PERFORMANCE OF THE LOCAL AVERAGING HANDOVER TECHNIQUE IN LONG TERM EVOLUTION NETWORKS

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Abstract: In this paper, we investigate the performance of an alternative received signal filtering technique based on local averaging to improve the quality of handover decisions in Long Term Evolution (LTE) networks. The focus of LTE-Advance (LTE-A) networks is to provide enhanced capacity and reliability of radio access as well as broadband demand for mobile users. The necessity to maintain quality of service, especially for the delay sensitive data services and applications, has made mobility and handover decisions between the base stations in the LTE networks critical. Unfortunately, several handover decision algorithms in the LTE networks are based on the Reference Signal Received Power (RSRP) obtained as a linear averaging over the reference signals. The critical challenge with the linear averaging technique is that the limited reference signal available in the downlink packet introduces an estimation error. This estimation error is a result of the effects of linear averaging on propagation loss components in eliminating fast-fading from the received signals. Moreover, prompt and precise handover decisions cannot be based on inaccurate measurement. The standardized LTE layer 3 filtering technique is applied to the local averaged layer 1 signal to render it suitable for LTE handover decisions. The local averaging technique produces better handover than the linear averaging technique in terms of the reduced number of handover failures, improved high spectral efficiency and increased throughput, especially for cell-edge users with high speeds. The findings of this study suggest that the local averaging technique enhances mobility performance of LTE-Advance networks.

Key words: averaging, evolution, filtering, handover, signal, network

1. INTRODUCTION

The Long Term Evolution (LTE) standard has evolved to the LTE-Advance in the Third Generation Partnership Project (3GPP) release 12 [1]. The specification of radio access networks was renewed to enhance the capability and reliability of the networks. The capability enhancement was achieved in the LTE networks because of the orthogonal frequency division multiplexing technology employed in the radio interface. The LTE radio interface technology supports a transmission protocol that uses both the Frequency Division Duplex (FDD) and the Time Division Duplex (TDD) mechanisms. The transmission mechanisms in downlink and uplink are based, respectively, on the Orthogonal Frequency Division Multiple Access (OFDMA) and Single Carrier Frequency Division Multiple Access (SC-FDMA) controls. The OFDMA allows for robustness of inter-symbol interference while enabling data and physical layer signals to be concurrently multiplexed. The smallest unit of resources transmitted in one OFDMA symbol that corresponds to one subcarrier is called a *resource element*. A group of resource elements that corresponds to 12 subcarriers in the frequency domain in one OFDMA symbol is called a *resource block*. Some resource elements within a resource block are reserved for special functions such as control signaling, system information broadcast, cell search and synchronization, while the remaining resource elements are used for data transmission.

The reference signals (RSs) which are multiplexed into resource elements are used by a user equipment (UE) to determine the RSRP and Reference Signal Receive Quality (RSRQ) [2]. The RSRP report from a UE is used to estimate the propagation channel condition. Some other methods that could be applied to estimate the channel condition include the exploitation of correlation properties of the channel, the use of deductive knowledge of a parametric model of channel, and blind estimation [3, 4]. The use of RSs for channel estimation is the most common solution because it is simple to implement [3]. However, this simplicity trades off spectral efficiency for tracking variations in the channel and reduces channel estimation accuracy because of the limited number of RSs available within each sub-frame. The limited RSs are the primary reason that the available RSs in adjacent sub-frames are exploited to yield more accurate results [3, 5]. The use of the linear averaging technique over the RSs in the derivation of RSRP limits the capability of the RSRP to make fast, accurate handover decisions for UE, especially when a sudden attenuation in the received signal is experienced by the UE [6, 7]. This is because linear averaging over RSs, necessary for removing the effects of fast-fading, interferes with other propagation loss components such as shadowing and path loss, and hampers the accuracy of the channel estimation.

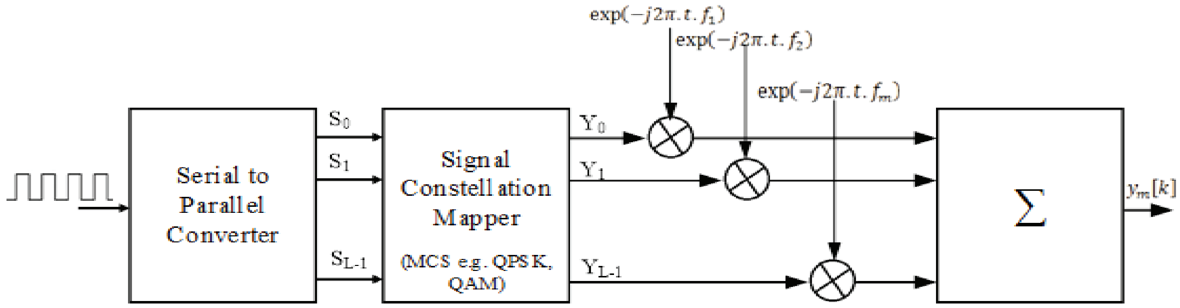

Figure 1: Model of an OFDM transmitter

Several variations of the linear averaging technique have been proposed in literature in an attempt to strike a balance between accuracy and complexity [8]. An alternative technique based on the local averaging can be used to solve the problem arising from the removal of fast-fading from the received signal [7, 9, 10] as well as assist in the protection of the integrity of other propagation loss components. It is particularly germane to note that the accuracy of the estimation made by a UE from the received signal depends largely on the averaging technique employed and has a significant impact on the ability of the handover algorithm to make fast, reliable decisions [11, 12]. Application of local averaging technique in cellular networks was demonstrated in [13]. It should be noted that LTE networks belong to the family of 3GPP technologies. Moreover, layer 1 (L1) filtering is not restrained by the 3GPP standards [14]. The local averaging technique is therefore investigated in LTE networks to achieve fast and reliable handover decisions for delay-sensitive data services, especially for a handover decision occurring at the cell-edge in the presence of multiple interfering signals from neighboring cells.

This paper reports the performance comparison of handover decisions made by using local averaging (L1 filtering) and linear averaging (L1 filtering) of RSRP. Performance is evaluated in terms of throughput, spectral efficiency and average number of handover failures between the UE speeds of 3km/h up to 120km/h [15]. The remainder of this paper is succinctly organized as follows: handover averaging techniques are first discussed; the simulation method and the parameters to compare the performances of the two averaging handover techniques are thereafter presented; and finally, results of the simulation experiments are presented. The paper concludes with a brief statement of achievement.

2. HANDOVER AVERAGING TECHNIQUES

A *handover* is a process of transferring a UE call or a data session from one cell site to another cell without disconnecting the session. The tasks of a handover can be classified appositely into handover measurement, handover processing and handover decision. Herewith we discuss these handover tasks.

2.1 Handover Measurement

The effects of interference on the signal received by a UE in a typical wireless propagation are classified into path loss, shadowing and fast-fading [12, 16]. The corresponding values of these losses, antenna gain and power transmitted from an eNodeB within the operating bandwidth are measured by the UE to facilitate dynamic allocation of network shared resources (E-UTRAN). The UE needs to provide a base station with measurement values of its downlink channel quality, from its cell as well as from neighboring cells, to facilitate the selection of an appropriate cell to connect to the UE. The measurement of UE is necessary for mobility of a user within the E-UTRAN. The UE measurement is performed using RSRP over cell-specific RSs which are multiplexed into the OFDM resource elements and transmitted by some subcarriers. The RS is available to all UEs in a cell for determining a phase reference demodulation of downlink control channels and for generating the Channel State Information (CSI) feedback [3]. Channel estimation is achieved through the transmitted OFDM signal using a filtering technique. Typical implementation of an OFDM transmitter is shown in Figure 1.

The transmitted serial data symbol is passed through a serial to parallel converter to generate L-dimensional parallel data block $S[k]=[S_0[k], S_1[k], \ldots, S_{L-1}[k]]^T$. Each component of the parallel data stream is independently modulated, resulting in a complex vector $Y[k]=[Y_0[k], Y_1[k], \ldots, Y_{L-1}[k]]^T$ used as an input to an Inverse Fast Fourier Transpose (IFFT) system to generate time domain M complex samples using Equation 1:

$$y_m[k]=\frac{1}{\sqrt{M}}\sum_{L=1}^{M} Y_L[k]\exp(2\pi jL\frac{m}{M}) \qquad (1)$$

A conjugate operation is performed at the receiver using an equivalent FFT operation to obtain the frequency domain vector of the transmitted signal. If *y(t)* is the transmitted symbol at time (*t*) where *h(t)* is a continuous time channel impulse and *n(t)* is additive noise, then the received signal, *x(t),* in a multipath environment is represented using the received discrete time OFDM symbol x[k] with cyclic prefix, CP given as:

$$\begin{bmatrix} x_0[k] \\ \vdots \\ x_{M-1}[k] \end{bmatrix} = \begin{bmatrix} y_0[k] & y_{M-1}[k] \cdots y_{M-CP+1}[k] \\ \vdots & \vdots \quad \ddots \quad \vdots \\ y_{M-1}[k] & y_{M-2}[k] \cdots \; y_{M-CP}[k] \end{bmatrix} \bullet \begin{bmatrix} h_0[k] \\ \vdots \\ h_{CP-1}[k] \end{bmatrix} + \begin{bmatrix} n_0[k] \\ \vdots \\ n_{M-1}[k] \end{bmatrix} \quad (2)$$

To simply matters, Equation 2 can be written further as follows:

$$\begin{bmatrix} x_0[k] \\ \vdots \\ x_{M-1}[k] \end{bmatrix} = \mathrm{A} \bullet \begin{bmatrix} h_0[k] \\ \vdots \\ h_{CP-1}[k] \end{bmatrix} + \begin{bmatrix} n_0[k] \\ \vdots \\ n_{M-1}[k] \end{bmatrix} \quad (3)$$

The FFT of matrix A containing the subcarriers with varying peak values produces a diagonal matrix [17, 18]. This implies that the matrix A is equivalent to $F^H YF$ where F is a FFT matrix and Y is a diagonal matrix whose elements are given, respectively, by
$F[k] = \frac{1}{\sqrt{M}} \exp(-2\pi L \frac{m}{M})$
and
$Y_m[k] = \frac{1}{\sqrt{M}} \sum_{L=1}^{M} y_L[k] \exp(-2\pi j L \frac{m}{M})$.
The frequency domain representation of the received signal sample *X*[*k*], after applying the FFT, is given by Equation 4:

$$\begin{bmatrix} X_0[k] \\ \vdots \\ X_{M-1}[k] \end{bmatrix} = \begin{bmatrix} Y_0[k] & 0 \cdots & 0 \\ \vdots & \vdots \ddots & \vdots \\ 0 & 0 \cdots & y_{M-1}[k] \end{bmatrix} \bullet \begin{bmatrix} H_0[k] \\ \vdots \\ H_{M-1}[k] \end{bmatrix} + \begin{bmatrix} N_0[k] \\ \vdots \\ N_{M-1}[k] \end{bmatrix} \quad (4)$$

The Channel Frequency Response (CFR) denoted by H can be expressed in terms of the Channel Impulse Response (CIR): h as $H = F.h$ [17].

2.2 Handover Processing

The handover processing, also called the L1 filtering as defined by 3GPP, is performed at the LTE physical layer [14]. The purpose of this filtering is to remove the effects of fast-fading in the signal received by a UE. Linear averaging and local averaging are two handover processing techniques studied for this purpose. Linear averaging is the common technique for estimating a channel over an RS. The channel estimation is performed either in the frequency domain or the time domain [3, 8]. The estimate of the channel is then performed using interpolation at several RS positions. For instance, the de-correlation of RS performed in the frequency domain is to determine the Channel Transfer Function (CTF) as given by Equation 5:

$$\hat{v}_i = F_i h + \widetilde{v}_i \quad (5)$$

Where i is a value within the interval $(0,\ldots,M)$; M is the number of the available RSs; $F_i h$ is the same as the CFR; and $\widetilde{v}$ is the white noise vector. If a generic linear filter D is used in the interpolation scheme for determining an estimate of a channel over a subcarrier at index n then the CTF at subcarrier n can be written as follows:

$$\hat{v}_n = D\hat{v}_i \quad (6)$$

The estimation error of the interpolated CTF of subcarrier n can be expressed as the difference between the actual value and the estimated value as follows:

$$\widetilde{v}_n = (F - DF_i)h + D\widetilde{v}_i \quad (7)$$

The common linear filters make use of techniques such as Least-Squares (LS) and Minimum Mean-Square Errors (MMSE) [8, 17, 19]. The LS is simple to implement, but it cannot be applied directly to LTE networks because of the ill-conditioning of the matrix inverse on the unmodulated subcarriers [3]. The MMSE produces a more accurate estimate than the LS; however, the MMSE is computationally expensive because it requires second order characteristics of the channel to perform the channel estimation [17].

Local averaging, an alternative technique to the linear averaging technique, is performed as a convolution of the exponential filter with the downlink received signal [7]. This averaging technique is based on the local scattering function that estimates the power spectrum of the measured data using an orthogonal window [9, 20]. The individual estimates of the spectra from the independent window data are aggregated by averaging to obtain a low variance estimate of the channel [21, 22]. If the CFR of the sampled spectra in time and frequency domains is represented by $H[x, y]$, and assuming that the index of each tapped spectral at a specific period corresponds to $w[t, f]$, the relative sampled spectral indices in time and frequency domains are given, respectively, by $x' \in (-\frac{x}{2},\ldots,\frac{x}{2}-1)$ and $y' \in (-\frac{y}{2},\ldots,\frac{y}{2}-1)$.
Where x *is* a time value from the interval of $(0,\ldots,X-1)$ and y *is* a frequency value from the interval $(0,\ldots,Y-1)$. The estimate of the local scattering function at each index corresponding to a discrete sample is given by Equation 8:

$$\xi[w_t, w_f] = \frac{1}{MN} \sum_{p=0}^{MN-1} \left| H^{(Q_p)}[w_t, w_f] \right|^2 \quad (8)$$

Where

$$H^{(Q_p)}[w_t, w_f] = \sum_{x'=\frac{X}{2}}^{\frac{X}{2}-1} \sum_{y'=\frac{Y}{2}}^{\frac{Y}{2}-1} H.Q_p \qquad (9)$$

Where M and N denote, respectively, the total number of tapped spectral used in both the time and frequency domains. The parameter Q_p is the window function equivalent to the exponential filter used for local averaging and N_{av} is the averaging window size. The parameter Q_p is determined as follows:

$$Q_p = \frac{e^{-n/N_{av}}}{1-e^{-1/N_{av}}} \qquad n = 0,1,2,3,\ldots \qquad (10)$$

2.3 Handover Decision

The UE keeps track of the received signal measurement from its serving cell and neighboring cells in order to recognize the cell with the best signal at the current position. The report of this measurement is sent to the serving eNodeB. Signal attenuation is experienced by the UE as it moves towards the target eNodeB in the strongest interfering cell from the serving eNodeB. In other words, the signal received from the serving eNodeB gradually deteriorates, while that from the neighboring eNodeB (target eNodeB) gradually increases. At a particular distance from the serving eNodeB, the received signal from the serving eNodeB goes below the handover threshold, a predefined value in the eNodeB. The farther a UE moves away from the serving eNodeB, the more the signal attenuates, while there is a corresponding increase in the received signal from the target eNodeB. At a point between the two eNodeBs, the received signal from the serving eNodeB becomes lower than that from the target eNodeB. Figure 2 illustrates the concept of handover margin, the maximum difference between the values of the received signals from two eNodeBs that can be tolerated before triggering a handover decision. The region beyond the handover margin where a handover decision occurs is called the *handover region*. Handover margin is considered in a handover decision before moving a UE to the target eNodeB.

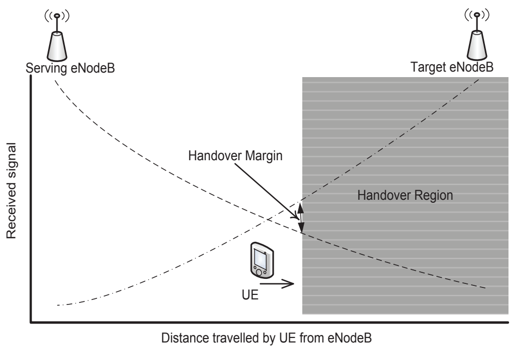

Figure 2: Received signal from two eNodeBs and handover margin

3. SIMULATION

The local filtering handover technique described in the previous section was implemented using the system level simulator [25] as a new module in the LTE networks. The original filtering technique implemented in the simulator is based on linear averaging, while the local averaging technique was implemented as a unique contribution of this study. The linear filtering algorithm implemented in the simulator was to determine the Mutual Information Effectiveness SINR (Signal to Interference plus Noise Ratio) Mapping (MIESM) to serve as a baseline for comparison with the implemented local averaging filtering technique. Two handover decision algorithms were implemented using the two filtering techniques to assess their performances on the overall network. Figure 3 shows a microcell network layout with the hexagonal grid using seven tri-sector sites (cell 0, cell 1 and cell 2) for the simulation experiments. The inter-site distance for each scenario was chosen according to the recommendation of ITU Radio communication (ITU-R) [26]. System bandwidth of 10MHz with 25 resource blocks and 2GHz carrier frequency was used for the simulation experiments.

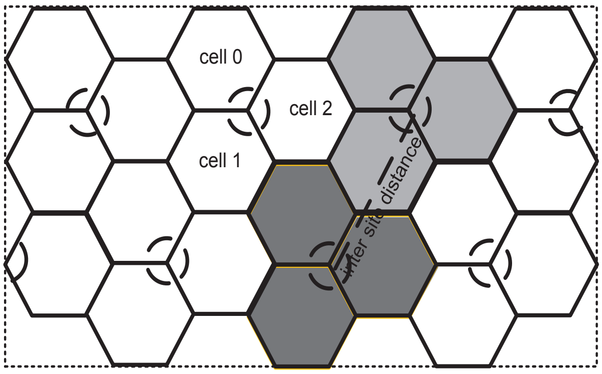

Figure 3: Network layout 7-sites hexagonal grid

The number of UEs at the commencement of the simulation experiments was kept constant. The UEs were uniformly distributed over the network coverage and their directions were randomly chosen from the range of 0^o to 360^o C. Each UE moved with a constant speed throughout the entire simulation. The speed of UE was chosen from 3 km/h, 30 km/h and 120 km/h depending on the scenario [15]. The channel estimation of the signal received at UE was dependent on the path loss, shadow fading and fast-fading [27-29]. The shadow fading with a standard deviation of 8dB and 0 mean was used for the simulation. The details of the simulation parameters are provided in Table 1.

Table 1: Simulation Parameters

PARAMETERS	ASSUMPTION
cell layout	Hexagonal grid (21 eNodeB, 3 sectors per eNodeB)
carrier frequency	2 GHz
resource block (PRB)	50
system bandwidth	10MHz , 180kHz per PRB
eNodeB Tx power	46 dBm
L3 sampling	200TTI
L3 filter coefficient	4
UE per eNodeB	20
UE noise figure	9 dB
packet scheduler	proportional fair
path loss	128.1 + 37.6log10 (R in km) dB
shadow fading	standard deviation = 8dB correlation mean = 0 correlation between eNodeB= 0.5
fast fading	winner channel model

4. RESULTS AND DISCUSSIONS

The results of the simulation experiments performed in this study are discussed in this section. Each simulation experiment was performed for the duration of 500 TTIs (Transmission Time Intervals) to ensure the reliability of results. The system performance is evaluated using the metrics of throughput, spectral efficiency and average number of handover failures for each of the L1 filtering techniques. Performance metrics have been selected to evaluate system and mobility-related performances [30, 31]. The throughput, the total number of the transmitted data packets per second, is measured in units of bits per second (bps) [3, 32]. The spectral efficiency which indicates the amount of spectrum used is the net UE data bit rate transmitted over the operating bandwidth and is measured in bits per second per hertz (bps/Hz) [9].

The values used for the averaging window N_{av} in the local averaging filtering techniques are, respectively, 5, 6 and 8.5 for the corresponding UE operating at standard speeds of 3, 30 and 120 km/h. In Figure 4, the empirical Cumulative Distribution Function (CDF) of the average UEs spectral efficiency at 3km/h is presented. The empirical CDF gives a fair estimate of the UEs CDF and a consistent estimate of the real CDF at any given point [24]. We have observed that a handover algorithm based on the local averaging technique is slightly more spectral efficient than the linear averaging technique in terms of the rate of information transmitted in number of bits per channel. There is no remarkable difference in the spectral efficiency for the 10th to 30th percentile, but the average user spectral efficiency gradually increases from the 40th percentile to about the 95th percentile. Results indicate that the capacity obtained within the cell is higher for average users and peak users when the local averaging filtering technique is used at this speed.

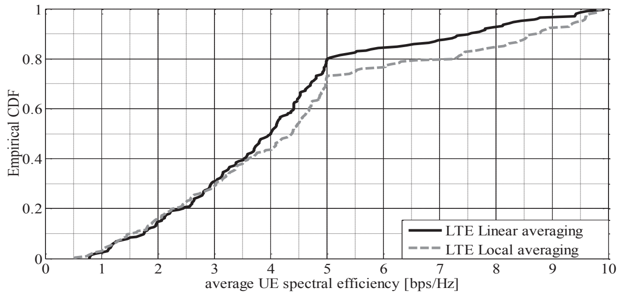

Figure 4: Empirical CDF of average UE spectral efficiency at 3 km/h

Figure 5 presents the results obtained when UEs are moving at 30 km/h in the simulated environment. The empirical cumulative distribution function (empirical CDF) shows that the probability of the average UE spectral efficiency is higher when the local averaging technique was used for a handover decision, suggesting that the number of bits transported within the bandwidth at this speed is higher for the local averaging technique than for the linear averaging technique. It is observed from this result that there is a significant difference between linear averaging and local averaging in terms of the amount of information transmitted by an average user at the 10th percentile to the 90th percentile. The local averaging technique produces higher average user spectral efficiency in bits per second per hertz than the linear averaging technique.

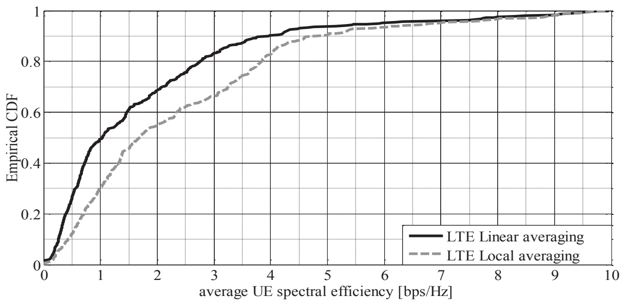

Figure 5: Empirical CDF of average UE spectral efficiency at 30 km/h

The empirical CDF in Figure 6 shows the average user spectral efficiency in bits per second per hertz (bps/Hz) when the UE speed is 120 km/h. The results suggest that the limited frequency spectrum is more utilized when the local averaging technique is employed than when the linear averaging technique is used, meaning that the average number of users accommodated to transmit call simultaneously over the limited spectrum is higher for the local averaging technique, although at about the 95th percentile there is only a slight difference between the performances of the two averaging techniques studied. However, there is a clear indication of the impact of differences in the averaging technique on the spectral efficiency within a cell from the 20th percentile to about the 90th percentile.

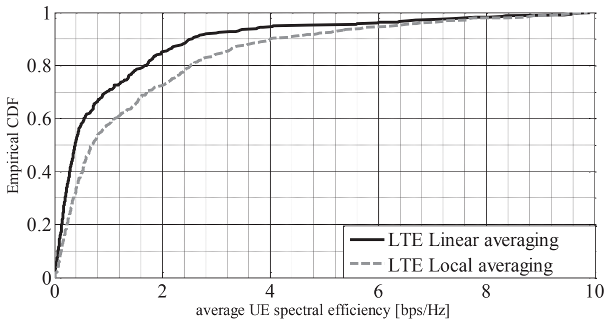

Figure 6: Empirical CDF of average UE spectral efficiency at 120 km/h

Figure 7 shows the results of the peak throughputs based on linear averaging and local averaging techniques. It can be observed from Figure 7 that the effects of these filtering techniques are not noticeably distinguishable at a relatively low speed of about 3 km/h. However, the local averaging technique achieves a better performance in terms of the peak throughput within the cells as the speed increases. It can be determined from Figure 7 that while the effect of the average multiple independent spectra used by the local averaging technique is not clearly visible at low speeds, it gives a better estimate of the channel quality that is achievable by a UE as the speed increases. The improved throughput experienced at higher speeds when the local averaging technique is employed is due to the accuracy of the channel estimate which influences the choice of MCS and increases the data rate achieved by the UE.

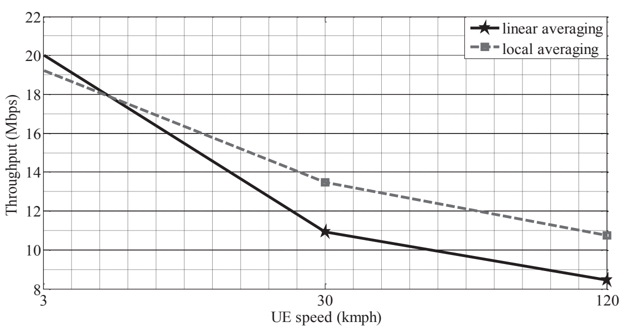

Figure 7: Peak user throughput at different UE speeds

The results of the simulation experiment for the average throughput experienced by a user are shown in Figure 8. The performances of the two filtering techniques are almost the same for the throughput experienced by the UEs. However, the average user throughput experienced when the local averaging technique was employed is slightly higher than that of the linear averaging technique at higher speeds. This is because at low speeds, the rate of change of the radio channel condition experienced by a user is very low, rendering the estimation error of both filtering techniques negligibly small. At higher speeds, however, the radio channel changes at a faster rate and requires a highly accurate filtering technique to keep track of the channel conditions.

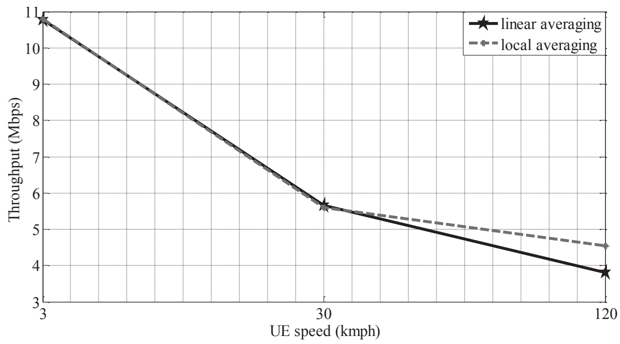

Figure 8: Average user throughput at different UE speeds

Figure 9 presents the results of the cell-edge user throughput at different UE speeds. The cell-edge user throughput performance with the local averaging technique is slightly better than with the linear averaging technique at higher user speeds. Although the cell-edge user throughput for the linear averaging technique is not as high as that of the local averaging technique at low user speeds, the rate of change is not as remarkable as in the local averaging technique. However, the rate of change for the cell-edge throughput based on the local averaging technique is remarkably better than that of the linear averaging technique at higher speeds. This result translates to the perceived QoS experienced by the cell-edge users as the speed increases. The low speed users might experience a sharp change in the QoS when the local averaging technique is used, though this might not be the case for a UE that employs the linear filtering technique. However, the experience is reversed in the case of a UE at higher speeds.

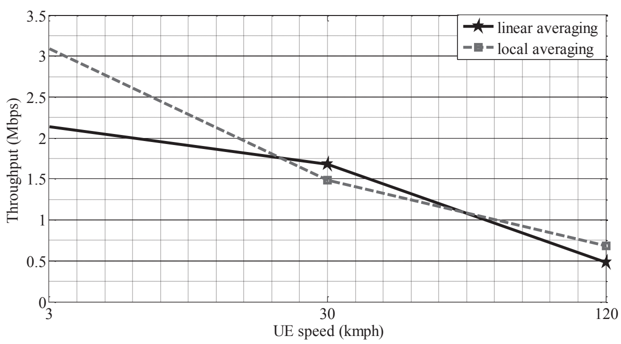

Figure 9: Cell-edge user throughput at different UE speeds

Figure 10 shows the average number of handover failures per UE speed. When the speed is as low as 3 km/h, the rate of handover failures obtained is low for both of the handover filtering techniques. The rate of handover failures due to the linear averaging technique is as low as less than 1.5%. The average number of handover failures observed is also remarkably low for the local averaging technique, with a value less than 1%.

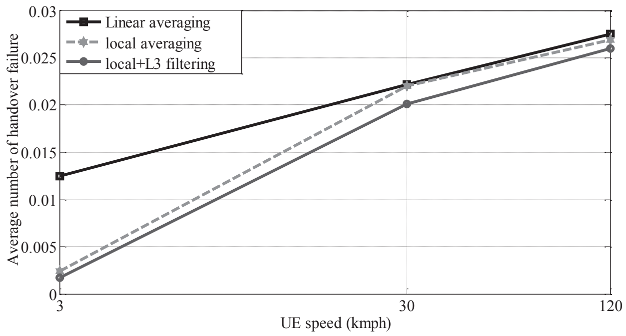

Figure 10: Effect of UE speeds on average number of handover failures

As expected, the average number of handover failures increases as the user speed increases. At higher speeds, the difference in performance of both handover filtering techniques is not particularly significant. However, the effect of L3 filtering on handover failures becomes apparent at a higher speed because L3 algorithms filter output used for triggering a handover decision. In addition, this reduces the L1 estimation error, which becomes higher as user speed increases because of the high uncorrelated nature of the time-varying channel between the UEs and the base stations.

5. CONCLUSION

This paper reports the performance of the local averaging technique in LTE networks. The evaluation metrics of throughput, spectral efficiency and average number of handover failures establish comparison between the local averaging handover technique and the linear averaging handover technique using UEs at various speeds. Performance analysis shows the effect of each handover filtering technique on achievable capacity within the system in terms of spectral efficiency, user throughput and mobility based on the average number of handover failures. The spectral efficiency for pedestrian speed (3 km/h) UEs for the local averaging technique when compared to the linear averaging technique produces, respectively, an increase of 9.1%, 10.8% and 15.1% for cell-edge, average and peak users. From the results obtained at a UE speed of 30 km/h, the comparison between the linear averaging technique and the local averaging technique shows, respectively, increased capacities of about 31.6%, 37.9% and 15.3% for cell-edge, average and peak users. The spectral efficiency at a higher speed of 120 km/h produces, respectively, 52.1%, 68.7% and 40.8% increased capacities for cell-edge, average and peak users. The system throughput for cell-edge users shows, respectively, a 44.8%, 11.7% and 42.8% improvement at UE speeds of 3 km/h, 30 km/h and 120 km/h when the local averaging filtering was employed. The peak user throughput for the linear averaging technique is 4.1% better than that of the local averaging technique. However, the local averaging technique shows, respectively, better performances of about 23.1% and 27.4% at the UE speeds of 30 km/h and 120 km/h.

The results ultimately obtained from the comparison of the average number of handover failures between the two L1 filtering techniques show a significant reduction in the average number of handover failures of about 80.9% for pedestrian users at the speed of 3 km/h using the local averaging technique. The results at the UE speeds of 30 km/h and 120 km/h show, respectively, reductions of about 0.5% and 4.6% in average number of handover failures of the local averaging filtering technique. The application of the L3 filtering in the local averaging technique further improves performance by 26.9%, 8.6% and 0.8% at the UE speeds of 3 km/h, 30 km/h and 120 km/h, respectively.

The results of this study reveal that both handover filtering techniques investigated are suitable for making handover decisions in LTE networks. However, the local averaging technique could ensure the provisioning of higher Quality of Service (QoS) on LTE networks because of the reduced average number of handover failures and improved cell capacity as reflected by the spectral efficiency. As maintaining QoS is particularly germane, diverse sophisticated techniques have been used to maximize the performance of networks for achieving high user throughput. The distribution of user throughput is a clear indicator of QoS. In codicil, it shows data rates experienced by users at different locations within the cell: the 95% user throughput is considered a peak throughput; the mean user throughput is considered a typical data rate achievable within the coverage area of the networks; while the 5% user throughput is termed cell-edge user throughput. The results of user throughput at different speeds as a result of applying two handover filtering techniques have been presented in this paper.

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