DYNAMIC NETWORK MANAGEMENT IN RECONFIGURABLE SYSTEMS - HSDPA POWER AND CODE ALLOCATION

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ABSTRACT

Mobile networks are planned based on the busy hour assumption, leading to an under utilization of the available capacity during many hours of the day. Dynamic network management adds flexibility to the network planning process by introducing adaptive processes monitored by the network management subsystem, leading to reduced roll-out expenses and better utilization of resources. Dynamic network management as such enables optimal resource distribution and element reconfiguration to best suit the traffic variation in both time and space. The moving hotspot is a typical example where the need for dynamic management is highlighted. In this paper, we discuss the effect of dynamic total power distribution for the shared channel (HSDPA) in 3G network systems enabled with reconfigurable network elements. Base stations are therefore able to reconfigurable their hardware (HW) and software (SW) to work under dedicated or shared conditions. This leads to a colored HSDPA total power allocation throughout the network depending on each cell's load. Moreover, a queuing model is introduced to simplify the key performance indicators of the shared channel and reduce the needed simulation time.

1. INTRODUCTION

Reconfigurable networks can effectively optimize the repartition of network resources between conflicting demands. By shifting the computing capacity of the radio interface in an intelligent way, user demands can be addressed without additional expenses for operators when compared to hardware duplication such as an increase in the number of base stations in a certain area. Examples of such methods are variable processing powers depending on the load for shared channels, flexible capacity and adaptive coverage of radio cells. For an efficient use of the dynamic network management in reconfigurable systems, the radio elements have to be reconfigured during the operating phase to the optimal operation mode, saving therefore time and expenses for the state of the art management where changes in the network are more static, long term based and necessitating the intervention of the network planning engineers. Well designed dynamic and independent network management schemes are hence believed to impact significantly the deployment costs of network operators in the future. An adequate example reflecting the need and benefit of such procedures is the moving hotspot issue. Users, especially at high concentrations, affect the number of antenna receivers needed without ensuring that the planned for capacity is always efficiently used. Peak load planning is therefore not anymore a must for a guarantee of the quality of service. Dynamic network management introduces flexible parameters allowing relaxed planning conditions. Users in suburban areas might move to central downtown during the day, imposing a high load in this area, and then might tend to form another hotspot somewhere else in the area because of some events taking place, before returning to their homes and repartitioning the load according to another distribution. In this paper, the shared channel capability that will be included in the first UMTS evolution and known as the High Speed Data Packet Access (HSDPA) is considered for the delivery of the data to users in the network and in the moving hotspot. The power allocation, controlled by the network's management subsystem, tries to adapt to the load changing in time and in space. The paper is divided as follows: section 2 introduces the considered scenario and the HSDPA functionality, section 3 the key performance indicators (KPI) to assess the benefits of the dynamic power allocation, section 4 the simulation assumption and results, and section 5 the conclusion.

2. SCENARIO: HOTSPOT AND HSDPA

The scenario considered is made of a number of cells covering a certain area, with a certain number of uniformly distributed users. During one day time, the uniform distribution changes its spatial-temporal characteristics to become a hotspot-like distribution, where most of the users are concentrated in one cell. This dynamic hotspot configuration implies a dynamic change of traffic requirements due to special events (sporting events, accident…) or simply changing user requirements (from working hours to leisure time …). At different times of the day, the peak load of the hotspot changes, as well as the number of connections in neighboring cells. Figure 1 shows an example of a spatial-temporal traffic variation.

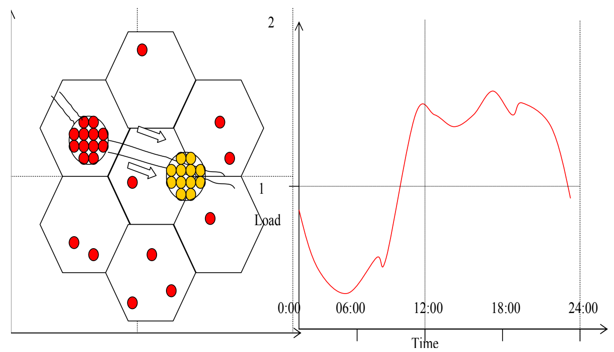

Figure 1: Spatial and Temporal traffic variation

We consider the data services provided by the shared channel in UMTS, the HSDPA. Users are scheduled each 3 slots, and their throughput depends on their received signal, which determines which modulation and coding to select for transmission. It consists of 15 spreading codes, which can be attributed to one or divided between more at each scheduling instance. To simplify the simulation model, in a first step, we assume that users of a cell will not be multiplexed at one time in the code domain, but each will receive all 15 codes when scheduled. Since the purpose here is not to design an optimum scheduler, the benefits of the dynamic network management and reconfiguration are not affected. The adaptive power allocation at each base station involves a shift of resources between dedicated services such as voice with variable power and shared services such as background traffic with constant power. Moreover, it involves a reconfiguration of the base station's DSP and ASIC boards to allow for a faster decoding of the information depending on its type. In the case of HSDPA, the base station has additional functionalities such as the fast scheduling (assigning resources to users on a 3-slot frequency), modulation and coding schemes selection, and H-ARQ as a fast retransmission mechanism. The power assignment is done at the network management level on a less frequent basis, though not standardized by 3GPP. In our proposal, the network manager sets frequent signals during the day to base stations as to which fraction of their available total power to allocate to HSDPA, and if necessary to reconfigure HW and SW to work under the dedicated or the shared mode. Figure 2 shows the network deployed considered in our analysis. A set of 12 cells with uniformly distributed users is created, and one of the cells contains an additional hotspot of users. This is similar to a week day case, where users head to work during the day and concentrate the use of resources in one region, the hotspot being mobile in case other events take place in other cells.

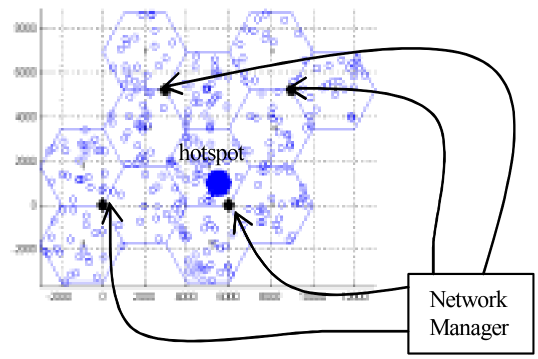

Figure 2: Network layout and power commands

3. KEY PERFORMANCE INDICATORS

The measured values to assess the benefits of the colored HSDPA power allocation throughout the network are the throughput and the delay. However, running extensive simulation campaigns requirement is waived out by approximations from queuing theory approximations. This section describes the procedure of using queuing models to analyze the performance of UMTS HSDPA channel for data services. The user arrival rate for such a system is Poisson distribution with rate R. Although the service demands for all users can be assumed to be negative exponentially distributed, capacity degradation due to signal attenuation, fading and interference from co-channel interferers makes the service time distribution to be not exponential any more. We assume every customer has the capability of processing all 15 spreading codes simultaneously, and all customers (mobile stations) access the shared radio resources in a pure time sharing context. By exploiting this fact, the HSDPA base station works like a single server and assigns radio resource in terms of small time intervals to mobiles when it is scheduled to be served. Therefore, such system can be modeled by the M/G/1 with processor sharing discipline. In this paper we denote such a system as M/G/1-PS (Packet Switched).

3.1. Response Time as M/G/1-PS

In the literature, there are a number of terms defining the 'time a customer spends in the system', such as the *sojourn time*, *transfer time*, *response time*, etc. In principle, this performance indicator is the sum of time to transmit a customer file $T_t(x) = d/c$ - with d the file size in bits and c the capacity this user receives from the network in bps - and the delay time T_w due to waiting for the transmission of other users' data. In this document, we use the name *response time* to evaluate the system performance. If the service time distribution is *b(x)*, and its corresponding cumulative density *B(x)*, we can calculate the user density having been serviced (amount of service time in second) related to the response time. From Little's results, the average number of customers *N(x)* having received service *x* is equal to the product of the average response time of those customers and the average arrival rate for customers who have not completed their services:

$$N(x) = \lambda(1 - B(x))T(x) \quad (1)$$

The average density of users with respect to the received service *x* is obtained by the following equation:

$$n(x) = \lim_{\Delta x \to 0} \frac{N(x+\Delta x) - N(x)}{\Delta x} = \lambda(1 - B(x))\frac{dT(x)}{dx} \quad (2)$$

The previous equation shows the distribution of the customers who were serviced as a function of the service time distribution, arrival rate and the response time.

The rate $\mu(x)$ of completing a service given an attained service age of *x* seconds is written as:

$$\mu(x) = \frac{b(x)}{1 - B(x)} \quad (3)$$

The density $n(x+\Delta x)$ must be equal to the density at *x* such that only customers requiring more service time than $x + \Delta x$ are left in the system. Therefore, the following equation holds:

$$n(x+\Delta x) = n(x)[1 - \mu(x)\Delta x] \quad (4)$$

Letting $\Delta x \to 0$ and solving the differential equation, we obtain:

$$n(x) = n(0)[1 - B(x)] \quad (5)$$

The average response time in this case is:

$$T(x) = \frac{n(0)}{\lambda} x \quad (6)$$

Since jobs might have very long service time $x \to \infty$, it stays in the system forever and allows other smaller jobs to pass by, so that

$$\lim_{x \to \infty} T(x) = \frac{x}{1 - \rho} \quad (7)$$

with

$$\rho = \frac{\lambda}{\mathrm{E}\left(\frac{c}{d}\right)} \quad (8)$$

The average response time for a customer requiring service time *x* can then be written as

$$T(x) = \frac{x}{1 - \rho} \quad (9)$$

3.2. Throughput and Code allocation

The power allocated to the shared channel is constant during the 3 slots after the scheduler has designed which user to serve. Nevertheless, due to the fact that the modulation and coding schemes (MCS) are discrete values and that throughput function not being continuous, there exists an optimal number of codes for each perceived CIR which, combined with the adequate MCS, maximizes the capacity in terms of bits per second. Figure 3 shows, for a range of possible received CIR, the number of codes as well the MCS to be chosen. Table 1 contains the MCS list of possible standardized combinations.

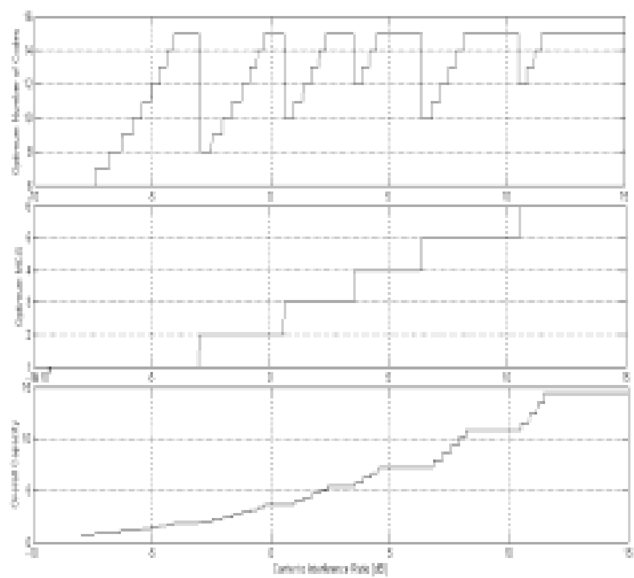

Figure 3: Optimal code and MCS allocation

Table 1: Modulation and Coding Schemes (15 Codes)

Modulation	Coding Rate	Throughput
QPSK	1/4	1.8 Mbps
QPSK	1/2	4.8 Mbps
QPSK	3/4	5.4 Mbps
16-QAM	1/2	7.2 Mbps
16-QAM	3/4	10.8 Mbps
16-QAM	4/4	14.4 Mbps

4. SIMULATION RESULTS

Power adaptation is done proportionally to the load in the cells. Simulation parameters are given in table 2. Throughput and response time computations are carried out separately in the cell containing the hotspot and the cells surrounding it. Figure 1 shows the scenario considered.

Table 2: Simulation parameters

Number of cells	12 - hexagonal
Sector configuration	120° - directional antennas
Average users per cell	50
Average users in hotspot	150
Channel used	HSDPA
Base station power	25 Watts
Power for HSDPA	60%
Cell radius	2000 m
Hotspot radius	500 m
File size *d*	100 kbits
Arrival rate λ	32 users/s

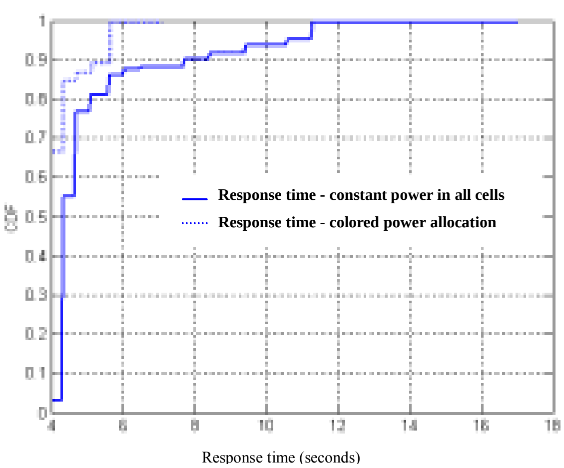

Figure 3: Average response time in the hotspot cell

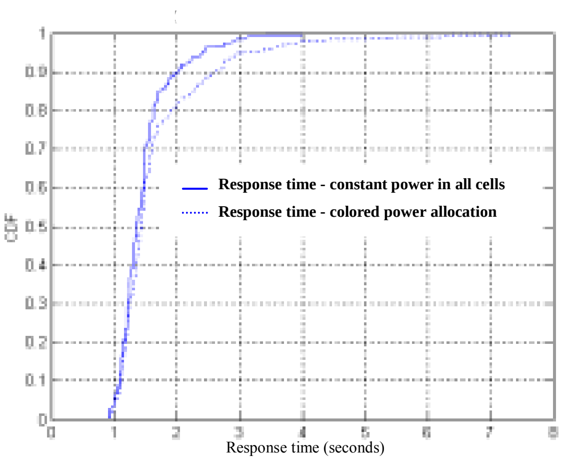

Figure 4: Average response time in the surrounding cells

Figure 3 shows the response time in the hotspot containing cell, and the reduction obtained by using colored power allocation proportional to the load. The hotspot cell gets, in this case, the full HSDPA power (60%), whereas neighboring cell's power is proportional to the fraction of users compared to the number of users in the hotspot cell.

$$P_i = P_{HSDPA} \frac{N_{users,i}}{N_{users,hotspot}} \qquad (10)$$

Figure 4 shows the effect of reducing the power in neighboring cells on the response time which increases. Table 3 is the response time change for different percentiles, and table 4 the throughput change. For the 90th percentile, the response time in the hotspot cell is reduced by more than 2 seconds for a very small increase in the response time of neighboring cells (about 0.5 seconds). The throughput of the 90th percentile in the hotspot is, similarly, increased by 360 kbps for a reduction of 3 kbps in neighboring cells.

Table 3: Gains in terms of response time (seconds)

Response Time	**Hotspot cell**	**Other cells**
70th percentile	0.34 sec less	0.13 sec more
80th percentile	0.75 sec less	0.24 sec more
90th percentile	2.18 sec less	0.58 sec more

Table 4: Gains in terms of throughput

Throughput	**Hotspot cell**	**Other cells**
40th percentile	0.72 Mbps more	0.0010 Mbps less
70th percentile	0.37 Mbps more	0.0013 Mbps less
90th percentile	0.36 Mbps more	0.0030 Mbps less

5. CONCLUSION

The use of adaptive power allocation as part of dynamic network management functions shows a significant gain the terms of response time reduction and throughput increase. The network's management subsystem is then able to adapt the network's functions and resources distribution, decreasing the network deployment costs by taking advantage of software enabled reconfigurability of the base station, moving processing power and functionalities from one technology to another. This could be managed by managing shared resources between HSDPA and dedicated channels. In hotspot areas, there are more packet calls and therefore more processing power is allocated while reducing at the same time inter-cell interference by reducing the transmission power at neighboring cells. The degradation is minimal because of fewer loads. Moreover, a queuing theory based model was introduced to investigate the behavior of HSDPA without having to run extensively long simulations. The throughput and code allocation was investigated for the single scheduled user case. An extension of this work would be more intelligent power distribution schemes, as well as multi user schedulers and code allocation algorithms to optimize the shared resources.

6. CONCLUSION

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7. REFERENCES

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