On the Performance of Integrator Handover Algorithm in LTE Networks

Naizheng Zheng
Aalborg University
Niels Jernes Vej 12, A6-108
9220 Aalborg Ø, Denmark
email: nz@es.aau.dk

Jeroen Wigard
Nokia Siemens Networks
Niels Jernes Vej 10,
9220 Aalborg Ø, Denmark
email: Jeroen.Wigard@nsn.com

Abstract
The 3GPP UTRAN Long Term Evolution (LTE) system utilizes packet based architecture with distributed mobility management, where the E-UTRAN Node-B (eNB) takes the responsibility of making the hard handover/handoff (HO) decisions based on the user equipment (UE) measurements. To cope with the corner effect due to the loss of the line of sight (LOS), a fast HO decision algorithm is required which can guarantee the LTE seamless HO requirement and keep the quality of service (QoS) criteria. In this paper, a HO decision algorithm, the integrator algorithm, has been evaluated in the Manhattan scenario, and is compared with the traditional power budget (PBGT) handover. The study focuses on the LTE intra-frequency HO scenario and uses the reference symbol received power (RSRP) measurement as input. The results show that the integrator algorithm has the same performance as the PBGT algorithm based on the number of HOs per UE and signal to interference plus noise ratio (SINR) evaluations for different UE speeds.

Keywords
LTE, Handover/Handoff, Intra-frequency HO, RSRP, Integrator, PBGT

I. INTRODUCTION
The evolved universal mobile telecommunication system (UMTS) terrestrial radio access network (E-UTRAN) is also known as long term evolution (LTE) of the third generation (3G) mobile communication system, which aims at increasing network capacity, lower latencies and reducing network complexity [1].

The LTE systems focus on services in the packet-switched domain to minimize transmission latency and increase robustness of communication. An important requirement for LTE is to provide support for IP-based traffic with end to end quality of service (QoS). Voice traffic will be supported mainly as Voice over IP (VoIP) enabling better integration with other multimedia services [1]. For VoIP transmission to be intelligible to the receiver, voice packets should not be dropped, excessively delayed, or suffer varying delay/jitter. For mobile-to mobile communication, the maximum tolerable one way (end-to-end) delay is 200 ms [2].

Handover/handoff (HO) is a critical procedure for QoS since it contains a so-called HO detach time, which is a gap in the data transmission. Typical values are in the range of 20 ms [1]. For the VoIP services, it is quite important to have a fast HO decision algorithm to avoid further delays and the risk of a call drop.

One of the challenging environments for the hard HO is the corner turning effect in the Manhattan scenario. It happens due to the loss of the line of sight (LOS) component from the source evolved UTRAN node-B (eNB) to the user equipment (UE), such as when a UE turns around a corner from one street to the other or a moving obstacle temporarily hinders the path between an eNB and a UE. The corner effect is very hard to predict and it might cause a sudden large drop (e.g. 20-30 dB) in the UE signal strength.

In this paper, a HO decision algorithm, integrator algorithm, is proposed for the LTE system. It is evaluated in the Manhattan scenario and compared with the traditional power budget (PBGT) algorithm. As main key performance indicators (KPI), the number of HOs and signal to interference plus noise ratio (SINR) before and after the HO are used. In section II, LTE intra-frequency HO procedure and reference symbol received power (RSRP) are briefly discussed. In section III, both PBGT and integrator algorithm are introduced. In section IV, the system evaluation parameters and setup are shown. And in section V and VI, the results and conclusions are presented, respectively.

II. LTE HANDOVER PROCEDURE
In the LTE system the HO can be described as network-initiated, network-controlled and UE-assisted [1].

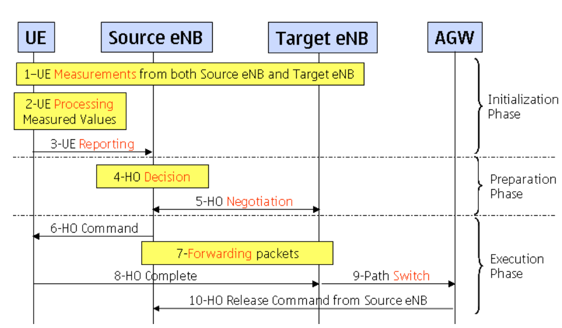

Figure 1: HO Procedure of LTE System

The HO procedure of the LTE system can be divided into three phases: Initialization, Preparation and Decision, as shown in Figure 1, where the intra-frequency handover procedure is presented. The initialization phase contains three main steps which are Measurements, Processing and Reporting. The preparation phase contains two main steps which are the source eNB Decision and the source eNB Negotiation with target eNB. The execution phase contains two main steps as well which are the source eNB temporary Forwarding packets to the target eNB and path Switch in access gateway (AGW) [1].

RSRP measurement is used by the LTE network in a number of mobility related network scenarios such as HO triggering based on absolute RSRP from serving cell [5][6].

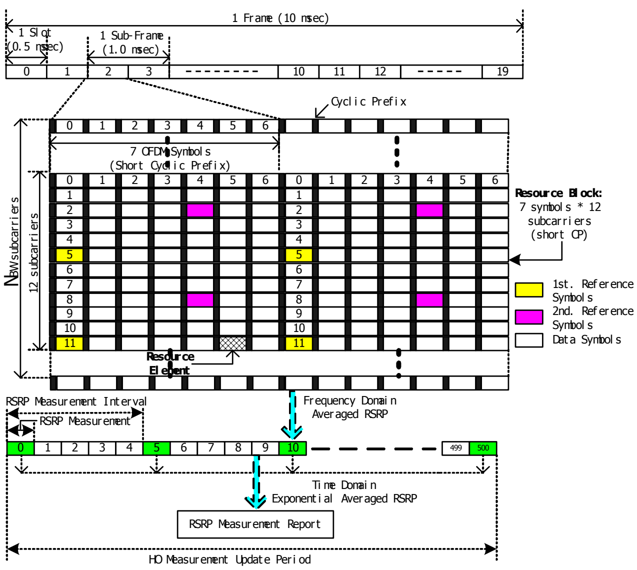

Figure 2: Frame and Downlink Sub-carrier Structure in LTE System

A single RSRP observation is defined as the mean measured power per reference symbol observed over a single sub-frame or transmission time interval (TTI) (1ms with 12 sub-carriers and 14 reference symbols), as shown in Figure 2. One or several such observations may be combined to form an RSRP measurement report in accordance with the specified frequency and time domain filtering procedure [5].

III. LTE HANDOVER DECISION ALGORITHMS

Two HO decision algorithms are evaluated in this paper, the PBGT algorithm and the integrator algorithm.

A. Power Budget (PBGT) Algorithm

The PBGT algorithm uses both HO margin (HOM) and time to trigger (TTT) timer to make the HO decision, as show in Figure 3. A HO is triggered when the triggering condition, $RSRP_T > RSRP_S + HOM$, is fulfilled during TTT, where $RSRP_S/RSRP_T$ are the source/target cell RSRP measurements.

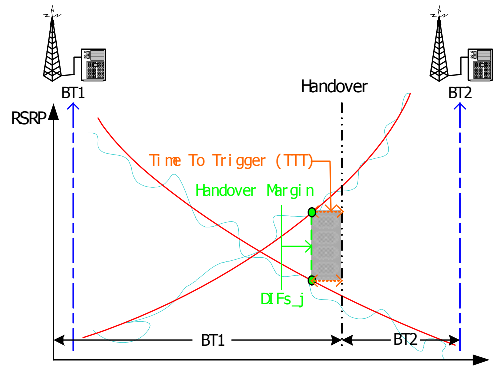

Figure 3: HO Decision Algorithms

B. Integrator Algorithm

The integrator algorithm considers both a triggering threshold and a forgetting factor to make the HO decision.

The general idea of integrator algorithm is to integrate the RSRP differences of the source and target cell, the shaded area shown in Figure 3, by using an infinite impulse response (IIR) filter. The HO decision is made according to the triggering condition between the filtered RSRP differences and the triggering threshold.

In this study, a special case of the first order auto regressive moving average (ARMA) filter is used and is shown below [6]:

$$FDIF_{s\_j}(t) = (1-\alpha)\bullet FDIF_{s\_j}(t-1) + \alpha \bullet DIF_{s\_j}(t) \quad (1)$$

$$DIF_{s\_j}(t) = RSRP_T(t) - RSRP_S(t) \quad (2)$$

where $DIF_{s\_j}(t)$ is the downlink RSRP measurement differences between the received signal level of the source cell 's' and the target cell 'j' at the time t, as shown in Figure 3. $FDIF_{s\_j}(t)$ and $FDIF_{s\_j}(t-1)$ are the filtered $DIF_{s\_j}(t)$ and $DIF_{s\_j}(t-1)$ value at the time t between the source cell s and the neighboring cell j. 'α' is known as the forgetting factor or smoothing constant ($0 \leq \alpha \leq 1$).

FDIFThreshold is the HO triggering threshold. If *FDIFs_j(t)* > *FDIFThreshold*, then the HO is triggered immediately.

The $FDIF_{s\_j}(t)$ value is influenced by choosing of the α value. If the choice of α value equal to or close to 1, it would result in the $FDIF_{s\_j}(t)$ value more likely to be reflected by the most recent $DIF_{s\_j}(t)$ value. The value of the $FDIF_{s\_j}(t)$ will be very instantaneous or responsive. Else, if the choice of α value is equal to or close to 0, it would result in the $FDIF_{s\_j}(t)$ value more likely to be reflected by the past $FDIF_{s\_j}(t)$ value. The value of the $FDIF_{s\_j}(t)$ would be very constant or unresponsive to the actual $DIF_{s\_j}(t)$ change.

The initial value of $FDIF_{s\_j}(t-1)$ can be defined either by averaging several early periods of $DIF_{s\_j}(t)$ values or simply the first observed value of $DIF_{s\_j}(t)$ [6]. In this study, it defined the initial value to be zero.

IV. SIMULATION MODEL AND KPI

A dynamic system level simulator, Mobile Radio Simulation Environment (MoRSE), is used to evaluate the proposed integration algorithm [7].

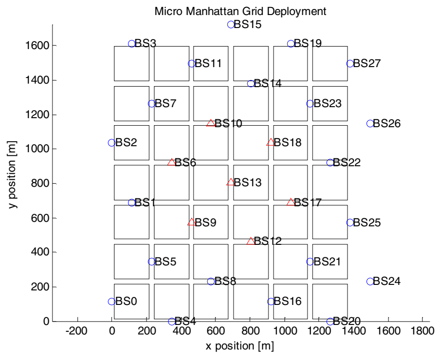

Figure 4: Micro Scenario Setup

A Manhattan scenario with micro cells is used as the network model. In Figure 4, the Manhattan scenario setup is shown. The Manhattan grid setup has 28 eNBs, which are located below the roof top, with the block size of 200 m and street width size of 30 m. The eNB antennas are omi-directional. The statistics are only collected from the central cells.

In Table 1, the detailed simulation parameters and their values are shown. The active UEs are uniformly distributed over the network area, and the UEs are allowed to move forward, backwards and turning corners (no wrap-around) with a constant speed during the whole simulation time. When the UEs reach the simulation border, they will simply turn around and move in the reverse direction.

As the traffic model, a standard VoIP model is used with 30 byte of packet size and 6 byte of full header size. The Round Robin packet scheduler is assumed during the simulations.

Path loss, shadow fading, and frequency selective fast fading have been included in the simulation. The path loss is modeled according to a distance based formula (Path Loss=$-39+67*\log_{10}(d)$, $d > 45$ m) with a center frequency of 2 GHz [8]. The shadow fading is modeled as log-normal distributed with a mean value of 0 dB and a standard deviation of 6 dB. The spatial de-correlation distance parameter used to describe the spatial correlation function of the shadow fading is set at 50 m. The frequency selective fast fading is modeled by using the 3GPP standard Pedestrian (3 kmph) or Vehicular A model (30 kmph/120 kmph) depending on the UE moving speed.

For the RSRP measurements, the reference symbols are not explicitly modeled. The reference symbol values in one TTI are assumed to be highly correlated in both time and frequency directions and are represented by one path loss plus fading value per physical resource block (PRB).

According to the 3GPP definition, the RSRP observations are only done for the given N central PRBs, which are then averaged in frequency domain. The 3GPP defined minimum measurement bandwidth (BW) is 1.25 MHz. During the simulation, the measurement bandwidth is chosen to be 1.25 MHz and the corresponding central number of PRBs need to be measured is 6. The 6 PRB values are measured independently and linear averaged afterwards.

Table 1: Micro-Scenario Simulation Parameters:

Parameter	Assumptions
Network Layout	Micro Cells, Manhattan Grid (Block Size – 200 m, Street Size – 30 m)
Number of eNBs	28
Number of UEs	1400
Average number of UEs per Cell	50
Inter BS Distance	200 m
eNB Height	10 m (below roof top level)
eNB Location	Outdoors
eNB Antenna	Omi-directional with linear gain = 1
UE Distribution	Uniform Distribution
UE Move Speed	30 kmph (3 kmph, 120 kmph)
Cell Edge UE	UE 'turned around' when reaches the edge
Traffic Model	Voice over IP (VoIP)
Length of Call	60 sec. in VoIP
Duration of simulation	90 sec.
Channel Model	Path Loss, Shadowing and Fast Fading
System Bandwidth	5 MHz
Duplexing	FDD
Sub-carrier spacing	15 kHz
Number of PRBs	25 PRBs, 12 sub-carriers/180 kHz per PRB
Num. of Subcarriers	300
Sub-frame length	1 ms
RSRP Measurement Bandwidth	1.25 MHz or 6 PRBs
RSRP Measurement Period	5 ms
Measurement Error Sigma	0.8
Sliding Window Size	500 ms

The UE sampling of the RSRP measurement is set to be 5 ms. An RSRP value is reported to the eNB every 500 ms. One report contains the exponential average in time of 100 RSRP samples. The exponential smoothing filter uses a forgetting factor of 0.1.

Within the measurement bandwidth, the limited numbers of reference symbols introduce measurement error. This measurement error is modeled as normally distributed [3]. During the simulation the error impact on the reference symbols is added to the UE sampling of the RSRP measurement. A log-normal distributed error with mean 0 and standard deviation 0.8 at measurement bandwidth 1.25 MHz is added in our case [3].

In order to evaluate the performance of the proposed HO algorithms, two KPIs: Number of HOs and Signal to Interference plus Noise Ratio (SINR) have been used during the investigation of the proposed algorithms.

- The Number of HOs shows what the average number of handovers per UE is by using of the proposed HO algorithms. Every HO comes with a risk of a HO failure. In general by lowering the number of handovers, the HO burden to the network can be reduced and the potential degradation in QoS due to the detach time gap introduced by the HOs can be minimized as well. However, the number of HOs cannot be infinitely minimized. There is always a tradeoff between the number of HOs and the signal quality parameter.
- The signal quality is evaluated by the scheduled SINR per UE. During the evaluation the SINR is divided into SINR before HO and SINR after HO. The SINR before HO tells the signal quality level before making the HO and the SINR after HO tells us the signal quality level after making the HO. In our simulation the observation time for SINR before and after HO is 500 ms.

V. SIMULATION RESULTS

In the simulations, the influences of the forgetting factor α and the *FDIFThreshold* to the integrator algorithm have been evaluated first. Afterwards the performance comparison with the PBGT algorithm has been done.

In order to evaluate the influence of α to the integrator algorithm, the *FDIFThreshold* parameter is fixed to be -5. The forgetting factor varies between to be 0.25, 0.5, and 1.

According to the theory, when α=1, it means that all the past FDIF values will be forgotten and the HO only depends on the present instantaneous DIF value. The filtered or integrated instantaneous DIF value also easily to reach the *FDIFThreshold* to trigger the HO. So it is expected that there are more number of HOs when α=1 than for lower values of α. As shown in Figure 5, α=1 has the highest number of HOs, and the number of HOs are decreasing when α is getting smaller. In Figure 6, all the SINR after HO are improved compared to the SINR before HO for all the varying α cases. Before making the HO, α =1 has the best SINR since it can make the HO without any delay in the source eNB with declining RSRP measurement, and there is about 5 dB difference at cdf probability 70% to compare with α=0.25. After the HO, it shows that α=1 has the lowest SINR.

To evaluate the influence of *FDIFThreshold* to the integrator algorithm, the α is fixed to be 0.5. The *FDIFThreshold* varies between -0.1 dB, -5 dB and -10 dB.

Theoretically higher values of the *FDIFThreshold* correspond to a larger HOM value in PBGT algorithm. So a lower number of HOs are expected with a higher value of *FDIFThreshold*. As it can be seen in Figure 7, *FDIFThreshold*=-0.1 dB has the highest number of HOs and *FDIFThreshold*=-10 dB has the lowest number of HOs.

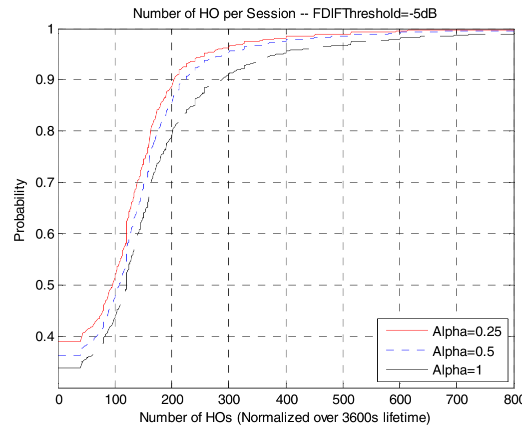

Figure 5: Number of HOs – Varying α Values

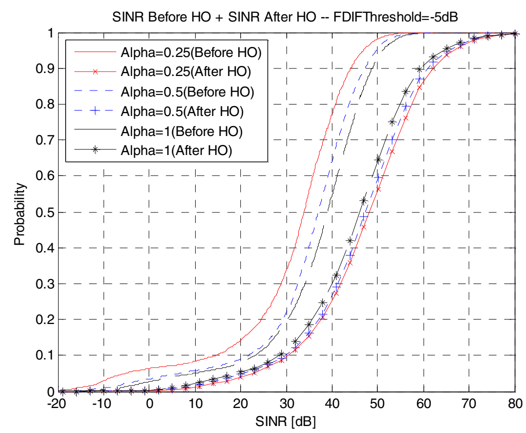

Figure 6: SINR – Varying α Values

As shown in Figure 8, in general, all the SINR after HO are improved compared to the SINR before HO for all cases. The best SINR before HO is achieved for *FDIFThreshold* equal to -0.1 dB. This is due to the fact that this setting leads to the fastest HO decision while the slowest HO decision (*FDIFThreshold*=-10 dB) leads to the worst SINR before HO. With the same cdf probability at 70%, there is about 5 dB difference in SINR between them. However, after making the HO, there is a big improvement for *FDIFThreshold* =-10 dB in SINR, and the improvement for *FDIFThreshold* =-0.1 dB is quite small.

Based on the above evaluations of the integrator algorithm, comparisons of the integrator algorithm with the traditional PBGT algorithm are done. The comparisons are performed in two steps.

In the first step, special parameters are used in both algorithms. For the integrator algorithm with α = 1, the HO decision depends only on the *FDIFThreshold*. For the PBGT algorithm with TTT=0 ms, the HO triggering relies only on the HOM. We set the value of *FDIFThreshold* equals to the HOM. It is expected that both algorithms are identical since HOM = *FDIFThreshold* = $RSRP_S(t)$ - $RSRP_T(t)$. As shown in Figure 9 and 10 the two algorithms are performed identically.

In the second step, more realistic parameters are chosen based on the first step evaluation. HOM=5 dB and TTT=500 ms are used in the PBGT version algorithm, and *FDIFThreshold*=-5db and Forgetting Factor=0.5 are used in the integrator algorithm for comparison at speed 3 kmph, 30 kmph and 120 kmph.

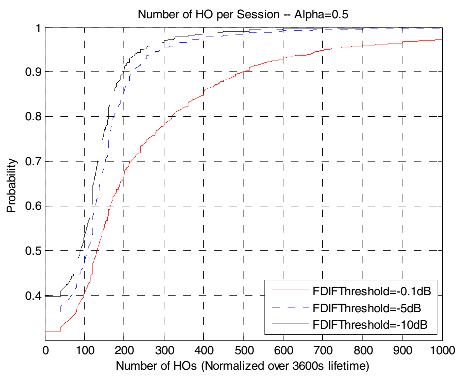

Figure 7: Number of HOs – Varying FDIFThreshold

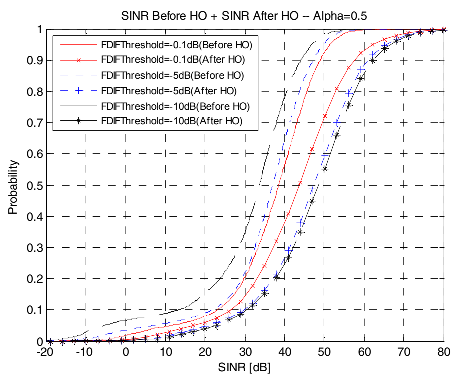

Figure 8: SINR – Varying FDIFThreshold

As it can be seen in Figure 9 and 10, with this specific parameter setup, the integrator and PBGT algorithms have also the same performances in both Numbers of HOs and SINR before and after HO evaluations at different UE speeds, and as expected the higher speed has a higher number of HOs.

VI. CONCLUSION

In this paper, the integrator handover decision algorithm is proposed and studied. The general idea of this algorithm is to integrate the RSRP differences of the source and target cell.

Two parameters, FDIF threshold and Forgetting Factor α, have been studied respectively, which can be used to tune the integrator algorithm. The performances of integrator algorithm are also evaluated and compared with the traditional PBGT algorithm in the LTE system.

The simulation results show that the integrator algorithm has the same performance as the PBGT algorithm based on the Number of HO analysis and SINR before and SINR after HO evaluations at different UE speeds.

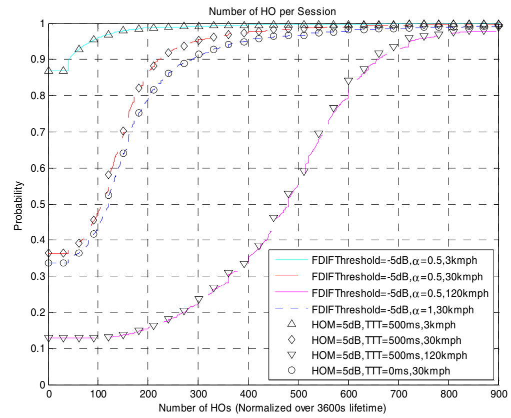

Figure 9: Number of HOs -- Comparison

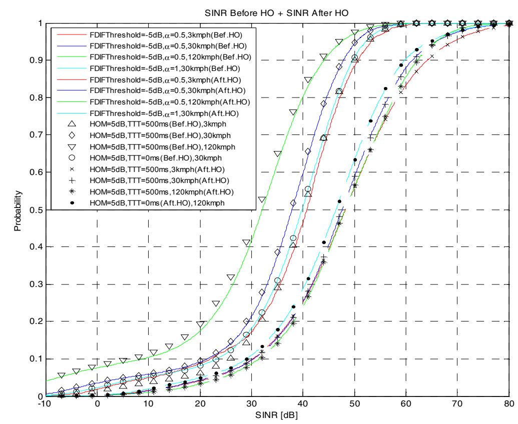

Figure 10: SINR -- Comparison

ACKNOWLEDGEMENT

The authors would like to thank Karol Slanina and Wilfried Kirmse for assistance and valuable comments during the work.

REFERENCES

[1] Ulrich Barth, '3GPP Long –Term Evolution/System Architecture Evolution Overview', 2006 Alcatel

[2] NGMN, 'Next Generation Mobile Networks Radio Access Performance Evaluation Methodology'

[3] Mohmmad Anas, Francesco Calabrese, Per-Erik Östling, Klaus Pedersen, Preben Mogensen, 'Performance Analysis of Handover Measurements and Layer3 Filtering for UTRAN LTE', PIMRC 2007

[4] Mohmmad Anas, Francesco Calabrese, Preben Mogensen, Claudio Rosa, Klaus Pedersen, 'Performance Evaluation of Received Signal Strength Based Hard Handover for UTRAN LTE', IEEE VTC 2007

[5] Jean Aicard Fabien, 'LS on LTE measurement supporting mobility, 3GPP TSG RAN WG4 R4-070440', 2-4 April, 2007, Sophia-Antipolis, France

[6] Ericsson, 'Proposed reference assumption for RSRP measurement accuracy, 3GPP TSG RAN WG4 R4-070593', 7-11 May, 2007, Kobe, Japan

[7] Siemens, 'Mobile Radio Simulation Environment, Requirement Specification Version 1.0.1 IUS

[8] Release 7, TR25814-A2 Simulation Scenario