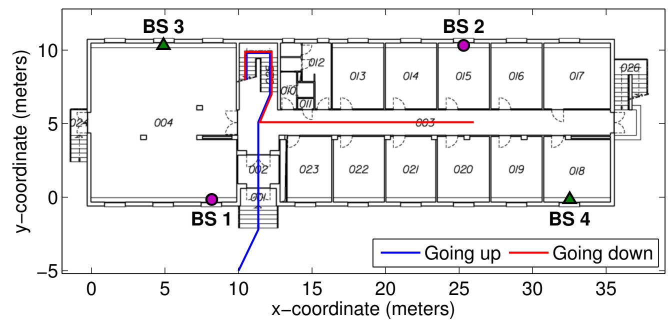
NB-IoT Ranging Performance in LTE Femtocell Networks

José A. del Peral-Rosado*, Michele Bavaro†, José A. López-Salcedo*,
Pravir Chawdhry†, Joaquim Fortuny-Guasch†, Gonzalo Seco-Granados*

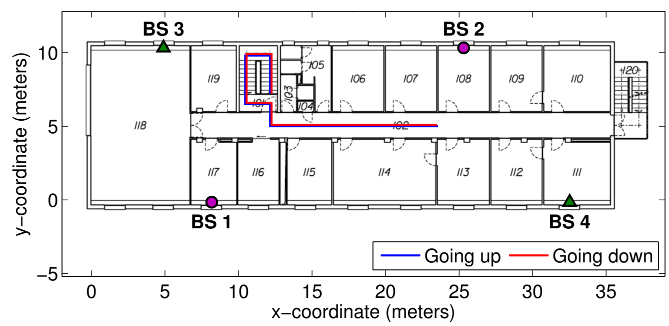
*Universitat Autònoma de Barcelona (UAB), Bellaterra, Spain
Email: {JoseAntonio.DelPeral, Jose.Salcedo, Gonzalo.Seco}@uab.cat
†European Commission, Joint Research Center (JRC), Ispra, Italy
Email: {Michele.Bavaro, Pravir.Chawdhry, Joaquim.Fortuny}@ec.europa.eu

I. Introduction

The standardization of cellular technologies for Internet of things (IoT) applications is aimed at complementing the existing proprietary solutions, such as LoRa and Sigfox, in order to cope with the market growth. These IoT applications are expected to demand localization capabilities in challenging environments, where Global Navigation Satellite Systems (GNSS) are not available, such as indoors and deep urban canyons. Therefore, the positioning support of cellular narrowband technologies is under study in the Release 14 of Long Term Evolution (LTE) standard [1]. These positioning capabilities are based on trilateration methods, such as observed time difference of arrival (OTDoA), with narrowband IoT (NB-IoT) configurations, which target a position accuracy below 50 meters, in order to fulfil location requirements for emergency services [2]. The current performance evaluations are mainly based on simulations over multipath channel models with low delay spread, i.e., Extended Pedestrian A (EPA) model [3]. However, to the best of authors' knowledge, there are no field results with NB-IoT signals. Thus, the objective of this preliminary contribution is to assess the performance degradation of NB-IoT ranging with respect to 10-MHz ranging measurements in an indoor LTE femtocell testbed, in order to assess the 3GPP simulation results.



(a) First floor (BS 1 and 2)



(b) Second floor (BS 3 and 4)

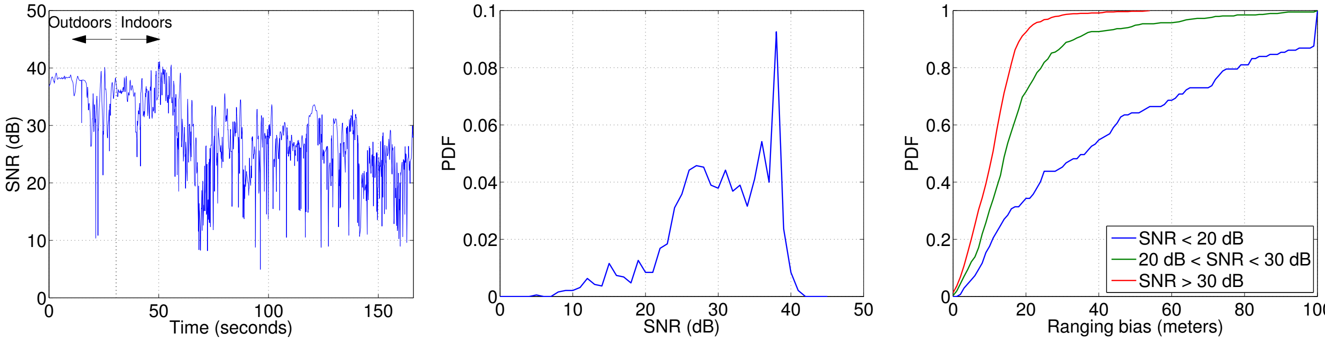
Fig. 1. Floor plans of the experimental LTE femtocell testbed.

II. LTE Femtocell Testbed

The experimental testbed is formed by four LTE femtocell base stations (BSs) placed in different parts of a two-story building, which is located at the Joint Research Center (JRC) in Ispra (Italy). As it is shown in Figure 1, two LTE femtocell BSs are installed in each floor. The femtocells are deployed by using USRP equipment controlled by a computer running the LTE software eNodeB of Amarisoft. The USRP N210 model is equipped for each BS with SBX transceiver daughterboard and a GPS disciplined oscillator (GPSDO), which ensures a precise time and frequency stability. The transmission of low-power signals with omnidirectional antennas is authorized by the Italian Ministry at band 7, i.e., carrier frequency equal to 2625 MHz, with a system bandwidth of 10 MHz.

The measurement equipment at the receiver is based on a low-cost software-defined radio (SDR), called HackRF One, in order to capture the LTE signals, and an omnidirectional OmniLOG 70600 antenna. The sampling frequency of the HackRF One is set to 12.5 Msps. The LTE RF baseband samples are then post-processed in snapshots of 200 ms by our MATLAB-based LTE software receiver.

Using this experimental testbed, the test scenario is defined by a user walking from outside to inside of the building, and between first and second floor, as in [4]. In order to calibrate the equipment, the user starts at a static outdoor position in the car park. Then, the user enters the building, goes up directly to the second floor, and walks through the main corridor. Immediately after, this path is repeated in the first floor. Periodical stops of ten seconds are included in this user path.



(a) SNR estimation (b) PDF of SNR estimates (c) PDF of NB-IoT ranging bias

Fig. 2. Experimental measurements with the LTE femtocell testbed.

III. NB-IoT Ranging Measurements

Once the LTE snapshots are captured, these samples are post-processed with our LTE software receiver in an opportunistic approach, without connecting to the network. The most powerful femtocell BS is acquired and tracked by using the full 10-MHz transmission, which contains 50 resource blocks (RBs) of 12 subcarriers each. The tracking of the time delay and the frequency is performed with a delay-locked loop (DLL) and a frequency-locked loop (FLL), as in [5], by using the cell-specific reference signal (CRS). The time delay and the frequency offset are estimated with a matched filter and a maximum-likelihood frequency estimator, respectively, by using CRS pilots over 50 RBs (i.e., 100 subcarriers). The receiver obtains 20 estimates per radio frame of 10 ms, which are then averaged and used in the tracking loops. These time and frequency synchronization errors are expected to be finely tracked at the end of the snapshot period, i.e., 200 ms. Thus, the averaged ranging estimates of the last radio frame are considered as reference ranging measurements. The NB-IoT measurements are performed by combining two CRS symbols over 1 RB (i.e., 4 subcarriers), and the resulting estimates are averaged over 20 symbols. The signal-to-noise ratio (SNR) is estimated over the 50 RB tranmission, as in [5], resulting in the estimates shown in Figure 2a. As it can be seen, the SNR levels decreases from outdoors to indoors, but they are still high enough to obtain a standard deviation of the 10-MHz filtered ranging estimates below 5 meters on the 80% of the cases. The probability density function (PDF) of the SNR estimates is shown in Figure 2b. The ranging performance degradation between wideband and narrowband transmissions is assessed with the difference or bias between the reference and NB-IoT ranging measurements, only for those snapshots with fine tracking (i.e., standard deviation of reference ranging estimates below 5 meters). The resulting NB-IoT ranging bias is grouped according to a low, medium and high SNR. As it shown in Figure 2c, the cumulative density function (CDF) of the NB-IoT ranging bias indicates a relatively low performance degradation below 20 meters for the 90% of the cases with a SNR above 30 dB, which is expected when the receiver is very close to a femtocell BS. For a medium range of SNR levels, the ranging bias degrades to below 30 meters for the 80% of the cases, while the performance is significantly poorer for lower SNR values. Therefore, these preliminary field NB-IoT results indicate the feasibility to achieve a ranging accuracy below 50 meters in the vicinity of small cells. Extrapolating this relative ranging performance to absolute positioning performance, our experimental results are expected to be in line with the 3GPP simulation results under EPA multipath [3], which indicate a horizontal positioning accuracy around 20 meters for the 67% of the cases.

IV. Conclusions and Future Work

This work has studied the ranging performance degradation between 10-MHz LTE transmissions and NB-IoT configurations of 180 kHz. Field measurements are conducted in an experimental LTE femtocell network formed by four base stations. The experimental results show a ranging error below 20 meters for the 90% of the cases between wideband and narrowband estimates for a high SNR. Despite the degradation on the NB-IoT ranging performance for medium and low SNR conditions, the relative NB-IoT bias is below 50 meters, which may allow the fulfilment of location requirements for emergency services. This initial study validates the difficulties encountered when performing narrowband ranging-based localization, and preliminary validates the 3GPP simulation results obtained with mild channel models. Future work is aimed at implementing the OTDoA solution with these field measurements, by addressing the network synchronization issues in an opportunistic approach.

References

[1] RP-161901, "Revised work item proposal: Enhancements of NB-IoT," TSG RAN #73, Sep. 2016.

[2] FCC, "Fourth report and order on wireless E911 location accuracy requirements," Tech. Rep., Jan. 2015.

[3] R1-1608620, "Evaluation of downlink positioning accuracy for NB-IoT," 3GPP, Huawei, HiSilicon, TSG RAN WG1 #86bis, Oct. 2016.

[4] J. A. del Peral-Rosado, M. Bavaro, J. A. López-Salcedo, G. Seco-Granados, P. Chawdhry, J. Fortuny-Guasch, P. Crosta, F. Zanier, and M. Crisci, "Floor detection with indoor vertical positioning in LTE femtocell networks," in *Proc. IEEE Globecom Workshops*, Dec. 2015.

[5] J. A. del Peral-Rosado, J. A. López-Salcedo, G. Seco-Granados, P. Crosta, F. Zanier, and M. Crisci, "Downlink synchronization of LTE base stations for opportunistic ToA positioning," in *Proc. ICL-GNSS*, June 2015.