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**Jokela, T., Kokkinen, H., Kalliovaara, J., Ojaniemi, J., Kivinen, A., Lakner, T., Hallio J., & Paavola, J. 2018. Trial of Spectrum Sharing in 2.3GHz Band for Two Types of PMSE Equipment and Mobile Network. 2018 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Valencia (Spain), 6-8 June 2018.**

DOI: <https://dx.doi.org/10.1109/BMSB.2018.8436685>

Pysyvä linkki rinnakkaistallenteeseen: <http://urn.fi/URN:NBN:fi:amk-201901291653>

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**Jokela, T., Kokkinen, H., Kalliovaara, J., Ojaniemi, J., Kivinen, A., Lakner, T., Hallio J., & Paavola, J. 2018. Trial of Spectrum Sharing in 2.3GHz Band for Two Types of PMSE Equipment and Mobile Network. 2018 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Valencia (Spain), 6-8 June 2018.**

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# Trial of spectrum sharing in 2.3GHz band for two types of PMSE equipment and mobile network

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**Abstract**—This paper presents a trial on sharing spectrum between different actors in a flexible manner in 2.3 GHz band. Trial demonstrates a flexible use of shared spectrum providing means for the broadcasters and other Programme Making and Special Events (PMSE) stakeholders to gradually upgrade their equipment towards LTE/5G radio based equipment.

**Index Terms**—LSA, Spectrum Sharing, PMSE, LTE

## I. INTRODUCTION

As the amount of data in mobile networks increases, mechanisms for efficient spectrum use have been developed. Sharing spectrum between the users enables efficient utilization of valuable spectral resources. Spectrum sharing can be divided in exclusive spectrum use, i.e. no spectrum sharing, static sharing with radio licenses, dynamic sharing using electronic control like geolocation database or listen before talk equipment, and license-exempt public access. From a global perspective, practically all spectrum bands are shared. Regionally or per country, there can be exclusively allocated spectrum bands, but even then, more than 50 percent of spectrum is shared by different types of users. By far, the most common way of spectrum sharing is static sharing. Mostly but not always, radio communication using exclusive radio licenses is protected from harmful interference by the radio administration. License-exempt use is not interference protected, and dynamic spectrum sharing can be used to provide coordination for both interference protected and unprotected radio spectrum. Between licensing models and sharing types, we can recognize different ways of coordination. Radio licenses are the typical way of spectrum coordination for a radio administration. On certain bands, the radio licenses may be required but the mutual interference coordination is carried out by the industry. For example, when Programme Making and Special Events (PMSE) bands require a license, the coordination can be industry coordinated with the exception of the very large events. Listen before talk equipment can coordinate transmissions locally. One of the most common uncoordinated spectrum use for general public is Industrial Scientific and Medical (ISM) band, which is used, for example, by WiFi and Bluetooth.

There are two streams of dynamic spectrum management frameworks developed during this decade. One contains the centrally managed systems, including TV White Space (TVWS), Licensed Shared Access (LSA), and Citizens Broadband Radio Services (CBRS). The other one has dynamic

spectrum sharing systems without central a coordination: Unlicensed LTE (LTE-U), Licensed Assisted Access (LAA), and MulteFire.

ETSI RRS [1] has started a work item to study feasibility and technology for local high-quality wireless networks to access spectrum temporarily on a shared basis. The objective of the work is to identify how the current sharing frameworks like LSA (2.3 GHz) and CBRS (3.5 GHz) fit for this purpose. A comparison of CBRS and LSA for local temporary use can be found in [2]. The concurrent use of spectrum in 2.3 GHz frequency band and the related interference limits are defined in [3] and measurements and trials on sharing the spectrum in this band have been presented for example in [4], [5].

In this paper we focus on Licensed Shared Access (LSA) [6]. The trial presented in this paper focuses on sharing 2.3 GHz spectrum between wireless cameras (PMSE) and mobile network operator (MNO) serving users. The 2.3 GHz frequency band could be used by MNO when wireless cameras (incumbents) do not require it, which is often the case in many geographical locations for example in Finland. When the spectrum is required by the incumbents, such as wireless video cameras during a sports event, the transmissions of the mobile network in this area need to be controlled to allow the operation of the wireless cameras in the band. The mobile network base stations on this band can be shut down or at least the transmission power and potentially operating frequency controlled. To enable this control, geolocation databases can be utilized.

The assumption is that the broadcasters and other PMSE stakeholders may have a mixture of proprietary and LTE/5G wireless technology in use in the future. This relates to the use case "remote live production" identified in 5GPPP 5G-Xcast project [7] where 5G enabled PMSE equipment is considered. This trial demonstrates how broadcasters can gradually move from proprietary 2.3 GHz wireless camera technology to LTE/5G 2.3 GHz without causing interference to the incumbents. Both old and new equipment can be used simultaneously. Naturally the concept scales technically to other frequency bands and user verticals as well. One major advantage of LTE/5G radio based PMSE is that the spectrum manager can directly control the equipment (for example, shift its frequency further away from a potential interferer). Also, it enables bidirectional communication between the base station and the camera (e.g. for control) as well as use of regular

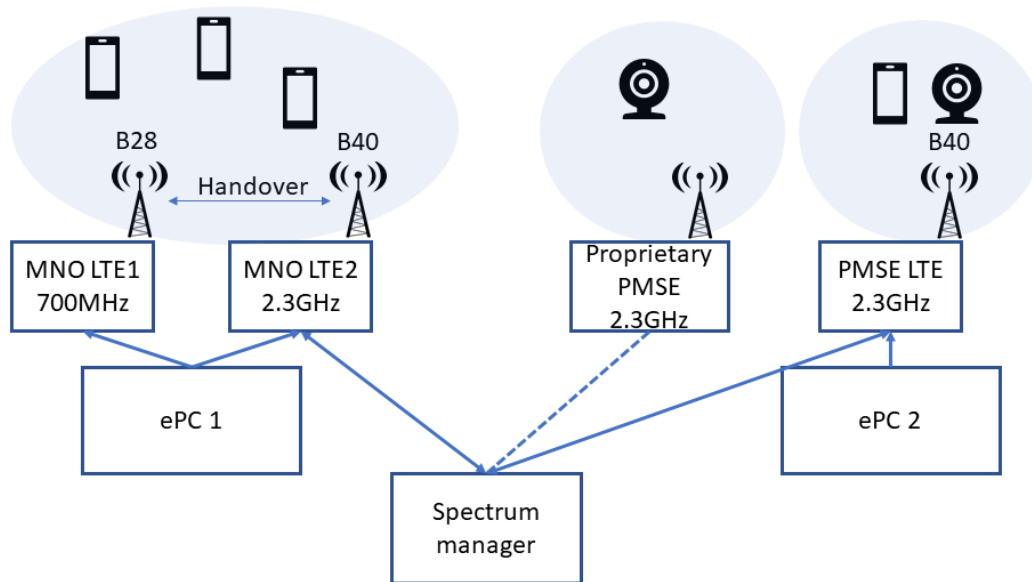


Fig. 1. Spectrum trial setup

high end mobile devices as "lightweight" production cameras for quick interviews among the audience for example. The advantage of having an own PMSE LTE system compared to using commercial LTE/5G networks for the PMSE traffic is that the PMSE stakeholder is able to control the use and thus the load of it's own PMSE system.

This paper is organized as follows: The built trial setup is presented in section II and the trial itself is described in section III. Main observations of the trials are presented in section IV. The conclusions and future directions are considered in section V.

## II. TRIAL SETUP

The trial presented in this paper was conducted in Turku University of Applied Sciences testbed (5GTNT) described in [8]. The 5GTNT testbed focuses on spectrum below 6 GHz. Currently the 700 MHz 5G candidate band and the 2.3 GHz Licensed Shared Access (LSA) band are supported for LTE. Equipment for the 5G candidate band 3.4-3.8 GHz is currently being added to the testbed. The test network sites are in Turku University of Applied Sciences campus area in Turku, Finland. The testbed is an integral part of 5G Test Network Finland (5GTNF) ecosystem [9], which coordinates the integration of the Finnish 5G testbeds.

In addition to the cellular systems, the testbed incorporates technologies such as digital television broadcast network, industrial radio modems, TV White Space radios, and LoRa. Further, a spectrum observatory network has been built in GlobalRF Spectrum Opportunity Assessment project in WIFIOUS program, which was jointly funded by the National Science Foundation (NSF) in the US and Tekes in Finland. The project built an international network of RF spectrum

observatories continuously collecting long-term spectrum data to study the trends in spectrum utilization and to identify frequency bands where spectrum sharing could be feasible.

The architecture of the trial setup shown in Fig. 1 consists of PMSE equipment operating occasionally on 2.3 GHz band and MNO LTE network operating on 700 MHz and 2.3 GHz bands. The latter represents MNO employing additional capacity on 2.3 GHz band using for example supplemental downlink concept. Proprietary PMSE equipment represents an OFDM based proprietary solution for wireless cameras operating on the band. PMSE LTE in Fig. 1 is a rapidly deployable LTE network that can be used for PMSE purposes. Different ePCs (evolved Packet Cores) are used for the MNO LTE and PMSE LTE networks. The ePC2 used for the private network is a limited feature core that includes only necessary components for the data transmission, thus enabling a rapid deployment.

Spectrum manager orchestrates the operation of the different systems on 2.3 GHz shared band. PMSE system information is collected with a web based reservation system. The users of the devices make reservations for their intended use. The reservation system has been piloted in the Netherlands in 2017-2018 [10]. The control of the PMSE devices also takes place through the reservation system so that the user of the devices are informed about required spectrum use changes with an email and the user has to deploy the configuration changes in the devices. Both PMSE LTE and MNO LTE systems have a direct machine-to-machine interface between the radio equipment and the spectrum manager. The priority order from highest to lowest considered in the trial is: PMSE, PMSE LTE, MNO LTE. When the priority user changes the configuration of the LTE network, a notification about the change is automatically received in the spectrum manager. The

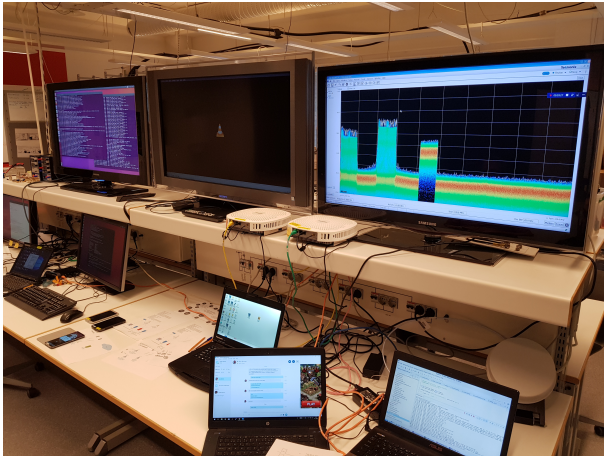


Fig. 2. Spectrum trial setup in the lab

spectrum manager processes the changed spectrum situation and evaluates if the lower priority use may cause harmful interference to the higher priority use. If there is a risk of interference, the spectrum manager evaluates which changes would be required to accommodate the higher priority use and to maintain the best possible service level also for the lower priority use. On the high level, this is implemented so that if there are frequency channels available, the lower priority use is transferred to those channels. If there are no other channels available, the power level of the secondary user is lowered or the transmission is denied. In this demonstration, the higher priority user is able to select the frequency channel to be used. An option for this could be that the higher priority user has the right to the spectrum resource in the band, but the specific frequency channel is determined by the spectrum manager.

The setup in the laboratory is shown in Fig. 2. The two base stations are shown in the middle and real time spectrum is shown on the screen behind them. In the figure on the spectrum screen, situation where all equipment is transmitting is shown. The used equipment is listed below:

- Nokia Macro 700 MHz BTS
- 2x Nokia Pico 2.3 GHz BTS
- Samsung S8 phones
- Tektronix spectrum analyzer
- DVB-T2 test transmission from R&S SFU Broadcast Test System
- Fairspectrum Manager

The spectrum manager communicates with the base stations operating at 2.3 GHz to alter their operation frequency, bandwidth and transmission power. Proprietary PMSE user informs the spectrum manager that spectrum is required, but the equipment cannot be directly controlled by the spectrum manager. Commercial base stations and LTE terminals were used in the trial. The proprietary PMSE equipment was emulated in the trial with a DVB-T/T2 transmission and Samsung S8 phones streaming video served as LTE based PMSE equipment.

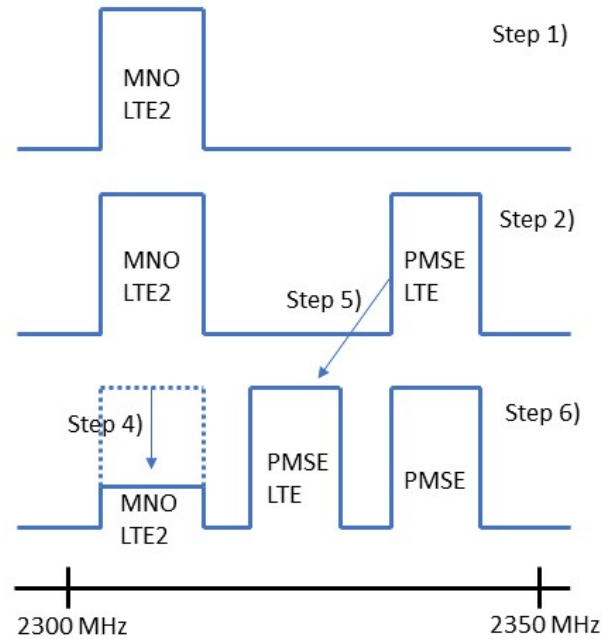


Fig. 3. 2.3 GHz spectrum use corresponding to trial steps

### III. TRIAL DESCRIPTION

The target of the performed trial is to demonstrate the LSA functions that have been developed to the Fairspectrum spectrum manager to enable dynamic spectrum sharing between users with different levels of priority. For the PMSE stakeholders operating equipment in the 2.3 GHz band this would allow a gradual transition from older PMSE equipment towards LTE/5G based equipment. The steps performed in the trial were:

- 1) MNO LTE1 (700 MHz) and LTE2 (2.3 GHz) serving users (web surfing, video streaming)
- 2) PMSE LTE (2.3 GHz) turns on as a rapidly deployable network for PMSE, spectrum is available for both MNO LTE2 and PMSE LTE
- 3) PMSE user registers to the spectrum manager registration system, on the frequency currently in use for PMSE LTE
- 4) MNO LTE2 limits its transmission power (if necessary) to follow interference limits and the users remain connected to at least B28 (700 MHz) base station
- 5) PMSE LTE changes channel to give space to PMSE
- 6) Proprietary PMSE equipment turns on

Corresponding snapshots of the 2.3 GHz spectrum band are visualized in Fig. 3. First the lowest priority LTE service, such as supplemental downlink of MNO LTE2, operates in the band. Then PMSE using rapidly deployable LTE air interface (PMSE LTE) requests for spectrum. At the same time, there is enough free spectrum for both to operate. Then the proprietary PMSE equipment requests for spectrum and the spectrum manager allocates suitable frequencies and power levels for all users. If necessary, MNO LTE2 adjusts the transmission

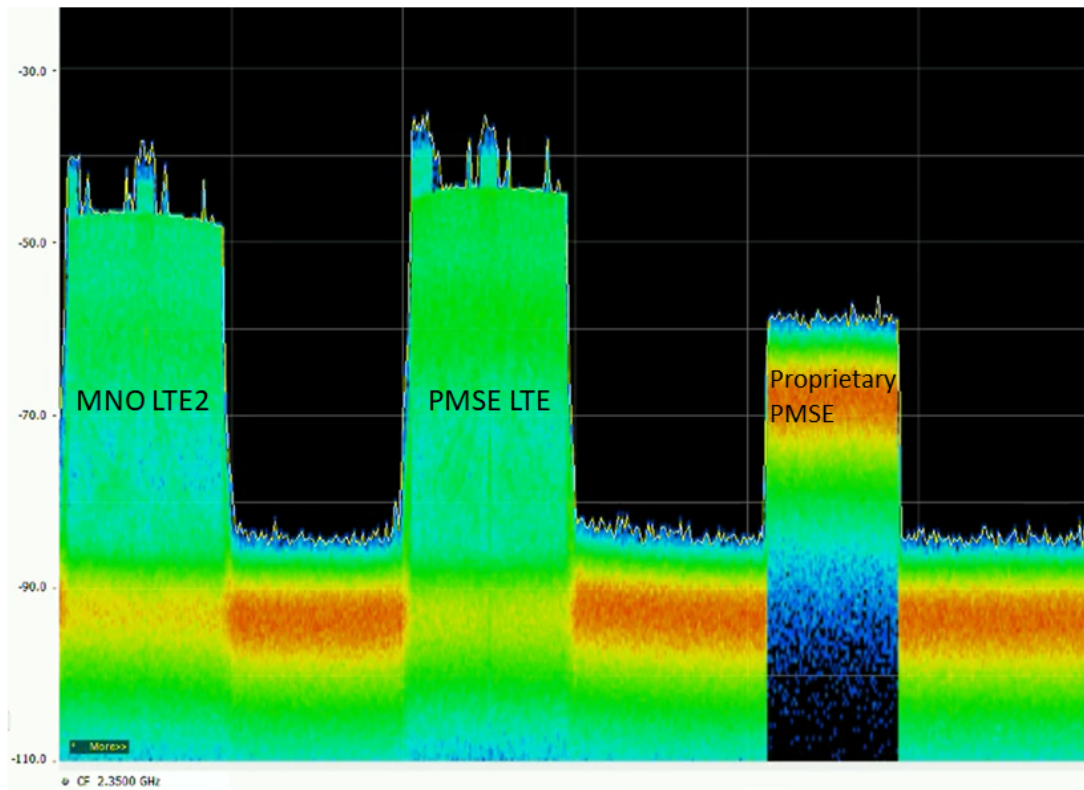


Fig. 4. Spectrum view (2.3 GHz) after step 6

power according to regulated interference limits to allow for the operation of higher priority users. Also, PMSE LTE that is controlled by spectrum manager via machine-to-machine interface switches frequency (for example due to limitations of proprietary PMSE equipment tuning range). Finally, all three networks operate on the shared spectrum as shown in the spectrum view from spectrum analyzer in Fig. 4.

#### IV. OBSERVATIONS

The trials indicated that the spectrum management using the tested equipment enables dynamic spectrum use in the frequency band. The spectrum manager allocates suitable frequencies for the LTE based equipment and follows the user priority order when spectrum is requested by the incumbent. In practice, there is some delay when changing the operation frequency of a base station when the RF components are restarted. During the trial, delays were in order of 10 seconds, but this value depends on the base station implementation and firmware version. Streaming live HD video over the PMSE LTE network works well, thus indicating possibility of using the network for PMSE purposes. Naturally, there is a period when video is stopped when the private LTE network is switching frequency. In real usage scenario for PMSE, however, it is not expected that the operating frequency of the systems would be constantly altered. As a conclusion, dynamic spectrum sharing between three users on the 2.3 GHz band was demonstrated illustrating a potential way for PMSE

stakeholder equipment technology evolution towards LTE/5G solutions.

In the standard systems, the incumbents are heterogenous, but the controlled devices (such as MNO LTE and PMSE LTE) are relatively unified. The demonstration shows that a dynamic spectrum management system can control simultaneously various types of devices and they may have differing capabilities and restrictions in spectrum use. MNO and PMSE LTE can technologically rather flexibly adapt to power level, center frequency, and bandwidth control. If MNO represents a geographically larger MNO network, only the power level of the base stations should be by default controlled by the Spectrum Manager, as altering for example the center frequency of one base station would potentially require some setup in the network side as well. The effect of such operation could be a topic for further studies.

#### V. CONCLUSIONS

The paper presented trials for dynamic spectrum sharing in 2.3 GHz band. The presented trial illustrated a mechanism that allows the the PMSE stakeholders to gradually upgrade their equipment operating in the band and also for the MNOs to employ additional capacity in the band simultaneously when spectrum is available. The same concept can also be applied to other frequency bands where spectrum sharing is allowed, for example for 5G systems coexisting with non-3GPP systems. 5G New Radio has the flexibility necessary to utilize spectrum

sharing paradigms. This allows for new innovations that will potentially make spectrum sharing integral component to the 5G [11].

In future, trials for sharing the spectrum on 3.4 - 3.8 GHz 5G pioneer band have been planned. In those trials, having dynamic priority order would be piloted. The priority order can be based for example on the state of the society. For example during a disaster, priority of the PPDR applications in the spectrum use would be raised. This way, the spectrum would be utilized in an efficient manner fulfilling the spectral requirements of the authorities at the same time.

#### ACKNOWLEDGEMENTS

This work was supported in part by the European Commission under the 5G-PPP project 5G-Xcast (H2020-ICT-2016-2 call, grant number 761498). The views expressed in this contribution are those of the authors and do not necessarily represent the project.

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