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USE OF A STATISTICAL MEASUREMENT BASED PROPAGATION MODEL FOR SMALL CELLS TO EVALUATE GLOBAL EXPOSURE

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Abstract

Nowadays wireless technologies play an important role in people's everyday life. As data traffic grows significantly, operators aim to improve the performance of their network in order to respond to the growing demand. Small cells seem to be a promising technique to achieve this goal. Meanwhile, along with the expansion in terms of mobile technologies, public concerns about exposure induced by radiofrequency (RF) electromagnetic fields (EMF) still persists. In this paper, a new method is presented to assess the global exposure of a population induced by small cells using measurement data. The path loss exponent parameter has been statistically modeled. These models have been used to assess the exposure of indoor and outdoor users in a scenario.

1. Introduction

As a result of technological advances, the majority of people now use wireless technologies regularly in different aspects of their daily life. At the same time, new devices and generations of wireless networks have introduced a large number of popular applications and usages leading to a strong growth in data traffic over the last decade.
As data traffic is estimated to grow significantly by 2020, cellular network operators attempt to improve network performances. To do so, one of the promising techniques is densifying the classic macrocell networks by small cells. This results in offloading traffic from macrocells to small cells and also increases network performance, coverage, and capacity. small cells are low height low-powered base stations deployed in indoor or outdoor environments. The medium coverage of a small cell is ranged from a few meters to a few hundreds of meters.
Meanwhile, as the role of wireless communication technologies becomes more and more important, the public concern about human exposure to radio frequency (RF) electromagnetic fields (EMFs) grow just as much, despite existing international safety limits.
In order to assess the global exposure induced by uplink and downlink transmissions for a specific population, a new metric called Exposure Index (EI) has been developed in the framework of European LEXNET project[1].
In order to characterize the global EMF exposure of a population, one has to take into consideration different factors such as environment, technology, usage, emitted and received powers, etc. Similar previous studies have used a precise attenuation map provided by a deterministic propagation model as in [2]. Although, such deterministic approach is strongly dependent on detailed building and terrain data. As a consequence, the simulation process becomes very time consuming and also the variability linked to propagation environment is not taken into account.
The propagation model in a given environment is a very important issue in network simulation. The main problem in propagation modeling is to consider the attenuation and variations in the propagation environment. In general, the propagation models benefit from the fact that the emitted power density decreases exponentially with distance. γ denotes the mean path loss exponent, which indicates how fast the power density decreases with distance. The value of γ varies over the propagation channel based on the complexity of the environment. In order to cover the variation of γ for a small cell in an urban area, a series of measurements have been performed. Measurements cover different sites and frequencies used by LTE technology systems at different times of the day.
A scenario has been designed in order to assess the global exposure of LTE small cell users using the constructed statistical propagation model as an input parameter.

2. Measurement campaign

In June 2017, measurement campaigns have been carried during 4 days in an urban French city on two small cells. SC's antennas are directional with 38 dBm as EIRP. Small cell's characteristics are presented in Table 1. The street width is about 8 m and average building height is 10 m.

Table 1, small cells characteristics

Cell identity	1	2
Activity bands	4G 1800, 4G 2600	
Height	3m	
Mast type	Bus station	Advertisement panel

We have used trace mobiles in order to monitor the network characteristics such as emitted power, received power, the position of each measurement point and power control algorithm parameters.
Path loss measurements are performed by traveling in line of sight (LOS) direction of the small cell's directive

antenna while measuring the received signal strength. At the same time uplink power emission measurements are carried while uploading 100 Mbytes data files to an FTP server.

3. Statistical characterization of path loss relative to small cell emission in urban environment

The received power by user equipment can be presented by the following equation:

$$P_{received\_by\_ue} = P_{emitted\_by\_sc} - PL \qquad (1)$$

$P_{emitted\_by\_sc}$ denotes the emitted power by the small cell and $P_{received\_by\_ue}$ stands for the power received by a user equipment. PL is the path loss between a user equipment and the small cell. It is a common practice to represent path loss as some power of distance d [3], [4].

$$PL = A + 10.\gamma.\log_{10}(d) \qquad (2)$$

In which γ is the path loss exponent. A is the path loss constant considering that the gain of the receiver is 0 dB. λ is wavelength of the emitted wave.

$$A = 20\log_{10}\left(\frac{4\pi}{\lambda}\right) \qquad (3)$$

By isolating γ, the following equation is used in order to assess the path loss exponent at each point [4]:

$$\gamma = \frac{PL - A}{10\, log_{10}(d)} \qquad (4).$$

The value of γ has been computed based on about 10000 measurement point on two sites at 1.8 GHz. Results show that it is possible to classify two different γ models in terms of distance.
According to results for distances less than 60 m from the small cell, γ follows a generalized extreme value (GEV) distribution and for distances more than 60 m follows a Beta distribution. These distributions were further used as inputs to assess the emitted and received power by user.

4. LTE uplink power control algorithm

The uplink exposure is induced by EM radiation emitted by mobile devices. In LTE technology, the emitted power by a user equipment is determined through an uplink power control algorithm. From the network operator's perspective, power control means to adjust the emitted power according to the channel condition. The goal is to reach a target SNR (signal to noise ratio) while reducing interferences. Multiple power control algorithms have been implemented on different LTE channels. In our case, we are interested in LTE PUSCH (Physical uplink shared channel), which contains the uplink transmitted data. The power control algorithm is shown in the following equation [5] :

$$\mathrm{P}_{Tx} = \min\{Pmax, 10log_{10}(M) + P_0 + \alpha PL + \Delta_{TF} + f_g\} \qquad (5)$$

This algorithm is a combination of open and closed loop components. The open loop power control (OLPC) is responsible for a rough setting of uplink transmitted power. It compensates slow changes of path loss in order to achieve a target received power P_0 for one resource block. Then this power is multiplied by the total number of allocated uplink resource blocks (M). The path loss compensation factor α varies from 0.4 to 1. When α is 1, the measured path loss is fully compensated on uplink transmission. For α = 0 the path loss between user equipment (UE) and base station (BTS) is ignored in power algorithm and the emitted power is constant all time. For α between 0.4 and 1, path loss compensation would be fractional. [2]
The closed loop power control (CLPC) component considers fast variations of propagation channel by use of a corrector (f_g) and also modulation scheme (Δ_{TF}). $Pmax$ is the maximum uplink transmit power in LTE and is equal to 23dBm (±2dBm). The minimum power a UE can be used in connected mode for an active channel in LTE is -40dBm [5]. In this study we ignore the CLPC component due to its minor effect on emitted uplink power.

4. 4G small cell scenario simulation

As observed on measurement data, path loss exponent is variable and can be influenced by any change in the environment. A statistical approach is used to take into account this variability.
The scenario considered in this study is a street of 8 m width and 400 m length. Two buildings are considered at each side of the street. The penetration depth is considered to be 6 m and the height of the UE from the ground is 1.5m. Each building has 4 floors and the height of each floor is 3 m. We have considered 10 dB as penetration loss. Figure 1 and 2 illustrate the structure of the scenario.
The simulation has been performed for 10^5 different observations in order to assess almost every possibility of user's positions. Users are distributed uniformly in the indoor and outdoor area. Since people spend about 70% of their time in indoor we have considered that 70% of our occurrences happen in the indoor area. [6]
The small cell is placed in the center of the map in the outdoor area.

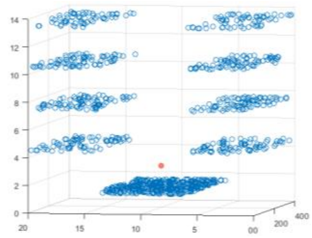

Figure 1, Structure of the scenario: indoor users are distributed in four floors at each side of the street.

Outdoor users are placed in the middle of the map. UE is placed at 1.5m from the ground and the small cell is placed at the center of the map in the outdoor area at a height of 3m.

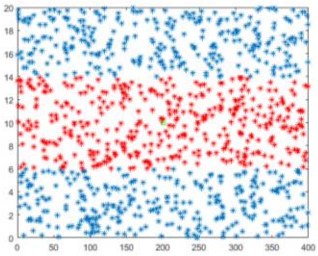

Figure 2, indoor and outdoor users. Outdoor users are placed in the street (middle) and indoor users are placed in the building (up and downside of the map). The small cell is placed at the center of the map in the outdoor area.

For each observation, we have computed the distance between user and the small cell. Then random sampling of the appropriate distribution of path loss distribution (GEV or Beta according to distance) has been carried out in order to assess the path loss distribution for each observation. Having the path loss distribution, we can assess the distribution of received and emitted powers for each observation. Figure 4 illustrates the distribution of received power by the user and figure 3 presents the distribution of emitted power by UE for 10^5 observations.

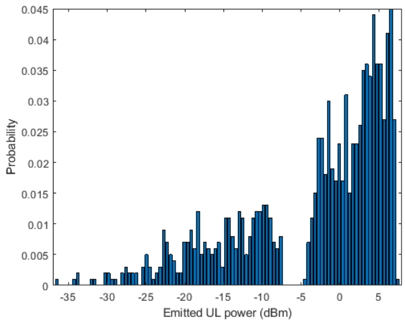

Figure 3, PDF distribution of mean uplink emitted power by UE

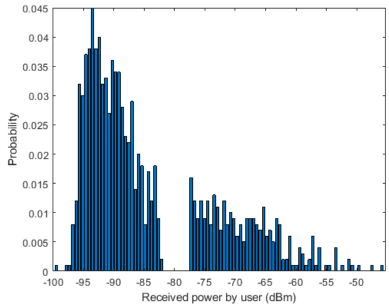

Figure 4, PDF distribution of mean received power by user

5. Exposure computation

Once the distribution of emitted and received power of each observation is computed, we are able to assess the global exposure distribution by using normalized whole-body specific absorption rate (SAR) values computed in the framework of LEXNET project[1].

6. Conclusion

This work proposed a new method to assess the global exposure of small cell users. Two statistical propagation models for an LTE small cell have been made by empirical data for different distances from the source. These models have been used in a simplified scenario. The received and emitted powers have been computed for different observations in the scenario. Results show that the received power by indoor users is lower than outdoor users in the downlink. The power emitted by UEs of indoor users is higher than outdoor users.

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