (II)

- Imposing **a maximum value to I/N** and evaluating the path loss attenuation at a certain distance, the I/N formula allows to compute the BTS EIRP (Pt+Gt) which guarantee due protection to the incumbent service

- **Incumbent protection levels**:
  - FSS service I/N= -12.2 dB ITU-R S.1432
  - FS service I/N = -10 dB ITU-R F 758-6

- **Propagation models**: ITU-R P.452-16 and ITU-R P.2108 taking into account terrain altimetry and clutter loss.

- **Antenna models**: generally based on radiation patterns provided by operators and incumbents. If this information is not available the **ITU-R M.2101-0 antenna model** is used for **BTS** while for **FS** and **FSS** respectively the **ITU-R F 699-8** and **ITU-R 465-6** models are considered.

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Coexistence analysis in 5G pioneer bands

- In Italy the management of coexistence in the 3600-3800 MHz and 26.5-27.5 GHz bands involves the analysis of different types of scenarios:
  - 5G NR systems and incumbent systems FS (fixed service)
  - 5G NR systems and incumbent systems FSS (Fixed Satellite Service)
  - 5G NR systems in the 26 GHz band (club use)
  - Both Co-channel and adjacent channel scenarios

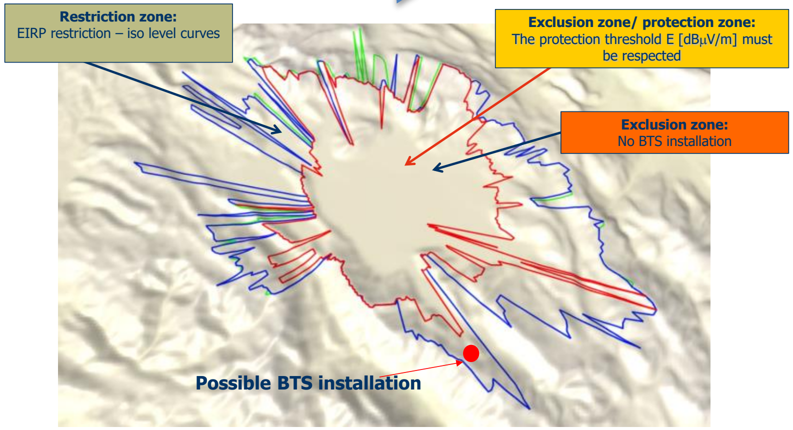
- Initial assessments: exclusion and restriction areas, then the protection criteria has been adopted evaluating protection thresholds for each type of incumbent FS and FSS as a function of angular resolution in azimuth.

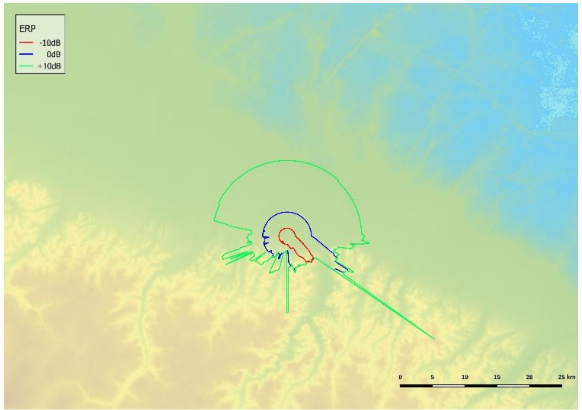
- Further investigation to improve efficient use of spectrum: mitigation techniques (e.g. optimization of AAS diagrams), site-specific analysis, protection criteria based on C/(I+N)

- Due to confidentiality issues only some qualitative examples of simulation results can be shown.

Example of simulation results

- Examples of Iso-lines curves (corresponding to specific BTS EIRP) delimiting the restriction and protection zones
- two different scenarios:
  - 5G BTS and FSS in the 3.6 GHz band, 5G BTS and FS in the 26 GHz band





- areas delimited by the iso-line curves where the incumbent protection criteria based on I/N is respected for a specific BTS EIRP value

Coexistence studies: 6 GHz band (I)

- The recently held WRC-19 decided to include the **6425-7125 MHz band** in the agenda for possible future identification of the band for IMT at the next WRC in 2023 for ITU-R Region 1.
  - This agenda item will require studies to verify the possibility to deploy IMT while protecting incumbent services in the band.
- In the meantime, parts of the 6 GHz band are also being considered for unlicensed usage, suitable for technologies such as Wi-Fi and New Radio – Unlicensed (NR-U).
- Coexistence studies on this band for 5G are currently starting after WRC-19 and specific technical parameters to be used for studies have to be provided by the end of June (ITU-R 5D). Incumbent users in this band are mainly Fixed Services (FS) and Fixed Satellite Services (FSS). In our study we focus the attention on coexistence of 5G with FS.

Coexistence studies: 6 GHz band (II)

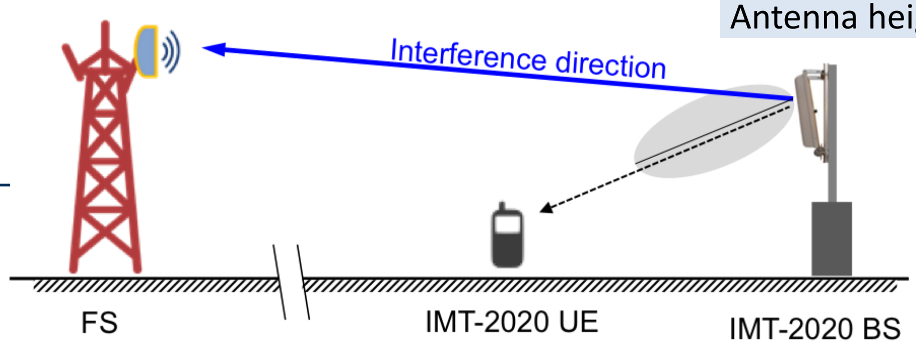
- Case study: impact of an **IMT-2020 interferer** on a victim **FS (P-P link)**.
  - Since technical parameters for 5G systems have still to be defined at this frequency band, parameters for different BTS types at 6 GHz are derived from Report ITU-R S.2367 which deals with IMT-advanced. Technical aspects of AAS considering 64-element (8x8) MIMO array with parameters are taken from Report ITU-R M.2412.
  - The worst case assumption for interference evaluation is based on the maximum base station EIRP (Equivalent Isotropic Radiated Power) towards the victim receiver.
  - The victim receiver radiation pattern is the one defined in ITU-R Rec. F.699.

IMT-2020 Simulation parameters (BTS)

	Macro urban	Indoor small cell
Pt	32 dBm/100 MHz	10 dBm/100 MHz
Element gain	5 dBi	5 dBi
EIRP	55.5 dBm	43.5 dBm
Antenna height (h_t)	20 m	3 m

Victim simulation parameters (FS P-P)

Rx noise figure (typical)	4 dB
Channel bandwidth (MHz)	30
Noise power	-95.22 dBm
Gr	38 dB
Maximum I/N	-10 dB
Antenna height (h_{FS}) (m)	15/30/60



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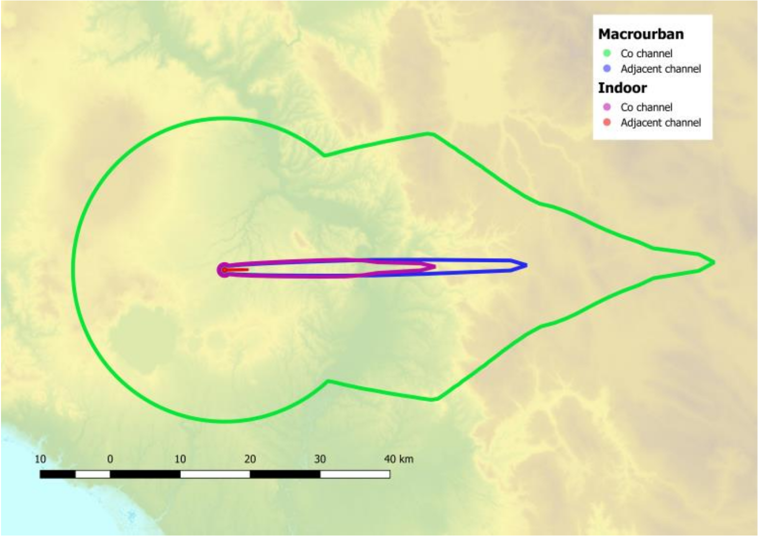
Coexistence studies: 6 GHz band (III)

- Co-channel and adjacent channel exclusion zones for macro and indoor scenarios
- Due to flat terrain conditions in the considered environment, the exclusion area is particularly large in the co-channel macrocell scenario while the extension is strongly reduced for the BTS indoor cell scenario and for the coexistence with FS in the adjacent channel
- Even a small angular separation between the IMT-2020 BTS and the FS P-P radiation pattern maxima will considerably reduce protection distances



Conclusions and further work (I)

- Sharing and coexistence techniques to improve spectrum sharing have been tested in real environments for both regulatory and research activity in different 5G frequency bands
- A proprietary software sharing tool developed by FUB is presented as a an applied model to real-world experiences to assess sharing and coexistence conditions in 5G bands
- Results show that coexistence is possible, both on a co-channel and on an adjacent channel basis.
  - The **separation distance depends on a lot of variables**: frequency, geometrical and electromagnetic characteristics of transmitters and receivers, etc.
  - **Active Antenna Systems** (AAS) can adapt the radiation diagram to minimise the power transmitted in some directions (e.g. through vertical beam steering introducing angular vertical discrimination between interferer and victim) to reduce harmful interference towards other systems
  - A proper choice of the active antenna configuration for both indoor and outdoor BS is essential to minimise the exclusion zones where coexistence is not feasible.

Conclusions and further work (II)

- Further work:
  - **Further investigation of sharing methodologies to improve spectrum usage efficiency:**
    - **interference mitigation techniques**
    - **Protection criteria based on C/(I+N)**
  - **Analysis of other coexistence scenarios in the new mmwave spectrum that will be identified for mobile service**

Acknowledgement

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