Demo: UE Assisted Ambient Internet of Things in LTE Downlink, Energy Autonomous

Jingyi Liao, Kalle Koskinen, Xiyu Wang,
Boxuan Xie, Kalle Ruttik, and Riku Jäntti
Department of Information and Communications Engineering
Aalto University, 02150 Espoo, Finland.
Email: {firstname.lastname}@aalto.fi

Dinh-Thuy Phan-Huy
Orange Innovation
92320 Châtillon, France
Email: dinhthuy.phanhuy@orange.com

***Abstract*—Ambient power enabled Internet of Things (AIoT) defined 3GPP is promoted as the next generation communication standard, 6G. AmBC is a communication technique aiming to zero-energy device (ZED) for massive Machine Type Communications (mMTC). This paper suggests a user equipment (UE) assisted AIoT, based on Long-Term Evolution (LTE) Cell specific Reference Signal (CRS) and channel estimation. We demonstrated an energy autonomous ambient backscatter device (BD) and a real-time AmBC reader. This paper's results indicates that AmBC can reach the bit error rate (BER) to 10^{-3} order of magnitude in practice. The proposed AmBC system is a promising candidate of AIoT solution.**

I. Introduction

Internet of Things (IoT) has received much attention during the recent years, and it is seen as one of the key technologies enabling digital disruption of the society. Cellular IoT technologies offer a way to connect various sensor and actuator devices to the Internet by utilizing existing mobile networks [1]. Most of the existing IoT devices are battery powered which limits their operation time [2]. Some IoT devices are designed to fail once their batteries are depleted contributing to the ever-increasing pile of e-waste. Even if changing batteries would be possible, it could be too expensive due to the high cost of the needed labor. 3GPP has recently started a Study on Ambient IoT (AIoT) aiming to develop new massive Machine Type Communications (mMTC) solution for mobile networks that would support devices that require several orders of magnitude less power than the existing 3GPP low-power wide area connectivity solutions [3]. Backscatter communications is seen as one of the key technology enablers AIoT [4].

We demonstrate integration of energy autonomous AIoT device into cellular downlink. The proposed system uses Long-Term Evolution (LTE) cell specific reference signal (CRS) to illuminate the backscatter device and User Equipment (UE) channel estimator as a receiver [5], [6].

The essence of the demonstration is to show utilization of IoT technology while addressing the issue of dwindling natural energy, e-waste and high cost of labour in changing battery in cellular IoT technologies.

In this extended abstract, an AmBC experiment is introduced in real commercial LTE CRS electromagnetic environment, which cannot be demonstrated on-site according to radio regulations. The results of AmBC Bit Error Rate (BER) are given to prove the AmBC feasibility in practice.

In order to avoid the need for a frequency license, we do the demo over cables using recorded signal from a real base station as the signal source and software defined radio implementation of UE channel estimator. This demo will be conducted over cables using a recorded signal from a real base station as the signal source, and a software-defined radio implementation of a UE channel estimator.

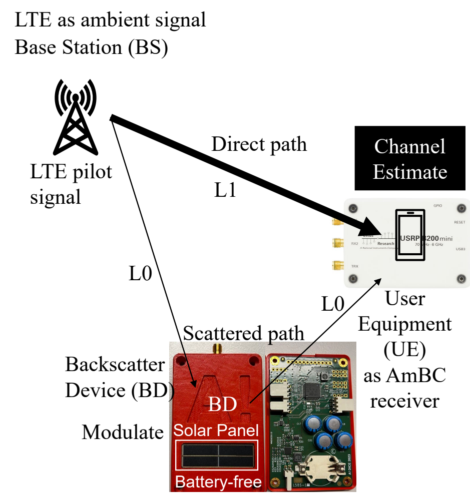

Fig. 1. Signal top level of proposed AmBC system.

II. Implementation

Figure 1 illustrates the top level of proposed AmBC signal model. Base Station (BS) continuously broadcasts LTE CRS and UE received that CRS. This downlink is called direct path. Proposed Ambient backscatter device (BD) is exactly illuminated by that ubiquitous CRS. The BD reflects or absorbs incident signal to UE by switching between two load impedance. This link is called scattered path. BD modulates the propagation channel in On-off keying (OOK) by matching or dismatching antenna impedance. That channel state changing is recognized by UE's channel estimation. In proposed AmBC, two frequency of BD flipping its switch modulates channel in square-wave FSK [7].

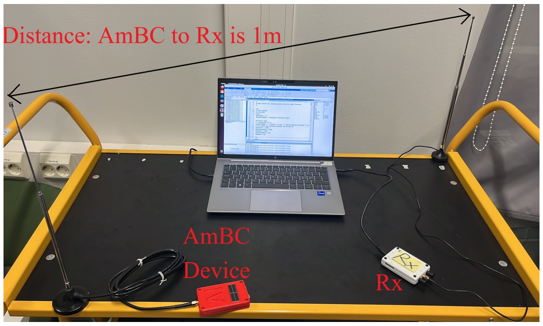

Fig. 2. Measurement setup.

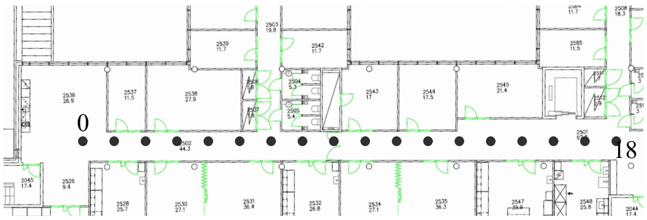

Fig. 3. The floor plan in the corridor for trolley trace. The black dot is measurement position with step 2 meters.

The proposed BD is energy autonomous. BD reflects or absorbs ambient signal does not consume any energy. But flipping state BD needs an MSP430 micro-controller, which is powered by a solar panel. The MSP430 is only several mW, whose energy could be accumulated from environment.

III. Measurement

The experiment setup was as figure 2. This experimental device was measured in a corridor of TUAS building, Maarintie 8, Espoo, Finland. We utilized commercial LTE signal in-the-air, whose center frequency is 806 MHz and band is 10 MHz. A B205 Universal Software Radio Peripheral (USRP) imitated UE, receiving LTE signal and estimating channel. The AmBC reader demodulation algorithm was running on the laptop. The AmBC was energy autonomous without any battery or out source power. The BD and Rx was fixed on a trolley, whose distance was 1 meter. The BD modulated propagation channel approximating 2-FSK, keying 250 Hz and 650 Hz respectively.

The trolley cruised in corridor as figure 3 floor plan showing. The measurement stepped 2 meters, from position 0 at west end to position 18 at east end in the corridor.

The BER results of experiment is in figure 4. The BER fluctuated a lot, depending on different position in the corridor. The good communication quality reached 0.002 BER at position 13. However the bad BER jumped to 0.22 at position 5. AmBC reader demodulated data package at each measurement point, which proves the feasibility of proposed AmBC system.

A possible explication of that various BER in the corridor is tunnel effect of ambient signal power strength. Considering the wavelength of LTE signal is 0.37 meters, the direct path and scatter path superposition may undermine AmBC unexpectedly when signals reflected on the wall of tunnel.

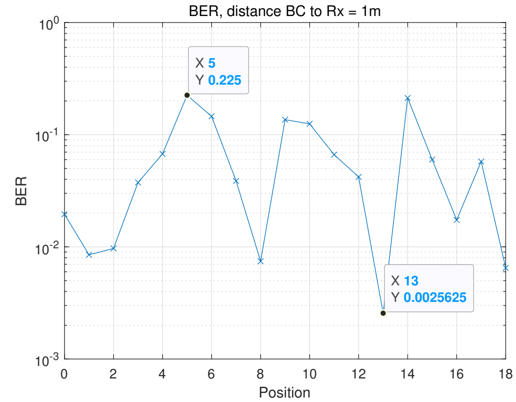

Fig. 4. BER in the corridor of AmBC.

IV. Conclusion

The experiment results shows the AmBC communication BER quality reaches 10^{-3} order of magnitude in the corridor, which proves the feasibility of proposed AmBC system.

This demonstration hopes to contribute to the studies and development of new mMTC solutions for mobile networks for devices that require less power than the existing 3GPP low-power, wide area connectivity solutions. Furthermore, it shows backscatter communications as one of the key technology enablers AIoT.

Acknowledgment

This work is in part supported by the European Project Hexa-X II under (grant 101095759) and Business Finland Project eMTC (Dnro 8028/31/2022).

References

[1] P. Ndiaye, D.-T. Phan-Huy, A. Hassan, J. Liao, X. Wang, K. Ruttik, and R. Jantti, "Zero-energy-device for 6g: First real-time backscatter communication thanks to the detection of pilots from an ambient commercial cellular network," 2023.

[2] M. A. Uusitalo and et al, "6G vision, value, use cases and technologies from european 6g flagship project hexa-x," in *IEEE Access, vol. 9*. IEEE, 2021, pp. 160 004–160 020.

[3] 3GPP, "Study on ambient IoT (Internet of Things) in RAN," 3rd Generation Partnership Project (3GPP), Technical Specification TS 38.848, Jun. 2023, version 0.2.0.

[4] Orange, "White paper: Orange's vision for 6G," in *Hello Future, available at: https://hellofuture.orange.com/app/uploads/2022/03/White-Paper-—Oranges-vision-for-6G-—March-2022.pdf*. Orange, March 2021.

[5] Technical Specification Group Radio Access Network, "Physical channels and modulation," in *Physical Channels and Modulation*, Valbonne, France, Mar. 2023, no. V17.3.0, pp. 147–150,180–184.

[6] K. Ruttik, X. Wang, J. Liao, R. Jäntti, and P.-H. Dinh-Thuy, "Ambient backscatter communications using LTE cell specific reference signals," in *2022 IEEE 12th International Conference on RFID Technology and Applications (RFID-TA)*, 2022, pp. 67–70.

[7] J. Liao, X. Wang, K. Ruttik, R. Jäntti, and D.-T. Phan-Huy, "In-band ambient fsk backscatter communications leveraging lte cell-specific reference signals," *IEEE Journal of Radio Frequency Identification*, vol. 7, pp. 267–277, 2023.