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TARGET CELL SELECTION SCHEME USING LMS ALGORITHM FOR LOAD ESTIMATION OF NEIGHBORING ENBS IN 3GPP LTE SYSTEM

Dong Hoi Kim

College of Information Technology
Kangwon National University
1 Kangwondaehak-gil, Chuncheon-si, Gangwon-do 200-701, Korea
donghk@kangwon.ac.kr

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Abstract. *Handover failure probability is one of the important factors to determine the handover performance in cellular radio system such as the 3rd generation partnership project (3GPP) long term evolution (LTE). To minimize the handover failure probability, the Hybird target cell selection (TCS) scheme considering both the received signal strength (RSS) and load information of neighboring evolved Node Bs (eNBs) based on X2 interface in 3GPP LTE system has been introduced. However, the amount of cell load in serving and neighboring eNBs can be drastically changed over time due to the handover operation, so the Hybrid TCS scheme should consider the cell load change between the serving and neighboring eNBs in the handover procedure for handover preparation. This paper proposes a modified Hybrid TCS scheme based on the least mean square (LMS) algorithm for estimating the load status of the neighboring eNBs in order to mitigate the handover failure probability. The proposed TCS scheme chooses the target eNB with minimum load based on the LMS algorithm and providing higher RSS. Experiment results reveal the effectiveness of the proposed scheme and its advantages over the conventional schemes in terms of handover failure probability.*
Keywords: Target cell selection, Handover failure probability, Least mean square, Load estimation, 3GPP LTE system

1. **Introduction.** Recently, the huge demands to deliver true mobile broadband services have motivated the 3rd generation partnership project (3GPP) long term evolution (LTE), which aims at the lower costs of providing mobile broadband connectivity, reduction of end-user monthly fees, and delivery of new and improved services and applications [1, 2, 3]. As these improved features in 3GPP LTE system have to be supported and guaranteed under various mobility conditions, handover operation within 3GPP LTE system is becoming more important. Generally, the handover operation is to transfer an active call from one cell to another cell [3, 4, 5]. Most of handover schemes in 3GPP LTE system are based on the network controlled hard handover [3], where the user equipment (UE) provides measurement reports to evolved Node Bs (eNBs), but the handover decision is taken by the severing eNB. Also, in the Admission Control block which is located at the target eNB, if a new eNB has an available bandwidth, it assigns the bandwidth to the handover call. However, if the bandwidth is not available, the handover call is dropped.

Various handover performance evaluation factors have been proposed in many researches and one of the most important factors for evaluating the performance of the handover scheme is handover failure probability which is defined as the ratio of the number of dropped handovers to the total number of generated handovers. Also, the target cell selection (TCS) scheme is regarded as an important technique for reducing the handover failure probability of cellular radio systems [6], where the target cell means the cell which the handover user has just selected.

In the previous studies about TCS scheme, there are received signal strength (RSS) based TCS scheme [4] that depends on the received signal strength (RSS) and load based TCS scheme [7] that depends on the load information from the neighboring cells including the serving cell. However, as the RSS based TCS scheme does not consider the load status of the target eNB, the handover request according to this scheme can be rejected if the target eNB load is overloading condition. Hence, the Hybrid scheme that depends not only on the RSS information but also on the load information exchanged between the eNBs via the X2 interface has been introduced [5]. However, the Hybrid TCS scheme, which is built in the serving eNB, may use the outdated load status reported from the neighboring eNBs, as there is an inevitable time interval gap between the serving and neighboring eNBs in the dynamic load environment with bursty traffic for the 3GPP LTE system. As this paper focuses on 3GPP LTE system performance under the time-varying bursty traffic conditions, a new TCS scheme overcoming the problem mentioned above is needed in the dynamic bursty traffic load conditions.

In order to solve the performance degradation problem in terms of the handover failure probability, which is brought about by the inaccurate load information of the neighboring eNBs under time-varying bursty traffic conditions, this paper presents a modified Hybrid TCS scheme based on the network-controlled hard handover that estimates the time-varying load change of the neighboring eNBs by using the least-mean square (LMS) algorithm [8-10]. A more accurate load estimation of the neighboring eNBs by the LMS method encourages an eNB with maximum available cell load among the adjacent eNBs to be selected, so the proposed scheme has significant advantage in terms of handover failure probability.

The remainder of this paper is organized as follows. Section 2 introduces conventional TCS schemes including the RSS based, load based, and Hybrid TCS schemes in 3GPP LTE system. Section 3 describes the proposed TCS scheme using LMS algorithm. Sections 4 and 5 explain the simulation environment and simulation results for performance evaluation of the proposed scheme. Section 6 concludes this paper.

2. **Conventional Target Cell Selection Schemes.** As shown in Figure 1, eNBs in 3GPP LTE network connect to each other via the X2 interface. Each eNB communicates

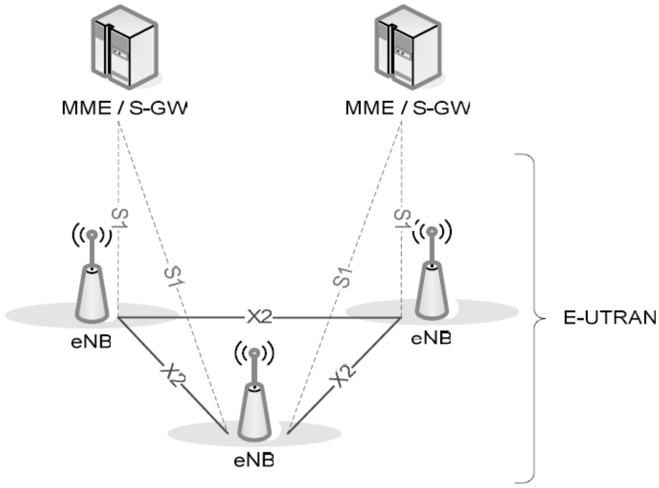

FIGURE 1. S1 and X2 interfaces in the 3GPP LTE system

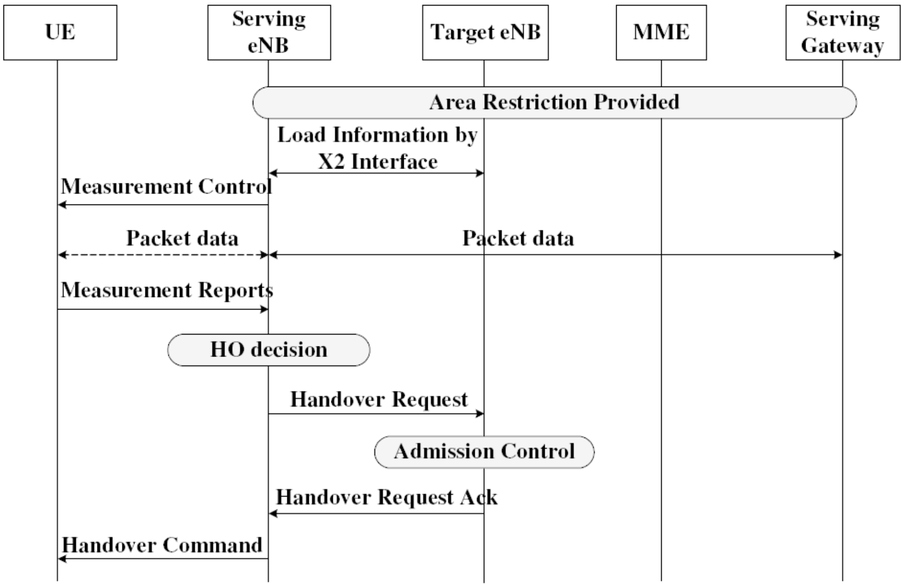

FIGURE 2. Handover procedure for handover preparation in 3GPP LTE system

with the evolved packet core (EPC) using the S1 interface, specifically with the mobility management entity (MME) and the user plane entity (UPE) identified as serving gateway (S-GW) using S1-C and S1-U for control plane and user plane, respectively.

As the load information among the neighboring eNBs can be periodically measured by the X2 interfaces, the information can be used for a handover algorithm to improve the handover performance. Here, the load measurement period by the X2 interface among eNBs is an important factor that poses a trade-off between performance and complexity; If the period is short, it may cause good handover performance but require a lot of message exchanges; otherwise, it may provide little message exchange but cause worse handover performance owing to the outdated load information.

In the conventional Hybrid scheme, the handover decision is mainly based not only on RSS in the border region of two eNBs but also on the load measurement information by the X2 interface among eNBs in the 3GPP LTE system. Figure 2 shows a handover procedure for handover preparation invoked by the HO decision block, where the MEASUREMENT REPORT message includes the measurement result such as the RSS and load information is periodically measured by the X2 interface between the serving and neighboring eNBs [2, 3].

2.1. **RSS based target cell selection scheme.** The most popular conventional TCS scheme is the received signal strength (RSS) based TCS scheme considering only the RSS from the serving and neighboring cells [4]. The scheme selects the eNB with the largest RSS as a pure physical-layer scheme. Therefore, in the RSS based TCS scheme, the UE i selects only the best target eNB j^* with the largest $RSS_{i,j}$ like (1).

$$j^* = \arg\max_{i,j} RSS_{i,j} \tag{1}$$

where j represents an index number of the neighboring eNBs. Also, $RSS_{i,j}$ indicates a signal strength of UE i received from the eNB j. As shown in Figure 2, the operation procedure of the RSS based TCS scheme is as follows.

1. UE is triggered by the MEASUREMENT CONTROL message from the serving eNB.

2. Each UE does continuous measurements of its neighbor cells with certain periodicity and filtering parameters, and then periodically sends the MEASUREMENT REPORT message to the serving eNB.

3. If the neighbor eNB RSS is found to be larger than the serving eNB RSS and a handover margin, which consists of the default hysteresis, minimum hysteresis and maximum hysteresis values, for a duration of a timer (called Time-to-trigger), the serving eNB issues a HANDOVER REQUEST message to the target eNB passing necessary information to prepare the handover at the target eNB.

4. If the amount of remaining cell bandwidth is available for the handover call after handover trigger, the handover call is accepted and sends HANDOVER REQUEST ACK message to the serving eNB.

In the above handover procedure, as the RSS based TCS scheme dose not reflect the load information of the neighboring eNBs, there is quite a possibility that the handover request will be rejected with no consideration of the load information of the target eNB by the Admission Control block located in the target eNB. Hence, the rejected handover request increases handover failure probability.

2.2. **Load based target cell selection scheme.** Another popular conventional TCS scheme is the load based TCS scheme considering only the load information from the serving and neighboring cells [4]. The scheme can be conducted by forcing handovers from highly loaded cells to lightly loaded ones. When an eNB is overloaded by a lot of UEs in use, the QoS of many users will be degraded and the load based TCS scheme can be used to enable lower handover failure probability. In the load based TCS scheme, the UE i selects a target eNB j^* with the lowest $Load_j$ among all neighboring eNBs like (2).

$$j^* = \arg\max_j (1 - Load_j) \tag{2}$$

where $Load_j$ means the load status, which is defined as a ratio of the occupied bandwidth to the total bandwidth in the j-th eNB, and is periodically measured by the X2 interface. Here, the total bandwidth is split into many sub-carriers. The load based TCS scheme is carried out based on the load information from the serving and neighboring eNBs. Finally, the scheme can find the eNB with the lowest load.

2.3. **Hybrid target cell selection scheme.** To overcome drawbacks of the RSS based TCS scheme and the load based TCS scheme mentioned above, the Hybird TCS scheme, considering both the RSS and load information of neighboring eNBs based on X2 interface, has been introduced in this section. The priority metric for the Hybird TCS scheme which is given by (3) depends not only on the RSS but also on the load information of neighboring eNBs by the X2 interface in 3GPP LTE system whenever handover is initiated [5]. In the Hybrid TCS scheme, even if the RSS is high, the priority metric can be low if the load in the target eNB is low. Through the priority metric, the UE i selects only the best target eNB j^* with the largest $RSS_{i,j} \times (1 - Load_j)$.

$$j^* = \arg\max_{i,j} RSS_{i,j} \times (1 - Load_j) \tag{3}$$

After all, the Hybird TCS scheme selects the target eNB with minimum cell load and maximum RSS.

3. **Proposed Target Cell Selection Scheme Using Least Mean Square (LMS) Algorithm.** The Hybrid TCS scheme combining the RSS based TCS scheme and the load based TCS scheme aims to minimize the handover failure probability, so it has better performance than the RSS based TCS scheme and the load based TCS scheme in terms of the handover failure probability. However, as shown in Figure 2, HO decision

block containing the Hybrid TCS scheme located in the serving eNB may make the wrong decision owing to the outdated load status of the target eNB. The reason is because that the load status of neighboring eNBs may be changed due to the time interval which represents a period of time of X2 interface to periodically report the load status information among the neighboring eNBs. For example, if the time interval is short, it may give better handover failure probability but suffer from the overhead of message exchanges. In reverse, if the time interval is long, it may provide a little message exchange but cause worse-handover failure probability due to the outdated load status information of the neighboring eNBs.

The above phenomenon should be seriously investigated because the amount of cell load among the neighboring eNBs can be drastically changed in the dynamic load environment. To solve the problem, this paper proposes a modification to the Hybrid TCS scheme estimating the cell load of the neighboring eNBs by LMS algorithm. The detailed explanation is as follows. As shown in Figure 2, notice that a load change in the Admission Control block located in the target eNB can occur after the HO decision block, which belongs to the serving eNB, makes the target eNB decision. Thus, to find the proper target eNB, it is necessary to exactly estimate the load change in the neighboring eNBs when the handover decision by the TCS scheme is made.

The goal of the proposed TCS scheme is to select the target eNB with the minimum cell load after estimating the load status of all neighboring eNBs using the least mean square (LMS) algorithm, which is the most widely used adaptive estimated algorithm. To examine the LMS algorithm for this purpose, first, the error signal is computed as the difference between the current measurement value and the estimated value for each of the candidate eNB. On the basis of this computation, the adaptive weight vector will change its values in an attempt to reduce the error. The weight vector of the j-th eNB by the LMS algorithm used in this paper is as follows.

$$W_j(t+1) = W_j(t) + \mu \times E_j(t) \times X_j(t) \tag{4}$$

where $X_j(t)$ is an input matrix including the current and previous cell load values of the j-th eNB and is a known value that is fed to the weight vector $W_j(t)$. In the LMS algorithm, the current real load $L_j(t)$ is tracked by adjusting the weight vector. The difference between $L_j(t)$ and $Y_j(t)$ (estimated load value) is the error $E_j(t)$ as shown in Figure 3. After all, the error $E_j(t)$ is then fed to the LMS algorithm to compute the weight vector $W_j(t+1)$ to iteratively minimize the error.

The convergence time of the LMS algorithm depends on the step size μ in (4). If μ is small, then it may take a long convergence time and this may defeat the purpose of using a weighting vector. However, if μ is too large, the algorithm takes a long time to converge.

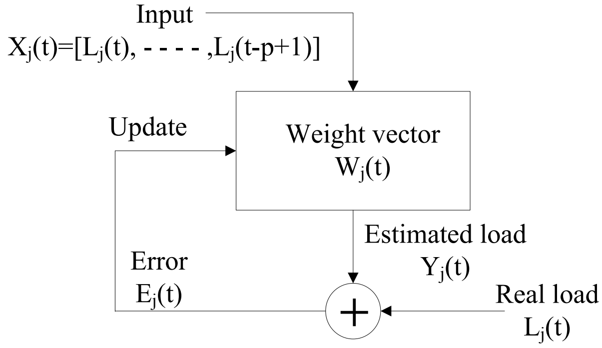

FIGURE 3. LMS weight update procedure

The value of μ should be carefully computed considering the effects that it affects $L_j(t)$. Therefore, it is a difficult problem to set the step size. In this paper, the LMS algorithm is reliably implemented using convergence parameter μ with the normalized input value rather than using a fixed convergence parameter μ.

(5) shows the priority metric of the proposed TCS scheme estimating the cell load of the neighboring eNBs by the LMS algorithm. Thus, the proposed TCS scheme allows UEs to effectively avoid overloaded cells, and implicitly balances asymmetric loads across the adjacent cells in a distributed manner. The UE i chooses only the best target eNB j^* with minimum load based on the exact load change of the adjacent eNBs by the LMS algorithm and providing higher RSS as follows.

$$j^* = \arg\max_{i,j} \left(RSS_{i,j} \times \left(1 - Load_j^{LMS}\right)\right) \tag{5}$$

where $Load_j^{LMS}$ means an estimated cell load information of the j-th eNB calculated by the LMS algorithm using (4), so $(1 - Load_j^{LMS})$ implies the amount of estimated available cell load of the j-th eNB. After all, through (5), it is expected that the proposed TCS scheme can lead to smaller handover failure probability than conventional TCS schemes because the exact cell load estimation of the neighboring eNBs provides a significant effect on the handover failure probability which is one of the most important handover performance evaluations.

4. **Simulation Environment.** This paper uses a self-made C++ simulator to compare the performance between the proposed TCS scheme and existing TCS schemes in the LTE system. This section explains simulation parameters and simulation environment. Table 1 shows simulation parameters used in this paper.

Table 1. Simulation parameters

Simulation Parameter	**Value**
Network layout	2-Tier 19 cells
Cell radius	1 Km
Cell bandwidth	5 MHz
Peak data rate	20 Mbps
Antenna type	Omni-directional
Transmit power of eNB	43 dBm
Distance-dependent path loss	$128.1 + 37.6\log_{10}^{R}$, R in Km [13]
Shadowing standard deviation	6.5 dB [14]
UE mobility model	RDM [11]
Default hysteresis	3.5 dB
Minimum hysteresis	2 dB
Maximum hysteresis	5 dB
Time-to-trigger	300 msec
Measurement report period	100 msec

4.1. **Radio propagation model.** For the simulation, this paper assumes a 19 cell system with wrap-around based on the 3GPP LTE downlink specifications defined in [12]. This paper uses the pathloss model in [13] and the shadowing model in [14]. The shadowing model, which is an updated model for the moving UEs, is represented by

$$S(t) = W_a \cdot S(t-1) + W_b \cdot C + W_c \cdot V \tag{6}$$

where W_a, W_b and W_c are the weighting factors that are calculated accordingly to statistical properties of autocorrelation and cross-correlation, for $S(t-1)$, C and V, respectively. The weight W_a is given by $W_a = e^{-1\times \frac{d}{d_{corr}} \ln 2}$ where d is the migration distance of an UE with the speed of 70 km/h for 100 ms and d_{corr} is the decorrelation distance between adjacent eNBs. This paper uses $d = 1.944$ m (= 70 km/h × 100 ms) and d_{corr} is set to 33 m. The weights W_b and W_c are given by $\sqrt{R_L {S_d}^2(1 - {W_a}^2)}$ and $\sqrt{{S_d}^2(1 - {W_a}^2) - {W_b}^2}$, respectively. Here, the cross-correlation of shadow fading between links (R_L) and shadowing standard deviation (S_d) are set to 0.7 and 6.5 dB. In (6), C is the common value for the wireless links and V is the zero-mean standard Gaussian random variable with the variance of 1 [14].

4.2. **Service type.** In this paper, it is assumed that a UE originates a call and supports integrated service composed of maximum four service types at the same time [15]. Firstly, voice over Internet protocol (VoIP) is a method of transmitting audio over the Internet by encoding analog audio in a digital form, transmitting it over the internet, and decoding it back to analog form for listening. Secondly, Video streaming is content sent in compressed form over the Internet and displayed by the viewer in real time. Thirdly, Web browsing is a software application for retrieving, presenting, and traversing information resources on the World Wide Web (WWW). Lastly, Peer-to-peer (P2P) is a communication model in which each party has the same capabilities and either party can initiate a communication session. As a result, the required bandwidth allocation per service is different. The bandwidth allocation and usage ratio per service type are shown in Table 2 [15, 16].

4.3. **Admission control scheme and mobility model.** This paper uses a simple hard QoS based admission control scheme which depends on only the bandwidth availability for the handover service after handover decision without service priority between real-time (RT) service and non-real time (NRT) service. For example, in the admission control scheme, if the amount of remaining cell bandwidth is available for the handover call after handover trigger, the handover call is accepted. Otherwise, the handover call is rejected. Therefore, the number of failed handover after handover trigger is influenced only by the bandwidth shortage of the target eNB. Since the mobility model of UEs is used as random direction model (RDM) [11], all UEs have a different velocity and their velocity is uniformly distributed between 0 and 140 km/h. Also, the UEs generate a Poisson arrival process and their lifetime is a random variable by an exponential distribution with a mean equal to 2 minutes. Each UE moves at its own uniform direction during the random time interval between 0 sec and 120 sec.

5. **Simulation Results.** This simulation evaluates effect of the cell load estimation of the neighboring eNBs by the LMS algorithm on the reduction of handover failure probability. First of all, in order to investigate the effect of handover failure probability by the load measurement period of the X2 interface, this paper observes the handover failure probability versus the Hybrid TCS scheme when the load measurement period of the X2 interface is changed. Then, following the given load measurement period, this paper investigates the difference between the estimated load by LMS algorithm and the actual load

Table 2. The bandwidth allocation and usage ratio per service type

	VoIP	Video streaming	Web browsing	P2P
Bandwidth allocation per service	64 Kbps	128 Kbps	512 Kbps	512 Kbps
Usage ratio per service	40%	15%	30%	15%

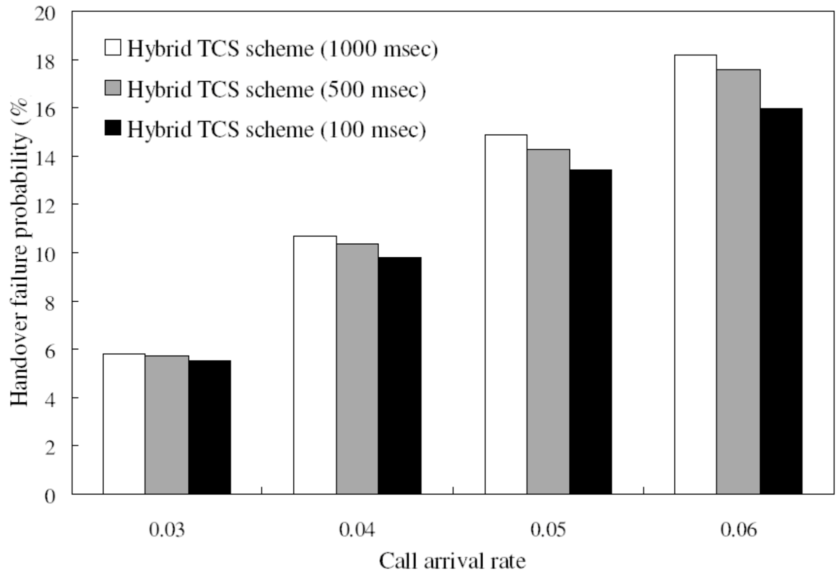

Figure 4. The handover failure probability versus the hybrid TCS scheme when the load measurement period is changed from 1000 msec to 100 msec

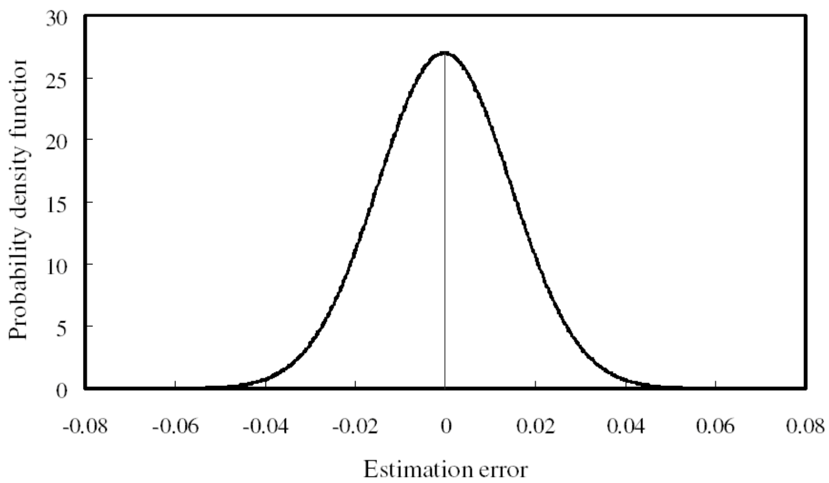

Figure 5. The probability density function of the measurement error between the estimated load by LMS algorithm and the actual load in the target eNB when the load measurement period is fixed at 100 msec

in the neighboring eNBs, and perform the performance comparison between the proposed scheme and the conventional schemes in terms of the handover failure probability.

Figure 4 shows the handover failure probability versus the Hybrid TCS scheme when the load measurement period by the X2 interface is changed from 1000 msec to 100 msec and call arrival rate increases. In the Hybrid based TCS scheme, as the load measurement period is shorter, the handover failure probability is lower. In this paper, as the period of 100 msec provides the least handover failure probability in all the Hybrid schemes, all TCS schemes except the RSS based TCS scheme in the following figures adopt the same value of 100 msec value as the load measurement period. Notice that shorter load measurement period can cause more overhead due to a lot of message exchange.

When the difference between the estimated load by the LMS algorithm and the actual load is investigated from the simulation result with the fixed load measurement period of 100 msec, it is found that the measurement error usually obeys the normal distribution.

The performance is determined by modeling the measurement error as a Gaussian random variable. Figure 5 shows the probability density function of the measurement error which is driven from the simulation result. The probability density function f is given by

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right), \quad -\infty < x < \infty \tag{7}$$

In the simulation result, the parameters μ and σ^2, which represent the mean and variance of the distribution, have -0.00018 and 0.014795^2, respectively. The distribution is denoted by $N(-0.00018, 0.014795^2)$. Because the measurement error exists from -0.04 to 0.04 and the variance is very small value as shown in Figure 5, this paper provides the conclusion that the LMS algorithm provides excellent performance over the load estimation in the neighboring eNBs.

Figure 6 shows the handover failure probability in the four TCS schemes when the load measurement period is fixed at 100 msec and call arrival rate increases. First, in the RSS based TCS scheme, note that it has nothing to do with the load measurement period because the RSS based TCS scheme does not consider the load information. The RSS based TCS scheme provides worse performance. From Figure 6, it is found that the proposed TCS scheme has the lowest handover failure probability while the RSS based TCS scheme has the largest handover failure probability. After all, it is concluded that the LMS algorithm provides good load estimation about the neighboring eNBs.

Figure 7 represents the difference of handover failure probability per service type by the four TCS schemes. From Figure 7, it is seen that RT service like VoIP and Video streaming provides lower handover failure probability compared with NRT service like Web and P2P. That is because RT service requests low bandwidth while NRT service requests high bandwidth as shown in Table 2 and this paper uses a simple hard QoS-based CAC scheme which depends on only the bandwidth availability for the handover call after handover trigger without service priority between RT service and NRT service. Also, Figure 7 tells that the proposed TCS scheme is superior to the Hybrid TCS scheme since the LMS algorithm estimates an exact cell load value of the neighboring eNBs in order to reduce the handover failure probability. From all simulation results, it is concluded that the employment of the LMS algorithm provides good performance results.

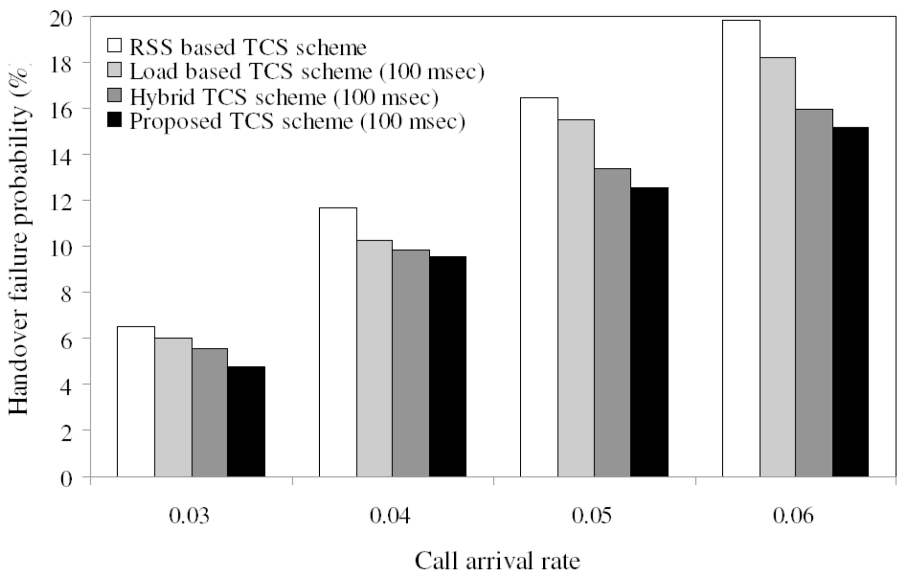

Figure 6. The handover failure probability versus the TCS schemes when the load measurement period is fixed at 100 msec

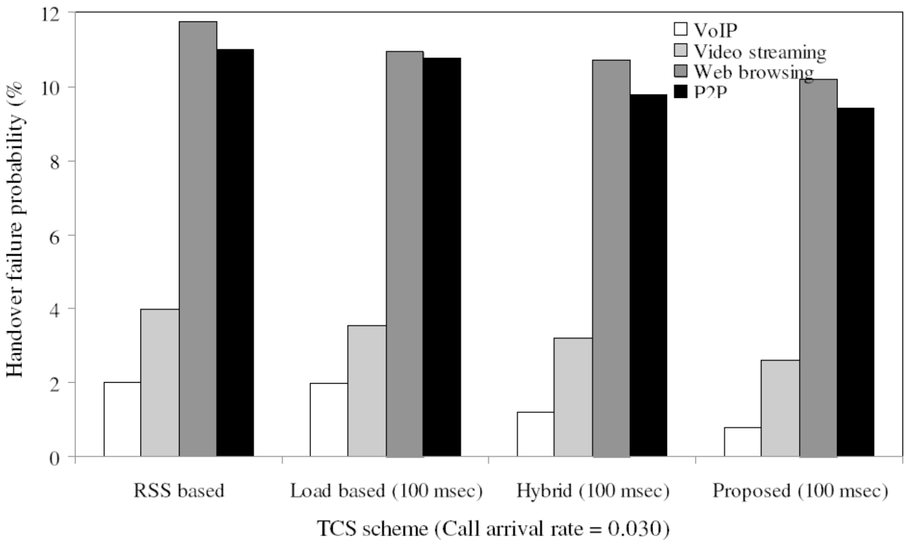

FIGURE 7. The handover failure probability versus the service types when the load measurement period and call arrival rate are 100 msec and 0.03, respectively

6. **Conclusion.** The reduction of handover failure probability can be accomplished by the Hybrid target cell selection (TCS) scheme combining both the received signal strength (RSS) based TCS scheme and the load based TCS scheme at the same time. However, the Hybrid TCS scheme in the serving eNB can make the target eNB decision with an outdated load information of the neighboring eNBs based on the X2 interface because there may be a load change in the dynamic load environment by an interval of time between the serving and neighboring eNBs. Therefore, to solve the problem, this paper proposes a modification to the Hybrid TCS scheme using the LMS algorithm for the exact cell load estimation of the neighboring eNBs in 3GPP LTE system. The simulation results reveal that the proposed TCS scheme has better performance than other conventional TCS schemes in terms of handover failure probability. In the future, another study will focus on investigating the cell load estimation of the neighboring eNBs by other estimation algorithms.

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