Utilization of Licensed Shared Access Resources

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Abstract. The increasing traffic demand will require additional spectrum to be used for mobile broadband. Licensed Shared Access (LSA) is one option for mobile network operators (MNO) to provide access to spectrum resources of other radio services, which are underutilized for specific time intervals and location areas, ensuring interference free coexistence between the sharing partners, i.e. this utilization of the spectrum requires decoupling of the resources in spatial or time domain. Indoor small cell deployments are particularly interesting for such a sharing scenario, due to the additional attenuation from the walls providing additional decoupling of the two systems. This article analyzes the network planning feasibility for LSA spectrum usage in indoor small cell scenarios. On basis of real indoor-to-outdoor propagation measurements and existing propagation models, a minimum decoupling range is determined where the LSA signal penetrating to the outdoor area falls below a certain threshold that guarantees interference free operation of the incumbent.

Keywords: Spectrum sharing · Spectrum efficiency · Licensed Shared Access (LSA) · Authorized Shared Access (ASA) · Indoor small cells

1 Introduction

The tremendous traffic increase observed during the last years, requires that the Mobile Network Operators (MNO) enhance their network capacities by improving the radio efficiency of their networks, increasing number of sites, etc. Furthermore, also additional spectrum for Mobile Broadband (MBB) provision will be required. Spectrum can be considered as the real estate for Mobile Broadband.

Exclusive access is the traditional means of making spectrum available to MNO. Currently there are around 600 MHz of total spectrum assigned to MBB. Although exclusive access is the preferred option, the amount of spectrum available is limited [1].

An alternative option to have access to additional spectrum is the use of the unlicensed spectrum. However, unlicensed spectrum requires new add-ons for LTE to provide fair co-existence for LTE with existing technologies [2]. Two

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similar solutions considering unlicensed spectrum are being standardized: LTE-U in the LTE-U Forum and Licensed Assisted Access (LAA) in 3GPP.

On the other side, getting exclusive sharing rights from other licensed bands, even though restricted in time and location, is a very efficient mean to boost operators spectrum resources for MBB use. Mobile networks target to offer predictable quality of service; therefore it is required that sufficient control mechanisms are implemented when applying spectrum sharing. Authorized Shared Access (ASA), also known as Licensed Shared Access (LSA)[1] provides a solution for bands belonging to other radio services that cannot easily be re-farmed or totally vacated by their incumbent users but where actual spectrum usage is underutilized and infrequent [3,4].

Under LSA, a national authority can grant rights to a few LSA licensees to utilize portions of an incumbent spectrum that are unused, at a given location and time, for mobile communications provided that it is not creating harmful interference outside of that spatially and/or temporally defined area.

Due to the popularity of smart phones and tablets, most of the data usage is indoor, necessitating extensive indoor small cells deployments. Around 80 % of all mobile broadband traffic is consumed by users located indoor. Indoor small cells provide the lowest total cost of ownership (TCO) for providing coverage and capacity in indoor hot spots in enterprises and public buildings [5].

Small cell indoor capacity enhancements by additional use of LSA spectrum is rather appealing due to the lower transmit power and the attenuation of the radiation through the walls of the building which helps to minimize the interference outside the building where the incumbent requires undistorted usage of its services. On the other hand, the variety of materials, building structures, wall distributions, windows, etc. increases the complexity to detect and control the interference from the indoor cells to areas outside of the building.

The next sections of this paper provides a detailed study of interference from the indoor small cells, and their use of the LSA spectrum. In Sect. 2, the interference detection in the case of LSA spectrum used by indoor small cells is introduced, in Sect. 3, the field measurements campaign carried out for model validation is described, and in Sect. 4, based on the results from the previous section, it is described how the LSA spectrum can be used respecting the requirements from the sharing arrangements and sharing framework.

2 Interference Detection

For LSA utilization, both parties, the incumbent and the LSA licensee contractually guarantee protection against harmful interference from both the incumbent and LSA licensees, thus allowing them to provide a predictable quality of service [3].

[1] The Radio Spectrum Policy Group (RSPG) and the European Commission largely adopted and generalized the concept but renamed it to Licensed Shared Access where ASA is framed within LSA.

The advantage of lower interference from the indoor small cells deployments, compared to the outdoor macro cells, is the possibility to use the LSA spectrum closer to the border of the protected area used by the incumbent, where usage of the macro cells, due to their higher power and the missing shielding by walls, would not be possible.

Before the LSA spectrum can be shared among different partners, a sharing framework must be established with the regulator, and a sharing arrangement must be established with the incumbent. Once sharing framework and sharing arrangement are established, the LSA licensee is allowed to use the spectrum when the conditions defined in both the sharing framework and the sharing arrangement are fulfilled. These conditions can include technical requirements, such as interference thresholds in certain areas where the incumbent users may use the LSA spectrum (protection zones). Hence, the LSA licensee needs a mechanism to control its radiation emission, respecting the requirements defined at the sharing arrangement and sharing framework, while exploiting the maximum from the transmission.

A previous study [6], described a method to adapt the transmission characteristics of a MNO macro network such that maximum coverage for LSA spectrum usage is achieved. In this study, the MNO network using the LSA spectrum consist of an indoor small cell deployment. Such a deployment requires a more complex propagation model to estimate the interference from the indoor network towards outside of the building, considering the penetration losses through the outer wall of the building as well as walls inside the building. Due to that most of the existing propagation models are considering outdoor-to-indoor but not the opposite way from indoor-to-outdoor that is required in this context, field measurements have been carried out to validate the considered model.

3 Indoor-to-Outdoor Propagation Validation by Field Measurements

In principle user measurements can be used to detect the interference in forbidden areas. However, it cannot always guarantee that there are no areas without measurements covered by base stations operating with LSA frequencies. Therefore, in addition to the user measurements, an interference prediction based on propagation models is also needed. This interference prediction requires information known from network planning tools: location of the sites, frequency, transmit power, orientation and gain of the antennas. If available, user measurements can further enhance the prediction quality. These user measurements could be obtained, for example, by enabling the functionality Minimization of Drive Test (MDT) [7].

Most of the propagation models consider basically the outdoor use case [8–10], and in the case of having also indoor cases, the focus is normally in the propagation from outdoor to indoor [11,12]. Moreover, in the few cases where a model from indoor to outdoor is considered, the main purpose is to maximize the coverage from indoor cells also outside of the buildings, while for the LSA use case, the objective is the opposite.

In order to check the feasibility of this model outdoor field measurements have been carried out from indoor base station deployments and compared with propagation model predictions.

3.1 Propagation Model

The WINNER II project [13], provides a reasonable model for this study, where one of the scenarios analyzed is the indoor to outdoor propagation (Fig. 1).

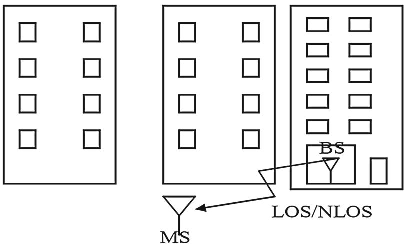

Fig. 1. Indoor to outdoor scenario

According to this model, the total path loss (PL) from indoor to outdoor is obtained from the sum of three components:

$$PL = PL_b + PL_{tw} + P_{in} \tag{1}$$

where:

- PL_b are the propagation losses from the transmitter to the receiver location considering the outdoor model
- PL_{tw} are the propagation losses due to penetration of the outer wall, considering the angle of penetration (θ), and the losses when the signal is crossing the wall perpendicularly (W_e), or tangentially (WG_e).

$$PL_{tw} = W_e + WG_e(1 - cos(\theta))^2 \tag{2}$$

- PL_{in} are the propagation losses inside the building, considering the number of walls (n_W), and the penetration loss per inner wall (L_W):

$$PL_{in} = n_W L_W \tag{3}$$

Table 1 shows the penetration losses parameters considered for the simulations.

Table 1. Penetration losses

Parameter		*Value*
W_e	Loss through external wall for the perpendicular penetration	18 dB
WG_e	Loss through external wall for the parallel penetration	15 dB
L_w	Loss through the indoor wall	5 dB

3.2 Indoor-to-Outdoor Field Measurements

The measurements took place in the Nokia Campus, in Munich. Due to the unavailability of equipment for the 2.3 GHz band, typically used for LSA in Europe, the measurement campaign was done using Wi-Fi access points operating at 5.4 GHz, which enable easy signal strength measurements by available tools and further analysis. In principle also the 2.4 GHz Wi-Fi could have been used, but in our case that was too much interfered by a large number of active SSIDs.

The access point (AP) was located in one of the meeting rooms in the ground floor, and the signal strength from this AP, transmitting at 5.4 GHz, was measured outside the buildings, in the street immediately next to the meeting room where the AP was located, as well as in the other streets surrounding the building. The measurements were taken in winter, having snow on the streets.

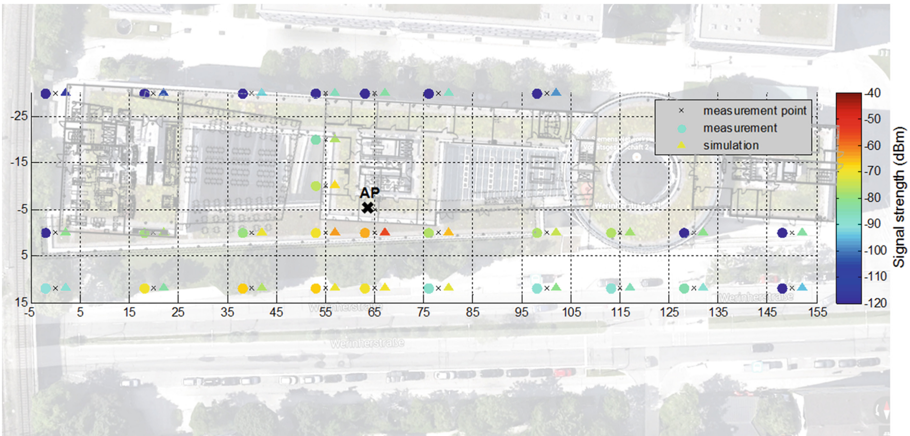

Fig. 2. Measurements and model prediction results

Figure 2 shows the signal strength measured and the propagation model predictions results at the measurement points in the campus.

First of all, both simulation and measurement results show that the signal strength of an indoor cell outside the building is still considerably high. This

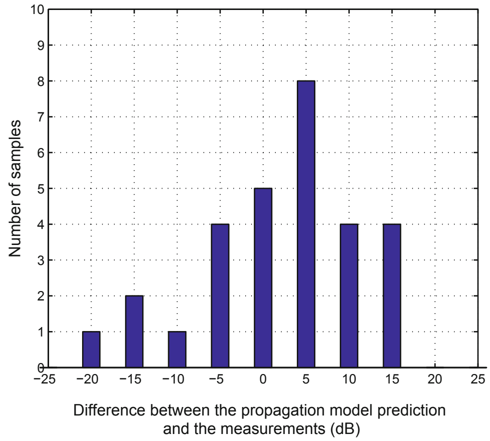

Fig. 3. Histogram of the difference between the propagation model prediction and the measured signal strength

effect is good when, the purpose of the deployments is to provide certain level of coverage outside the building. However, in the case of utilization of LSA spectrum, the purpose of the deployment of the small cells is to provide good coverage inside the building, but almost no coverage outside the building.

It is also observed that the results obtained from propagation model differ quite heavily with differences of up to 20 dB in both directions, under and over estimation.

Figure 3 shows the histogram of the difference between the results from the model and the measurements. The inaccuracy of the model requires an additional guard range of about 20 dB for confident interference prediction.

4 Indoor Deployment Options for Utilization of LSA Spectrum

Once the interference from the indoor small cells is estimated, it can be determined for which small cell base station depending on their location inside the building the LSA spectrum can be used.

At this step, the following information from the incumbent is required:

– Protection zone: Area where the incumbent users will use the spectrum
– Interference criterion: Maximum level of interference allowed by the incumbent spectrum users, that guarantees normal operation of the incumbent services.

Comparable to the LSA macro deployment study, the objective is to find optimal small cell indoor deployment and base station configuration that provides best LSA spectrum efficiency for allowed area while keeping the interference within the allowed range, which is investigated for a group of reference points

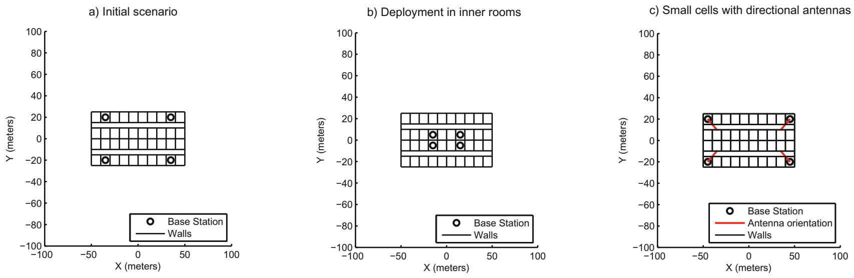

Fig. 4. Small cell indoor deployment options

in the protection zone, to compare it with the maximum interference allowed by the incumbent.

The previously described path loss model has been used to calculate the out-of-building emission for three different small cell indoor deployment options as given in Fig. 4. The deployment effecting parameters are Tx power, location of the base stations and their antenna characteristics. The received signal strength of the LSA frequency used indoor has been calculated for all reference points and is obtained summing up the signals from each indoor cell.

The three different deployment options of the small cell base stations inside the buidling can be classified as following:

(a) *Initial scenario:* The initial scenario consists of a single floor of a building, where there are four small cells placed at four different rooms.
(b) *Deployment of LSA small cells in inner rooms:* This option decreases the interference by locating the small cells in the inner rooms of the building, increasing the penetration losses due to the higher number of walls between the transmitter and the exterior of the building.
(c) *LSA small cells with directional antennas:* The small cells are located close to the external walls of the building, but oriented towards the inner part of the building. Although there will be some backward lobes of the antenna, the main lobe of the antenna will point to the inner part of the building, reducing the out-of-building emission received.

Considering the case of the wireless cameras [14,15], with an interference criterion (acceptable received interference power) of -95 dBm and the Tx power of 30 dBm of the small cell base stations the maximum interfere distance is determined, i.e. the further location measured from outer wall of the building.

Figure 5 shows the maximum interfered distance from the building for the three indoor small cell deployments, which corresponds to the further location from the outer wall where the signal exceeds the interference criterion.

The use of directional antennas provides the lowest out-of-building emission and allows the closest location of incumbent operation. For instance, if the equipment receiving the signal from wireless cameras is at least 40 m away from the building, the indoor small cells can be used without harming the wireless cameras communications.

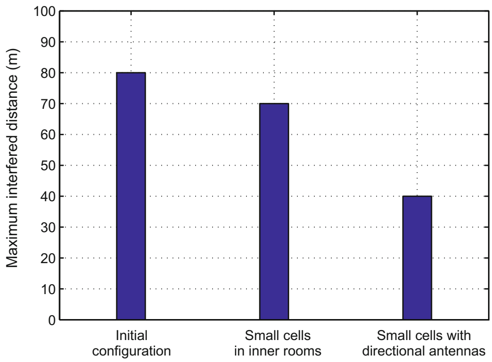

Fig. 5. Maximum interfered distance per small cell deployment

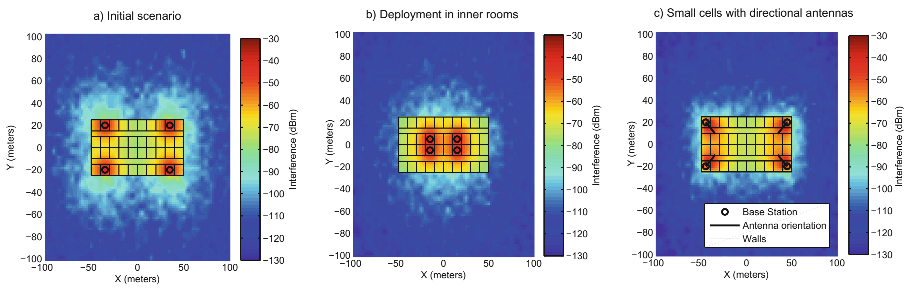

Fig. 6. Interference map per small cell deployment

The so-called heat maps visualizing the interference from all indoor sites are shown in Fig. 6.

5 Conclusions

LSA gives the mobile broadband operator the opportunity to use additional spectrum, which is currently licensed to other systems, and which is quite often unused for certain time intervals in certain locations. The LSA spectrum usage by small cells in indoor deployment outperforms the usage of outdoor macro cells since interference-free usage can be guaranteed even quite close to protection areas. With intelligent indoor small cell deployments the interference distance can be reduced to below a hundred meters, compared to couple of kilometers in case of the macro cells.

To determine that distance, network planning methods using empirical outdoor-to-indoor can be used. Although the match between the measurements and the model is not completely equivalent, the model can be used to estimate the areas where the current MNO cells may interfere.

The indoor small cell deployment option with directional antennas pointing to the inner part of the building showed the minimum out-of-building emissions. In case of LSA spectrum usage is planned is recommended to use this option.

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