Introduction

* 1. Introduction
  2. Background and Motivation and previous works

Put pictures of Green Tech.

BS consumes a lot of energy 80% Fethwiser [1]

Refs from goal doc

Winner and traffic model

Poisson distribution user setup and

Ericsson also did it[2]

Quote Mills paper and cisco paper from Maria’s research paper. (teen paper yahin mil gaye refs ke liye)

Cite all the 10 top google paper on the Heterogenous networks Energy Efficiency a nad earth power model

Follow Intro background Motivation Theory Base Stations macro pico Energy/Power Model Earth Previous work (Fettweis, Henrik forssell, Gunther how much power, Laetitia ka paper, saare paper jo tu padhe unka result conclusion quote kar, feature saving Kihl ki quote kar, )

Simulation (explain Axcel, network Earth power long term short term Gunther ke paper se, Laetitia , Fethweiss se)

Result and Conclusion

Future Work

1.1 Introduction [3]

The global mobile communication industry is growing rapidly. Today there are already more than 4 billion mobile phone subscribers worldwide [1], more than half the entire population of the planet. Obviously, this growth is accompanied by an increased energy consumption of mobile networks. Global warming and heightened concerns for the environment of the planet require a special focus on the energy efficiency of these systems [2]. The EARTH1 project [3] is a concerted effort to achieve this goal and as part of its objectives, a holistic framework is developed to evaluate and compare the energy efficiency of several design approaches of wireless cellular communication networks. For the quantification of energy savings in wireless networks, the power consumption of the entire system needs to be captured and an appropriate energy efficiency evaluation framework (E3F) is to be defined. The EARTH E3F presented in Section 1.2 provides the key levers to facilitate the assessment of the overall energy efficiency of cellular networks over a whole country. The E3F primarily builds on well-established methodology for radio network performance evaluation developed in 3GPP; the most important addendums, introduced in Sections 1.3 and 1.4, are to add a sophisticated power model of the base stations 1 EU funded research project EARTH (Energy Aware Radio and neTwork tecHnologies), FP7- ICT-2009-4-247733-EARTH, Jan. 2010 to June 2012. https://www.ict-earth.eu 1 2 Chapter 1. How Much Energy is Needed to Run a Wireless Network? Global Metric (long term, large scale) Large scale area & Long term traffic load Metric (short term scenario specific) S ll l (short term, scenario specific) system SmallͲscale, shortͲterm system level evaluations BS power P model Pin performance evaluations mobile channel P model out mobile Figure 1.1 EARTH Energy efficiency evaluation framework (E3F). (BSs) as well as a large-scale long-term traffic model extension to existing 3GPP traffic scenarios. Then, using the metrics defined in Section 1.5, in Section 1.6 the E 3F is applied in order to provide an assessment of the BS energy efficiency of a 3GPP LTE network deployed within an average European country. The energy efficiency of LTE is compared to that of already deployed networks is discussed in Section 1.7, and targets for the energy efficiency of future wireless networks are given.

*A. Power consumption model* [2]

To evaluate and compare the power consumption of the

reference network and the heterogeneous network, the power

model developed by the european project EARTH for year

2010 state-of-the-art base stations has been used [5]. Note that a micro node in EARTH corresponds to a pico node here.

In the EARTH model, the power consumption consists of a

fixed part that is consumed in idle mode and a variable part

based on the traffic load served by the base station. The output

RF power *Pout* scales with the number of frequency resources

scheduled at the given time. If all frequency resources are

scheduled at a certain time, *Pout* reaches the maximum power

*Pmax*. This power model is an approximation of the measured

power consumption of a BS transceiver [5] as depicted in Fig.

1 for a macro BS that handles three sectors.

The modelled power consumption *Pin* of a node is expressed

as

*Pin* =

􀀀\_\_

*P*0 +Δ*p ・ Pout* if 0 *≤ Pout ≤ Pmax*

*Pμ* if *Pout* = 0 and micro DTX on

*Ps* if *Pout* = 0 and sleep mode on

The power model parameters are given in Table I. The values

for the micro DTX mode were obtained from [9]. For the pico

node sleep mode, a remaining power consumption of 10W is

assumed at the pico node. This is aligned with [10].

III. ENERGY EFFICIENCY SCHEMES [2]

A radio access node, i.e. a base station, is composed of

different components: power amplifier (PA), radio frequency

(RF) transceiver, the base band (BB) unit and finally the

power supply (DC) and cooling (CO). Basically in current

base stations, all components contribute to the overall power

consumption of the node even during the idle time when there

is no data nor signalling transmission to perform, as shown

in Fig. 1 [5]. The two energy efficiency features considered

here are based on the deactivation of certain base station

components during the idle time of a BS. Thus, a lower power

consumption in idle mode can be achieved. This puts however

new requirements on the hardware of a BS that may not be

met by current BSs but could be taken into account when

designing future base stations.

Macro and pico nodes have different roles in the network

and therefore shall meet different requirements concerning

their availability. Consequently different kinds of sleep mode

can be applied to them.

Macro nodes provide the basic coverage meaning they must

be always reachable by potential users. For that purpose,

even if there is no active user in a macro cell and no

data transmission is scheduled, the macro node still needs

to broadcast regularly cell-specific signalling information and

monitor the uplink to identify if a user wants to establish a

connection. A sleep mode based on the complete shut down of

a macro base station is thus hardly conceivable. Even if several

RATs are implemented at a macro node, the radio components

0 0*.*2 0*.*4 0*.*6 0*.*8 1

0

250

500

750

1*,*000

1*,*250

1*,*500

Resource utilization

Power consumption [W]

PA

CO

DC

BB

RF

Fig. 1. Power consumption breakdown of a 3-sector macro BS

related to at least one RAT should remain active so as to supply

mobile communication coverage.

Pico nodes are redundant nodes deployed to help the macro

node handle high traffic demand at certain points in time. A

larger variety of sleep mode mechanisms are hence applicable

to pico nodes.

*A. Micro DTX*

Micro Discontinuous Transmission (DTX) is a sleep mode

technique, introduced in [6] and [3], and which is suitable

for an Orthogonal frequency-division multiplexing (OFDM)

based system such as LTE. The idea is to deactivate the power

amplifier of a LTE base station (BS) during empty OFDM

symbols. In LTE an OFDM symbol with a normal cyclic prefix

length lasts 71.4*μ*s. So, the micro DTX assumes a quick

reactivation of the power amplifier in the order of less than

one OFDM symbol according to [6], [3].

The main advantage of this technique is to exploit very

short idle periods of the BS. These are expected to occur more

often in the future as there will be an increased amount of

traffic generated by means of regular small packets, e.g. social

networking type of traffic.

To enable a quick return to the normal operation mode, the

cell should remain visible to the legacy users. Therefore the

cell-specific signaling still need to be transmitted in certain

OFDM symbols even when there is no data transmission. In

particular the cell-specific reference symbols (CRS) which are

transmitted regularly limit the time where micro DTX can

be applied. Basically, a BS can go to the micro DTX mode

and reduces its power consumption only between two CRS

transmissions. For LTE, the highest possible micro DTX ratio

would be of 10/14, since from the 14 OFDM symbols that

compose each normal subframe, 4 OFDM symbols contain

CRS in case of a transmission with up to two antenna ports.

*B. Pico node sleep mode*

In addition to the micro DTX, the pico nodes introduced

in a heterogeneous network can be subject to a deeper sleep

mode technique, in which not only the PA but also the RF and

BB components of a pico node are deactivated. The inactive

state here is assumed to last in the order of a few hundred

milliseconds.

When applying this mode the control signaling can not be

transmitted by the pico node anymore, and therefore the pico

cell becomes invisible to the user. So all remaining users must

be handed over to another cell before entering the sleep mode.

This kind of deep sleep mode is possible for a pico node

in a heterogeneous network, as the overlaid macro cell that

provides the basic coverage can take care of remaining users.

Several implementations of the pico node sleep mode are

possible depending on the criteria used to trigger the reactivation,

and also on the level of integration of the pico nodes

into the macro network. For instance one could think of a

pico node sleep mode in which an uplink (UL) signal strength

sensor remains active and triggers the pico node reactivation

when the measured UL signal strength exceeds a threshold.

This indicates the presence of a user in the surroundings of

the pico node.

In this paper we consider a heterogeneous network in which

the pico nodes are able to tightly cooperate with the overlaid

macro node. A good connection between the macro and its

pico nodes is thus required. But such a setup offers a more

flexible pico node reactivation that can be based on more

elaborate criterion. In the following the macro node controls

the activation and deactivation of its underlaid pico nodes and

takes its decision based on the traffic load in the different

cell layers. This enables to react quickly to the traffic demand

variation and avoids the re-activation of pico nodes for users

that would not benefit from a higher available bitrate, e.g.

VoIP users. Moreover, compared to the pico node activation

based on uplink signal measurement, the present scheme does

not require long measurement filtering before triggering the

activation.

As shown in Fig. 2, the macro node regularly checks the

traffic load level in its cell. If the traffic load exceeds a certain

threshold, all pico nodes under its control are activated. An

activation delay of 100ms is assumed here. Note that a macro

node equipment is serving all sectors (or cells) of a site.

Here we assume that the macro node activates the pico nodes

located in the macro sector where the load is increasing. After

triggering the pico node activation, the macro node requests all

users to measure the signals from neighboring cells. This may

result in a handover of some users towards the pico nodes.

The activated pico nodes regularly monitor the served traffic.

If the traffic load remains low after a certain delay, *δactive*,

these pic