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SOFT AND SOFTER HANDOVER AND RADIO RESOURCE MANAGEMENT IN UMTS NETWORK

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Abstract – *Soft and softer handover are one of the key features in UMTS radio resource management. In this paper we will investigate impact of soft handover on downlink capacity and network performance in case of cell congestion. Connection between probability for soft handover and Active Set Threshold parameter will be derived. Finally, we will propose optimal soft handover parameters values.*

1. INTRODUCTION

Handover is a key concept in providing mobility. Term handover stands for event when mobile station starts to communicate with another base station. It makes possible for a user to travel from one cell to another, with no interrupt - seamless connection.

One of the greatest changes that third generation mobile systems brought, was in handover realization. In GSM, handover was realized in a way that mobile station set connection with new base station after connection with previous base station was terminated – "break before make" concept. Handover is realized in UMTS as soft handover, which is technique whereby mobile station – UE (user equipment in UMTS) in transition from one cell to another communicates with both base stations – (Node B in UMTS) simultaneously.

The Soft Handover procedure is composed of several functions: measurements, filtering of measurements, reporting of measurement results, the soft handover algorithm and execution of handover. In UMTS system, UE measures level of CPICH (Common Pilot Channel) of neighboring cells, and handover decision is based on these measurements. Monitoring set can hold up to 32 inter-frequency cells. Cells from monitoring set are periodically checked against so called "triggering conditions" defined in soft handover algorithm. In order to understand the soft handover algorithm, it is necessary to introduce some new parameters:

- AS_Th: Active Set Threshold - Threshold for macro diversity (reporting range)
- AS_Th_Hyst: Hysteresis for the above threshold
- AS_Rep_Hyst: Replacement Hysteresis
- ΔT: Time to Trigger
- AS_Max_Size: Maximum size of Active Set

Instead of serving base station, here we have term Active Set, which presents several base stations with whom UE communicates during soft handover. The soft handover algorithm is described on Figure 1.

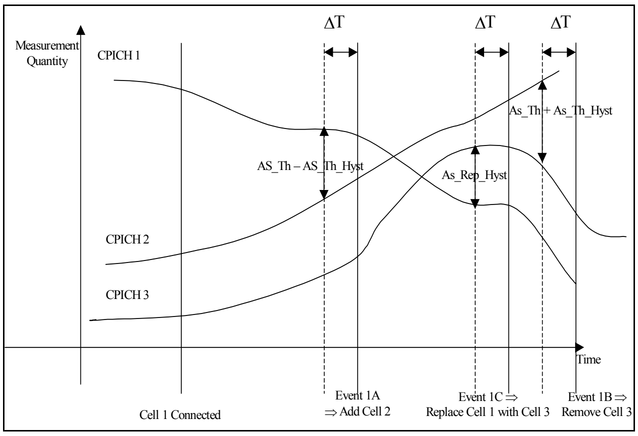

Figure 1. Soft handover algorithm

We can see that neighbor Node B can enter to Active Set in case that difference between level of CPICH from best serving Node B and candidate Node B is less than AS_Th - AS_Th_Hyst during ΔT. Condition for deleting Node B from Active Set is that difference between level of CPICH from best serving Node B and candidate Node B raise over AS_Th + AS_Th_Hyst during ΔT. Condition for replacing one Node B with another is that level of candidate Node B CPICH is larger then level of CPICH from replacing Node B for AS_Rep_Hyst during ΔT. Algorithm is described in [7].

If one of conditions mentioned above is fulfilled, UE will report to UTRAN. Entire evaluation process – soft handover algorithm happens in UE. This type of handover is called mobile assisted handover. Report does not contain measurement results, only action proposal (f.e. *Node B replacement*) which might be approved or denied, by Call Admission Control in RNC.

2. SOFT HANDOVER AND DOWNLINK TRANSMISSION POWER

Realization of soft handover on uplink and downlink is different. On uplink, signal from UE is already received in several Node B's. Soft and softer handover combine these signals, and achieves benefits – we have macro diversity. It was shown in [5] that soft handover on uplinks brings only benefit and improves coverage. The main difference is that on downlink, without soft handover feature, only one Node B transmits signal to UE. Soft handover gain on downlink has to be paid by transmitting signals from several Node B's. In UMTS network, downlink capacity is limited with Node B's transmission power. On the other hand, in order to maintain soft handover, additional signalization on downlink is needed, which additionally raises power consumption of Node B. We will try to model impact of soft handover parameters on power consumption. If we ignore thermal noise, SIR ratio in receiver in UE without soft handover can be expressed as:

$$\frac{E_b}{I_0} = \frac{W}{\nu \cdot R} \cdot \frac{P_S \cdot L_1}{P_{T1}(1-a)L_1 + \sum P_{Tn} \cdot L_n} \qquad (1)$$

where W is chip rate, ν is activity factor, R is bit rate, P_S is Node B transmission power dedicated to UE, P_{Tn} is total transmission power of n-th Node B, L_n is attenuation on propagation path from n-th Node B to UE. Required BS transmit power can be derived as:

$$P_S = \left(\frac{E_b}{I_0}\right)_{target} \frac{\nu \cdot R}{W} P_T \left[(1-a) + \sum_n \frac{L_n}{L_1}\right] \qquad (2)$$

Last formula can be written as:

$$P_S = \beta_1 \cdot \left(\frac{E_b}{I_0}\right)_{target} \frac{\nu \cdot R}{W} P_T \qquad (3)$$

where

$$\beta_1 = \left[(1-a) + \sum_n \frac{L_n}{L_1}\right] \qquad (4)$$

Factor β_1 depends on propagation conditions, and the rest in formula (3) depend on type of service. Let's consider situation when UE communicates during soft handover with two Node B. We have maximum ratio combining in the receiver, so received SIR is:

$$\left(\frac{E_b}{I_0}\right)_{total} = \left(\frac{E_b}{I_0}\right)_1 + \left(\frac{E_b}{I_0}\right)_2 \qquad (5)$$

$$\frac{E_b}{I_0} = \frac{W}{\nu \cdot R} \cdot \left[\frac{P_{s1} \cdot L_1}{P_{T1}(1-a)L_1 + \sum P_{Tn} \cdot L_n} + \frac{P_{s2} \cdot L_2}{P_{T2}(1-a)L_2 + \sum P_{Tn} \cdot L_n}\right] \qquad (6)$$

We will make following assumptions:

1. $P_{S1} = P_{S2}$, since according 3GPP recommendations [7], power control algorithm will try to avoid power drifting and maintain equal power on BS transceivers for UE in soft handover state
2. users are uniformly distributed, and cell load is well balanced, which means: $P_{T1} = P_{T2} = P_{Tn}$.

In such case:

$$P_{S1} = P_{S2} = \frac{\frac{\nu R}{W}\left(\frac{E_b}{I_0}\right)_{target} P_T}{\frac{1}{(1-a) + \sum_n \frac{L_n}{L_1}} + \frac{1}{(1-a) + \sum_n \frac{L_n}{L_2}}} \qquad (7)$$

Total transmission power dedicated to UE can be written, similar to (3) as:

$$P_S = \beta_2 \cdot \left(\frac{E_b}{I_0}\right)_{target} \frac{\nu \cdot R}{W} P_T \qquad (8)$$

here:

$$\beta_2 = \frac{2}{\frac{1}{(1-a) + \sum_n \frac{L_n}{L_1}} + \frac{1}{(1-a) + \sum_n \frac{L_n}{L_2}}} \qquad (9)$$

In case of three Node B soft handover, factor β_3 is:

$$\beta_3 = \frac{3}{\frac{1}{(1-a) + \sum_n \frac{L_n}{L_1}} + \frac{1}{(1-a) + \sum_n \frac{L_n}{L_2}} + \frac{1}{(1-a) + \sum_n \frac{L_n}{L_3}}} \qquad (10)$$

Factors β_1, β_2 and β_3 indicate power consumption, and we can see in formulas (4), (9) and (10) that they depend on propagation – path loss from serving and neighboring base stations. In order to investigate connection between power consumption and soft handover parameters, β_1, β_2 and β_3

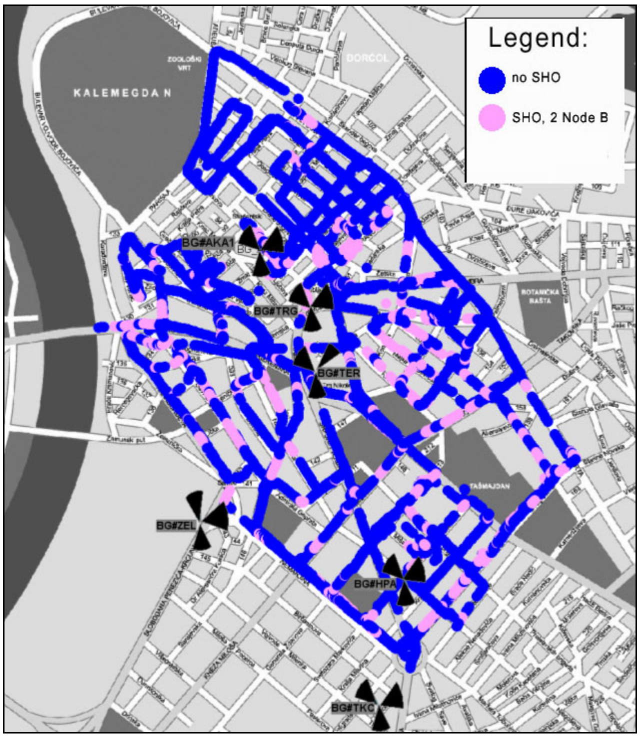

Figure 2. SHO zones, As_Th=2dB

factors were calculated. Since UMTS base stations are going to be co-sited with GSM base stations, we decided to use drive test measurements of DCS signal (GSM on 1800 MHz) as input for calculations. Figure 2. shows drive test route.

At the beginning, we compared power consumption in case of UE connected to best server only and UE in soft handover, for different soft handover parameters. If n=1 is best server Node B, then we have:

$$\sum_{n\neq 1}\frac{L_n}{L_1} \leq \sum_{n\neq 2}\frac{L_n}{L_2} \qquad (11)$$

If we apply (11) in calculations of β_1 and β_2, it is not hard to prove that $\beta_2 > \beta_1$. Hence we have power consumption growth. Figure 3. shows power consumption growth as function of AS_Max_Size and AS_Th parameters. We can see that power consumption growth is larger for AS_Max_Size = 3 comparing AS_Max_Size = 2, and it is larger for higher values of AS_Th as well.

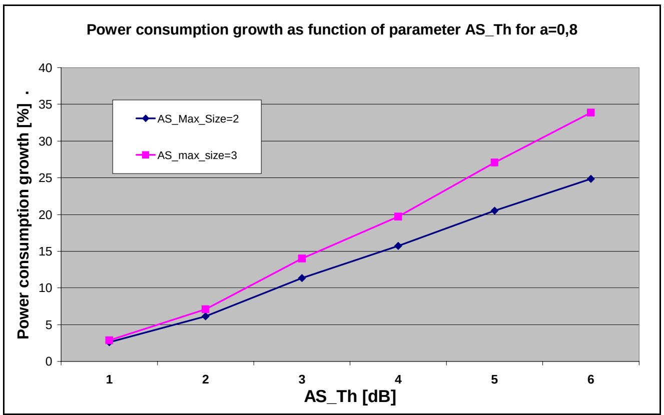

Figure 3. Power consumption growth as function of soft handover parameters AS_Max_Size and AS_Th

3. SOFT HANDOVER PROBABILITY AS FUNCTION OF ACTIVE SET THRESHOLD PARAMETER

As we showed in previous chapter, soft handover can cause higher Node B power consumption an decrease downlink capacity. It is very important to optimize soft handover probability in order to achieve optimal network performance. Holma and Toskala in [6] recommend that soft handover probability should not be more than 30% - 40%. Soft handover probability can be optimized by setting parameter AS_Th. Table 1. presents soft handover probability as function of Active Set Threshold parameter, derived from measurements described in previous chapter.

AS_Th	1 dB	2 dB	3 dB	4 dB	5 dB	6 dB
SHO probability [%]	10.6	16.2	23.1	28.5	34.5	40.3

Table 1. SHO probability as function of AS_Th

After connection between soft handover probability and Active Set Threshold parameter is derived for specified cell plan, we can ask ourselves: what happens with addition of new sites? Will decreased cell distance affect to derived results? It was shown in [9] that for hexagonal cell model soft handover probability does not change with cell radius change.

In order to check this conclusion in practice, we compared relation between soft handover probability and AS_Th parameter for cell plan with all cells included and for cell plan without one Node B, BG#TRG was excluded. Figure 4. shows relation between SHO probability and AS_Th parameter for those two cases. We can see that relation does not change with change of cell to cell distance, so derived relation can be used without limitation.

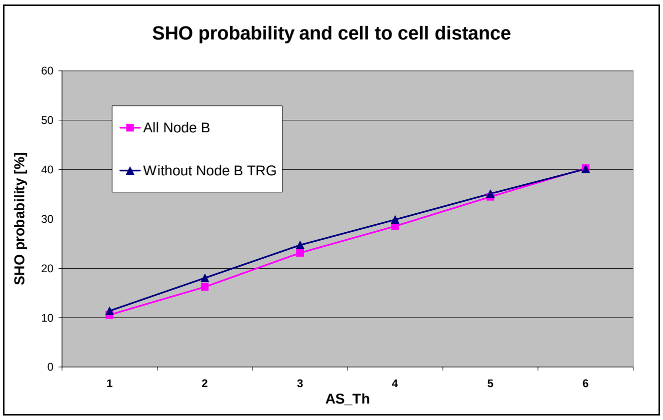

Figure 4. SHO probability and cell to cell distance

4. SOFT HANDOVER VS HARD HANDOVER, GAIN IN DOWNLINK CAPACITY

Power consumption growth presented in figure 2. was derived comparing situation when UE is connected to best server. But in case of hard handover, UE will not always be connected to best server, because of several reasons:

- Measurements are passing through filter, which cause some delay of decision
- Handover procedure is not immediate procedure, it need some time
- When we set AS_Max_Size = 1, fact that neighbor cell signal is stronger is not enough for handover - difference must be higher than AS_Th. Similar in GSM, we had parameter handover margin.

Problem of UE, which is not connected to best server, is not new. We encountered it even with GSM system with fractional load planning implemented as frequency planning technique (frequency hopping 1/1, see [3]).

If we focus on AS_Th, we can assume that in case of difference between serving cell signal level and best neighbor signal level is less than AS_Th, probability of UE is served by the best server is 50%, and in 50% of cases it is not served by the best server. With such assumption:

$$\beta_{HARD} = \frac{1}{2}\left((1-a) + \sum_{n\neq 1}\frac{L_n}{L_2} + (1-a) + \sum_{n\neq 2}\frac{L_n}{L_2}\right) \qquad (12)$$

If we compare power consumption for AS_Max_Size =2, 3 with hard handover (AS_Max_Size=1), we can see that soft handover brings benefit, since power consumption is smaller, and downlink capacity is improved. Capacity gain as function of AS_Th parameter is presented on figure 5.

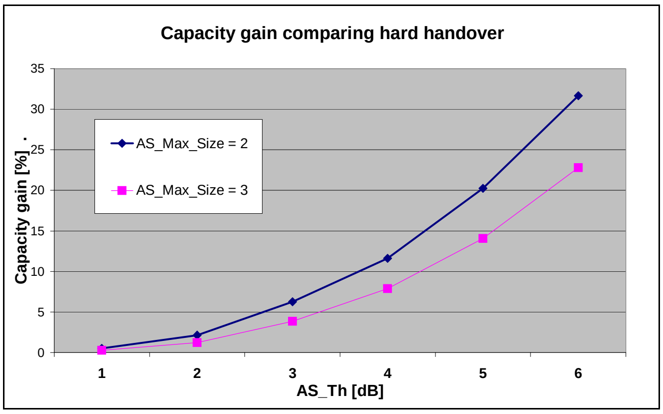

Figure 5. Capacity gain comparing hard handover as function of soft handover parameters AS_Max_Size, AS_Th

5. SOFT HANDOVER AND CELL CONGESTION

In all previous considerations, we assumed that system is well balanced – we assumed traffic uniformly distributed over cells. It was done with assumption that in case of balanced load, all base stations have same transmission power: $P_{T1} = P_{T2} = P_{Tn}$ (chapter 2). It is interesting to investigate, what happens when some cells are congested or loaded more than others. Cell congestion or higher cell load can be simulated if we introduce load factor K, as:

$$P_{Tn} = (1 + K) \cdot P_{T1} \quad (13)$$

which means that n-th cell is loaded 1+K times more than others, so it transmits 1+K times more power. We compared power that system transmits to user on drive test route, where n-th cell is the best server, in situation with soft handover and AS_Th parameter value of 4 dB, and in situation without soft handover when user is connected to the best server. Gain comparing hard handover, described in Chapter 4 is additional gain, and is not considered here. Figure 6. presents growth of transmitted power as function of load factor K.

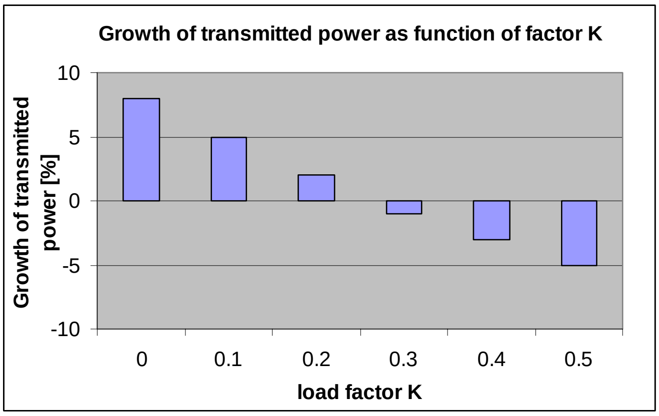

Figure 6. Transmitted power growth as function of factor K

Let's analyse results presented in Figure 6. We can see that in case of K=0 and uniformly distributed load we have power consumption growth and loss in capacity, which was expected and corresponds to results from chapter 4. With raise of factor K, growth decreases, and for K=0.3 and larger we have lower downlink transmission power and capacity gain. If we add gain comparing hard handover described in chapter 6, overall gain is even more significant. We can conclude that soft handover, in case of cell congestion, move users near cell border to neighboring cells and brings capacity improvement.

6. CONCLUSION

Soft handover improves coverage and network performance in presence of congestion. On the other hand, soft handover may decrease downlink capacity. We believe that soft handover should be encouraged immediately after UMTS network launch, since we can expect problems with coverage at the beginning. But, with traffic growth, soft handover parameters should be optimized from downlink capacity point of view. According achieved results, parameter AS_Max_Size should be set to two Node's B- AS_Max_Size = 2, since power consumption is higher for AS_Max_Size = 3, and improvement that soft handover brings comparing hard handover is achieved with soft handover with two Node's B already. Parameter AS_Th should be set between 3dB and 5dB.

7. REFERENCES

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Sadržaj – Mek i mekši handover su jedna od ključnih funkcija upravljanja UMTS radio mrežom. U ovom radu ćemo istražiti uticaj mekogi i mekšeg hendovera na kapacitet direktnog linka i performance mreže u uslovima ćelijskog zagušenja. Na kraju ćemo predložiti optimalne vrednosti parametara algoritma mekog hendovera.

MEK I MEKŠI HENDOVER I UPRAVLJANJE RADIO RESURSIMA UMTS MREŽA

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