**EARTH Validation Activities and Telecom Italia Test Plant**

The European project EARTH has put forward a challenging target to improve the energy efficiency of the mobile communication infrastructure to satisfy the future traffic demands with a limited carbon footprint. During the project, many solutions have been proposed at network deployment and management level as well as on hardware and component level.

Several of the above solutions have been object of measurement campaigns inside the Work Package 5 and under the responsibility of Telecom Italia, carried out for their performances evaluation aimed to validation after their integration in Telecom Italia Test Plant LTE network and their deployment as hardware prototyping platforms. The obtained measurements illustrate the feasibility and validity of the developed solutions and of their savings under realistic operation conditions.

The validation has been done on the following platforms:

- The "ON/OFF scheme" for switching on/off cells of a radio access network in LTE technology
- The EARTH transceiver system for LTE macro-cell base station
- The EARTH transceiver system for LTE small-cell base station
- The Low Loss Antenna interface for small-cell base station.

These platforms will be hosted in Turin at Telecom Italia Test Plant and here will be submitted to Final Review on September 25th-26th by the European Community.

The validation has been focused on several technical enablers, on the corresponding hardware features and/or functionalities defined inside the four Integrated Solutions proposed by EARTH. The enablers and the corresponding functionalities object of performance evaluation have been the following ones:

The enabler "Cell Discontinuous Transmission" (Cell DTX) that on the network side acts at macro-cell BS and small-cell BS levels and builds on the hardware feature component de-activation which facilitates low power consumption states. In this investigation the focus has been on Micro Cell DTX entailing that when no user data is transmitted, the radio is put into sleep mode.

The enabler "Bandwidth Adaptation" (BA) is a dynamic management method for adapting the power consumption to the actual traffic demand of individual BSs. BA is based on a stepwise adaptation of the bandwidth usage (1.4 MHz, 3 MHz, 5 MHz, 10 MHz, ...) to the required traffic load, i.e. by an adaptation of the maximum number of radio resources that are used during each LTE subframe. This enabler uses the Operating Point Adjustment (OPA) feature in order to adapt the transceiver to reduce the Power Amplifier's supply voltage so that it operates more closely to its most efficient operation point.

The enabler "Low Loss Antenna Interface" whose design and development have been conceived for small-cell BS and whose objective is a global energy efficiency optimization of the RF front-end in the transmission path, with a focus on the opportunities offered at the antenna level to reduce the constraints on the power amplifier and on the transmission filter. Validation of this hardware solution consists in comparing, in terms of energy efficiency, a standard RF front-end ("EARTH OFF") with a low loss RF front-end entailing a load adaptive power amplifier with a tunable matched network filter ("EARTH ON").

The last but not the least the energy efficient technique named "ON/OFF scheme" has been object of validation. It is a network management method whose main objective is to switch off or on a single LTE cell on the basis of the number of UEs inside the same cell. By means of a proper monitoring of the number of UEs inside each cell belonging to an LTE BS, the scheme can decide whether to maintain switched on or to switch off the cell; every time the number of UEs inside the cell goes below a predefined threshold the scheme is able to switch off the cell; this action avoids energy wasting whenever there is no need to maintain switched on the cell assuring in such way energy savings during the day.

It is pointed out that the validation of these four platforms has entailed the set-up of four appropriate test scenarios and the adoption of all the needed laboratory equipment.
The ON/OFF scheme has been successfully validated in the measurement campaign, showing the energy saving from taking the decision to switch off the cells of a complete LTE radio access network. The energy savings that have been obtained by means of comparisons of the average currents consumption without and with the adoption of the “ON/OFF scheme” have been around 15% confirming the results expected from theory and obtained by simulation of the “ON/OFF scheme” behaviour.

As far as SLA transceiver system for macro-cell base station is concerned, the reduction on power consumption is evaluated by using LTE signals of different traffic load levels and by applying the component deactivation feature in the transceiver system. “Snapshot” signals of 20ms length each, have been used for micro DTX application for several traffic load levels to evaluate the power reduction individually for different levels. The maximum average RF output power, which still meets the LTE standard requirements for adjacent channel leakage, when applying the component deactivation feature has been determined and shows 44.5dBm and this value has been used for the measurements. The power reduction in the adaptive transceiver system has been evaluated for traffic load levels between 100 and 0%. The improvement in the transceiver system level are up to 20.5%, while the maximum is at 0% traffic load, the situation without user data transmission but with regular transmission of signalling. The improvements on the adaptive PA only are up to 32.1% while for the small signal transceiver up to 8.6% have been measured. Evaluations with LTE signals of variable load, which follow the daily traffic load profile within 480ms, have been done for dense urban and rural scenario. The measured power reduction averaged daily is 10.3% and 14% respectively and shows the benefit on energy efficiency improvement when applying micro DTX in combination with component deactivation features of transceivers for macro-cell base stations.

As far as the transceiver system for small-cell base station is concerned, four different test cases have been evaluated. The first one foresees that the bandwidth is kept constant to 10MHz, independent from the variation of the traffic load over the day. For this scenario, micro-DTX can be activated (test case 1) or deactivated (test case 2). The second one foresees that the bandwidth can be adapted to 1.4MHz, 3MHz, 5MHz and 10MHz according to the variation of the traffic load over the day. Depending on the
traffic load, the available test signals are used to obtain the closed match with the daily traffic load profile; for this scenario, micro-DTX can be activated (test case 3) or deactivated (test case 4).

Given that the test case 4 is the best approximation of the daily traffic load profile, it can be concluded that about 43.3% measured energy efficiency gain is obtained over the RF-TRX and the AEEPA when applying bandwidth adaptation and micro-DTX while as regards the reference test case 1 about 35% measured energy efficiency gain is obtained over the RF-TRX and the AEEPA when applying micro-DTX alone.

All the results above reported on the selected key technology components of the EARTH concepts have been successfully validated under realistic conditions and motivate to proceed in the future with the research, design and development of this type of energy efficiency solutions conceived for radio access network LTE technology based.