Spectrum Sensing with VSS-NLMS Process in Femto/Macro-cell Environments

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Article Info	ABSTRACT
	Handover is a process that allows a mobile node to change its attachment point. A mobile node connected to a network can, in order to improve the quality of service, have the need to leave it to connect to a cell either of the same network or of a new network. The present paper introduce three techniques using adaptive Variable Step-Size Least Mean Square (VSSLMS) filter combined with spectrum sensing probability method to detect the triggering of handover in heterogeneous LTE networks. These techniques are Normalized LMS (NLMS), Kwong-NLMS and Li-NLMS. The simulation environment is composed of two femtocells belonging to a macrocell. Five User Equipements (UEs) are positioned in one femtocell and are assumed closest to its circumference. Simulation results show that sensing probability with Li-NLMS algorithm has a better performance compared with classical NLMS and Kwong-NLMS

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1. INTRODUCTION

The capacity of wireless networks has doubled every 30 months in the last 104 years [1]. Over time, demand for high transmission rates continues to rise. For example, Cisco anticipated a 39-fold increase in data traffic between 2009 and 2014 [2]. In Forecast, the authors claim that in 2010 the amount of mobile data traffic nearly tripled for the third consecutive year [3]. Also, they forecast that by 2015 about 1 billion people should access the Internet through a wireless mobile device. To cope with this tremendous growth in demand, several technologies and standards have been developed. The most advanced cellular networking standards include: High Speed Packet Access (HSPA), Long Term Evolution (LTE), and LTE Advanced (LTE-A) of 3GPP, the norms Evolution-Data Optimized (EVDO) and Ultra Wide Band (UWB) of 3GPP2 and finally the Worldwide Interoperability for Microwave Access (WiMAX) standards. At the same time, different WLAN standards have also been developed.

Although cellular network standards have several advantages in terms of mobility and coverage over WLAN standards, cellular networks suffer from lower throughput, which makes them less competitive in many contexts. For cellular networks to offer services comparable to those of WLANs, the architecture of cellular networks needs to undergo major changes such as passage from circuit switching to packet switching [4]. Despite various changes, cellular networks cannot provide the best services to consumers through these techniques often prove very costly for the operators of the cellular networks since they require a complete or partial modification of the existing infrastructure. Recently, more and more research has pushed operators to

adopt a new solution, namely the deployment of a femto-cell. This new technology has been adopted by operators as it dramatically reduces their spending [1].

Femto-cells are small qualified base stations often in the standards of home base stations. They are characterized by their very small size (of the order of a WiFi access point), their low power and low cost. Femto-cells can be easily deployed by consumers and businesses in a completely arbitrary manner. Since femto-cells are installed in existing cellular networks, they use the same commercial standards and transmit on the same radio spectrum. The connection between the femto-cells and the base network of cellular network operators is usually via a DSL connection through the access network link [4].

Initially, femto-cells were designed to have better voice coverage in homes. Indeed, many consumers suffer from poor signal quality inside their home during handover. Nowadays, they are mainly regarded as a cost-effective way to offload data traffic from cellular networks. For example, 2.3 million femto-cells were deployed in 2011. By 2014, this number has quadrupled to already 8.1 million. Also, all global data traffic will be supported by femto-cells in conjunction with WiFi [5].

In this paper, the triggering of handover [6] in heterogeneous LTE networks will be based on spectrum sensing probability (SSP) method, where, we will be introduced three techniques using the adaptive Variable Step-Size Least Mean Square (VSS-LMS) filter, such as: NLMS, Kwong-NLMS and Li-NLMS.

The spectrum sensing technique [7], [8] has been widely used to predict the presence of a Primary Base Station through the estimation of Received Signal Strength Indication (RSSI) at UEs. And in the literature, the RSSI measurement has been also taking into account to estimate the handover decision [9]. As a result, the triggering of handover in the present paper will be predicted with using SSP method, which will be quantified via the detection probability. In *Hachemi et al.*, spectrum-sensing probability of the Link Down of the current cell depends on the convergence of the classical NLMS algorithm [10]. For fixed step-size LMS algorithm, the Mean Square Error (MSE) is directly proportional to the adaptation step-size while the convergence rate increases as the step-size decreases [11]. However, adaptive filtering research has shown that a variable step-size offers a better compromise between the convergence rate and a low estimation error.

This paper is an improved version of *Hachemi et al* [10] which is itself inspired by the work developed in [12], [13]. The remainder of this paper is organized as follows. Section II includes some related works. Section III describes briefly variable step-size LMS algorithms used in the simulation part. Section IV presents simulation results and finally Section V concludes the paper and discusses future works.

2.   RELATED WORKS

In this section we will cite some works on femtocell access modes followed by a brief description of the handover decision algorithms. Handover or intercellular automatic transfer is a fundamental mechanism in cellular communication. It represents the set of operations implemented so that a mobile station can switch cells without interruption of service. The process consists in that a mobile terminal maintains the current communication during a movement, which causes the mobile to change the cell. Indeed, when the transmission signal between a handset and a base station is weakened, the handset system finds another base station available in another cell, which is able to ensure communication again under the best conditions. This mechanism allows roaming between cells or operators.

The number of handovers depends significantly on the mode of access for the femtocells. The femtocells can be deployed in either closed or open access [14]. Several studies have studied the femto-cells access modes. In *Xia et al.*, authors were studied femtocells in Open Access (OA) and Closed Access (CA) modes [15]. They characterized the difference between the two categories and showed theoretically and by simulation that the access modes of femtocells depend profoundly on the multiple access technology adopted by the operators (TDMA, OFDMA, or CDMA). They stated that it is preferable to use CA femto-cells in a TDMA or OFDMA multiple access cellular network. On the other hand, it is preferable to use OA femto-cells in a CDMA multiple access cellular network. In *Yun et al.* the authors studied the OA and CA femto-cells from an economic point of view [16].

They analyzed the impact of user incentives on the turnover of any network operator. Using an economic model based on game theory, they showed that OA femto-cells are more beneficial for operators. *Jo et al.* have studied and demonstrated mathematically, by calculating the distribution of SINR in function of the distance between the macrocell and the femto-cells, that there is a conflict between the consumers inside and those outside for the choice of femto-cells access mode in the downstream direction, i.e. indoors consumers prefer CA femto-cells while outdoors consumers prefer OA femto-cells [17]. In this case, they showed that an intermediate access mode is preferable for both types of consumers.

G. Godor *et al.* provide an overview about handover decision algorithms, which are classified into four groups based on the used input parameters and independent procedures such as positioning service [18]. The location of femtocells can be used as an input parameter to emend the handover efficiency and this type

is known as location based algorithms. The second group of algorithms takes into account UE velocity during handover decision while the third category of algorithms uses some predefined policy to make the appropriate decision. Finally, the last group of algorithms utilizes some learning techniques to collect some information from the surrounding environment to improve the decision's goodness.

In case of location based algorithms, authors [19], [20] use any type of spatial information about UEs or HeNBs (Home evolved NodeB) such as the rough position of the possible neighbors of HeNB, the exact location of HeNBs using the coverage area of each femtocells, or the distance of a UE from a given HeNB. When the speed of UE becomes important, it could be necessary to take into account this parameter to make handover decision. Authors Wu *et al.* propose an algorithm named a periodic scan mechanism where the UE might be forced to handover into femtocell even if the RSSI of the serving macrocell is better than a given femtocell [21]. An other handover decision algorithm based on mobility prediction of the UE is proposed in [22].

It uses the current position and the velocity of the UE to estimate the next position where the process of handover is initiated either by HeNB or UE. In Shih-Jung Wu *et al.* propose a handover decision strategy for hybrid femtocell systems [23]. To make handover decision this algorithm takes into account the RSSI measurement, the velocity of UE, the required QoS (Quality of Service), and the bandwidth. Authors in introduced a handover mechanism named femtocell collaboration based approach in which the UE sends continuously measurement reports to each HeNB, which includes the SIR value (Feedback Indicator) of each PRB (Physical Resource Block) [24]. Learning based decision algorithms use Q-Learning, which is the most popular reinforcement-learning algorithm. C. Dhahri *et al.* [25, 26] propose a cell selection technique for open access femtocells using □-greedy algorithm extended with Q-learning.

3.   DESCRIPTION OF THE USED ALGORITHMS
In the following, we will briefly describe the various algorithms used in simulation section.

3.1. LMS Algorithm
In 1960, Widrow and Hoff were devised one of the most celebrated algorithm in adaptive signal processing: the Least Mean-Square (LMS) algorithm, which is a member of stochastic gradient algorithms. It is characterized by its robustness, simple structure, low computational complexity and easy implementation; it has been used in a wide spectrum of applications such as adaptive control, radar, system identification, channel equalization, spectral analysis, signal detection, noise cancellation and beamforming [27], [28]. In LMS algorithm, the Mean Square Error (MSE) is directly proportional to the adaptation step-size while the convergence rate increases as the step-size decreases [11]. Ensuring the stability of the LMS algorithm requires the permanent adjustment of the step-size μ so that it is maintained in the appropriate range. A simple way of obtaining this result is to normalize the step by the variance of the excitation signal, assumed to be known a priori or estimated on the samples of the signal.

3.2. NLMS Algorithm
The Normalized LMS is a special case of APA algorithm. APA stands for Affine Projection Algorithm and belongs to the data reusing family. It was proposed originally by T. Hinamoto *et al.* [29] and later by K.Ozeki *et al.* [30]. Two parameters influence the Normalized Least Mean Square algorithm: the normalized step-size and regularization terms, which can be controlled in order to address the contradictory requirement of fast convergence and low misadjustment [31]. The implementation of the NLMS is governed by the same steps and the same equations as the LMS. The difference lies in the level of the update of weights. The originally NLMS algorithm updates the weights using the following formulas:

$$e(n) = d(n) - y(n) = d(n) - \omega^T(n)\omega(n) \tag{1}$$

$$\mu(n) = \frac{\alpha}{x^T(n)x(n)} \tag{2}$$

$$\omega(n+1) = \omega(n) + 2\mu(n)e(n)x(n) \tag{3}$$

x(n), w(n) and e(n) denote respectively the input vector, the weighting vector and the error vector. $\mu(n)$ denotes the step size vector where $0 < \alpha < 2$. In case the signal power in the filter should be zero, a small number γ is added to it. This method is known as γ-NLMS algorithm.

γ-NLMS algorithm is a variant algorithm of the classical NLMS. It just appends a small positive number in the denominator of the formula (4) to avoid the result equals to 0. Weights in γ-NLMS algorithm are updated using the following formula:

$$\omega(n+1) = \omega(n) + 2\frac{\alpha}{\gamma + x^T(n)x(n)}e(n)x(n) \qquad (4)$$

Where $0 < \gamma < 1$.

3.3. Kwong NLMS Algorithm

Kwong *et al.* propose a variable step-size LMS algorithm where the step-size adjustment is controlled by the square of the prediction error in order to reduce the trade off between misadjustment and the tracking ability of the fixed step-size LMS algorithm [32]. The used time varying step-size is given by [33]:

$$\mu(n+1) = \alpha\mu(n) + \gamma e^2(n) \qquad (5)$$

where $0 < \alpha < 1$, $\alpha > 0$ and μ(n + 1) belongs to the interval.

3.4. Li-NLMS Algorithm

Minchao Li and Xiaoli Xi [34] propose a new NLMS algorithm based on gradient vector to update step-size using the following formulas:

$$g(n+1) = \beta g(n) + (1-\beta)\frac{e(n)x(n)}{\gamma + x^T(n)x(n)} \qquad (6)$$

$$\mu_g(n) = p.\|g(n)\|^2 \qquad (7)$$

$$\omega(n+1) = \omega(n) + \mu_g(n)\frac{e(n)x(n)}{\gamma + \mu_g(n)x^T(n)x(n)} \qquad (8)$$

Where g(n) is the smooth of gradient vector, γ is the as in the γ-NLMS algorithm, $\alpha > 0$, $p > 0$, β is close to 1.

4.   RESULTS AND SIMULATION

In order to simulate the algorithms cited in the previous section, we assume that the scenario is composed of two femto-cells (HeNB1 and HeNB2) and one macro-cell (eNB). Both HeNBs are located in eNB in Figure 1. Five UEs are positioned in different locations in HeNB1 and are close to its circumference in Figure 2. The UEs are referred to as UE#1, UE#2, UE#3, UE#4 and UE#5.
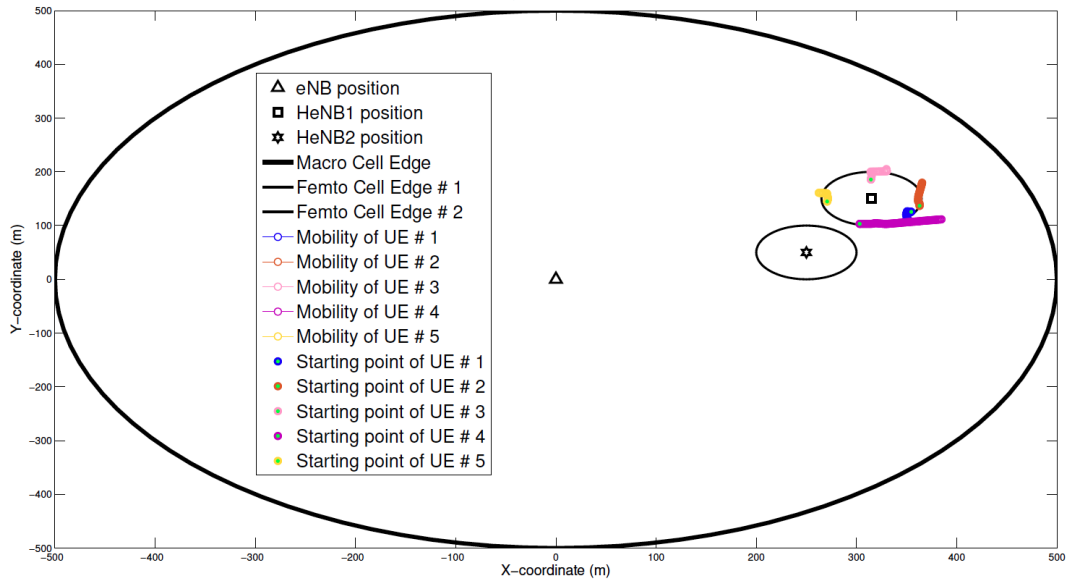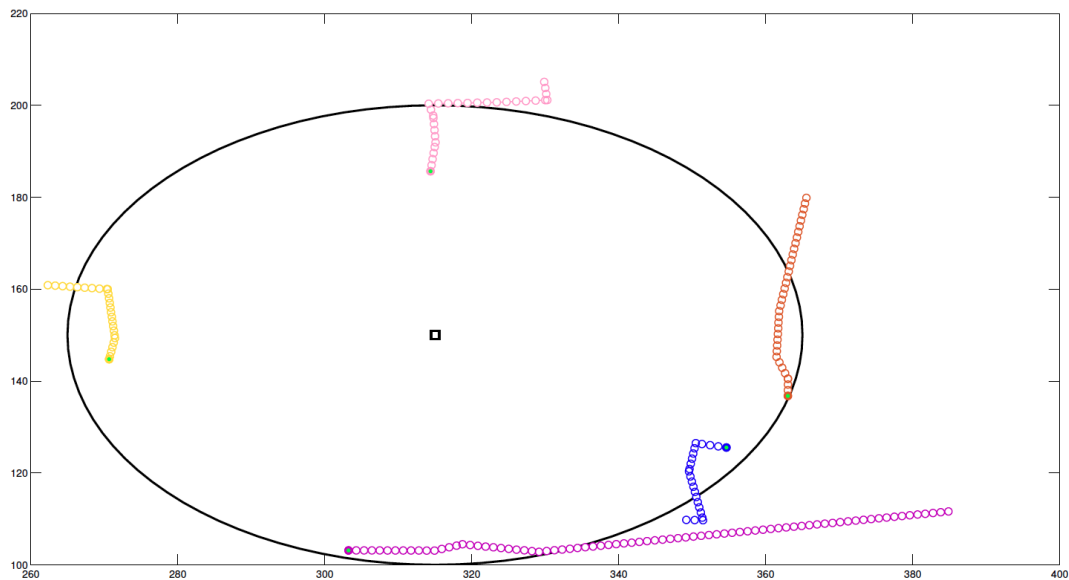
Figure 1. Pedestrians' mobility

Figure 2. Movement of the UEs in femtocell

Pedestrian mobility was taken from METIS-2020 group [35] and is implemented in our topology model. The simulation time of each UE depends on its mobility. Tables 1 and 2 respectively summarize the parameters of the adaptive algorithms and the simulation parameters.

Table 1. Parameters of Adaptive Algorithm

Algorithms	Parameters
NLMS	$\mu=0.08$
Kwong-NLMS	$\alpha=0.997; \mu(0)=0.01;$ $\gamma=4\times10^{-6}; \mu max=1;$ $\mu min=0.01$
Li-NLMS	$\alpha=0.25; \beta=0.999$ $\gamma=0.02; \mu(0)=0.01;$ $p=1; g(0)=0$

Table 2. Parameters Simulation

Spectrum Sensing with VSS-NLMS Process in Femto/Macro-cell Environments (Sidi Mohammed Hadj Irid)

Parameter	Value
Simulation area	1000 m x 1000 m
UEs' numbers	5
Macro-cell radius	500 m
Femto-cell radius	50 m
Frequency	2 GHz
Path loss exponent	3
Reference distance	Starting UE's point
Outdoor penetration loss	20 dB
Indoor penetration loss	5 dB
Transmit power of eNB	46 dBm
Transmit power of HeNB	23 dBm
Wavelength of the radio signal	0.124 m
# of walls separating apartment between HeNB / UE	3
UE's mobility	Pedestrian mobility METIS trace
Observation channel	AWGN
Prediction order of femtocell	3
Standard deviation macro/femtocell	8/3
Thermal noise	-174 (dBm/Hz)
Noise figure	9 dB
Sensing level for femtocell	-75 dBm
Propagation model	Log-normal shadowing

In Figures 3 to 7, the red line represents the threshold sensing probabilty of HeNB1 Link Down. The two curves drawn by empty blue and bottle green circles represent respectively the probabilities of detection of HeNB2 and eNB. The curve drawn by a succession of two empty circles followed by a filled circle represents the sensing probability vector of HeNB1 signal at each input of adaptive filter. The cyan, green and black filled squares represent respectively the prediction sensing probability of HeNB1 by NLMS, Kwong-NLMS and Li-NLMS algorithms (outputs of adaptive filters).

Throughout the simulation, we note that the second femto-cell signal sensing probability is null, which results in the decision phase of [10] where the probability of finding eNB signal is imminent. According to Figure 3, sensing probability of triggering handover during the movement of UE#1 by NLMS process is equal to zero. On the other hand, both Kwong-NLMS and Li-NLMS processes trigger respectively the beginning of handover at t = 39 sec and t = 33 sec with sensing probability of eNB equal to 0.7594 and 0.7469.

Figure 4 illustrates different handover trigger points for UE#2 by the three proposed methods. First, NLMS algorithm provides switching point at t = 45 sec with a detection probability of eNB equal to 0.6171. However, Kwong-NLMS algorithm predicts cell changing to eNB at t = 39 sec with a detection probability equal to 0.6969. While, the pre diction triggering handover occurs at t = 30 sec with a detection probability of eNB equal to 0.7087 using Li-NLMS algorithm.
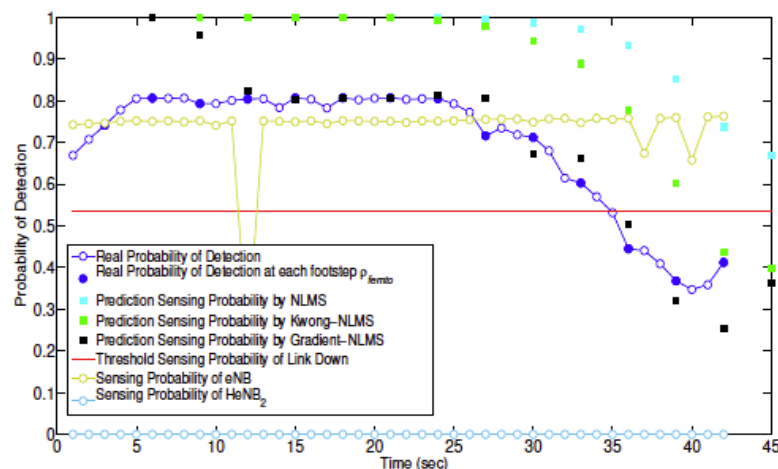

Figure 3. Prediction of sensing probability with three methods for UE#1
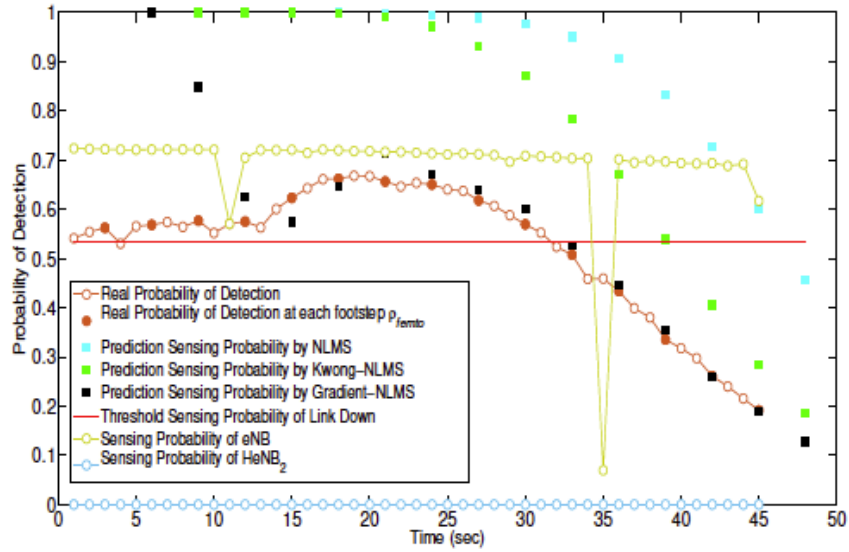
Figure 4. Prediction of sensing probability with three methods for UE#2

The different prediction curves of triggering handover for UE#3 are shown in Figure 5. By using the NLMS algorithm, the handover occurs at t = 54 sec with a sensing probability of eNB equal to 0.7240. For Kwong-NLMS algorithm, the handover happens at t = 45 sec with a sensing probability of eNB equal to 0.7317. Whereas with Li-NLMS algorithm, handover occurs at t = 15 sec with a sensing probability of eNB equal to 0.7480. Simulation results in Figure 6 indicate that handover for UE#4 is triggered at instants t = 48 sec, t = 39 sec and t =27 sec with detection probabilities of eNB equals to 0.7671, 0.7671 and 0.8028 using respectively the three precited algorithms.

Finally, from Figure 7, we observe that handover for UE#5 is triggered at t = 42 sec and t = 39 sec with sensing probabilities of eNB equals to 0.8597 and 0.8551 using respectively Kwong-NLMS and Li-NLMS algorithms. It is also noted that the sensing probability of others signals (eNB or HeNB2) by NLMS process is null. The NLMS standard algorithm generates a considerable loss of data by a delay in handover triggering. This is due to the process convergence speed. The simulation results show that the probability of detection by the Li-NLMS method presents better performances in terms of accuracy; convergence speed and stability compared with the two others techniques, Kwong-NLMS and NLMS.
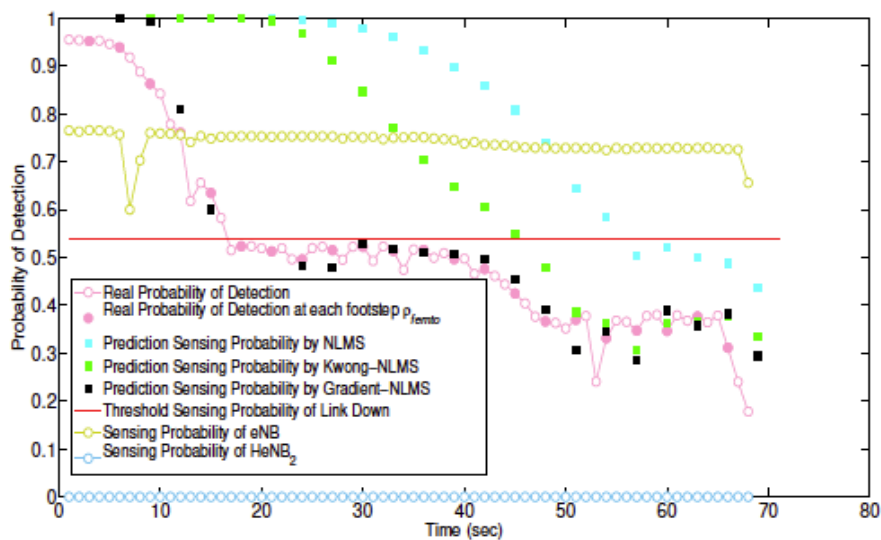

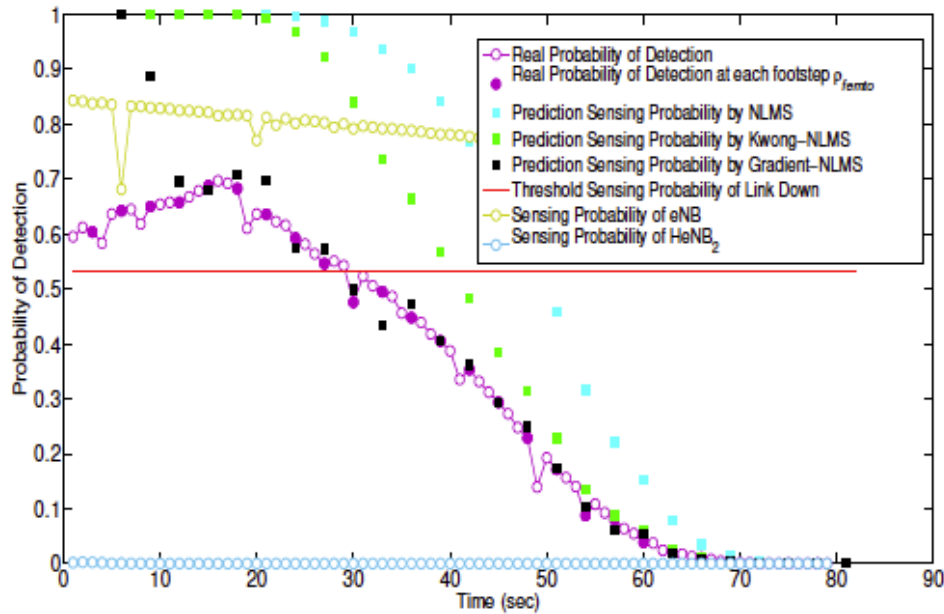Figure 5. Prediction of sensing probability with three methods for UE#3

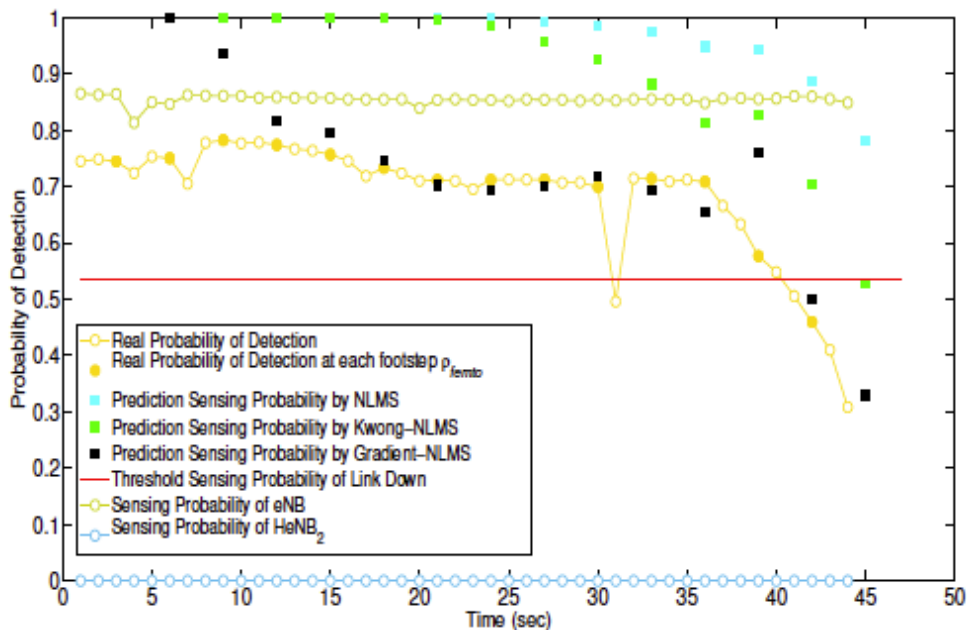Figure 6. Prediction of sensing probability with three methods for UE#4

Figure 7. Prediction of sensing probability with three methods for UE#5

5. CONCLUSION

The In this paper, we have used three variant of NLMS algorithms to address the problem of triggering handover in heteregeneous LTE network where UEs are situated near the circumference of a cell. The first one is the classical NLMS, the second algorithm is Kwong-NLMS and the last one is Li-NLMS. As the simulation results reveal, the sensing probability with Li-NLMS algorithm has a better detection of triggering handover for all UEs included initially in femtocell and consequently reduces the amount of lost data compared with classical NLMS and Kwong-NLMS algorithms. As part of our upcoming work, other derivated NLMS algorithms will be introduced to improve the triggering handover process.

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