

Active Set Size Effects at HSUPA in WCDMA Systems

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Abstract: WCDMA cellular networks support soft handover, which guarantees the continuity of wireless services and enhanced communication quality. Cellular networks performance depends upon Soft handover parameters. In this paper, we have shown the effect of soft handover parameters on the performance of WCDMA cellular networks. We consider $timeToTrigger1a$, $timeToTrigger1b$, $timeToTrigger1c$ and max active size as the Soft handover parameters. A very useful statistical measure for characterizing the performance of WCDMA cellular system is the mean active set size and soft handover region. It is shown through numerical results that above parameters have decisive effect on HSUPA, mean active set size and soft handover region and hence on the overall performance of the soft handover algorithm.

Keywords: HSUPA, WCDMA, Active Set Size, SHO, $timeToTrigger$

1. Introduction

Wide-band Code Division Multiple Access (WCDMA) based cellular standards support soft handover, which makes smooth transition and enhanced communication quality. Soft handover offers multiple radio links to operate in parallel. Mobile users are separated by unique pseudo-random sequences and multiple data flows are transmitted simultaneously via radio interface. The User Equipment (UE) near the cell boundary is connected with more than one Base Station (BS). Consequently, in soft handover UE is able to get benefit from macrodiversity.

Soft handover is associated with active set and its size. The inclusion and drop of a particular BS in/from the active set is determined by the initiation trigger utilized for soft handover algorithm.

1.1. Active Set Size in WCDMA

Initiation trigger include, received pilot signal strength, Signal to Interference Ratio (SIR), Bit-Error Rate (BER), Energy per chip to noise power density (E_c/N_0). Due to the random nature of the received signal at UE, there are frequent inclusion and drop of BS(s) in the active set. Active set consists of those base stations which are connected with UE and soft handover region [15] is that region in which UE is connected with more than one base station. It is essential for properly designed soft handover algorithm [16, 17, 18, 19, 21, 22, and 23] to reduce the switching load of the system while maintaining the quality of service (QoS). In this paper, we have considered mean active set size and soft handover parameters as the metric for performance evaluation of the HSUPA throughput. It is directly related to performance of handover process with active set size.

The rest of the paper is organized as follows. Section 2 describes the system model used for real time measurements; Soft handover algorithm follows cellular layout. It is followed by

description of soft handover algorithm and numerical results are obtained, plotted and discussed in Section 3. Finally, conclusion is drawn.

2. The System Model

System level results are obtained by TEMS Discovery generating the statistical statements for the EUL throughput and real-time measurements are done by TEMS Investigation tool with Huawei Data card (E182) in a city. Test is done by a car and Tems logs are collected via GPS in a laptop.

2.1. WCDMA System Model

Received Signal Code Power (RSCP) at UE is affected by three components as follows:

- (i) Path loss attenuation with respect to distance
- (ii) Shadow fading
- (iii) Fast fading

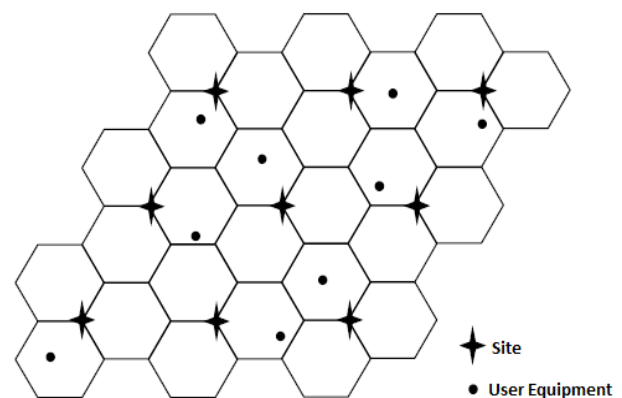


Figure 1. Network Configuration

Path loss is the deterministic component of RSCP, which can be evaluated by outdoor propagation path loss models [9 - 10]. Shadowing is caused due to the obstruction of the line of sight path between transmitter and receiver by buildings, hills, trees and foliage. Multipath fading is due to multipath reflection of a transmitted wave by objects such as houses, buildings, other man

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made structures, or natural objects such as forests surrounding the UE. It is neglected for handover initiation trigger due to its short correlation distance relative to that of shadow fading.

The UE measures RSCP from each BS. The measured value of RSCP (in dBm) is the sum of two terms, one due to path loss and the other due to lognormal shadow fading. The propagation attenuation is generally modeled as the product of the η^{th} power of distance and a log normal component representing shadow fading losses [9]. These represent slowly varying variations even for users in motion and apply to both reverse and forward links. For UE at a distance 'd' from BS₁, attenuation is proportional to

$$\alpha(d, \zeta) = d\eta 10\zeta/10 \quad (1)$$

where ζ is the dB attenuation due to shadowing, with zero mean and standard deviation σ . Alternatively, the losses in dB are

$$\alpha(d, \zeta)[\text{dB}] = 10\eta \log d + \zeta$$

where η is path loss exponent. The autocorrelation function between two adjacent shadow fading samples is described by a negative exponential function as given in [11]. The measurements are averaged using a rectangular averaging window to alleviate the effect of shadow fading according to the following formula [12]. Let d_i denote the distance between the UE and BS_i, $i=1, 2$. Therefore, if the transmitted power of BS is P_t , the signal strength from BS_i, denoted $S_i(d)$, $i=1, 2$, can be written as [14].

$$S_i(d) = P_t - \alpha(d_i, \zeta)$$

$$S_i(k) = (1/N_w) \sum_{n=0}^{N-1} S_i(k-n) W_n$$

where; S_i is the averaged signal strength and S_i is the signal strength before averaging process. W_n is the weight assigned to the sample taken at the end of $(k-n)$ th interval. N is the number of samples in the averaging window

$$N_w = \sum_{n=0}^{N-1} W_n$$

Table 1. Simulation Parameter

D=400 km	Drive distance per test
UL=10 Mhz	UL Bandwidth
ds=1s	Sampling time
CPICH=340 dBm	Base station transmitter power
N=126	Site count in the city

3. Soft Handover Algorithm

Based on the E_c/I_o measurements of the set of cells monitored, the mobile station decides which of three basic actions to perform; it is possible to add, remove or replace a NodeB in the active cell. These tasks are respectively called Radio Link Addition and Radio Link Removal, while the latter is Combined Radio Link Addition and Removal. The example below is directly taken from the original 3GPP specifications. Discussing this scenario gives a good insight into the algorithm itself and forms an introduction to the illustrating simulations included in the next paragraph. This scenario can be based on a user following a trajectory as shown below. Delays in handovers can cause a user to penetrate deeply in an adjacent cell and generate harmful interference before the cell is added to the active cell.

Figure shows how the pilot signal strengths of the different cells evolve in time.

When the measurement values satisfy the following formulas, the UE deems that a primary pilot channel has entered the reporting range:

Path Loss:

$$10\text{Log}M_{\text{new}} < W \times 10\text{Log}(\sum_{j=1}^{N_a} M_i) + (1-W) \times 10\text{Log}M_{\text{Best}} + (R - H_{1a/2}),$$

Other measurement values:

$$10\text{Log}M_{\text{new}} < W \times 10\text{Log}(\sum_{j=1}^{N_a} M_i) + (1-W) \times 10\text{Log}M_{\text{Best}} - (R - H_{1a/2}),$$

Where,

M_{new} is the measurement result of the cell that has entered the reporting range

M_i is the measurement result of the cells in the active set

N_a is the number of cells in the current active set

M_{Best} is the measurement result of the best cell in the current active set

W is the weight factor

R is the reporting range. With the signal strength as an example, R equals to the signal strength of the best cell in the current active set minus a value

H_{1a} is the hysteresis value of event 1A

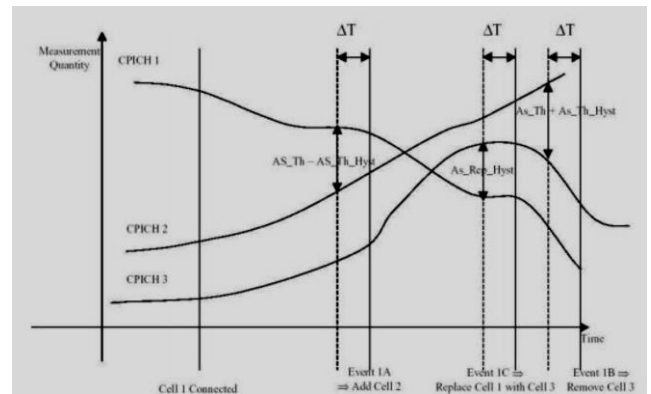


Figure 2. WCDMA handover algorithm

In explanation of soft handover algorithm, the following terms are crucial, and have to be defined:

Active set contains the list of cells, having the connection with MS, in other words, the cells, which are in soft handover connection.

Monitored set contains the list of cells, which pilot channels power is not high enough to be added to the active set, or active set is already full.

Detected set contains the list of cells, which are not defined as neighbour to the AS cells. Detected cells pilot-channels power can be high enough (must defined neighbour) or not.

At the start of the scenario the user is connected to cell number 1 which has the strongest pilot signal. Due to the user moving or to slow fading the perception of the signal strengths to the mobile user can change and following actions are taken:

- Event 1A: cell 2 is added
- Event 1B: cell 1 is replaced with cell 3
- Event 1C: Cell 3 is removed from the active set

3.1. EUL - Enhanced Uplink:

HSUPA uses an uplink enhanced dedicated channel (E-DCH) on which it employs link adaptation methods similar to those employed by High-Speed Downlink Packet Access HSDPA,

namely:

Shorter Transmission Time Interval enabling faster link adaptation;

HARQ (hybrid ARQ) with incremental redundancy making retransmissions more effective.

Similarly to HSDPA, HSUPA uses a packet scheduler, but it operates on a request-grant principle where the UEs request a permission to send data and the scheduler decides when and how many UEs will be allowed to do so. A request for transmission contains data about the state of the transmission buffer and the queue at the UE and its available power margin. However, unlike HSDPA, uplink transmissions are not orthogonal to each other.

In addition to this scheduled mode of transmission the standards also allows a self-initiated transmission mode from the UEs, denoted non-scheduled. The non-scheduled mode can, for example, be used for VoIP services for which even the reduced TTI and the Node B based scheduler will not be able to provide the very short delay time and constant bandwidth required.

Each MAC-d flow (i.e. QoS flow) is configured to use either scheduled or non-scheduled modes; the UE adjusts the data rate for scheduled and non-scheduled flows independently. The maximum data rate of each non-scheduled flow is configured at call setup, and typically not changed frequently. The power used by the scheduled flows is controlled dynamically by the Node B through absolute grant (consisting of an actual value) and relative grant (consisting of a single up/down bit) messages.

At the Physical Layer, HSUPA introduces new channels E-AGCH (Absolute Grant Channel), E-RGCH (Relative Grant Channel), F-DPCH (Fractional-DPCH), E-HICH (E-DCH Hybrid ARQ Indicator Channel), E-DPCCH (E-DCH Dedicated Physical Control Channel) and E-DPDCH (E-DCH Dedicated Physical Data Channel).

E-DPDCH is used to carry the E-DCH Transport Channel; and E-DPCCH is used to carry the control information associated with the E-DCH.

As shown in Table 2 below all UE categories support maximum data rates.

Table 2. UE HSUPA Categories

HSUPA CATEGORY NUMBER	MAXIMUM NUMBER E-DPDCHS	MINIMUM SPREADING FACTOR	SUPPORT FOR 2 MS TTI*	MAXIMUM TRANSPORT BLOCK SIZE (10 MS TTI)	MAXIMUM TRANSPORT BLOCK SIZE (2 MS TTI)	MAXIMUM DATA RATE (MBPS)
1	1	SF4	-	7110	-	0.7 Mbps
2	2	SF4	Y	14484	2798	1.4 Mbps
3	2	SF4	-	14484	-	1.4 Mbps
4	2	SF2	Y	20000	5837	2 Mbps for 10 ms TTI 2.9 Mbps for 2 ms TTI
5	2	SF2	-	20000	-	2.00 Mbps
6	2 + 2**	SF2	Y	20000	11520	2 Mbps for 10 ms TTI 5.74 Mbps for 2 ms TTI

3.2. EUL Throughput Measurement Analyse:

In this section, mean active set size, soft handover and EUL throughput has been measured as the function of different system parameters and characteristic parameters of radio propagation environment. Numerical results for this performance metric are obtained via TEMS Investigation for the system parameters indicated in Table 1. System measurement is performed TEMS Investigation 15.1 and analyzed by TEMS Discovery 10.1. To

obtain different active set size and EUL throughput for each system parameter setting, 3 drive tests are performed in the same city center.

Figure 3a & 3b show the effect of AS Size on the SIR and EUL TTI usage. 2ms TTI usage decreased when Active set size increases. When the UE start to connect more cells upload direction, capacity usage increased so that 10ms TTI usage increased. For both 3 drive test SIR values or very similar to each of them.

Figure 4a shows the EUL Throughput Distribution for all AS Size in the city. That figure shows that distribution percentage of all band. Figure 4b shows the Median throughput for each active set size measurements. If we tell the for same SIR values, EUL tput increases with the 2ms TTI usage.

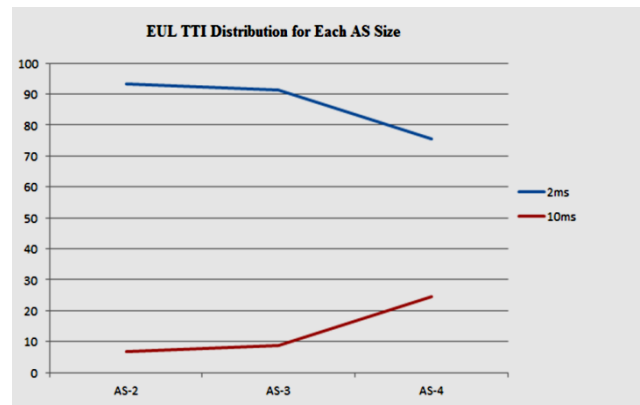


Figure 3a. Effect of AS size for EUL TTI Usage.

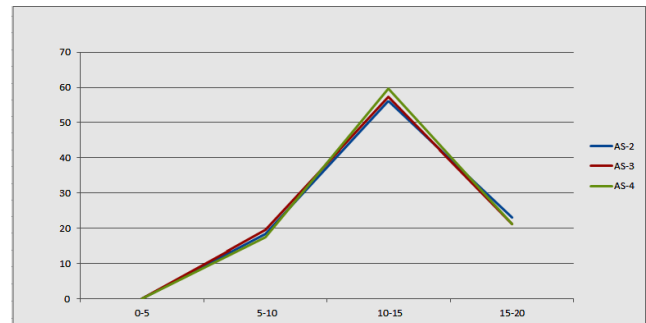


Figure 3b. Effect of AS size for SIR

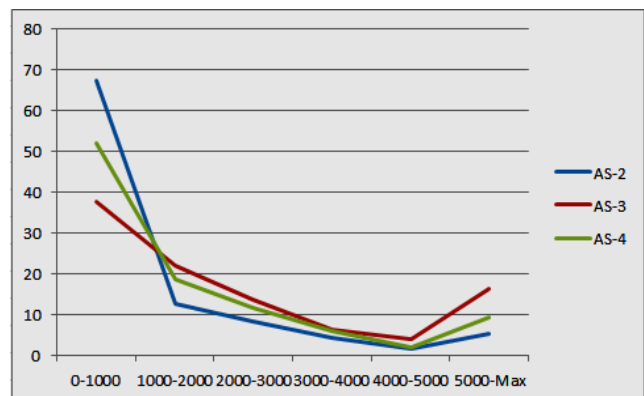


Figure 4a. Effect of AS size for EUL Distribution

EUL Median Tput(kbps)	kbps
AS-2	2034.7
AS-3	1781.1
AS-4	1579

Figure 4b. EUL Median Tput

4. Conclusion

In this paper, we have tried to understand the impact of Active Set Size on EUL performance, which was measured in a city with TEMS Investigation tool. Measurement results show that active set size setting has a decisive effect on the EUL performance. By careful tuning and setting appropriate values for the active set size parameter, a higher system performance can be achieved.

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