LTE-Advanced Handover: An Orientation Matching-Based Fast and Reliable Approach

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***Abstract*—We propose a fast and reliable target Evolved Node B (TeNB) selection scheme for Long Term Evolution-Advanced (LTE-A) handover (HO). Selection of the TeNB in LTE-A HO procedure is based on signal strength requirements and thus may not be ideal. Also, during each measurement period the user equipment (UE) needs to perform scanning of multiple neighboring eNB (NeNB) frequencies resulting in delays too large for high speed services. In our scheme, the TeNB is chosen based on three different parameters: the orientation match, the current load (CL) of NeNBs and their received signal strengths (RSS). This selection based on three independent parameters makes it more reliable, enhancing HO performance. Moreover, as a UE only measures the NeNBs shortlisted based on these parameters, the measurement time is also reduced, which leads to a reduction in the overall HO time.**

***Index Terms*—LTE-A, fast and reliable handover, orientation match, load, RSS zones, measurements, direction of motion, eNB**

I. Introduction

Performing fast and reliable HOs are the key requirements in seamless roaming of users in a wireless network environment. While the concept of fast HO is a fairly common topic of research [1], reliability is not. Reliability in HO means that a call should be successfully and seamlessly transferred from the SeNB in the current cell to the TeNB in the adjacent cell without call drop. A reliable HO can be usually ensured by choosing as the TeNB the NeNB that promises to give the strongest signal, is lightly loaded so that it can offer good QoS, and lies close to the UE's movement path [2].

In both Long Term Evolution (LTE) and LTE-A (3GPP Rel. 10 and beyond) [3], hard HO is the default HO framework. The selection of the TeNB in LTE-A HO is made based on the signal strength measurement reports of the UE gathered through scanning activities [4]. Within a measurement period, which can be of 200 ms duration or longer, a UE simultaneously scans the frequencies of eight NeNBs [5]. However, it has been found that the current requirement of scanning only eight NeNB frequencies per measurement period is insufficient for a reliable HO performance [4]. Most of the research carried out in this context has focused on reducing handover delays and facilitating fast HOs [4],[6-7]. However, none of these works take care of the HO reliability issue. We address this issue by developing a UE-assisted, network-controlled fast and reliable TeNB selection scheme for LTE-A HO.

The scheme proposed in this paper is an extension of our work presented in [8]. In this scheme, the SeNB selects the TeNB for the next HO activity based on the weighted average of scores for each NeNB assigned against three different parameters, namely, the orientation matching (OM) between the geographical position of each NeNB and the UE's broad direction of motion (both with respect to the SeNB), the CL of each NeNB and the RSS-based measurements recorded by the UE from each NeNB. Choosing the TeNB based on these multiple parameters ensures that, after HO to the TeNB, ping pong effects are less likely and the UE stays for the maximum possible period within this SeNB's coverage before the next HO. Moreover, as the UE only measures NeNBs shortlisted based on these parameters, the measurement time taken is less and the overall HO becomes faster. The scheme also employs novel ways of measuring the current loads of NeNBs and assigning individual scores to each of them.

The rest of this paper is organised as follows. Our proposed scheme is described in Section II. Section III discusses the concepts of current load calculation and weighted averaging of scores. Section IV describes the simulation studies and the obtained results. Finally conclusions are drawn in Section V.

II. Fast and Reliable HO Scheme

A novel predominantly network-controlled technique for fast and reliable selection of TeNB in an LTE-A HO scenario is presented here. The UE plays an important role in the whole process. In order to select the TeNB, the SeNB employs OM, CL and RSS as the three different parameters as mentioned in Section I. The proposed scheme works as follows. Immediately after entering the cell of a new eNB (i.e., the new SeNB for the UE), the UE sends a Status Report message to the SeNB and continues its independent motion. We propose this new message for the purpose of informing the SeNB about the present direction or orientation of the UE's motion. The message contains a dynamically maintained Visited eNodeB List (VeNBL) that stores the chronological sequence of the eNB-Identifiers (eNB_ID) of up to K SeNBs that the UE has most recently visited. On receiving this VeNBL, the SeNB performs an OM procedure between the UE's direction of motion as represented by the VeNBL and the geo-location orientation of the centroid of each NeNB using a Polar Coordinate Table (PCT) maintained by it [2] as shown in Table I. We assume that every eNB stores in its PCT the polar coordinate of every other eNB (with respect to its own centroid as the origin of this polar coordinate system) against the latter's eNB_ID [2]. Based on the OM performed, the SeNB assigns an OM score, S_{OM} to each NeNB. Those NeNBs, whose geo-locational orientations with respect to the direction of the UE's motion represent a progressive or forward movement for the UE, are assigned a positive S_{OM} while others get a negative S_{OM}. Details of OM and assigning of S_{OM} can be found in [8].

Then the SeNB collects, through the backbone network (the X2 interfaces), the information about the CL of each NeNB and assigns individual CL-based scores, S_{CL}, to them. Any overloaded NeNBs that are unlikely to be able to offer satisfactory QoS to additional connections or may even drop calls are assigned a negative S_{CL}. Section III explains how CL-based scores are assigned. In this context, it should be noted that in a cellular network scenario, load of eNBs changes over a time frame of minutes. In our scheme, as the SeNB gathers the CL information almost immediately before the UE switches to the TeNB, we can justifiably argue that the CL status of NeNBs remain unchanged until the completion of HO activity [2]. Next, the SeNB checks the two scores S_{OM} & S_{CL} of each NeNB, identifies any NeNB with a negative score and sends Measurement Control REQ message to the UE containing not only the parameters to measure and their thresholds but also IDs of all NeNBs except those with either a negative score for S_{CL} or a negative score for S_{OM}. The UE then scans these NeNBs and sends the Measurement Report back to the SeNB when the reporting threshold conditions are fulfilled [3]. After receiving the RSS-related measurement values of those shortlisted NeNBs, the SeNB assigns the signal strength score S_{RSS} to each of them. From here on we will call these shortlisted NeNBs as the potential target eNBs (PTeNB). Finally, the SeNB computes the weighted average of the three individual scores S_{OM}, S_{CL} & S_{RSS} of each PTeNB and chooses as the TeNB, the PTeNB which has the highest Weighted Average Score (WAS), S_{WAS} [2, 8]. Once chosen, the UE immediately carries out the HO with the selected TeNB as per the X2-based HO procedure [3]. Two important points needs to be noted in this context. In the LTE-A HO scenario, a UE periodically scans all available NeNB frequencies to gather RSS-related measurements and reports them back to the SeNB in the Measurement Report message [1]. A UE needs time duration in form of measurement periods, which are only available at discrete moments, to successfully measure the signal quality of NeNBs [4]. As mentioned in Section I, within a measurement period, even though a UE scans frequencies of eight NeNBs [5], it is insufficient for a reliable HO performance [4]. On the other hand, in comparison to the measurement period, the SeNB signal quality can degrade much faster leading to a call drop or an outage in the link before the UE finds a suitable TeNB and completes the HO. As a potential solution to these issues, an LTE-A compliant UE in

TABLE I. PCT OF EACH ENB IN A N ENB NETWORK

eNB_ID (i)	Polar Coordinate (j)
1	r_{i1}, θ_{i1}
2	r_{i2}, θ_{i2}
.	.
.	.
j	r_{ij}, θ_{ij}
j + 1	$r_{i(j+1)}, \theta_{i(j+1)}$
...	…
N	r_{iN}, θ_{iN}

our scheme measures fewer NeNB frequencies (only the shortlisted NeNBs) and thus completes the measurements much faster leading to an overall improved HO performance. Moreover, as in our scheme, the TeNB is chosen based on multiple parameters (OM, CL and RSS), it provides a more reliable choice of TeNB for the HO activity in comparison to the current LTE-A HO framework.

III. CALCULATION OF CURRENT LOAD AND WEIGHTED AVERAGING OF DIFFERENT SCORES

To measure the CL of each NeNB, we use a technique which is simple to implement and offers a fairly stable estimate of the CL. It estimates the CL by counting the number of connections currently being handled (or passing through) by an eNB_i. We assume that all eNBs in the network are identical in design and the maximum number of connections that can be maintained or sustained by each eNB, i.e. the connection capacity of each eNB, is N. Next we assume that during a HO, the SeNB has L NeNBs $\{NeNB_l\}$, l=1,2,...,L and that the number of connections passing through the $NeNB_l$ is M_l, so that the $NeNB_l$ has a CL of $CL_l = M_l/N$. It is obvious that higher the value of CL_l, more is the CL of $NeNB_l$ and lower should be the score $S_{CL}(l)$ assigned to that $NeNB_l$. To prevent any overloaded NeNB from getting selected as the TeNB and then offer poor QoS, we choose to set a higher limit CL_LIMIT of, say, 0.9, to disqualify any NeNB with CL $\geq$ 0.9 from being further considered for possible selection as a TeNB. We assign a score of $S_{CL}(l) = 0$ to such excessively overloaded NeNBs. To each of the remaining (tentatively) qualified NeNBs, {NeNB(l)}, we assign scores $\{S_{CL}(l)\}$, which are inversely proportional to their respective CLs $\{CL_l\}$. In this context, it should be noted that any of these remaining tentatively qualified NeNBs may ultimately fail to qualify as a PTeNB, if disqualified against one or both of the other two criteria toward TeNB selection, namely OM and RSS. The method of assignment of scores $\{S_{CL}(l)\}$ to {NeNB(l)} is described here.

To assign scores to the tentatively qualified NeNBs, we first take the complement value of each CL_l and call this the CL_COMPL(l). Then we assign the individual scores as the ratio of the CL_COMPL(l) values to the sum of the CL_COMPL(l) values of all the L NeNBs except the disqualified NeNBs. For computing the CL_COMPL of all the NeNBs, we choose a reference CL value CL_REF = 0.89 (since CL $\geq$ 0.9 indicates an overloaded NeNB) so that the

CL_COMPL values {CL_COMPL(l)} of $\{NeNB_l\}$ may be computed for each l as

$$CL\_COMPL(l) = CL\_REF - CL_l = 0.89 - CL_l \qquad (1)$$

It should be noted that the CL_COMPL values of the qualified NeNBs may range between 0 – 0.89. Now, the scores for the $\{NeNB_l\}$ is computed as

$$S_{CL}(l) = CL\_COMPL(l) / \sum_{l=1}^{L} CL\_COMPL(l) \qquad (2)$$

In the case of calculating the RSS-based scores, we make an obvious assumption that the RSS score assigned to each NeNB is directly proportional to the respective RSS values. Accordingly, the scores for the NeNBs may be computed using Eq. 3 shown below.

$$S_{RSS}(l) = \frac{RSS_l}{\sum_{l=1}^{L} RSS_l} \qquad (3)$$

A. Weighted Averaging of Scores towards TeNB Selection

As per the explanations in Section II, once the SeNB has obtained the scores of the eligible NeNBs (i.e., the PTeNBs) of the UE against each of the three parameters (OM, CL and RSS), it finally computes the weighted average of these scores for each PTeNB. The PTeNB that receives the highest WAS is then selected as the TeNB. The $S_{WAS}(l)$, for the PTeNBs, where l = 1, 2, …, L, is computed using the Eq. 4 as shown below.

$$S_{WAS}(l)=S_{OM}(l)*W_{OM}+S_{CL}(l)*W_{CL}+S_{RSS}(l)*W_{RSS} \qquad (4)$$

where W_{OM}, W_{CL} and W_{RSS} are the weights, $0 \leq W_{OM}, W_{CL}, W_{RSS} \leq 1$, assigned to the three parameters, respectively, with the condition given by Eq. 5.

$$W_{OM} + W_{CL} + W_{RSS} = 1 \qquad (5)$$

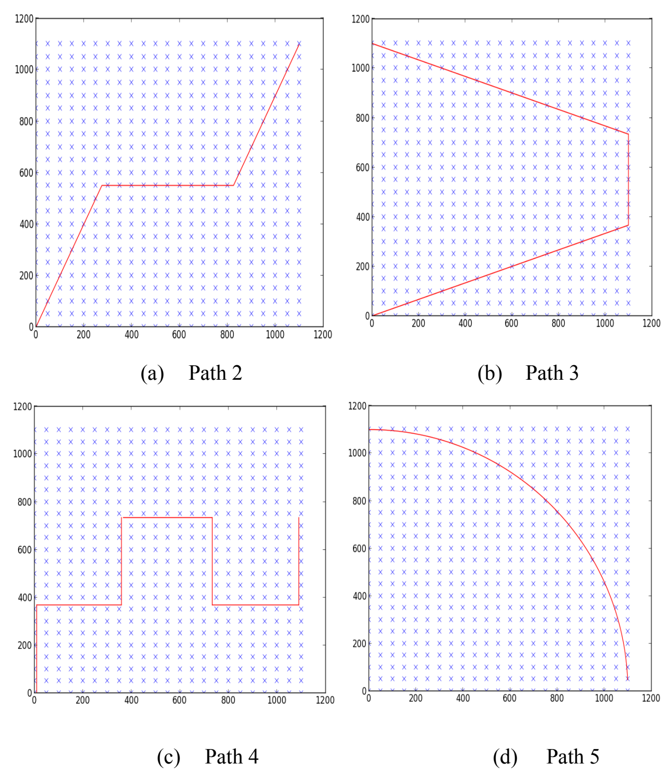
OM being the most important parameter out of the three, W_{OM} is assigned a higher weight (0.5) compared to W_{CL} and W_{RSS} (both assigned 0.25). Using Eq. 5, the WAS for the PTeNBs are computed and that with the highest S_{WAS} is chosen by the SeNB as the TeNB for the HO activity, which is carried out immediately following the procedure mentioned in [3].

IV. Validation of the Proposed Scheme

A Python-based simulator developed by us is used to validate the proposed scheme. In the simulation topology, 400 cells are considered in a 20 x 20 square array, with each cell having one eNB in it marked by a small "cross" (x) in Fig. 1. eNBs are thus arranged in a square grid format. The terrain area considered for simulation is 20 x inter-eNB distance. The vertical and horizontal spacing between two adjacent eNBs is equal to the inter-eNB distance and the range of coverage of each eNB is considered to be 75% of the inter-eNB distance. We assume that each eNB has eight NeNBs around it. We also arbitrarily assume that the distance between two grid lines is 10 m and the UE moves with a 10 m resolution. There exists coverage overlap between adjacent eNBs. We assume that each eNB has a random and dynamically changing CL, lying between 0 and 1. During a HO, the current SeNB hands over the UE to the selected TeNB that then becomes the next SeNB in the UE's movement path. Five different movement paths of the UE, paths 1 through 5 (shown in red in Fig. 1), are considered for running the simulation program. Path1 (not shown in the Figure due to space shortage) is a diagonal straight line between the bottom left corner and top right corner. Each path passes through a large number of eNBs. We assumed a VeNBL of length 3 so that the method of OM is performed using 3 previously visited SeNBs. The Walfisch-Ikegami model [3] is implemented to simulate the pathloss. To calculate the S_{WAS}, for each NeNB, we have considered the following weights: 0.5 for OM and 0.25 each for CL and RSS.

We primarily aim to validate the reliability of the proposed scheme, i.e., whether the scheme result in the right choice of TeNBs for HO activities based on the three HO parameters. To do that, for every path of the UE, we have tracked its movement carrying out multiple successive HOs with different PTeNBs en-route (these PTeNBs after HO become the successive SeNBs for the UE). We have also recorded whether the eNBs with which HOs are actually performed match the eNBs as per the prediction of our scheme (in that case we call it a 'correct' or reliable HO) or not (an 'incorrect' HO).

Figure 2 shows the percentage of correct HO results for our proposed scheme in comparison to the LTE-A's existing signal strength-based HO scheme for each movement path. In this case, we regarded NeNBs having a CL $\geq$ 90% as overloaded and thus not suitable as PTeNBs. Clearly, for all



(a) Path 2 (b) Path 3

(c) Path 4 (d) Path 5

Fig. 1. UE's movement paths in the simulation topology

the paths, the number of correct or reliable HOs performed by an UE as per our proposed HO scheme is much more than the existing scheme. Results for both the proposed and existing schemes are best for path 1 in which the UE moves in a straight path. Figure 3 shows the percentage of correct HO results when three different CL thresholds (≥ 90%, ≥ 80% and ≥ 70%) are considered. The percentage of correct HOs for a ≥ 90% CL threshold is best and that for ≥ 70% is the least owing to the much smaller weighting considered for CL (0.25) in comparison to that for OM (0.5). Both the graphs depict results based on the method of multiple independent replications each of which continued until the UE stops its movement at the end of each path. For the proposed scheme, the fluctuations in the percentage of correct HOs are due to (i) the randomness in the assigned CL values to each NeNBs and (ii) the topology of the UE's movement paths. Owing to randomness in the CL values any NeNB that has scored well in OM and RSS, may get a poor load value and thus a low S_{WAS} so missing out on the chance of getting selected as the TeNB. The reverse situation may also occur if the NeNB gets too high a score for CL and gets selected as the TeNB simply because of this high S_{CL}. However, implementing this technique in networks with real load numbers is expected to improve the overall reliability of the TeNB selection and HOs performed. The topology of the UE's movement path also plays a role in incorrect HOs. For example, percentages of correct HOs are less for paths 2-4 owing to their sudden and sharp turns. Owing to lack of space, we could not show the fast HO-related result for the proposed scheme. However, as mentioned in Section II, as the UE performs measurements of only the selected PTeNBs instead of all the NeNBs, the measurement time is reduced leading to a reduction in the overall HO time.

V. Conclusions

The paper has presented a novel fast and reliable TeNB selection scheme for the LTE-A hard HO procedure, where, based on three independent parameters, namely, OM, CL and RSS, an SeNB assigns scores to each of the NeNBs and finally selects the TeNB based on the highest weighted average score. In contrast to the current LTE-A HO framework in which the TeNB is selected based on signal strength measurements, the proposed scheme offers a comparatively more reliable TeNB selection process. Also, as a UE needs to perform measurements of only the NeNBs shortlisted based on OM and CL scores, measurement time will be less leading to a faster HO overall.

References

[1] M. Fei and P. Fan, "Position-assisted fast handover schemes for LTE-Advanced network under high mobility scenarios", Journal of Modern Transportation, vol. 20, No. 4, pp. 268-273, December 2012.

[2] S. K. Ray, "On the design of fast handovers in Mobile WiMAX networks", Ph.D Thesis, University of Canterbury, Christchurch, New Zealand, 2012.

[3] C. Cox, An Introduction to LTE, LTE-Advanced, SAE and 4G Mobile Communications, Wiley, 2012.

[4] V. M. Nguyen, C. S. Chen and L. Thomas, "Handover measurement in mobile cellular networks: analysis and applications to LTE", in Proc. of IEEE International Conference on Communications (ICC), Kyoto, Japan, 5-9 June 2011, pp.1-6.

[5] 3GPP TS 36.133, "Evolved Universal Terrestrial Radio Access: Requirements for Support of Radio Resource Management", Tech. Spec. v9.4.0.

[6] S. K. Ray, K. Pawlikowski and H. Sirisena, "Handover in Mobile WiMAX networks: the state of art and research issues", IEEE Communications Surveys and Tutorials Magazine, No. 3, pp. 376-399, Aug 2010.

[7] B. V. Quang, R. V. Prasad and I. Niemegeers, "A survey on handoffs-Lessons for 60GHz based wireless systems", IEEE Communications Surveys and Tutorials Magazine, vol. 14, No. 1, pp. 64-86, First Quarter 2012.

[8] S. K. Ray, H. Sirisena and D. Deka, "Fast and reliable target base station selection scheme for Mobile WiMAX handover", in Proc. of Australasian Telecommunication Networks and Applications Conference (ATNAC), Brisbane, Australia, 7-9 November 2012, pp. 1-6.

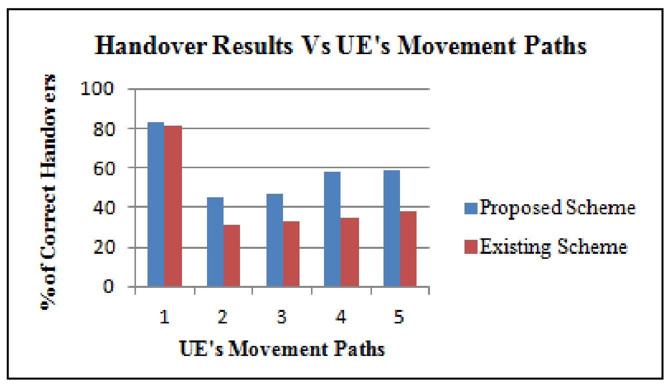


Fig. 2. Comparison between proposed and existing LTE-A HO schemes

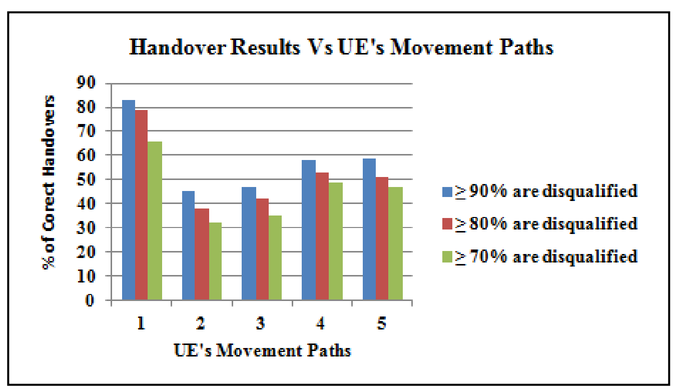


Fig. 3. HO results for different load cut-off thresholds