LTE-A UE Power Consumption for Carrier Aggregation Scenario

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***Abstract*— User equipment (UE) power consumption is a permanent concern for device manufacturers and users, which can be influenced by the network configuration. One of the main settings in LTE systems is carrier aggregation (CA). This paper compares real current measures over recently launched smartphone devices in CA and non-CA scenarios with the latest 3GPP releases. Results show that the most recent device had a reduction in power consumption of up to 39% and 44% for CA and non-CA scenarios, respectively. Allocating another carrier of 10 MHz increases only 13% in the newest model, while 61% in the previous one.**

***Keywords*— LTE, User Equipment, power consumption, carrier aggregation.**

I. INTRODUCTION

Smartphone manufacturers have been concerned to obtain smartphones with longer battery life, while the volume of mobile data is continuously increasing, especially with high demand for data from emerging applications. Network settings aim to support high data rates but decrease power consumption.

The Carrier Aggregation (CA) was introduced in 3GPP LTE Release 10 as one of the main features to support high data rates. A CA-capable UE can potentially aggregate up to 5 Component Carriers (CC) of 20 MHz each, reaching a total of 100 MHz of bandwidth. Also bringing benefits in frequency diversity with different propagation properties [1], [2].

Three techniques can be used to aggregate multiple CCs as follow [3], [4]:

- Intra-band contiguous CA: when two or more available CCs within the same operating frequency band are adjacent to each other.
- Intra-band non-contiguous CA: when two or more available CCs within the same band are non-adjacent to each other.
- Inter-band non-contiguous CA: when multiple available CCs are separated along the frequency bands.

In references [1], [5], [6], it was shown the CA impact with real measurements of the current consumption over a smartphone launched in 2012. However, both smartphones and 3GPP LTE Release have changed since then and no other work has been presented in this matter.

In this paper, we analyze power consumption and energy efficiency by adding CA in a recently launched smartphone.

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II. SCENARIO

The measurements were carried out using the following equipment:

- Anritsu Signaling Tester (Base Station Simulator) MD8475A: able to run an LTE-A cell with up to 5 carrier aggregations and total bandwidth of 100 MHz.
- Anechoic Test Chamber: a small box used to avoid external interference and guarantee high and stable SINR values;
- DC Power Analyzer Keysight n6705c: external equipment that replaces the smartphone battery and allows to measure the current consumption in hardware basis with samples of 1 millisecond;
- Smartphone: a high-end smartphone with Android 10.0 Operating System and launched in 2020.

The experiment is driven by sending a 1 GB file in the downlink with `iperf` over a UDP connection. The power current is measured during the data transfer every 1 millisecond. The phone's display is turned off manually before the experiment starts. The phone received signal is excellent with values around these values: Signal-to-Noise Ratio (SNR) = 30 dB, Reference Signal Received Power (RSRP) = -76 dBm, and Reference Signal Received Quality (RSRQ) = -8 dB, leading to a constant Modulation and Coding Scheme (MCS) 28.

The carrier aggregation configuration applied for the experiment is as follows:

- No CA: the phone is connected in band 4 with bandwidth of 10 MHz;
- Inter-band CA: the phone is connected to bands 4 and 7 (CA_4-7 [7]) with bandwidth of 10+10 MHz;
- No CA: the phone is connected in band 4 with bandwidth of 20 MHz;

The results are presented in the next section.

III. RESULTS

This study aimed to compare the power consumption and energy efficiency of a commercial CA-capable smartphone released in 2020 under different network conditions.

Figure 1 presents the profile of UE current consumption for a 1 GB downlink transfer using the whole bandwidth of the physical channel, measured during 185 seconds. It is easy to differentiate the period of active transfer from the idle period, that is, when the UE is transitioned to `RRC_IDLE` state and power consumption drops close to zero. We can see that the higher consume is equal both in 10 MHz and 20 MHz Single Carrier (SC) configurations, but the first scenario takes twice the time to finish the transfer than the second one. It is an

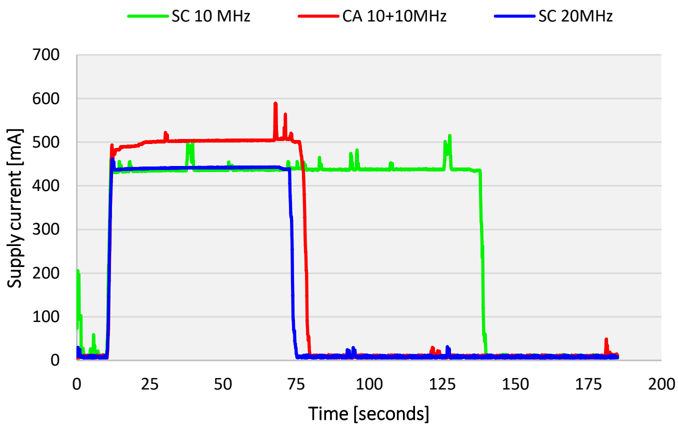

Fig. 1. Energy consumption from an external constant 4 V DC source in three different network connection configurations, during 185 seconds.

expected result since we are doubling the bandwidth without changing any other parameter. When considering 10+10 MHz CA, we can notice that the power consumption is not equal to 20 MHz SC, as would be reasonably expected. It consumes more energy and takes more time to finish the bytes transfer. Most of the power consumption is due to the Digital Signal Processor (DSP) to handle the LTE base band, the CPU to run the Android Operational System and the Radio Frequency circuit.

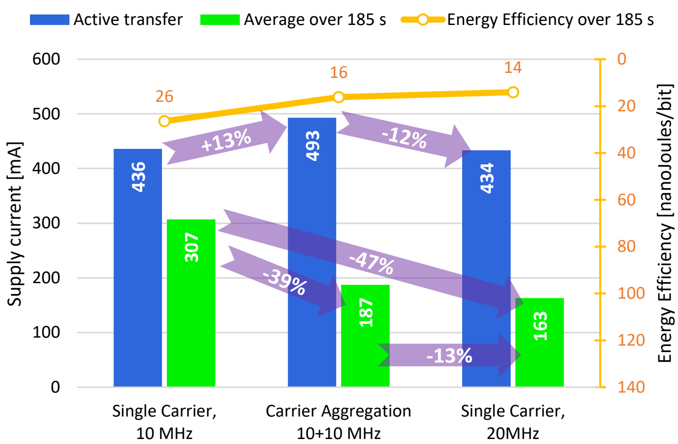

Fig. 2. Average energy consumption and energy efficiency of each connection configuration over 185 seconds.

Figure 2 presents the comparison of the average energy consumption among each scenario. CA scenario presented an increase of 13% of current consumption during the active transfer time, compared to the SC configuration. On the other hand, the transfer time was shorter when CA was enabled and the UE transitioned to the idle state sooner, what reduced the average consumption in 39%. When comparing SC 20 MHz with CA 10+10 MHz, we observe that the SC configuration consumes less energy during active transfer time and on average as well. The extra power consumption is probably due to the use of two digital circuits (bands 4 and 7) and the signaling overhead caused by the CA.

Considering the energy efficiency in the UE perspective, we can see in Figure 2 that the SC 20 MHz scenario spends less energy per transferred bit than the other scenarios, what can benefit users with longer battery life or more data transferred in the same period of time.

Comparing our work with [6], where the authors use a LTE UE launched in 2012 from the same manufacturer, the supply current over the active transmission is presented in Table I.

TABLE I

SUPPLY CURRENT FOR THE ACTIVE TRANSMISSION.

Reference	SC 10 MHz	SC 20 MHz	CA 10+10 MHz
Lauridsen, 2014 [6]	500	772	806
This work	436	434	493
Difference	-13 %	-44 %	-39 %

As can be noticed, the new smartphone is much more efficient than the old smartphone in the scenario without CA. Allocating a second carrier of 10 MHz increases 61% in the previous model but only 13% in the newest one.

IV. CONCLUSIONS

In this study, we presented the power consumption of a high-end smartphone launched in 2020, containing several advances in electronics, radio frequency and standardization when compared to another model launched 8 years ago. Energy consumption was assessed in an inter-band carrier aggregation scenario with 10+10 MHz. The results show that the most recent device had a reduction in power consumption of up to 39% and 44% in the scenarios with and without CA, respectively. The power consumption of latest launched smartphone improved meaningfully due to technology advances.

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