Dual-Cell HSDPA for Network Energy Saving

Micallef, Gilbert

Published in:
I E E E V T S Vehicular Technology Conference. Proceedings

DOI (link to publication from Publisher):
10.1109/VETECS.2010.5494049

Publication date:
2010

Document Version
Accepted author manuscript, peer reviewed version

Dual-Cell HSDPA for Network Energy Saving

Gilbert Micallef*, Preben Mogensen*/**, Hans-Otto Scheck**

**Dept. Of Electronic Systems, Aalborg University (email: gmi@es.aau.dk)*
***Nokia Siemens Networks*

Abstract **- The increasing demand for mobile broadband is pushing existing 3G networks closer to their capacity limit. Additional carriers together with new HSPA features (HSPA+) are expected to provide the next necessary boost in network capacity. One specific feature in HSPA+ is referred to as Dual-Cell HSDPA (or Dual-Carrier HSDPA). This feature allows for a single user to be simultaneously scheduled over two carriers, effectively doubling its achievable data rate. The addition of a secondary carrier will require additional radio equipment at the base station site, increasing the overall energy consumption.**

This paper proposes an energy saving feature that exploits variations in network traffic. Based on the individual load of each sector, the feature determines if the secondary carrier is detrimental for reaching some pre-set minimum requirements. Each sector is allowed to switch off one of their two carriers, during periods of low network traffic. It is concluded that an energy saving ranging between 14% and 36% is possible. This saving comes without degradation of network performance.

Index Terms – Energy Saving, Dual-Cell HSDPA, Dual-Carrier HSDPA.

I. Introduction

Over the last couple of years, energy consumption has become a major issue within most industries. Companies of all types and sizes are actively seeking for adequate alternatives that can improve their energy efficiency, reducing energy costs while also improving their corporate image (being environmentally conscious). The operation of mobile networks consumed nearly 80TWh electricity in 2008 [1] and mobile communications contributed about 0.2% of global CO2 emissions in 2005 (combined impact of operations and manufacturing) [2].

In order to provide nationwide coverage, network operators have a large number of base station sites. These sites, which provide the wireless link between the mobile terminal and the network, contain the necessary radio equipment for mobile communication together with other for backhaul, cooling, and backup. The energy inefficiency of each site, coupled with the large numbers of such sites, make them the major energy consumer within mobile networks. For this reason, a major effort is directed towards reducing energy consumption at these sites.

This becomes even more crucial when considering the fact that the industry is still rapidly expanding, both in developing and developed countries. In developed countries, the introduction of mobile broadband has brought a surge in the volume of traffic, with a specific study showing an increase in traffic by a factor of 5 within 12 months [3]. While predictions about how steep traffic growth may vary, it is certain that a considerable growth will be observed for the years to come. This growth is being fueled by an increase in the number of mobile broadband subscriptions together with an increase in volume of traffic used by each user [4].

Planning for a communications network has always been focused and scaled around the busy hour, the one hour of the day where a peak in network traffic is observed. In data networks this is done in order to guarantee a specific minimum data rate required for a specific service the user is requesting. A network that can cope well with traffic during the busy hour can easily cope throughout the remaining hours. However, during the remaining hours, when traffic volumes are far less, the network becomes underused, decreasing its energy efficiency (carried bits per consumed watt) even further.

Mobile networks follow a stepped evolutionary path. Installed hardware is repeatedly upgraded, through software, improving to some extent its capabilities and efficiency (such as the upgrade to HSPA). After a couple of years, when software upgrades cannot meet the new capacity requirements, additional equipment and possibly new technologies (such as LTE) needs to be installed. Besides the networks' capacity, this also boosts energy consumption. If no action is taken to dynamically improve the energy efficiency of mobile networks, the energy consumption will keep growing in proportion to the increase in peak hour traffic.

This paper is organized as follows. Section II introduces the basic concepts of Dual-Cell HSDPA, highlighting its advantages and required upgrades. Section III introduces the details of the proposed energy saving feature. Section IV introduces the various models used throughout the investigation. Section V then presents the results by showing the potential energy savings and the effect this has on the performance of the network. Section VI concludes the paper through a short summary and discussion of the obtained results.

II. Dual-Cell HSDPA

The majority of all UMTS networks (90 percent) have already been upgraded to high-speed packet access (HSPA). Such networks exploit the various features and functionalities, on both downlink (HSDPA) and uplink (HSUPA), introduced in 3GPP Releases 5 and 6 [5]. The upcoming 3GPP Releases, 7 and beyond, are being grouped under the term HSPA+ (or Evolved HSPA) and introduce functionalities that will boost the peak data rates currently achievable by HSPA. Amongst others, some of the main features include:

- 2x2 multiple input multiple output (MIMO)
- Continuous Packet Connectivity
- Higher Order Modulation (64QAM DL/16QAM UL)
- Dual-Cell HSDPA

Initial UMTS networks were deployed with a single 5MHz carrier, with widespread coverage being the primary objective. In order to meet the demand of increasing network traffic additional carriers are added. While the addition of a secondary carrier doubles the site's capacity, increasing the amount of available resources per user, this has no effect on the maximum achievable data rate. On layer 1 and layer 2 these two carriers are operated independently, with the only coordination occurring for the purpose of load balancing [6], where users are assigned to one particular carrier based on a decision that considers the current load of both carriers.

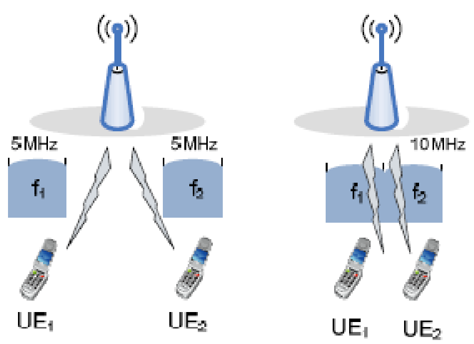

Figure 1 – Single carrier vs. Dual-Cell Transmission [6]

Dual-Cell HSDPA (DC-HSDPA), or Dual-Carrier HSDPA, is aimed at improving the spectrum efficiency by jointly allocating resources from two adjacent carriers. Besides balancing the load over the two carriers, this will also allow for users to achieve higher peak data rates (resources on both carriers for every TTI), going from 21Mbps up to 42Mbps [5][7]. While this increase in peak data rate is desirable throughout, the main purpose for dual-cell operation is to improve the data rate of users experiencing bad channel conditions, especially at the cell edge, where benefits from existing techniques, such as MIMO, have a limited effect [6][8]. This improves the network performance by increasing the percentage of satisfied users. The term *satisfied users* refers to those users who for a specific service can obtain a predefined minimum data rate.

During DC-HSDPA operation, the two carriers are separately identified. The primary carrier, which contains all physical channels, is referred to as the *anchor carrier*, while the secondary carrier is referred to as the *supplementary carrier* [9]. Selection about which carrier is the anchor and which is the supplementary is arbitrary but is controlled by the network for load balancing purposes.

Legacy radio power amplifiers within existing 3G base station sites can only support a single carrier. For the addition of a secondary carrier, an additional power amplifier is required. While next generation base station equipment can handle multiple carriers on single power amplifier - by appropriately changing their bias point - network operators are likely to prolong the operation of their existing equipment. Besides the addition of a secondary carrier, separate equipment will also enable the use of MIMO, which will always require two (or more) parallel and separate systems.

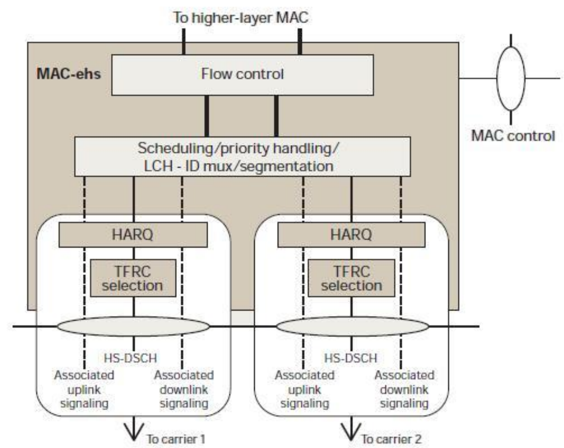

Figure 2 – Layer-2 architecture for dual-cell operation in downlink [5]

This paper investigates the energy saving potential that can be obtained by implementing a dynamic feature that can systematically shut down the secondary carrier, during periods of low network traffic – 'excess' network capacity.

III. Proposed Energy Saving Feature

The feature being proposed in this paper exploits variations in traffic, and network redundancies in an attempt to reduce the networks' energy consumption. The selection for which sectors can have their secondary carrier switched off is based on the instantaneous load of each individual sector. If the load in a particular sector is low enough so that all users can be guaranteed their minimum data rate over a single carrier, then and only then can the secondary carrier can be switched off. This is clearly illustrated in figure 3, which depicts the two distinct cases. Out of the two, it is only the second case (b) that can guarantee all three users can obtain their minimum requested data rate over a single carrier. To note that during this investigation it is always the same carrier that is selected for switching off. If sectors share enough information about which carriers are active a dynamic selection to which carrier to switch off can be carried out, minimizing the interference for neighboring cells. This is likely to improve the performance of the network, possibly allowing for more sectors to have their secondary carrier switched off, and reducing energy consumption even further.

This method ensures that the number of users obtaining their minimum data rate is not affected as a result of switching off the secondary carrier. By always having at least one active carrier, this also reduces the probability of having coverage holes as a result of switching off. Besides, this also ensures that the distance between users and their serving base station does not increase, safeguarding, to some extent, the performance on the uplink channel.

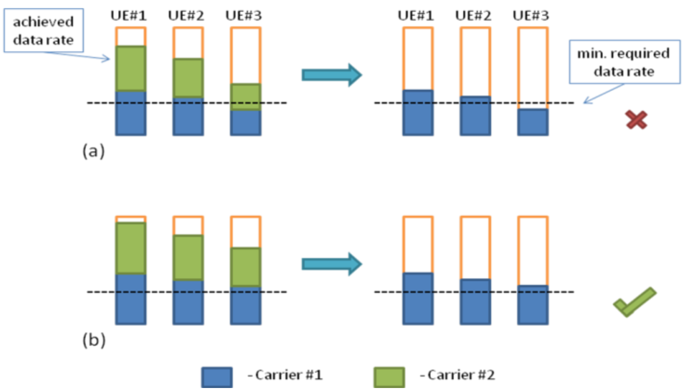

Figure 3 – Trigger of energy saving feature. In case (a), switching off is not allowed since UE#3 would not be satisfied. In case (b) switching off would be carried out, reducing the energy consumption of that site.

While energy consumption is the main parameter being investigated, this feature clearly demonstrates that network performance (user satisfaction) is given priority over energy saving. The feature attempts to maximize network energy saving while sustaining the same levels of network performance.

IV. System Model

A. Cellular System Model

The investigation presented in this paper is based on an urban wide area cellular network. The network is composed of a number of three sector base station sites arranged in a regular hexagonal pattern with an inter-site distance of 500 meters between neighboring sites. The path loss from every site to every other point within the area is measured, and used for obtaining the signal-to-interference-plus-noise-ratio (SINR). For every point within the network, the base station site responsible for the minimum path loss will be assigned as the serving site for that point.

A number of network users with a specific requirement are uniformly distributed throughout the network area. By assuming an HSDPA system, the SINR for each user is calculated and converted into data rate through a lookup table. This lookup table is obtained through detailed link-level simulations.

B. Traffic Model

This investigation exploits the variation in network traffic for obtaining reductions in the networks' energy consumption. Within the simulator this is achieved by changing the number of users being simulated in the network.

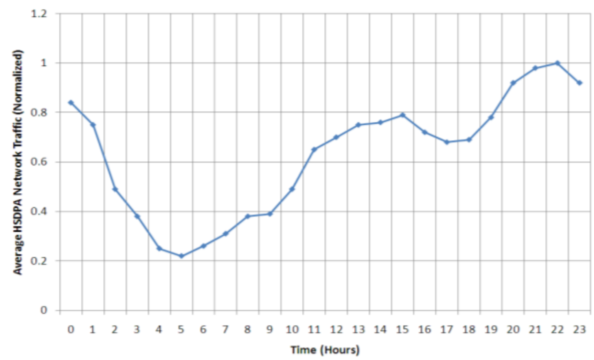

Figure 4 – Typical daily HSDPA traffic profile. The graph highlights the variations in network traffic over a 24 hour period.

Network traffic is split into three main categories: low, medium and high. The number of users used for each of the three categories is appropriately scaled against the maximum number of users supported by the network when all sites are operating DC-HSDPA. Table II described how these categories are scaled and the number of hours within a day that such a load is observed for.

The investigation starts by quantifying how many users are required to represent the network at full load. This is achieved by continuously increasing the number of users until the set key performance indicators (KPIs) could no longer be met. At this point the traffic for the three categories is appropriately scaled.

Traffic	Load Range	Hours
Full	*load* = 100%	-
High	75% ≤ *load* < 100%	10
Medium	40% ≤ *load* < 75%	7
Low	0% ≤ *load* < 40%	7

Table I – Network traffic categories showing the load range for each category and the number of hours during a weekday that the network experiences that amount of traffic.

C. Resource Allocation Algorithm

When more than one user is present within a specific cell, available resources need to be shared. In the simulation tool being used scheduling is performed in the following way: All users within a specific cell are sorted according to their SINR. Available resources (codes) to guarantee their minimum requirements are first allocated to the users with the highest SINR, thus requiring the least amount of resources. If possible, all users are first allocated the appropriate amount of resources to meet their minimum data rate. After that, any remaining resources are shared in a round robin fashion amongst all users. During periods of low traffic, this also allows for the remaining users to obtain higher data rates.

D. Dual-Cell HSDPA Model

As a starting point it is assumed that all sites and users in the network have DC-HSDPA enabled. With regards to their configuration, it is assumed that both carriers are identically setup. During dual-cell operation, the achievable data rate is set to be the summation of the achievable data rate on both separate carriers. In contrast to multiplying the achieved data rate on the anchor carrier by 2, this addition process becomes relevant when selected sites have their secondary carrier switched off, reducing their interference to neighboring sites.

E. Energy Model

Throughout this investigation, the power consumption within each base station site (radio equipment) depends on the number of active carriers. It is assumed that a site having two active carriers consumes twice the power of a site operating with a single carrier. This is based on the assumption that an entire parallel system is added to appropriately handle the increased site capacity. Energy consumption is based on both power and time. Over a 24 hour period this is used to obtain the relative amount of energy consumed, which is then used for evaluating the potential energy saving.

Parameter	**Value**
Network Area	6x6 km
Inter-site Distance	500 meters
Number of Sites	20 sites – 60 cells/sectors
Operating Frequency	2150, 2160 MHz
BS Antenna Height	30 meters
Propagation Model	COST 231 Hata model
Indoor Penetration Loss	10 dB
Antenna Pattern	3GPP horizontal patter [10]
Max. Data Rate	14.4 Mbps
Traffic Model	Full buffer, uniformly distributed
KPIs	min. 256kbps with 95% coverage
Site Rated Power	20W
CPICH Power	10 %

Table II – Sample of main scenario and network parameters used.

V. SIMULATION RESULTS

Simulations for this investigation (only in downlink) are carried out by a static, monte carlo based, system-level simulator. A rectangular mask, which excludes sites around the edges, is applied to mitigate edge effects. This is the effect of having cells covering a large area due to the lack of interference from neighboring cells. All statistical data and information is extracted from within this central area of the network map. A sample of parameter settings and assumptions is presented in Table II.

The results (Table III) show that a reduction in network traffic can on average improve the data rate of the remaining users by as much as 77%. This is the weighted average (depending on the number of hours) of the individual gains obtained for the different traffic categories. During hours of low network traffic, a maximum gain of 181% is noted. These values are used as a reference for comparing the effects that switching off the secondary carrier has on the performance of the network.

Traffic	**Cells on DC-HSDPA**	**Average User Data Rate (Mbps)**	**Gain in Data Rate**
Full	100%	1	-
High	100%	1.13	13%
Medium	100%	1.65	65%
Low	100%	2.81	181%
Gain in Data Rate (weighted)			**77%**
Gain in Energy (weighted)			**0%**

Table III – Network configuration (number of cells with dual-cell) and performance (data rate) and gains for the various traffic categories – with no switching off.

The same process is repeated again while allowing each cell to independently switch off the secondary carrier. Switching off is based on the condition that all users can still obtain their minimum required data rate, of 256kbps, over a single carrier. Figure 5 shows the percentage of cells within the network that have dual-cell HSDPA enabled. It is noted that for high network traffic, all sites retain dual-cell operation, whereas for medium traffic only a small percentage (17%) of secondary carriers are switched off. On the other hand, during the hours with low network traffic (7 hours), almost three quarters of the cells can guarantee the minimum networks requirements over a single carrier.

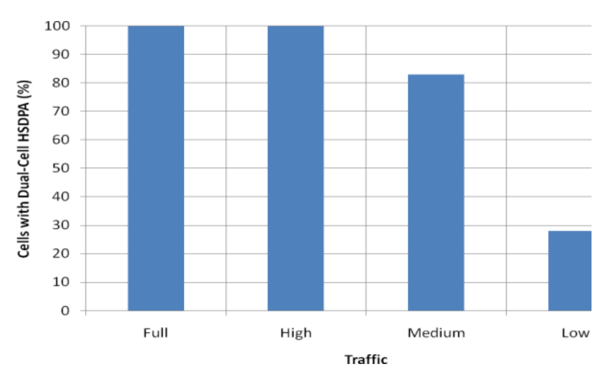

Figure 5 – Bar chart showing the percentage of all network cells that operate with dual-cell HSDPA, for the different traffic categories.

The number of cells having their secondary carrier switched off directly reflects the amount of energy saving. The energy consumed by the network over a 24 hour period with and without switching off enabled are compared. It is noted that given this specific traffic profile and switching constraint, a reduction in the energy consumption of 14% is possible (Table IV).

Table IV also shows the affect that switching off has on the performance of the network. The numbers show that during hours of medium and low network traffic, switching off the secondary carrier brings a reduction in data rate gain (77% to 50%). This is expected since switching off a carrier affectively reduces the sectors' capacity by half (assuming a maximum of two carriers). By focusing on the set KPIs (min. 256kbps with 95% user satisfaction), this reduction in capacity is noted to have no effect. This is ensured through the strict switching requirements, which do not allow switching off if users' satisfaction is likely to becoming affected, prioritizing network performance over energy saving.

Traffic	Cells on DC-HSDPA	Average Data Rate (Mbps)	Gain in Data Rate
Full	100%	1	-
High	100%	1.13	13%
Medium	83%	1.57	57%
Low	28%	1.95	95%
Gain in Data Rate (weighted)			**50%**
Gain in Energy (weighted)			**14%**

Table IV – Network configuration (number of cells with dual-cell) and performance (data rate) and gains for the various traffic categories – with switching off enabled.

The amount of energy saving (in this case 14%) is specific to the traffic profile and therefore the area of the network being considered. If a more industrial/office area is considered, the number of hours allocated for each of the traffic categories is likely to be different (as opposed to that of a busy urban area), with more hours associated to medium and low traffic.

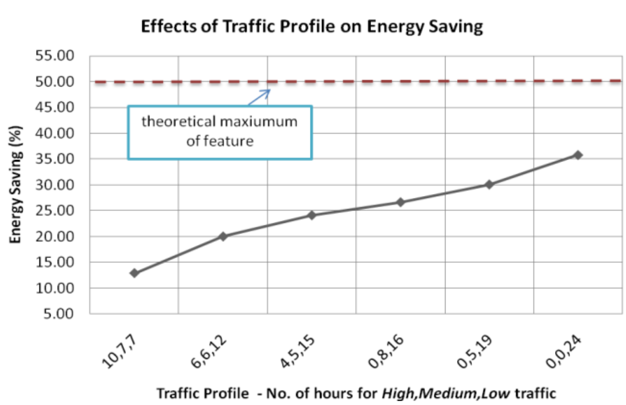

Figure 6 –Energy savings for different network traffic profiles.

By assuming such a scenario, where the number of hours for high, medium, and low traffic is set to 6, 6, and 12 respectively, an energy saving of 20% is observed. To put the obtained results into perspective, the theoretical maximum energy saving of this feature is 50%, which reflects having all cells running 24-7 on a single carrier. However by assuming the network configuration obtained for low traffic, i.e. having 28% of the cells with DC-HSDPA, the maximum achievable energy saving (considering low traffic over 24 hours) approaches 36%. In reality, an area that could represent such a low traffic profile would be one which users are attracted towards based on the season. For instance some areas close to the coast might experience regular traffic profiles during the summer period, but relatively constant low traffic during colder seasons. A small sample of the energy savings possible for different traffic profiles is presented in Figure 6.

VI. Conclusions

Given the specific traffic profile, switching off the secondary carrier that enables DC-HSDPA is noted to result in an energy saving of 14%. This gain is achieved without any affect to networks' performance, ensuring the same levels of users' satisfaction. However, a reduction in network capacity, through switching off one of the two carriers, is noted to reduce the achievable gains in data rate that generally result from a reduction in network traffic.

By considering variations to the traffic profile, representing different scenarios, the energy savings are noted to increase in proportion to the number of low traffic hours. The maximum daily energy saving, for an area experiencing only low traffic, is 36%.

The reduction in energy consumption and/or improvement in the average data rate might be improved further if the selection of the carrier to switch off is based on the status of neighboring sites. Another option could be that of considering antennas that have different tilt angles for the two carriers.

References

[1] Hans-Otto Scheck, "CO2 Footprint of Cellular Networks", The Green Basestation Conference, Bath, U.K., April 2009.
[2] J. Malmodin, "Carbon footprint of mobile communications and ICT", October 2008.
[3] Ericsson – Capital Markets Day, Stockholm, May 2008.
[4] W. Mohr, W. Konhauser, Siemens, "Access Network Evolution Beyond Third Generation Mobile Communications", IEEE Communications Magazine, December 2000.
[5] J. Bergman, D. Gerstenberger, F. Gunnarsson, and S. Storm, "Continued HSPA Evolution of mobile broadband," in Ericsson Review Journal 2008, vol. 86, no. 1, pp. 7–11.
[6] E. Seidel, j. Afzal, G. Liebl, "Dual Cell HSDPA and its Future Evolution" Novel Mobile Radio Research (Nomor) White Paper, January 2009.
[7] R1-081361, "System Benefits of Dual Carrier HSDPA", Qualcomm Europe, 3GPP TSG-RAN WG1 #52bis, April 2008.
[8] D. M. de Andrade, A. Klein, H. Holma, I. Viering, G. Liebl, "Performance Evaluation on Dual-Cell HSDPA Operation", IEEE Vehicular Technology Conference Fall 2009, Anchorage, Alaska, 2009.
[9] 3GPP Technical Report, TR 25.825 version 1.0.0 "Dual-Cell HSDPA Operation", 2008.
[10] 3GPP Technical Report, TR 25.814, version 7.1.0, "Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA) (Release 7)", 2006.