eNodeB Power Saving in LTE Network

BTS Embedded Power Meter for Energy Efficiency Monitoring
and

eNodeB Power Saving MicroDTX

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Abstract—**Nowadays it has become very important to preserve the environment. By reducing power consumption of the eNodeB it possible to minimize negative impact on environment. On the other side, one of the main target of the telco operators is to decrease operational expenses. Mobile vendors have introduced new features that are allowing to achieve both of the mentioned goals. In this paper, two features will be presented and their functionalities will be closer described.** *BTS Embedded Power Meter for Energy Efficiency Monitoring* **feature is necessary to activate in order to measure power consumption of eNodeB. After the activation of the mentioned feature and power consumption measurements have been collected, another feature is introduced.** *eNodeB Power Saving MicroDTX* **feature provides energy saving of the eNB. It is obtained by switching off the cell's power amplifier (PA) for the duration of unused orthogonal frequency-division multiplexing (OFDM) symbols. In the final part of the paper influence of the features on the major LTE KPIs is presented, as well as achieved power consumption reduction.**

Key words – Measurements, Power consumption, Power saving, Micro DTX, eNodeB, LTE, KPIs

I.   INTRODUCTION

BTS Embedded Power Meter for Energy Efficiency Monitoring

First of it is necessary to activate this feature prior the activation of eNodeB Power Saving – Micro-DTX.

BTS Embedded Power Meter for Energy Efficiency Monitoring feature introduces new software to support power metering function available with the new hardware to monitor the power consumption of the RF module.[2]

BTS Embedded Power Meter for Energy Efficiency Monitoring feature enables the operators to monitor the power consumption from RF modules, and system modules, which enhanced power management and optimization of a particular site.

TS Embedded Power Meter for Energy Efficiency Monitoring feature introduces a new hardware called power meter, which is embedded in the BTS hardware's RF module.

The power meter is capable of measuring power consumption in DC voltage and amperage.

New counters within the M5008 measurements are created that are based on the reports from the power meter in RFs and static values in system modules. Power reports and counters are viewed in the BTS site manager (BTSSM), while only counters are collected in NetAct.

The power meter function is available in RF modules that have embedded power meter. Reporting mechanism is shown on the figure 1.
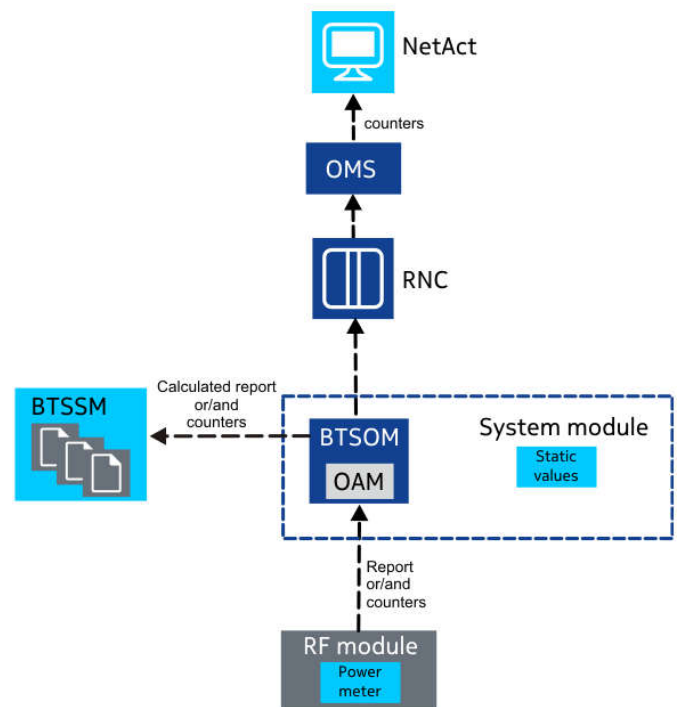

Figure 1 - Reporting Mechanism

A power meter is embedded in the RF modules, and it measures the power consumption in voltage (V) and amperage (A) of RF (with RRH) for every one-minute. The measured values are reported to the Operations, Administrations and Maintenance (OAM). The OAM uses these measured values to create counters and power reports to the BTSSM.

II. MAIN FEATURE DESCRIPTION

eNodeB Power Saving – Micro-DTX

Micro-DTX feature provides energy saving of the eNB. It is obtained by switching off the cell's power amplifier (PA) for the duration of unused orthogonal frequency-division multiplexing (OFDM) symbols. It enables to save up to 20% of power only in cells with very low or without user-related DL traffic.[1]

The mechanism used for this purpose is based on the concept of unused OFDM symbols and the DL scheduler's role in switching off the PA.

Each LTE DL transmission is built of a sequence of subframes (TTIs- Transmission Time Intervals) that last 1 ms. The subframes are divided into 14 OFDM symbol durations (only for the normal cyclic prefix). Even if there is no user-related data to transmit, a transmitter sends some reference signals in a well-defined OFDM symbol space within a subframe. In the LTE1891: eNodeB Power Saving – Micro-DTX feature, the Micro-DTX (discontinuous transmission) functionality allows switching off the PA of the LTE cell, for the duration of individual OFDM symbols, at times when the scheduler has determined that there is no DL signal to be sent in the air. As a result, the power consumption of the eNB is reduced.

This feature works only at times of a very low DL traffic load and not more than five UEs RRC connected to the cell. The maximum muting is only reached if no users are connected. The LTE1891: eNodeB Power Saving – Micro-DTX feature works for setups with a single system module (MAC) entity controlling one or more PA(s) which are serving no other cells. The MAC monitors the OFDM symbol durations in a future timespan of 40 ms, collects the data into a message covering these 40 ms, and sends a PA muting pattern for the next 40 ms to the radio frequency (RF) module.

The Micro-DTX feature operates on three time scopes:

- OFDM symbol time scope with respect to PA on/off control

- TTI scope to define when DL signal (DL-S) operates or not and when OFDM symbols are muted

- 40-ms duration scope with respect to pattern selection and its ability to follow the traffic demand (the trend in DL load)

The DL scheduler monitors the radio resource usage in a timespan of 40 ms, builds an estimate for the next 40 ms, and, based on that estimation, selects the appropriate power-muting pattern. Power-saving mechanism with scheduler and RF module is shown on the figure 2.
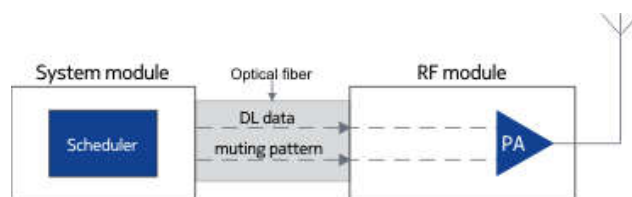

Figure 2 - Power-saving mechanism

The power-saving mode is applied in the following scenarios:

- cell without any RRC-connected UE (maximum saving) or a cell with a maximum of five UEs RRC-connected and with a low DL traffic load (reduced savings)

- one or more micro-DTX-capable power amplifiers are connected

- cell bandwidth is five MHz or higher

Micro-DTX uses subframe patterns to define which TTIs are allowed for DL scheduling. The patterns are chosen in such a way that they cause a minimal impact on other, timing-sensitive, functions. In macro cells, they also allow straightforward cooperation with eICIC features. An O&M parameter controls the level of DL resource usage at which the transition is made between a reduced power saving and provision of full capacity.

Regarding the composition of activated features and parameter settings, the eNB chooses one of the following power-muting patterns for a cell:

- the minimum ON power-muting pattern (*mdtxMinimumState*), no UEs connected

- one of the predefined standard-muting patterns (*mdtxMutingState*), up to five UEs connected and low DL traffic load: either the standard20 or standard40 pattern. The standard40 pattern is selected if the SI window length (*siWindowLen*) parameter value is set to 40. The standard20 pattern is selected if the SI window length (*siWindowLen*) parameter value is set to 20 (set in VIP mobile network).

- applying NO power-muting (*mdtxNonMutingState*), more than five UEs connected; no muting patterns are sent to the RF unit

The conditions for going from mdtxMinimumState to mdtxMutingState and from mdtxMutingState to

mdtxNonMutingState are evaluated in parallel. Therefore, if a SIB10/11/12 message is queued, the eNB enters mdtxNonMutingState.

The conditions for going from mdtxMinimumState to mdtxMutingState are the following (even if only one of the conditions is true, the transition will take place):

- a RACH preamble that is valid for the cell was received

- one or more (up to five) UEs are RRC_CONNECTED

- one or more SCell activation notifications were received

- if a SIB10/11/12 message is queued for transmission, this will cause a direct transition to mdtxNonMutingState

The conditions for going from mdtxMinimumState or mdtxMutingState to mdtxNonMutingState are the following (even if only one of the conditions is true, the transition will take place):

- there are more than five UEs in an RRC_CONNECTED state

- a SIB10/11/12 message is queued for transmission

- if LTE1113 is activated, ABS muting pattern 2 or higher is selected

- the averaged DL PRB (Physical Radio Block) usage ratio (ratio R) is >= mdtxAggressiveness

- there is data available for (one or more) DRX UEs which have all TTIs of their on-duration coinciding with power-muted subframes in the standard muting pattern assigned to the current siWindow's length

While configuring the mdtxPdcchSymb O&M parameter, the operator should consider muting of the physical downlink control channel (PDCCH). The micro-DTX has an inherent impact on the PDCCH usage because all DL traffic that would otherwise be handled in a subframe must now be covered in one of the remaining non-muted subframes. This increases the number of scheduled UEs per TTI, and it may cause an increase in the PDCCH blocking rate. Even without any UEs connected to the cell, some PDCCH capacity must be provided in order to serve random access channel (RACH) attempts of newly incoming UEs.

III. EVALUATION OF THE RESULTS

Test cluster consisted of 8 LTE800 cells with the least traffic in the network and the 6 LBTS with the most traffic. The ENodeBs have been chosen in such manner so it was possible to analyze samples with low PRB usage, as well as extremely high PRB usage. In purpose to get the most accurate results it was not compared average hourly consumption of energy per ENodeB or even cluster, yet it was average consumption of

energy normalized on PRB usage. Traffic on LTE network is constantly increasing and network is getting more loaded. Even in a short period during the trial increase was such that it was not possible to compare simply average consumption With the rise of traffic average consumption was also rising. Samples were classified in groups with same PRB usage, and than they compared average energy consumption were in both scenarios (with and without DTX activated).

A. Impact on main KPIs

Based on vendor recommendations following KPI were monitored: RACH (Radio Access Channel) setup, RRC (Radio Resource Control) setup, E-UTRAN(Evolved Universal Terrestrial Radio Access), Average Latency in eNB, Spectral efficiency, PDCCH (Physical Downlink Control Channel) Success rate.

RACH setup success rate has remained almost the same (99.46 →99.42). As it is expected this feature does not have impact on this KPI. RACH Set up success rate is presented on figure 3 and it is represented in percentage (%).
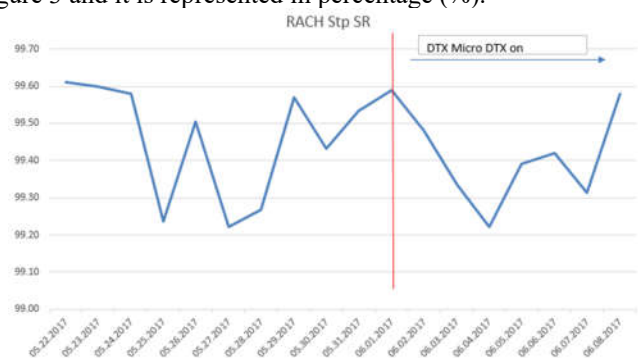
Figure 3 - RACH setup

RRC set up success rate has slightly degraded. As it shown on the figure 4, from average value of 99.53%→99.48%. It should not be considered as a drawback. User that were on excellent radio conditions moved from LTE800 to LTE1800 so average distance from LNBTS (LTE eNodeB Base Transceiver Station) of reaming users were increased.
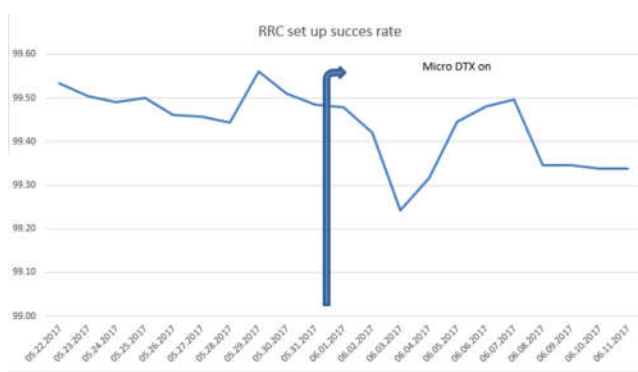
Figure 4 - RRC setup

Average latency was in the list as one of the main drawbacks of this feature 27.51ms→28.99ms [3]. For CQI8 users (standard mobile users) latency has slightly increased from 27.51 ms to 28.99 ms as it is shown on figure 5.
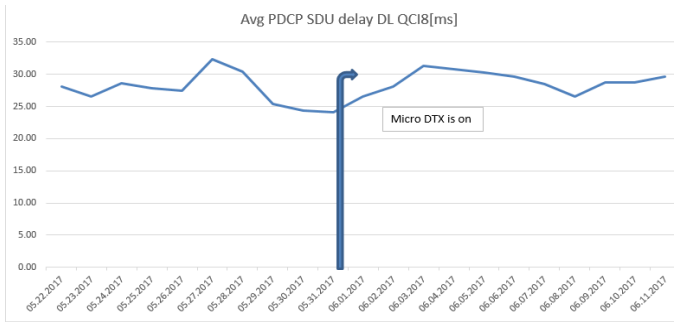

Figure 5 - Average latency

Due to 2.60→2.59 Spectral efficiency has remained almost at the same value (displayed on figure 6).
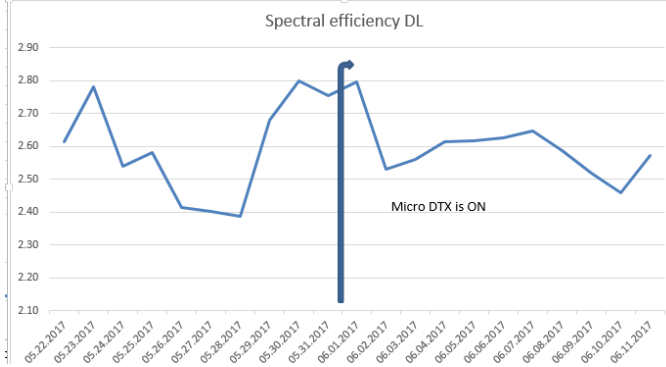

Figure 6 – DL Spectral Efficiency

The micro-DTX has an inherent impact on the PDCCH (Physical Downlink Control Channel) usage because all DL traffic that would otherwise be handled in a subframe must now be covered in one of the remaining non-muted subframes. This increases the number of scheduled UEs per TTI, and it may cause an increase in the PDCCH blocking rate. After the feature had been activated PDCCH SR decreased from 98.56 to 98.18 as it was expected (figure 7).

Figure 7 – PDCCH Success rate

B. Comparison of energy consuption before and after eNodeB Power Saving MicroDTX

Due to traffic increased that was occurring during the trial it was not possible to say what percent of energy was saved. Because of that, subclaster was created with 4 ENodeB that had had similar (or even greater) traffic distribution during the whole period. Energy savings on the graph below was almost 20%. On the right side is on hourly basis presented DL traffic and on the right axis is energy consumption[W]. Practically speaking, with even more traffic in average, every hour were saved 66W per LNBTS (expected savings are even a bit bigger). On the figure 8 it is possible to that traffic has risen (right vertical axis) and that power consumption has decreased(left vertical axis).
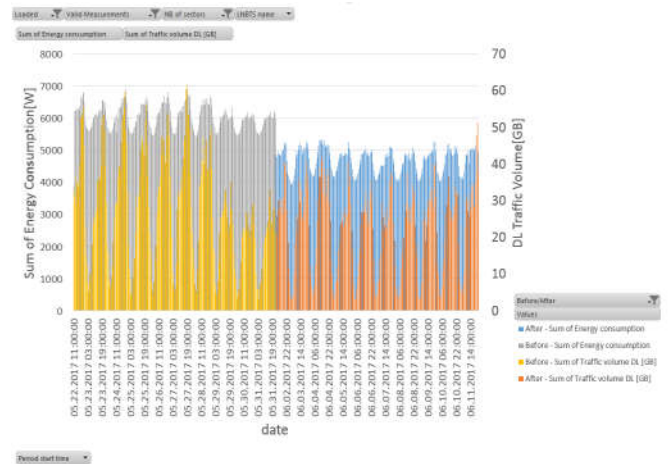

Figure 8 - Average hourly consumption vs traffic volume

Data from other ENodeB were also used in final analysis. All data (of energy consumption) were divided in two categories (samples before and after the feature activation). After that every sample was classified into few categories based on hourly Physical Radio Block usage.

It is possible to see that 30.5% (figure 9) of energy was saved after feature activation for extremly low loaded samples (PRB usage less than 1). This amount of energy saved is possible to expect for all samples that have average less than 1 PRB (extremly low loaded samples) occupied during one hour on LNBTS level.
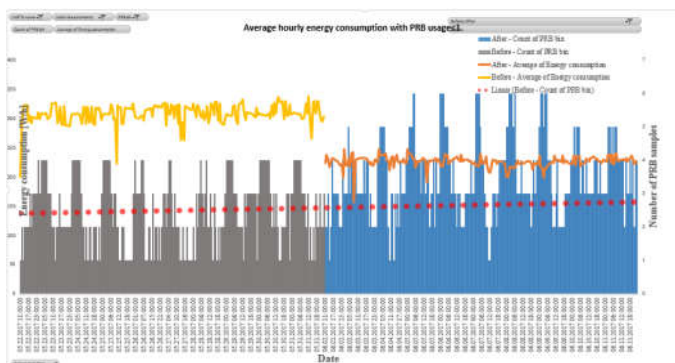
Figure 9 - Average hourly consumption for PRB usage≤1

For low loaded samples (figures 10), with a bit more DL traffic (between 1 and 5 PRB occupied) it is still possible to expect significant amount of energy saved. On the graph bellow is shown that 19% of energy were saved. It is possible to see that there were almost the same number of samples with this traffic distribution before and after the micro DTX activation.
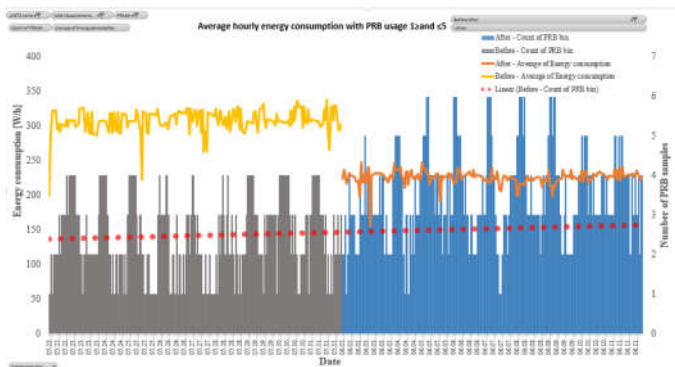

Figure 10 - Average hourly consumption for PRB usage 1≥and ≤5

For the samples (figure 11) with average amount of load (between 5 and 16 PRB occupied) expected energy savings were still significant 19%. Graph distribution remained almost the same for the averaged loaded ENodeBs.
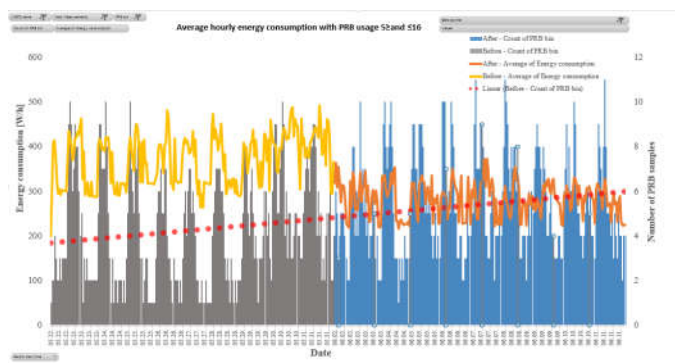

Figure 11 - Average hourly consumption for PRB usage 5≥and ≤16

For samples with a significant amount of DL data traffic(between 16 and 35 PRB occupied) 14% of energy were saved (figure 12). As it was expected with greater PRB usage benefit of the feature was a bit smaller.
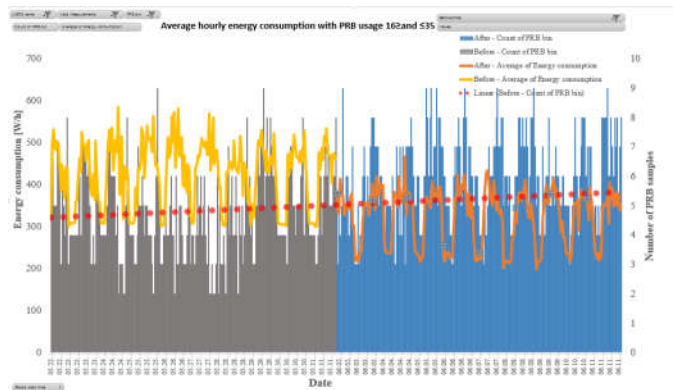

Figure 12 - Average hourly consumption for PRB usage 16≥and ≤35

For extremely loaded LNBTSs (with average hourly PRB usage greater than 35) gain from this feature was the least - 12% (figure 13). It is still respectful number because in conditions with constant load power saving mechanism is activated rarely. Amount of the samples was not significant in this category, but it was constant before and after the change.
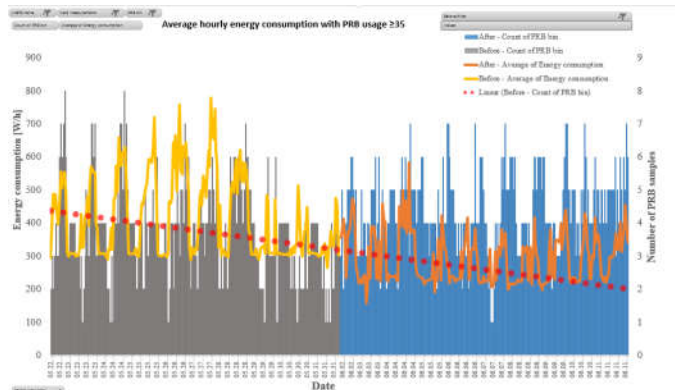

Figure 13 - Average hourly consumption for PRB usage ≥35

C. Data traffic VS PRB usage

As it was shown before spectral efficiency was not change after the feature activation. From the figure 14 it is possible to see that similar amount of DL data were transferred using same number od PRBs. Smaller amount of data transferred can be noticed for heavy users group (more than 50 PRBs) and can be explained due to small amount of samples, especially after the change.
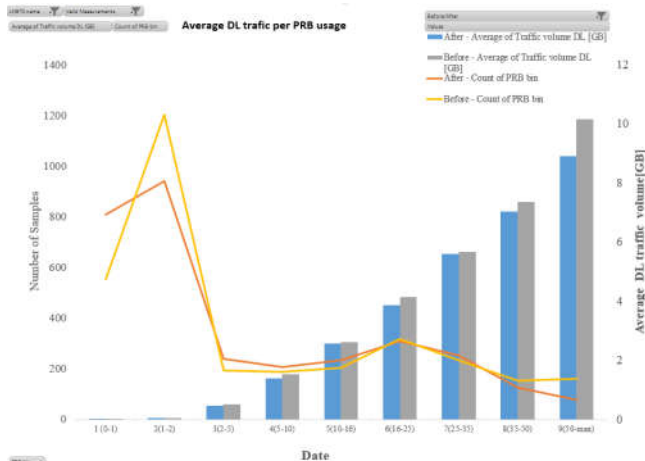

Figure 14 – Average traffic volume per PRB usage class

D. Energy savings VS PRB usage

Going further, more PRB classes were made and for each class of PRB usage is shown delta value on the graph (amount of W/h that have been saved per PRB usage class). Perceptually the biggest saving were made on the samples that have had the least PRB usage. Numerically looking, the biggest energy saving was achieved for samples with moderate DL data load (class 4 and 5) as it is shown in figure 15.
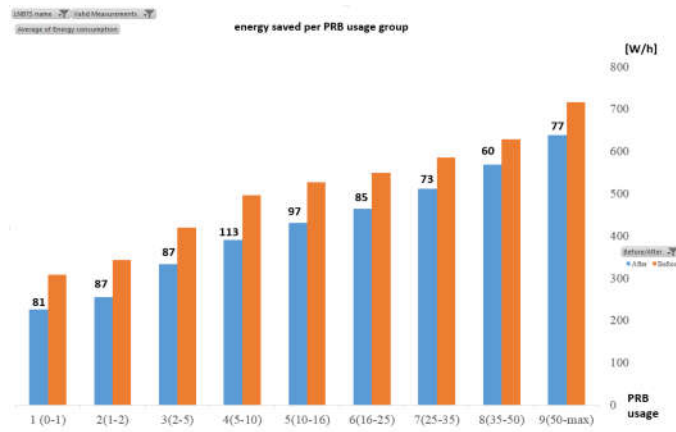

Figure 15 –Amount of saved W/h per PRB usage class

IV. CONCLUSION

According to Nokia, micro-DTX feature enables to save up to 20% of power only in cells with very low or without user-related DL traffic [3]. This gain was verified and we got even better results. In average (cluster were contained from low and heavy loaded LNBTSs) we had almost 20% on energy saved. On the low loaded cells, feature reached maximum benefit saving more than 30% of energy. Almost all main KPIs remained the same after the feature activation.The most sensible KPI for this feature (PDCCH Success rate) was degraded but degradation was not significant having in mind that traffic redistribution also had influence on this.

REFERENCES

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