

# A Handover Decision Strategy with a Novel Modified Load-Based Adaptive Hysteresis Adjustment in 3GPP LTE System

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**SUMMARY** This paper introduces a hard handover strategy with a novel adaptive hysteresis adjustment that is needed to reduce handover drop rate in 3GPP long term evolution (LTE). First of all, we adopt a Hybrid handover scheme considering both the received signal strength (RSS) and the load information of the adjacent evolved Node Bs (eNBs) as a factor for deciding the target eNB. The Hybrid scheme causes the load status between the adjacent eNBs to be largely similar. Then, we propose a modified load-based adaptive hysteresis scheme to find a suitable handover hysteresis value utilizing the feature of the small load difference between the target and serving eNBs obtained from the result of the Hybrid scheme. As a result, through the proposed modified load-based adaptive hysteresis scheme, the best target cell is very well selected according to the dynamically changing communication environments. The simulation results show that the proposed scheme provides good performance in terms of handover drop rate.

**key words:** Handover decision strategy, adaptive handover hysteresis, hybrid scheme, load balancing, handover drop rate

## 1. Introduction

In 3GPP LTE system, there have been many studies about self organizing network (SON) to minimize capital expenses (CAPEX) and operating expenses (OPEX), and to maximize the revenue of operator through the management of automatic network. The SON is mainly composed of self-configuration and self-optimization [1]. By the way, the handover procedure in the network controlled handover of the 3GPP LTE system has a close relationship with the self-optimization which collects measurement information from user equipment (UE) and eNB, and then it automatically tunes the configuration data to optimize the network. The self-optimization contains load balancing, handover parameter optimization, and capacity and coverage optimization.

In 3GPP LTE system, eNB is the basic access network element covering a single cell. It supports the evolved universal terrestrial radio access (E-UTRA) user plane such as header compression, ciphering and reliable delivery of user plane protocol data units (PDUs) and control plane such as admission control and radio resource management towards the UE [2]. Two eNBs are connected with each other

through X2 interface which allows the interconnection between eNBs. The X2 interface exchanges the signal information between two eNBs, along with the forwarding of user plane PDUs to their destination [3].

This paper deals with hard handover procedure based on the load information exchanged between the eNBs via the X2 interface in 3GPP LTE system, which is operated as a kind of self-optimization for load balancing and handover parameter optimization [4]. The handover procedure is mainly made up of handover decision in serving eNB and admission control in target eNB. We focus on the handover decision strategy with the adaptive hysteresis adjustment for self-optimization. The adaptive hysteresis adjustment scheme can find a good hysteresis value adapted to the many handover factors affecting the handover performance, so that the scheme is proposed to very well control the handover decision process. However, the scheme has a big problem in finding the optimum combinatorial value of the corresponding weights among the many handover factors [5]. Therefore, it is necessary to design the hard handover strategy with adaptive hysteresis adjustment based on the load difference between the target and serving eNBs with goal of minimizing handover drop rate, which performs an important role as a kind of self-optimization for handover parameter optimization in 3GPP LTE system.

First of all, to accomplish the self-optimization for load balancing with the purpose of redistributing traffic from highly load cells to underutilized cells, it is useful to adopt a hybrid handover algorithm considering the received signal strength (RSS)-based handover algorithm [6] and load-based handover algorithm [7] at the same time.

When the RSS-based handover algorithm considering only the RSS between the UE and the adjacent eNBs is adopted, eNB with the highest RSS will be chosen as target eNB. However, it causes the handover drop to increase in case that the target eNB is overloaded. Also, when the load-based handover algorithm by the only load information from the adjacent eNBs is used, it can bring about a handover drop in case that the RSS of the target eNB is low. The Hybrid scheme with the objective of overcoming the disadvantages of the two handover decision algorithms effectively causes the load to be equally distributed among multiple cells through load balancing [8]. However, because the load difference between the target and serving eNBs is largely concentrated near 0 after the Hybrid scheme, a new adaptive hysteresis scheme exploiting such a property is urgently required. In other words, a new Hybrid scheme with

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modified load-based adaptive hysteresis scheme considering the nonlinear characteristic of load difference between the target and serving eNBs can provide better performance than the existing Hybrid scheme with load-based adaptive hysteresis scheme without considering it in terms of handover drop rate.

Therefore, we propose a modified adaptive hysteresis scheme based on the feature having a small load difference between the target and serving eNBs. The proposed hysteresis scheme can adaptively find a proper hysteresis value which is one of the important handover parameters for handover trigger adapted to the small load difference characteristic. As a result, the proposed scheme can operate like an auto-tuning process which realizes a kind of handover parameter optimization for the self-optimization in 3GPP LTE system. This paper is organized as follows. Section 2 introduces a handover decision strategy with the proposed modified adaptive hysteresis in 3GPP LTE system. Section 3 and 4 explain the simulation environment and results. Section 5 concludes the paper.

## 2. Handover Decision Strategy with Various Hysteresis

Figure 1 shows the handover procedure in the 3GPP LTE downlink system which consists of handover preparation, handover execution, and handover completion phases. First of all, the preparation phase is composed of the handover decision stage and admission control stage [2], [9]. In the preparation phase, if the RSS from the serving eNB is less than a given minimum threshold, the UE sends the Measurement Report message to the serving eNB as shown in Fig. 1. Based on this message, the serving eNB selects the eNB with the largest RSS among the neighboring eNBs. If the selected eNB satisfies the hysteresis value during the given time-to-trigger, the handover decision is performed. Upon performing the handover decision, the UE will disconnect itself from the serving eNB and request for connection with the target eNB to the admission controller. After the target eNB sends the Handover Request Confirm message to the serving eNB, the handover preparation phase moves to the handover execution phase where the serving eNB forwards all data of the UE to the target eNB. Finally, by exchanging Handover Complete message that indicates this handover is completed, handover completion phase is performed.

In this paper, in order to find a good handover strategy considering adaptively hysteresis value that is an important control parameter for improving the handover performance, we focus on handover decision scheme in the handover preparation phase which is the first phase of handover procedure in 3GPP LTE system.

### 2.1 Handover Decision Scheme

There are mainly two existing representative handover decision schemes; One is the RSS based scheme [6], and the other is the load based scheme [7]. The RSS based scheme is based on the RSS from the serving cell and the neighbour-

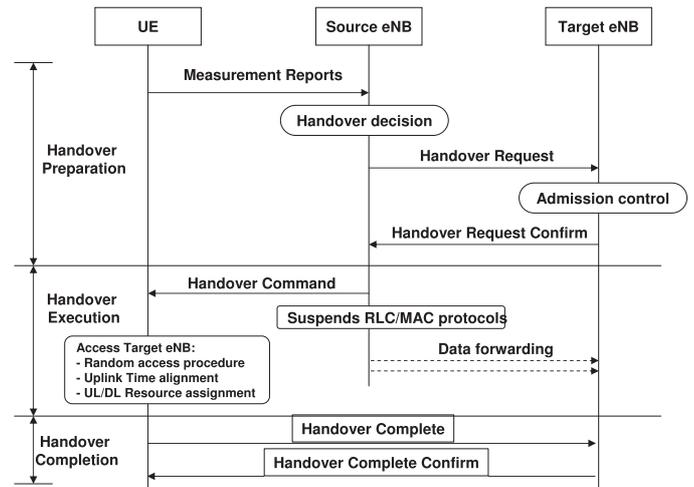


Fig. 1 Handover procedure in 3GPP LTE system.

ing cells, so that the scheme selects the eNB with the largest RSS. The load based handover scheme is carried out based on the load information from the serving eNB and neighboring eNBs, so that the scheme can find the eNB with the lowest load. However, in the above handover schemes, as the RSS based handover algorithm does not reflect the load change between serving and target eNBs, and the load based scheme does not consider the RSS, the handover drop rate can be increased. To overcome these drawbacks of the two handover decision schemes, the Hybrid scheme considering both the RSS and load information of target eNB based on X2 interface is preferred [8]. In the Hybrid scheme, even if the RSS from the candidate target eNB is high, the handover may not be triggered if the load in the candidate target eNB is high.

### 2.2 Fixed Hysteresis

As shown in the handover procedure of Fig. 1, if the RSS difference between the serving and target eNBs is larger than a given hysteresis ( $H_{fixed}$ ) and it holds during a given time-to-trigger, handover decision is made and admission request for handover call is initiated by sending a Handover Request message [10]. Figure 2 illustrates the handover decision scheme with fixed hysteresis.

If the handover decision scheme is based on a given fixed hysteresis value without considering any radio resource information such as the RSS and load status from the adjacent eNBs, it causes handover drop rate to increase. For this reason, many studies for handover decision with adaptive hysteresis adjustment have been undertaken in order to effectively reduce handover drop rate. In the existing fixed hysteresis scheme, if the power budget quantity (PBQ) is higher than the given fixed hysteresis value, an UE connected to the serving eNB triggers a handover to the target eNB.

$$PBQ = RSS_{it} - RSS_{is} \geq H_{fixed} \quad (1)$$

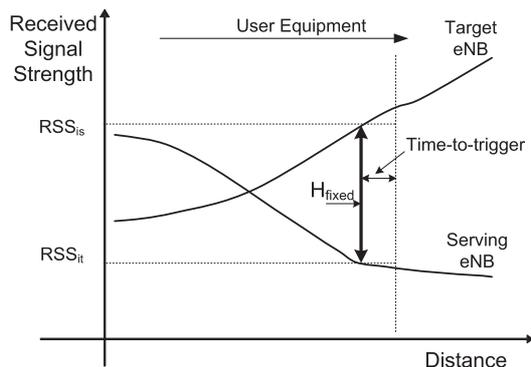


Fig. 2 The handover decision scheme with fixed hysteresis.

where  $RSS_{it}$  and  $RSS_{is}$  indicate a signal strength of UE  $i$  received from the target eNB  $t$  and the serving eNB  $s$ , respectively. Also,  $H_{fixed}$  is a specific value between  $H_{min}$  and  $H_{max}$  which indicate allowable minimum and maximum hysteresis values respectively.

### 2.3 Adaptive Hysteresis

As the hysteresis value is one of the most important parameters for improving the handover performance as a kind of self-optimization for handover parameter optimization in 3GPP LTE system, the research for the handover decision scheme with adaptive hysteresis adjustment is largely needed. To effectively improve the handover drop rate performance due to the load imbalance among neighboring eNBs, we consider handover decision scheme with adaptive hysteresis based on the load status information of the neighboring eNBs. For example, the under-utilized eNBs easily allow handover from the neighboring eNBs because of their enough bandwidth. In the adaptive hysteresis, we consider the relation between the load difference and hysteresis value. If the load of the serving cell is less than the load of the target cell, the adaptive hysteresis adjustment scheme allows the hysteresis value to increase, so that the increased hysteresis value may not let boundary UEs switch over to the eNB, in reducing the number of handover try and pursuing potentially the lower handover drop rate due to less competition in target cell. Otherwise, the adaptive hysteresis adjustment scheme allows the hysteresis value to decrease since the serving cell experiences a bandwidth shortage, so that it makes boundary UEs switch over to the target eNB in order to reduce the handover drop rate. Figure 3 shows the handover decision scheme with adaptive hysteresis, where the hysteresis has a value between  $H_{min}$  and  $H_{max}$ .

$\Delta H(s, t)$  is the handover margin between the serving eNB  $s$  and the target eNB  $t$  and is a key parameter that affects the handover performance.  $H_{fixed} + \Delta H(s, t)$  dynamically ranges between  $H_{min}$  and  $H_{max}$  in the load-based adaptive hysteresis scheme while  $\Delta H(s, t)$  is fixed to 0 in the fixed hysteresis scheme. Also,  $f(L)$  represents a function for determining the handover margin by a certain  $L$  value. If the  $L$  value has multiple values, the solution for finding the

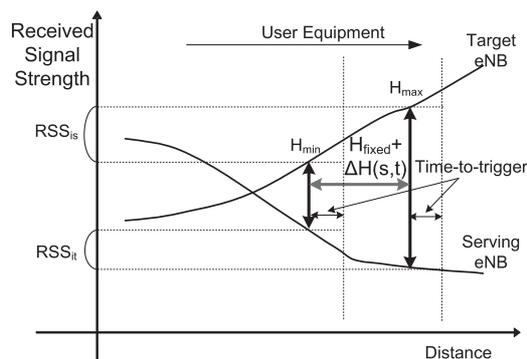


Fig. 3 The handover decision scheme with adaptive hysteresis.

optimum combinatorial value of the corresponding weights among the values becomes more complex [5]. Hence, we deal with the load-based adaptive hysteresis scheme depending on the certain  $L$  value that represents only the load difference between the target and serving eNBs. After all,  $\Delta H(s, t)$  is represented by multiplication of  $f(L)$  and  $k = H_{max} - H_{fixed}$  (or  $k = H_{min} - H_{fixed}$ ) as follows

$$\Delta H(s, t) = k \cdot f(L) \quad (2)$$

The hysteresis value is adaptively calculated by the addition of  $\Delta H(s, t)$  and  $H_{fixed}$  as shown in (3). The adaptive hysteresis scheme is operated as a kind of self-optimization for handover parameter optimization in 3GPP LTE system by dynamically adapting the handover margin.

$$PBQ \geq H_{fixed} + \Delta H(s, t) \quad (3)$$

If the PBQ is higher than the calculated hysteresis value, the serving UE handovers to the target eNB.

#### 2.3.1 Load-Based Adaptive Hysteresis

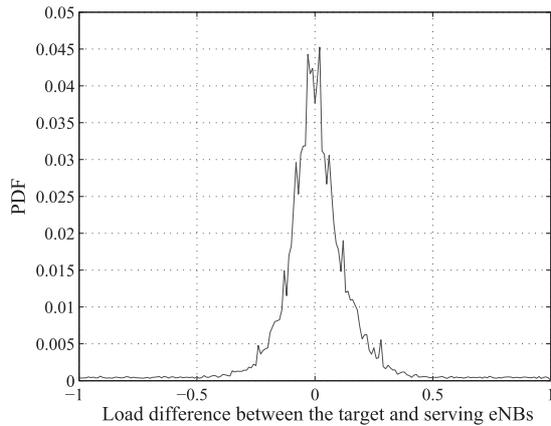
One of representative adaptive hysteresis schemes is load-based adaptive hysteresis scheme [11] considering the load difference between the target and serving eNBs based on the load information by the X2 interface. In the scheme, the function ( $f(L)$ ) only depends on the load difference between the target and serving eNBs, so that it is represented as follows

$$f(L) = L_t - L_s \quad (4)$$

where  $L_t$  and  $L_s$  mean the load information of the target eNB  $t$  and the serving eNB  $s$ , respectively. The load information is defined as a ratio of the occupied bandwidth to the total bandwidth in the eNB and is exchanged by the X2 interface. Where, the total bandwidth is split into many sub-carriers in 3GPP LTE downlink system with orthogonal frequency-division multiplexing access (OFDMA) transmission.

#### 2.3.2 Modified Load-Based Adaptive Hysteresis

In this Section, we minutely introduce a novel modified

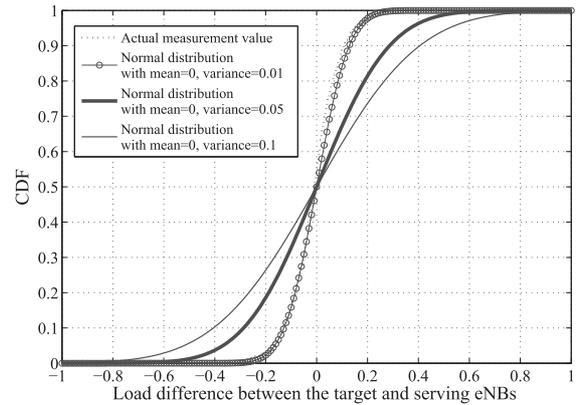


**Fig. 4** The PDF of the actually measured load difference between the target and serving eNBs after the Hybrid scheme is applied.

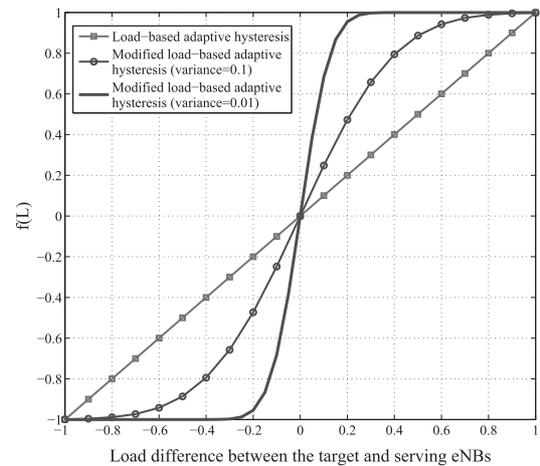
load-based adaptive hysteresis scheme exploiting the special feature of the load difference between the target and serving eNBs actually measured from our simulation result after the Hybrid scheme is applied. Figure 4 shows the probability density function (PDF) of the actually measured load difference between the target and serving eNBs measured after the Hybrid scheme is applied. Unlike the PDF of the load difference between the target and serving eNBs by the existing load-based adaptive hysteresis scheme, when we consider the PDF of the load difference between the target and serving eNBs after adopting the Hybrid scheme, the small load difference between the target and serving eNBs is obtained as shown in Fig. 4. From that, we find that the load difference usually obeys the normal distribution. By deriving the cumulative distribution function (CDF) corresponding to the PDF in Fig. 4, the CDF of the actually measured load difference can be obtained too. Figure 5 shows the CDFs of the actually measured load difference and the normal distributions with different means and variances. Where, the parameters  $\mu$  and  $\sigma^2$  represent the mean and variance of the CDFs for the normal distributions. From Fig. 5, as we observe that the CDF of the actually measured load difference is more similar to the CDF of the normal distribution with smaller variance, it would be better to set smaller 0.01 than 0.1 as  $\sigma^2$  for better performance.

Hence, if we make good use of the real measured distribution that the load difference between the target and serving eNBs is mostly distributed near 0 since load balancing is significantly achieved by the Hybrid scheme, we can effectively find a suitable hysteresis value with aim of reducing handover drop rate in 3GPP LTE system.

As a result, as shown in Fig. 5, we find that the CDF of the load difference is not linear to the load difference, that is, its CDF is not directly proportional to it. To solve the problem, we make full use of concept of a nonlinear function like Fig. 6. The nonlinear function is very helpful because it fully utilizes the nonlinear characteristic of load difference between the target and serving eNBs after handover decision operation by the Hybrid scheme considering



**Fig. 5** The CDFs of the actually measured load difference and the normal distributions with different means and variances.



**Fig. 6** The function ( $f(L)$ ) on the load difference between the target and serving eNBs by the existing load-based adaptive hysteresis scheme and proposed modified load-based adaptive hysteresis scheme after the Hybrid scheme is applied.

both the RSS-based handover algorithm and the load-based handover algorithm. As the proposed scheme can take advantage of the fact that it usually helps to have more precision of the detail near 0, most of the load difference will be significantly perceived compared to an linear function such as existing load-based adaptive hysteresis scheme. The proposed scheme effectively reduces the dynamic range of the load difference and decreases the handover drop rate because nonlinear function for the measured distribution of the load difference is more real than linear function for that. Figure 6, which illustrates how the proposed scheme concentrates sampling in the smaller values, represents  $f(L)$  on the load difference between the target and serving eNBs by the existing load-based adaptive hysteresis scheme and proposed modified load-based adaptive hysteresis scheme with 0.01 and 0.1 as  $\sigma^2$ . As shown in Fig. 6, it can be observed that the proposed scheme uses an exponential curve like  $f(L)$  in (5) while the existing load-based adaptive hysteresis scheme adopts a linear curve like  $f(L)$  in (4). As a result, the function  $f(L)$  for the proposed adaptive hysteresis scheme is

modified from (4) and is defined as (5).

$$f(L) = erf\left(\frac{L_r - L_s}{\sqrt{2}\sigma}\right) \quad (5)$$

As a result, the handover margin in (2) is automatically updated by (5) based on  $L_t$  and  $L_s$ , the load information by the X2 interface in LTE system. Hence,  $f(L)$  in (5) provides much more dramatic curve for the load difference near 0, thus most load differences around 0 are minutely used for dynamical adjustment of the handover margin with the objective of finding a suitable hysteresis value, one of the mayor handover parameters, through the proposed scheme.

### 3. Simulation Environment

The performance evaluation is based on the 3GPP LTE downlink specifications defined in [12]. Taking into account the above, we focus on a dynamic user distribution in the 2-tier 19-cell and therefore experiencing different RSS. The system parameters are summarized at Table 1. We used the pathloss model in [14] and the shadowing model in [13]. The shadowing model, which is an updated model for the moving UEs, is represented by

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

where  $W_a$ ,  $W_b$ , and  $W_c$  are the weighting factors that should be 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 a vehicle with the speed of 70 km/h for 100 ms,  $d_{corr}$  is the decorrelation distance between adjacent eNBs. We used  $d = 1.944$  m ( $= 70$  km/h  $\times$  100 ms) and  $d_{corr}$  was 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 ( $S_d$ ) were 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 [13].

[16] contains requirements on the UE regarding measurement reporting in RRC CONNECTED state and control of measurement reporting is specified in [17]. In our simulation, time-to-trigger, that is the observation time for RSS before and after handover, is 300 ms. Also,  $H_{min}$ ,  $H_{fixed}$  and  $H_{max}$ , that are handover margin parameters, are 1.5, 3.5 and 5.5 dB respectively. Hence,  $H_{fixed} + \Delta H(s, t)$  dynamically ranges between 1.5 dB and 5.5 dB in the load-based adaptive hysteresis scheme while  $H_{fixed} + \Delta H(s, t)$  is 3.5 dB because  $\Delta H(s, t)$  is fixed to 0 in the fixed hysteresis scheme.

In this paper, we assume that an UE originates a call and supports integrated service composed of maximum four service types at the same time [18]. The bandwidth allocation and usage ratio per service type is shown in Table 2. Also, we adopt a simple hard QoS-based call admission control (CAC) scheme which depends on only the bandwidth availability for the handover service after handover decision

**Table 1** System parameters.

Parameter	Value
Network layout	2-tier 19-cell wrapping model
Cell radius	1 Km
Cell bandwidth	5 MHz
Peak data rate per cell	20 Mbps
Frequency efficiency	4 (Bit/s/Hz)
Transmit power of eNB	46 dBm
Antenna type	Omnidirectional
Path loss model	$128.1 + 37.6 \log_{10}^R$ , $R$ in Km [14]
Shadowing factor	Std. deviation = 6.5 dB [15]
Handover margin parameters	$H_{max} = 5.5$ dB, $H_{min} = 1.5$ dB $H_{fixed} = 3.5$ dB
Time-to-trigger	300 msec
Measurement report period	100 msec [16]

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

	VoIP	Video streaming	Web browsing	P2P
Bandwidth allocation	64 Kbps	128 Kbps	512 Kbps	512 Kbps
Usage ratio	50%	20%	15%	15%

without any service priority among the service types. As this paper adopts the random direction model (RDM) as the mobility model of UEs [19], each UE moves with a uniformly distributed velocity from 0 km/h to 140 km/h and it moves at its own uniform direction during the random time interval between 0 sec and 120 sec. Also, each UE is generated according to a Poisson arrival process and its lifetime is a random variable by an exponential distribution with a mean equal to 2 minutes [5].

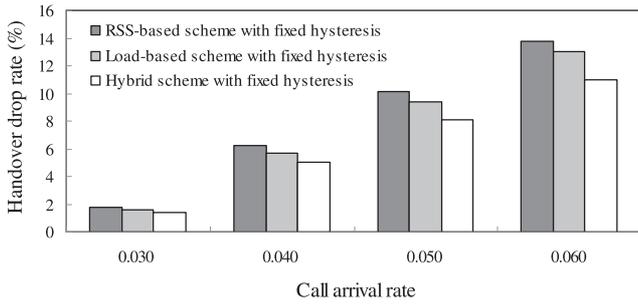
## 4. Simulation Results

### 4.1 Performance Analysis by the Hybrid Scheme with Fixed Hysteresis

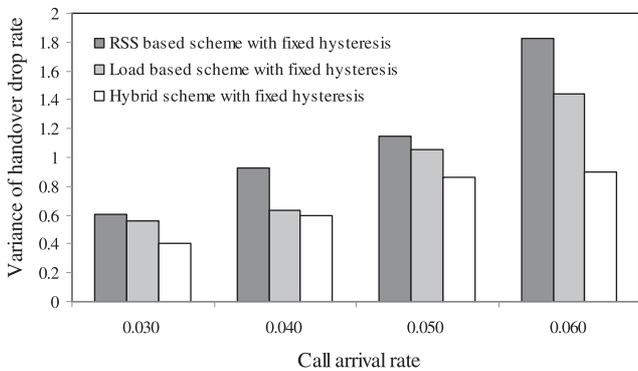
Figures 7 and 8 show the handover drop rate and its variance in the three types of handover decision schemes with fixed hysteresis when call arrival rate increases. From Fig. 7, we know that the Hybrid scheme with fixed hysteresis provides the least handover drop rate performance since it considers both the RSS and the load information among the adjacent eNBs at the same time. Also, Fig. 8 illustrates that the load balancing is successfully carried out in the Hybrid scheme since it means that the handover drop rate is evenly distributed every cell if the variance of the handover drop rate is small. The simulation results indicate that the Hybrid scheme with fixed hysteresis is identified as an effective handover algorithm which plays an important role in improving the load balancing and handover drop rate.

### 4.2 Performance Analysis by the Proposed Modified Adaptive Hysteresis Scheme

Figure 9 shows the handover drop rate by the Hybrid schemes with three types of hysteresises when call arrival



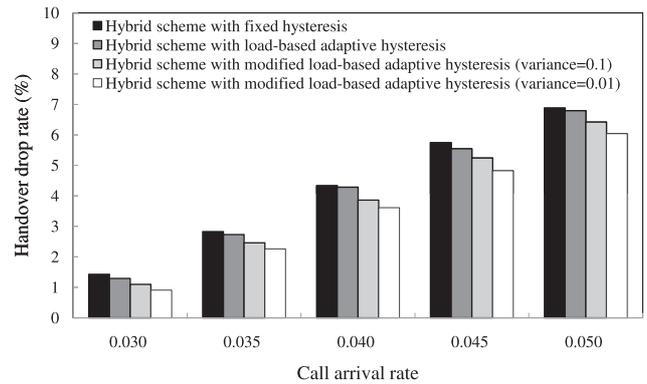
**Fig. 7** The handover drop rate by the three types of handover schemes with fixed hysteresis.



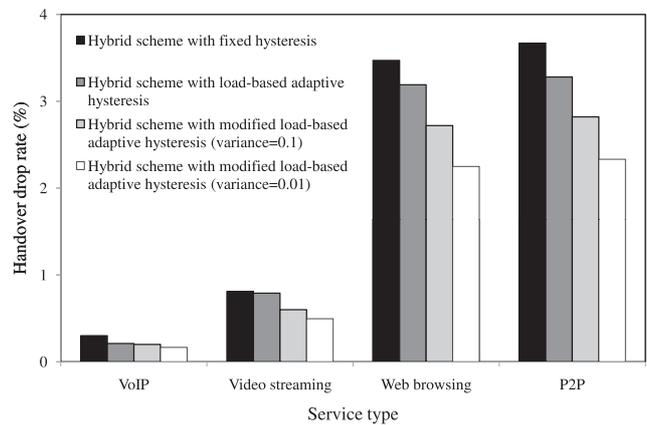
**Fig. 8** The variance of handover drop rate by the three types of handover schemes with fixed hysteresis.

rate increases. From Fig. 9, we find that the Hybrid scheme with the proposed modified load-based adaptive hysteresis has the lowest handover drop rate than the Hybrid schemes with other adaptive hysteresises. We conclude that the proposed scheme can find a good hysteresis value that is one of the key handover parameters. Through the proposed adaptive hysteresis, a kind of self-optimization for handover parameter optimization in 3GPP LTE system can be achieved. Figure 10 represents the handover drop rate per service type by the Hybrid schemes with three types of hysteresises when call arrival rate is fixed at 0.03. From Fig. 10, we see that the handover drop rate is lower in order of VoIP, Video streaming, and Web browsing (or P2P). That is because the required amount of bandwidth for service type is smaller in order of VoIP, Video streaming, and Web browsing (or P2P) as shown in Table 2.

As shown in Figs. 9 and 10, the reason how the proposed modified load-based adaptive hysteresis scheme outperforms the other two schemes is explained as the follows. First of all, the Hybrid scheme with load-based adaptive hysteresis provides less handover drop rate than the Hybrid scheme with fixed hysteresis scheme because the adaptive hysteresis adaptive scheme allows the hysteresis value to decrease or increase according to the load difference between the serving and target eNBs. Furthermore, the proposed Hybrid scheme with modified load-based adaptive hysteresis scheme by nonlinear function  $f(L)$  in (5) provides much more dramatic curve for the load difference near 0 compared



**Fig. 9** The handover drop rate by the Hybrid schemes with three types of hysteresises.



**Fig. 10** The handover drop rate per service type by the Hybrid schemes with three types of hysteresises when call arrival rate is fixed at 0.03.

to the Hybrid scheme with load-based adaptive hysteresis scheme by linear function  $f(L)$  in (4), thus most load differences around 0 are minutely used for dynamical adjustment of the handover margin with the objective of finding the best hysteresis value, one of the mayor handover parameters, through the proposed scheme. Also, the proposed scheme with 0.01 as  $\sigma^2$  provides less handover drop rate than the proposed scheme with 0.1 as  $\sigma^2$  because the CDF of the actually measured load difference between the target and serving eNBs after the Hybrid scheme is more similar to the CDF of the normal distribution with smaller  $\sigma^2$ .

### 5. Conclusion

This paper introduces a Hybrid handover scheme with a novel modified load-based adaptive hysteresis adjustment which performs an important role as a kind of self-optimization for handover parameter optimization in 3GPP LTE system. It is identified that the Hybrid scheme considering both the RSS and load information of target eNB based on X2 interface in 3GPP LTE system effectively leads to the small load difference between the target and serving eNBs. Therefore, if we exploit the feature that the load difference between the target and serving eNBs is small after

the Hybrid scheme is adopted, the proposed scheme can effectively find a good hysteresis value which is one of the most important handover parameters. The simulation results show that the proposed modified load-based adaptive hysteresis adjustment provides good performance in terms of the handover drop rate.

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