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The effectiveness of Pico cells on mobile technology

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Abstract
The Implementation of small cells in mobile phones has created large interests from past few decades. This paper investigates the effects of implementation of Pico cells on the working performance as well as power consumption of mobile networking .Since different network updates introduce different pursuance gain comparing different configurations exclusively on their overall power Consumption can be rather biased. That is why, a new key word commonly known as "Energy Efficiency" introduced and frequently used throughout this study. In the first stage of this paper, a detailed study for the Erlang is performed which is the capacity of a network by considering a uniform topology and traffic by using queuing theory analysis, namely processor sharing queues. Results proved that in all cases the implementation of pico cells improve the performance of the network, however the efficiency dependent on the deployment scenario to be considered. In the second part of the study, a more naturalistic outline with non-uniform topology and traffic is considered, which is carried out through a large scale system level simulator. Results proved that by implementing pico cells in areas experiencing high level of traffic, the energy efficiency of network can be drastically improved. The last part of this study includes the areas of applications of pico cells which include building coverage capacity, filling network black spots, etc, advantages and disadvantages of implementing pico cells in mobile network.

Keywords: mobile technology, Pico cells, energy efficiency

1. Introduction

Since its first release, 3G wireless technology has come along way forward. Each new release of 3GPP specifications has introduced a number of new features that offer greater opportunities for both consumers and network operators alike. 3GPP Release 10 specifies LTE-A, which introduces several significant improvements over LTE Release 9[1]. This paper investigates a special aspect of Heterogeneous Networks, which is the deployment of pico cells to off load parts of the traffic from the macro layer of the network. Note that, although small cell deployment is a part of the LTE-A standard, it is in no way entirely restricted to LTE-A. In fact, there is a large interest from network operators to assess the impact of small cell deployment on the performance of their HSPA networks, in an attempt to define an optimal deployment strategy for the next couple of years.

The subject of pico cell deployment is in this study covered from both a theoretical and a practical point of view. At first, we start by considering a uniform deployment within a network with homogeneous traffic. Using queuing theory techniques, the Erlang-like capacity, i.e., the maximum traffic intensity that can be served by the network under a target quality of service (QoS) is calculated. Following this, a real HSPA network topology and traffic distribution are considered for deploying picocells in traffic hotspots. In both cases, energy models for both macro and picocells are used to calculate the power consumption of the network. Results show that in some scenarios, picocells have the potential of increasing the energy efficiency of mobile networks. This is however dependent on the maturity of the equipment and the evolution of the macro layer of the network.

Since the traffic carried by the network varies constantly and considerably over time, a sleep mode feature for the deployed picocells is investigated for both cases. By putting a number of picocells in sleep mode, further energy savings are observed.

2 Analysis of a uniform deployment of Pico cells

2.1 Throughput calculations

For the analytical calculations proposed in this paper, the downlink of a uniform network configuration is considered. A user equipment (UE) M in the target cell 0 is characterized by a distance R to base station 0 and an angle θ with a reference axis as shown in the Fig. 1. The points at the center of all surrounding cells indicate the interfering evolved node Bs (eNBs). An Omni-directional pattern antenna has been considered. The Okumura–Hata propagation model is used for macro cells. For pico-cells, the 3GPP model for outdoor relays is used. For each point of the cell, we derive the signal-to-interference-plus-noise-ratio (SINR) received from the target eNB and the different picocells. The aim is to calculate the throughput of a UE located at this point and that is served by either the macro cell or the pico cell. Throughout these calculations, the interference generated from surrounding macro cells and picocells is taken into consideration. For each node i (it being a pico cell or macro cell) an average load in the interfering cells equal toc is assumed.

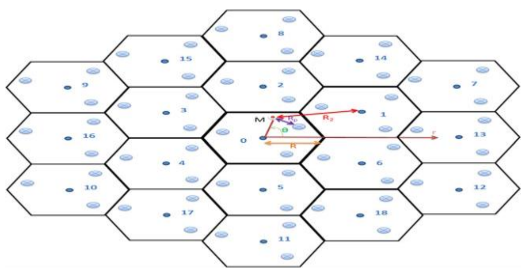

Fig 1: Network configuration with three picocells per site

2.2 Power consumption of network nodes

Macro base stations through empirical studies, the power consumption of a base station site is given as a function of the cell load for different configurations (number of sectors, installed baseband processing capacity), as shown in [5]:

$P_{macro}(ð)=Pp+m(P_{TRX}+P(ð)P_{max}/c)$ Where m is the number of installed sectors, Pp the power consumption of the processing unit, P_{TRX} is the fixed power consumption of the radio module, P_{max} is the maximum output power and c is the DC to RF conversion factor.

Pico base stations

In comparison to macro BTS, picocells operate at much lower transmission power (1 watt). The energy model above shows that the power consumption of a BTS is only lightly correlated to the load. This means that in a picocell that is transmitting little power, the variation in power consumption with load will have an insignificant impact on the overall consumption of the network. As a result, picocells are assigned fixed power consumption. In order to study the sensitivity of the results, the power consumption (Ppico) is varied from 10 to 70 W. Actual consumption

Figures of picocells are believed to be in the region of 60–70 W; however, this is likely to decrease as the efficiency of the equipments is improved.

2.3 Sleep mode application

When dimensioning a mobile communications network, the busy hour traffic is taken as a reference to calculate the required network capacity and the number of base station sites needed. However, such high volumes of traffic can only be observed for about 2 to 3 h a day. For this reason, a sleep mode mechanism that shuts down capacity enhancing sites when traffic is below a certain threshold can be used to improve the energy efficiency of the network. In this study, sleep mode is only allowed for the deployed pico cells.

2.4 Results

In order to evaluate the impact of pico cell deployment and sleep mode on the power consumption and QoS of the network, some numerical results are hereby presented. An LTE-A network in a dense urban area, with an inter-site distance of 800 m, is assumed. The transmission power for picocells is set to 30 dBm (1 watt). These are deployed close to the cell edge, at 450 m from the macro eNB.

In order to compare the impact that a different number of picocells have, four deployment strategies are considered:

- Macro only: no picocells are deployed.
- Light-pico: deploying three picocells/sites (one pico cell per cell).
- Medium-Pico: deploying six picocells/sites (two picocells per cell).
- High-Pico: deploying nine picocells/sites (three picocells per cell).

3. Non-uniform traffic case

In reality, base station sites of actual mobile networks are organized in an irregular (but yet planned) topology, with sites being individually positioned and oriented. The traffic carried by each cell varies considerably over time, and for a specific moment in time, the traffic within one cell is likely to be different from that of a neighboring cell. Due to such issues, a simple link budget analysis is not sufficient to fully understand the implications that the deployment of picocells could have within a real mobile network. Because of this, in addition to the previously presented theoretical analysis, detailed network simulations based on a real HSPA network have also been carried out. In existing HSPA networks, the deployment of picocells is not the only option for boosting capacity. Other options include: the upgrade of existing sites to HSPA+, the deployment of new macro sites (site densification), the installation of additional HSPA carriers, and the upgrade of selected sites to six sectors. For this reason, the impact of picocells on the power consumption and efficiency is also compared with a small selection of the above capacity enhancing options.

3.1 Network simulator description

An irregular network composed of 245 cells (about 85 sites), representing an urban area, representing an actual network, is used as a scenario basis for all of the following simulations. In the beginning, all available sites are assumed to have a single carrier, and be HSPA enabled. Statistics for the various performance results are extracted from a central area of the network, allowing for a "ring" of sites to provide interference, avoiding any edge effects. Being an irregular network, the inter-site distance (ISD) between the various base station sites varies. The simulation tool used in the investigations is a static network simulator. Based on the Okumura–Hata model, the Path loss from every base station to every user is calculated. Since most data traffic originates indoors, all users are considered as indoor users, applying a further 12-dB penetration loss onto the path loss. By knowing the transmission power of every site, the signal-to interference-plus-noise ratio (SINR) is then calculated.

3.2 Traffic management

Traffic is simulated by adding a number of active users, all requesting the same minimum data rate, within the network. The location of where users are placed is based on a traffic density map, which is generated based on actual traffic statistics for the same network. Simulations are carried out over a number of years (one simulation representing a single year), with the number of active users added on a year by year basis to represent increasing traffic demand. Over the 8-year period investigated, traffic is increased based on a prediction model, which increases the penetration rate of mobile broadband along an s-shaped curve. Besides the number of active users, traffic is also increased on a per user basis. During the first 2 years of the evolution period, a minimum data rate of 256 kbps is requested by every active user. As per 2012 onwards, this is doubled to a minimum of 512 kbps. In order to investigate the evolution of the network, and its ability to carry the expected traffic growth, traffic volumes and distributions representing the busy hour are considered. In addition to this, the ability of the network to carry the expected traffic during hours of low traffic is also considered. This low traffic case is also used to investigate the possibility of further power savings by enabling sleep mode for picocells during hours of low traffic.

A dense urban area traffic model is used for identifying the number of users that are to be simulated within the network. For the year 2010, the number of active users obtained from the model is compared and verified against the actual traffic statistics available for the real network being used. The penetration rate of mobile broadband users is assumed to increase from a current value of about 15% up to a maximum of 60%, which is reached in the year 2017.

3.3 Network evolution scenarios
When the existing configuration of the network is not capable of delivering the requested traffic, if possible, heavily loaded sites are upgraded to the next available level. The first upgrade assumed for macro sites is the addition of a second and/or third carrier. This is the easiest and cheapest (Assuming operator already holds spectrum license) way of upgrading the network capacity. In the simulations with three carriers, adjacent 5 MHz bands are assigned. The frequency bands can be grouped such that in the event that both or all three carriers are enabled, dual-cell can be supported. This means that the base station site can schedule a single user concurrently on multiple carriers. The deployment of picocells is implemented by specifying the number of cells that are to be deployed for a specific year. This is always carried out before any additional macro upgrades. Selection of where to deploy new picocells is based upon a weighted factor, which can be set to prioritize between traffic density and coverage (SINR). For this specific investigation, the weights are selected to prioritize areas with high-traffic density and offload surrounding macro sites. If after deploying the new picocells the overall performance of the network is still below the required level, available macro upgrades are carried out to provide the additional capacity required. The investigated area is noted to have four cells that carry relatively higher volumes of traffic that the rest.

3.4. Network energy efficiency
In order to bring together the performance of the network together with the power consumption, this investigation also considers the energy efficiency of the network. This is measured in kilobits per second per watt and measures the traffic that the network (kilobits per second) can carry per unit of power (watt). This overall increase in efficiency comes from the fact that necessary network upgrades are carried out in the areas with high traffic, so the increase in capacity overcomes the increase in power consumption.

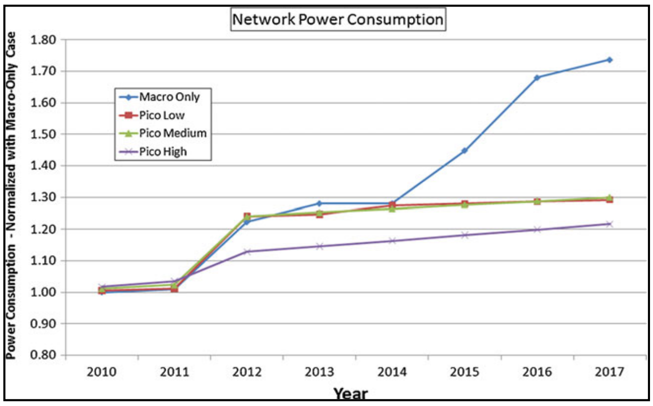

Fig 2: Power consumption of network over evolution period. The reference used is the power consumption of macro-only network of the year 2010.

4 Conclusions
In this paper, the impact of picocell deployment on the performance (network capacity, power consumption, and energy efficiency) of mobile networks has been studied for different deployment scenarios. A first analysis is performed for uniform topologies and homogeneous traffic, which is based on link budget and queuing theory methods, to show the gain in network capacity. However, the energy efficiency is improved only when the consumption of picocells is very low. A simulation-based study on a real mobile network, with non-uniform and non-homogeneous traffic, is also carried out. This shows energy efficiency gains in the order of 30%. The reason for this difference is that in a non-uniform traffic case, picocells are deployed in hot spots of large traffic, thus off-loading neighboring microcells. This also reduces the need for alternative macro upgrades, which are more power hungry than picocells. On the other hand, in the uniform traffic case, when traffic is high, it is high everywhere and a large number of picocells have to be deployed everywhere in the network, thus increasing the power consumption.

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