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Anas, Mohmmad; Calabrese, Francesco Davide; Mogensen, Preben; Rosa, Claudio; Pedersen, Klaus

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Performance Evaluation of Received Signal Strength Based Hard Handover for UTRAN LTE

Mohmmad Anas, Francesco D. Calabrese
Department of Electronic Systems, Aalborg University
Niels Jernes Vej 12, DK-9220 Aalborg, Denmark
{ma, fdc}@es.aau.dk

Preben E. Mogensen, Claudio Rosa, Klaus I. Pedersen
Nokia Networks
Niels Jernes Vej 10, DK-9220 Aalborg, Denmark
{Preben.Mogensen, Claudio.Rosa, Klaus.I.Pedersen}@nokia.com

***Abstract*— This paper evaluates the hard handover performance for UTRAN LTE system. The focus is on the impact that received signal strength based hard handover algorithm have on the system performance measured in terms of number of handovers, time between two consecutive handovers and uplink SINR for a user about to experience a handover. A handover algorithm based on received signal strength measurements has been designed and implemented in a dynamic system level simulator and has been studied for different parameter sets in a 3GPP UTRAN LTE recommended simulation scenario. The results suggest that a downlink measurement bandwidth of 1.25 MHz and a handover margin of 2 dB to 6 dB are the parameters that will lead to the best compromise between average number of handovers and average uplink SINR for user speeds of 3 kmph to 120 kmph.**

I. Introduction

Universal Terrestrial Radio Access Network Long-Term Evolution (UTRAN LTE), also known as Evolved UTRAN (E-UTRAN), is a system currently under development within the 3rd Generation Partnership Project (3GPP) [1][2][3]. One of the main goals of UTRAN LTE is to provide seamless access to voice and multimedia services with strict delay requirements, which is achieved by supporting handover (HO) from one cell i.e., serving cell, to another i.e., target cell. Since for UTRAN LTE, inter-NodeB macrodiversity is not included as a working assumption [4], this paper concentrates on hard handover. A handover process can typically be divided into four parts: measurements, processing, decision, and execution as shown in Fig. 1. Handover measurements (channel measurements on which handover decisions are based) are made in downlink and are processed in the user-equipment (UE). Processing is done to filter out the effect of fast-fading and layer 1 measurement/estimation imperfections. These processed measurements are reported back to the base-station (BS/NodeB) in a periodic or event based manner. Hence a handover is initiated based on the processed handover measurements and if certain criteria are met then the target cell becomes the serving cell performing the network procedures with the assistance of the UE [5].

Several handover studies have been done previously for the legacy systems like GSM and WCDMA [6][7][8][9]. In [6] and [7] a detailed description of various handover techniques is presented for GSM and WCDMA systems respectively. [8] studies how handover parameters such as margin and averaging interval affects the handover performance. In [9] an adaptive handover algorithm based on the estimated UE speed is presented. The idea in this paper is to adaptively control the averaging interval based on the UE speed. Handover algorithms presented in [8] and [9] are both based on received signal strength (RSS) measurements.

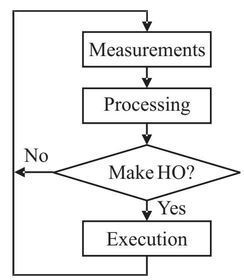

Fig. 1. The different parts of handover process

To the best of our knowledge, effect of handover parameters on different key performance indicators (KPIs) in UTRAN LTE for a realistic scenario has no extensive studies in the open literature. This paper presents algorithms based on RSS measurement and average path-gain (APG) which is used as a baseline reference. APG calculation assumes no fast fading effect while RSS measurement includes the fast fading effect. For algorithm based on RSS measurement, a realistic estimate of measurement imperfection due to the limited number of reference symbols is modeled and added to the RSS measurements before the processing. The target of this paper is to evaluate the performance of a RSS based handover algorithm for handover parameters such as measurement bandwidth, margin and measurement period at different UE speeds based on the parameters described in [2]. The KPIs chosen to evaluate this study are number of handovers, time between two consecutive handovers and uplink signal-to-interference-plus-noise ratio (SINR) for UEs about to experience the handover.

The rest of the paper is organized as follows. In Section II, a realistic handover algorithm based on RSS measurement is analyzed and a modification is proposed. These algorithms are verified and evaluated using a dynamic system level simulator briefly described in Section III. In Section IV, simulation results are discussed and Section V contains the concluding remarks.

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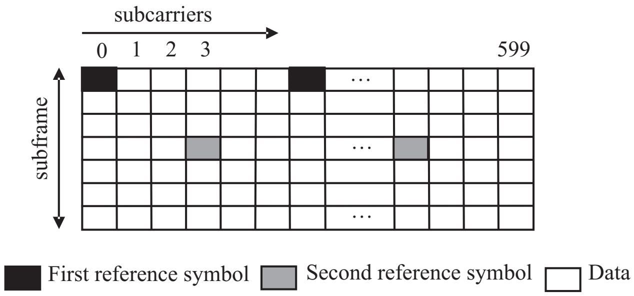

Fig. 2. Basic downlink reference-signal structure for UTRAN LTE [2]

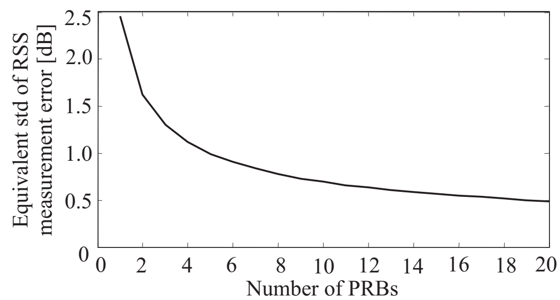

Fig. 3. Impact of frequency domain averaging (Layer 1 averaging) on RSS estimation error per TTI [11][12]. The physical resource block (PRB) size in UTRAN LTE is determined as 12 subcarriers.

II. Handover in UTRAN LTE

In the following section we present APG based handover as a baseline reference, followed by the analysis of a realistic handover algorithm based on RSS measurement. Further, a modification to RSS based handover is proposed.

A. APG based handover

In this reference scheme the UE is assumed to have the APG from each sector[1] which includes pathloss, antenna gain and log-normal shadowing. This algorithm excludes fast fading effect which means it assumes ideal fast fading filtering, hence the name APG based handover. If condition given in (1) is true, where H_m is handover margin (in dB), handover is executed and the target sector becomes the serving sector. The target sector (TS) is defined as the sector in the network, excluding serving sector (SS), from which the UE experiences maximum APG.

$$APG_{TS} \geq APG_{SS} + H_m \tag{1}$$

B. RSS based handover

In this algorithm the UE measures the RSS which includes pathloss, antenna gain, log-normal shadowing and fast fading averaged over all the reference symbols (pilot) within measurement bandwidth BW_m. The downlink reference-signal structure for UTRAN LTE is shown in Fig. 2. The filtered RSS, $\overline{RSS}$, is measured every handover measurement period (T_m) at the UE as the output of a first order infinite impulse response (IIR) filter as defined in (2). The relative influence on $\overline{RSS}$ of the recent measurement and older measurements is controlled by the forgetting factor β. In this paper β is chosen depending on the handover decision update period (T_u) and T_m as $\beta = T_m/T_u$, where T_u is an integer multiple of T_m.

$$\overline{RSS}(nT_m) = \beta RSS(nT_m) + (1-\beta)\overline{RSS}\left((n-1)\,T_m\right) \tag{2}$$

The limited number of reference symbols available in a handover measurement bandwidth for RSS measurement introduces measurement error. This error is modeled as normally distributed in dB (log-normal) with mean 0 and standard deviation σ dB as defined in (3) [10]. This measurement error is added to each RSS measurement before the filtering in (2). For smaller measurement bandwidth (i.e., lower number of reference symbols) we expect larger error level as compared to the larger measurement bandwidth (i.e., higher number of reference symbols) as shown in Table I which is estimated using Fig. 3 [11][12].

$$\Delta RSS \sim N(0, \sigma^2) \text{ dB} \tag{3}$$

TABLE I
Standard deviation of measurement error

Measurement bandwidth [MHz]	Number of PRBs	σ [dB]
1.25	6	0.8
2.5	12	0.6
5	25	0.45
10	50	0.35

The handover decision is based on the $\overline{RSS}$ and is executed if the condition in (4) is satisfied. The RSS based handover process is summarized in Fig. 4.

$$\overline{RSS}(nT_u)_{TS} \geq \overline{RSS}(nT_u)_{SS} + H_m \tag{4}$$

C. RSS based handover with time-to-trigger (TTT) window

This algorithm is similar to the RSS based handover algorithm except that the handover is initiated if the same sector remains the potential target sector for a certain number of time windows, called TTT window size. Each TTT window is equivalent to T_u. Let us assume that the Id_{TS} and Id_{SS} are the memory queues of target and serving sector identifications respectively, each of TTT window size, while id_{TS} and id_{SS} are the target and serving sector identities. The pseudo code of the proposed algorithm using stack push

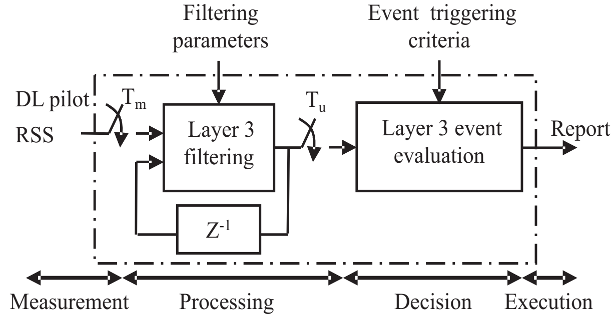

Fig. 4. RSS based handover using [7]

[1]Terms sector and cell are used interchangeably with the same meaning.

operation is as follows:

1. INITIALIZE Id_{TS}, Id_{SS}
2. IF (4) is true
   Id_{TS}.push(id_{TS})
   ELSE
   Id_{SS}.push(id_{SS})
3. IF $Id_{TS}[i] \neq Id_{SS}[i]$ and $Id_{TS}[i]$ = $Id_{TS}[j]$
   for all i, $j \in$ TTT window size, $j \neq i$
   EXECUTE handover

RSS based handover algorithm with n TTT window size will be represented as RSS$_n$ based handover, with a subscript n. RSS based handover, as described in *B*, is a special case of this algorithm with TTT window size of 1 i.e., RSS$_1$ based handover.

Introducing TTT window is one way to suppress the number of unnecessary handovers. The unnecessary handover is called the ping-pong handover, which is a handover to one of the neighboring BS that returns to the original BS after a short time. Each handover requires network resources to reroute the call to the new BS. Thus, minimizing the expected number of handovers minimizes the signaling overhead. Another solution to reduce the number of handovers is to introduce a handover avoidance timer which allows handover only after the timer expires.

III. Simulator Description

ELIISE - Efficient Layer II Simulator for E-UTRAN, is an indigenously developed multi-cell, multi-user, dynamic system level simulator to study advanced radio resource management (RRM) in uplink. The functionalities which are implemented include channel model, mobility, handover, power control and packet scheduling with fair as well as channel aware allocation schemes.

The simulated network layout is shown in Fig. 5. The network scenario considered assumes a hexagonal grid with 8 BSs and 3 sectors per BS with a corner-excited structure. The

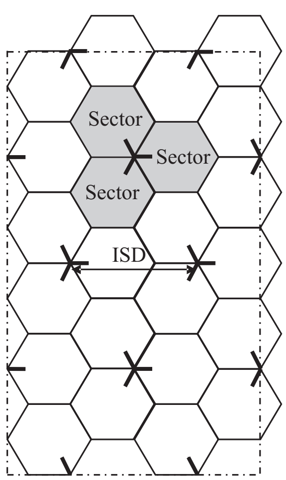

Fig. 5. Network layout

TABLE II
SIMULATION PARAMETERS

Parameter	Assumptions
Cellular layout	Hexagonal grid, 8 BSs, 3 sectors per BS
Inter site distance (ISD)	500 m
Pathloss	$128.1 + 37.6 \log_{10}(R)$ dB, R in Kilometers
Log-normal shadowing	standard deviation = 8 dB correlation distance = 50 m correlation between sectors of same BS = 1.0 correlation between BSs = 0.0
Fast fading	TU3 (20 taps) [13]
Antenna gain	UE: 0 dBi, NodeB: 14 dBi
Antenna pattern	$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3\text{dB}}}\right)^2, A_m\right]$ $\theta_{3\text{dB}} = 70°$, $A_m = 20$ dB
System bandwidth	10 MHz, 180 kHz per PRB
TTI	1 ms
Total BS TX power	46 dBm
Noise figure of NodeB	5 dB
UE power class	24 dBm (250 mW)
UE distribution	Uniform distribution
UE speed	3 kmph, 30 kmph, 120 kmph
UE direction	randomly chosen within $[0°, 360°)$
Minimum distance - between UE and BS	35 m
Number of UEs	100 (fixed during simulation time)
Simulation time	50 s

active UEs, whose number is decided in the initialization phase and kept constant for the whole simulation time, are uniformly distributed over the network area. Each UE is given a uniform random direction in the range $[0°, 360°)$ and it moves in the same direction at constant speed during the whole simulation time. In order to avoid the drawback of a limited network area the wrap-around technique is deployed. Single transmit and dual receive antennas are used both in uplink and downlink with maximal ratio combining (MRC).

The channel model includes pathloss, log-normal shadowing and frequency selective fast fading. The shadowing samples are spatially correlated following a negative exponential function. The Typical Urban (TU) power delay profile with 20 paths is assumed [13].

The closed loop slow power control adjusts the transmit power of the UE depending on the received uplink SINR in order to match the SINR target. If received uplink SINR at NodeB is less than the SINR target, a power-up command is given to UE while if received uplink SINR at NodeB is greater than the SINR target, a power-down command is given to UE. In this study, the power control step-size is set to 1 dB and the SINR target is set to 6 dB corresponding to 10% block error rate (BLER) for 16QAM modulation and coding rate of 1/2.

In this paper the packet scheduling algorithm is fair with respect to the bandwidth allocation in the sense that it distributes the available PRBs equally to the UEs associated with the same sector [14].

General simulation parameters listed in Table II are chosen according to the specifications and assumptions given in [2].

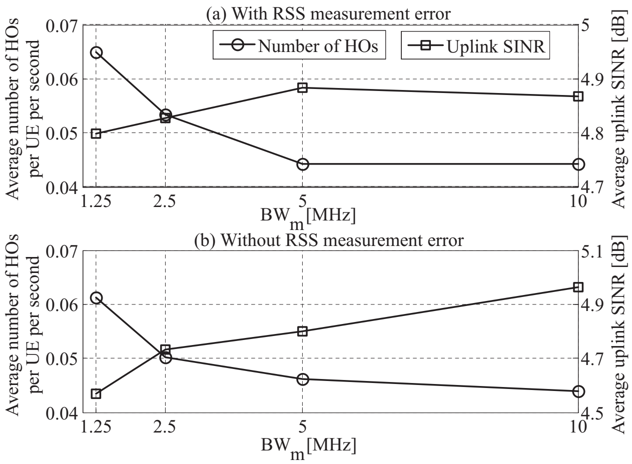

Fig. 6. Effect of varying BW_m for the RSS based handover at the UE speed of 3 kmph on average number of handovers per UE per second and average uplink SINR. $H_m = 2$ dB and $T_m = 150$ ms.

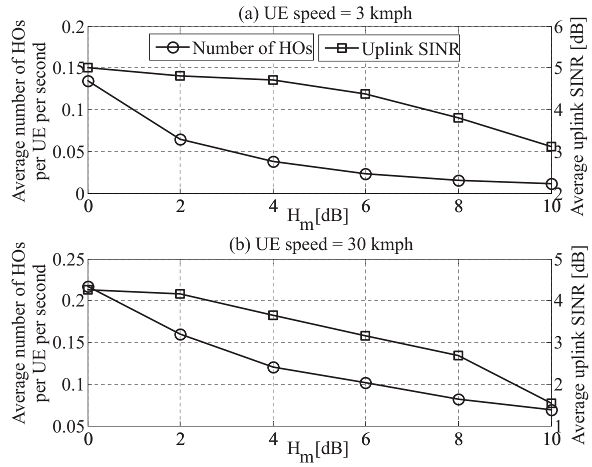

Fig. 7. Effect of varying H_m for the RSS based handover on average number of handovers and average uplink SINR at the UE speeds of 3 and 30 kmph. $BW_m = 1.25$ MHz and $T_m = 150$ ms.

IV. Simulation Results

The system performance is measured using the following KPIs: number of handovers per UE per second, time between two consecutive handovers and uplink SINR of UEs having a potential target sector. For UEs having a potential target sector, we mean UEs which will make a handover within one TTT window (T_u). In this paper, all simulations are run assuming handover avoidance timer = 1 s and $T_u = 300$ ms.

Fig. 6 (a) shows the effect of varying downlink measurement bandwidth for the RSS based handover at UE speed of 3 kmph on average number of handovers and average uplink SINR with RSS measurement error. Increasing the measurement bandwidth from 1.25 to 10 MHz we notice a decrease in average number of handovers for a negligible change in average uplink SINR of the UEs with a potential target sector. This is because larger BW_m means improved frequency domain averaging of fast fading as compared to smaller BW_m. Though there is a performance gain in using 10 MHz of measurement bandwidth similar average performance is seen to be attained using 1.25 MHz. The control channels, synchronization channel (SCH) and broadcast channel (BCH), used for handover procedures in UTRAN LTE are based on constant bandwidth of 1.25 MHz regardless of the scalable overall transmission bandwith [2]. Hence, rest of the simulations in this paper assume $BW_m = 1.25$ MHz.

Comparing Fig. 6 (a) and (b) we notice that at 1.25 MHz there is a small decrease in average number of handovers in the case of no measurement error when compared with the case including measurement error for a negligible penalty on average uplink SINR. Hence we can say that average number of handovers and average uplink SINR are not very sensitive to the RSS measurement error at 3 kmph. We expect that at higher speeds the chosen KPIs will be less sensitive to measurement error because of larger variations in channel condition. Rest of the simulations in this paper are run with RSS measurement error.

Fig. 7 shows the effect of varying H_m for the RSS based handover at UE speeds of 3 kmph and 30 kmph. We notice that at 3 kmph, going from H_m of 0 to 2 dB, leads to a significant decrease in average number of handovers per UE per second while there is a negligible decrease in average uplink SINR; from 2 to 8 dB there is a large decrease in average number of handovers per UE per second for about 1 dB decrease in average uplink SINR; from 8 to 10 dB there is a small decrease in average number of handovers per UE per second for about 0.7 dB decrease in average uplink SINR. We notice similar trends at 30 kmph in Fig. 7 (b). Gain in reduction of the average number of handovers will decrease at higher speeds since log-normal shadowing samples are not highly correlated at higher speeds over the handover decision update period. On

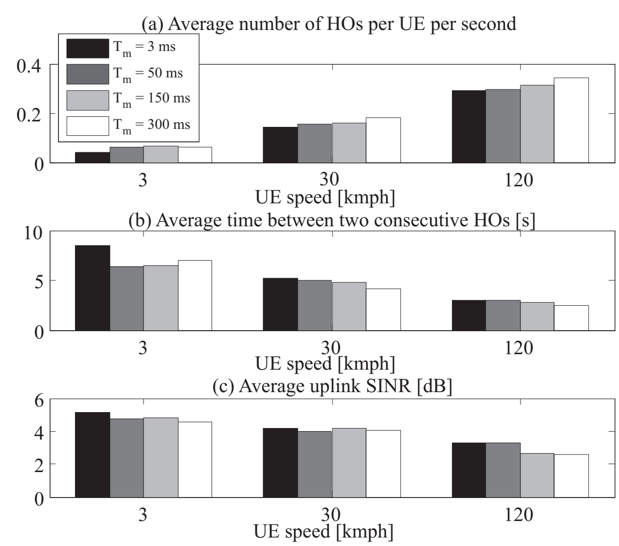

Fig. 8. Effect of varying T_m and UE speeds for the RSS based handover on different KPIs: (a) Average number of handovers per UE per second, (b) Average time between two consecutive handovers, (c) Average uplink SINR. $H_m = 2$ dB and $BW_m = 1.25$ MHz.

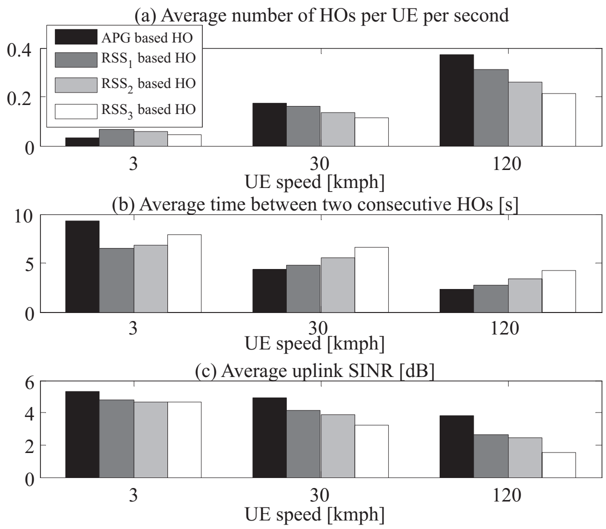

Fig. 9. Effect of different handover algorithms and UE speeds on different KPIs: (a) Average number of handovers per UE per second, (b) Average time between two consecutive handovers, (c) Average uplink SINR. $H_m = 2$ dB, $BW_m = 1.25$ MHz and $T_m = 150$ ms.

an average, uplink SINR is lower at higher speeds since power control is unable to track the changing channel conditions. The reduction in number of handovers per UE per second is one of the desired criteria but at the same time it also leads to the reduction of average uplink SINR, which is not desired. For these reasons we choose to use the range of H_m for which there is a penalty on uplink SINR within 1 dB. Hence we recommend H_m of 2 to 8 dB at 3 kmph and 2 to 6 dB at 30 kmph depending on the design tradeoff required between number of handovers and average uplink SINR of the UEs with a potential target sector.

Fig. 8 shows the effect of varying measurement update period and UE speed for the RSS based handover on different KPIs. Increasing the measurement update period we notice, that average number of handovers per UE per second increases, which results in a decrease of average time between two consecutive handovers for a negligible penalty on average uplink SINR. Though there is a benefit in using shorter measurement update period, it will lead to increase in signaling overhead and processing at the UE as compared to larger update periods. Hence even a single measurement that is $T_m = T_u = 300$ ms should be enough to take the handover decision without any noticeable impact on the performance of UEs experiencing handover. This is because of the diversity gain from the dual antenna MRC at the UE receiver.

Fig. 9 shows the effect of different handover algorithms and UE speed on different KPIs. It shows that increasing TTT window size for RSS based handover, average number of handovers per UE per second decreases while average time between two consecutive handovers increases. At the same time we notice a penalty in the form of reduced average uplink SINR. Increasing TTT window is a way to reduce the number of ping-pong handovers. At higher speeds there are higher number of ping-pong handovers due to lower correlation in log-normal shadowing samples over the handover decision update period. Hence, the reduction in number of handovers is more pronounced at higher speeds.

V. Conclusion

In this paper, we have studied the hard handover algorithm based on the downlink RSS measurement for UTRAN LTE. RSS measurement error is modeled and is taken into account for the RSS based handover. Further a modification in RSS based algorithm with TTT window is proposed. This algorithm is shown to reduce the average number of handovers with increasing TTT window size while decreasing the average uplink SINR. Moreover, effect due to handover measurement bandwidth, margin and measurement update period is analyzed for different KPIs and UE speeds. For the parameter set studied, use of 1.25 MHz of measurement bandwidth, a 2 to 6 dB of handover margin and 300 ms of measurement update period is recommended for UE speeds of 3 to 120 kmph. In the future, we plan to investigate the quantitative effect of different handover parameters on the UE throughput, signaling overhead and delay.

Acknowledgment

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