Handover Management in Femtocell LTE Networks Under Fast Varying Channels

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Abstract. To increase network capacity of a mobile communication system, three main ways can be derived from Claude Shannon equation. These are the use of smaller cells, increase of bandwidth and improvement of communication technology. Since there is only a finite amount of radio spectrum available and it is also required by other applications, there are limits to bandwidth increment. Combining the later and former, LTE small cells method is best practical way to increase system capacity of mobile communication system. However, deployment of femtocells with small coverage range leads to frequent handover initiation. The problem escalates when femtocells operate in open access mode while accommodating highly mobile users who initiate unnecessary handovers as they stay in a femtocell for short time. To tackle these challenges, a hybrid handover decision algorithm is presented. The proposed algorithm selects the most appropriate target femtocell for handover using velocity of the user, throughput gain and adaptation of signal averaging and hysteresis margin methods. Simulation results show 1.7 times reduction in the amount of handovers in comparison with the traditional handover schemes.

Keywords: LTE network, femtocell, throughput, velocity, hysteresis margin, femtocell to femtocell handover, open access, received signal strength, quality of service.

1 Introduction

To increase network capacity of a mobile communication system, three main ways can be derived from Claude Shannon equation. These are the use of smaller cells, increase of bandwidth and improvement of communication technology. Since there is only a finite amount of radio spectrum available and it is also required by other applications, there are limits to bandwidth increment. Combining the later and former, LTE small cells method is best practical way to increase system capacity of mobile communication system. These small cells are called femtocells [1]. Femtocells are used to improve the signal quality indoors where the signal from the nearby Macrocell Base Station (MBS) is weak. The femtocell is a miniature base station with very low power connected to the MBS using broadband wireline connections, optical fibers or optical wireless last mile technologies [2][3][4]. In the femtocell coverage area, the user can access the network through three main ways. These are open, closed and hybrid. The open access allows maximum share of the full capacity of the femtocell by all users in its coverage area. The advantage of this method is on the offloading the MBS by serving several outdoor users in areas with heavy traffic or those users which are far from the MBS. For closed access, only mobile equipment belonging to the owner of the femtocell or a small group of users is allowed to access the network. Other users cannot access the network through these femtocells. The hybrid access is combination of both, open and closed accesses. This means part of the femtocell bandwidth is dedicated to a small group of users and the rest is shared by other users [5]. Femtocell increases capacity by offloading traffic from the macrocell base station. Typical coverage area of a femtocell is a few tens of meters. In densely populated areas deployment of femtocells is an ultimate objective. However dense deployment of these small cells in a small coverage area, causes strong interference and frequent handovers. As the coverage of femtocells and macrocell overlap, the handover is initiated more frequently since user equipment (UE) can receive signal from both cells. To support seamless mobility in femtocell networks, efficient handover mechanisms are essential since the traditional handover algorithm used in macrocell cannot cope with user mobility in these networks. Three different handover scenario can be distinguished in femtocell networks: inter-femtocell (handover between two femtocells), hand-in (handover from the macrocell to femtocell) and hand-out (handover from femtocell to macrocell). In hand-out scenario the UE has only one possible target to handover which simplify the process. But inter-femtocell and hand-in handovers are complex due to many candidates to which the ME can be handed over. UEs encounter frequent handovers due to small coverage range and high density of deployed femtocells. The frequency of handover increases for high moving MEs since these users stay in a femtocell coverage area for a short time. Frequent and unnecessary handovers cause increase in the signaling overhead and reduction of both users's Quality of Service (QoS) and system's capacity [6]. In conventional handover techniques, decisions are made solely on signal levels i.e. Received Signal Strength (RSS) or Signal to Interference plus Noise Ratio (SINR). Thus proposing an efficient handover decision algorithm is essential, which will ensure unaffected QoS for mobile users, improve network performance and minimize the number of frequent handovers in femtocell networks. Efficient handover means handover technique that is fast and not initiated redundantly but only in cases where it is necessary to maintain higher QoS, to the target base station that will maintain the longest connection and improve the network performance. In order to maintain network performance and reduce the number of initiated handovers, the velocity of the user and throughput gain acquired by performing the handover should be considered.

In conventional networks without femtocells several techniques have been introduced to eliminate redundant handovers. These are Hysterisis Margin (HM), Handover Delay Timer (HDT) and Windowing (also known as signal averaging). Authors in [7][8] suggest that these techniques can be implemented in femtocell networks. Both papers demonstrate reduction of an amount of redundant handovers but could not account on a negative impact of the techniques on drop of throughput. In [9] adaptive HM is proposed which uses Carrier to Interference plus Noise Ratio (CINR) levels for adaptation of the actual value of HM. The approach strengthens throughput but does not decrease the amount of handovers. The authors of [10] propose an efficient handover algorithm which uses available data volume as a decision criterion to eliminate frequent handovers in integrated macro-femtocell networks. Reference [11] suggests an asymmetric handover scheme which uses the Double Threshold Algorithm (DTH) and the call admission control scheme to reduce the number of unnecessary handovers between macrocell and femtocell. Both are successful in reducing the frequency of handovers but at an expense of throughput drop. The authors in [12] propose a handover strategy to minimize the number of handovers which considers the RSS, SINR, bandwidth and velocity of UEs as handover decision criteria. Reference [13] analyses an LTE based handover decision criteria and proposes a reactive mechanism to reduce frequent handovers and postpone handovers as long as possible. The handover is triggered if the UE almost loses the signal from serving femto access point. Reference [14] further proposes handover decision scheme for femto/macrocell overlay networks that includes the velocity and the RSS into the handover decision to reduce unnecessary handovers to a femtocell. Authors in [15] proposes femtocell – to – femtocell handover algorithm in an LTE-based network with open access mode. The authors assume random distribution of femtocells on both sides of a direct street within the coverage area of a macrocell. The target femtocell is chosen in such a way that the time interval between successive handover triggers is extended and consequently reducing the number of handovers during a call connection. The algorithm manages to reduce the number of handovers but fail to adapt the threshold parameter according to the channel quality related to the user's position in the cell.

In this paper a hybrid handover decision algorithm based on the work done in [10] is proposed. The aim is to reduce the number of femtocell – to – femtocell handovers in an LTE – based network. The proposed method uses velocity of the user, throughput gain and adaptation of windowing and HDT methods proposed in [4] and [6] respectively, for choosing appropriate target femtocell. The handover decision is based on the investigation of user's velocity, throughput gain estimated from the evolution of the signal levels of all involved cells measured by the UE and dynamic threshold power level based on the adaptation of windowing and HDT methods. The rest of the paper is organized as follows: the next section describes the system model and the principles elimination of redundant handovers. The third section presents the proposed algorithm which reduces the number of unnecessary handovers in LTE femtocell networks. The section four evaluates the performance of the proposed algorithm and finally section five presents the conclusion remarks.

2 System Model

The proposed handover algorithm, in this paper, considers an LTE macrocell-femtocell network that consist of one mobile user equipment, N femtocells and one base station illustrated in Fig.1. The first femtocell is deployed at a distance *D* meters from the user equipment (UE) and the other $N-1$ femtocells at a distance of 30 meters from each other, mimicking true urban environment. It is assumed the transmit power is 2dB and the user equipment moves with different velocities i.e V1, V2, V3

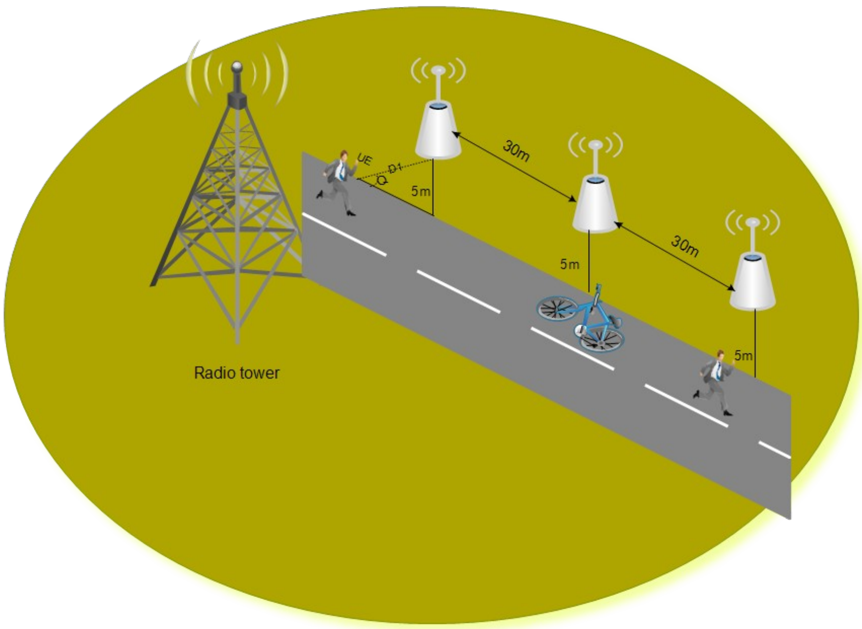

Fig. 1. Design overview of femtocell/macrocell in LTE system model

etc along the street. All femtocells operate in the open access mode in which any UE is allowed to access any femtocell that is close to it. It is also assumed that femtocells and the base station are synchronized and occupy the same spectrum in communicating to user equipment. Redundant handover represents a case when the handover is initiated but it is not completed before the next handover decision criteria is met. It is also caused by short time channel variation, fast fading or the movement of user along the edge of two neighboring cells. In handover decision it is assumed that the UE periodically sends its position to the serving femtocell when the user is moving. All femtocells will be registered with an ID for identification, the velocity of the user and all other important parameters was observed. Obtained information is kept in a database in order to know the target femtocell with minimum received signal strength as the serving cell seeks all possible target cells. The UE will also record the cell ID, RSSI value and the time of encounter for all femtocells as it moves across the street shown in Fig 1. This information will be recorded in set denoted in this work as Set 1. The instantaneous distance of the UE from any femtocell is governed by the following equation:

$$D = \sqrt{\left(\left(d_F - \left(\frac{U_o + V}{2}\right)t\right)^2 + 25\right)} D = \sqrt{\left(\left(d_F - \left(\frac{U_o + V}{2}\right)t\right)^2 + 25\right)} \tag{1}$$

where $D D$=UE-Femtocell distance, $t t$=time in seconds $U_o U_o$=Initial velocity, $d_F d_F$ =initial UE- femtocell distance $V V$=Velocity at time t The handover process is triggered when power of the serving femtocell falls below threshold. Hence, the process is initiated by comparing the average power of the served, P_{av}^{Tar} and the target, P_{av}^{Ser} femtocell;

$$P_{av}^{Tar} > P_{av}^{Ser} \tag{1}$$

From the inverse square law, the received power decreases in proportional to the square of the distance from the transmitting antenna. Taking into consideration the transmitter and receiver antenna gains, and the Doppler effect due to user mobility, the received power is given as;

$$P_{rx} = P_{tx} G_{tx} G_{rx} \left[\frac{C^4}{\left(4\pi\left(d_F - \left(\frac{U_O + V}{2}\right)t\right)^2 + 25\right)^2 [(C + VCos\vartheta)^2] f_o^{\,2}} \right]$$

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where C is speed of light, G_{tx} and G_{rx} are transmit and receive antenna gains respectively, λ is the wavelength , d is the transmitter-receiver separation, $P_{tx} P_{tx}$ is the transmitted power, $P_{rx} P_{rx}$ is the received power and c =speed of light, $f_o f_o$ =fundamental frequency. The comparison of the average values of power in equation 2 are taken using specific number of samples as;

$$\frac{\sum_{i=1}^{WS} P_{av,i}^{Tr}}{WS} > \frac{\sum_{i=1}^{WS} P_{av,i}^{Ser}}{WS} \tag{1}$$

The Window Size (WS) is obtained as shown in [5] as;

$$WS = \max\left\{ WS_{\max} x \left(1 - 10^{\frac{CINR_{act} - CINR_{min}}{CINR_{min} - CINR_{max}}} \right)^4 ; 0 \right\} \tag{1}$$

The value of WS is obtained based on the user’s position in the cell coverage. The signal characteristics depend on the user’s position in the cell, hence, carrier to interference noise power ratio (CINR) is used to estimate WS value. The CINRact depend on actual channel state, while CINRmin and CINRmax are derived from all cells in Set 1. The estimation of the target and serving femtocell power in (4) is done to eliminate the instantaneous variations due to varying channel power profile. The channel model used in this work is presented in [9] as;

$$h(t,\tau)=\sum_{n} a_n(t)e^{j\phi_n(t)}\cdot e^{j\varphi_n(t)}\cdot\delta(\tau-\tau_n) \qquad (1)$$

The channel in (6) is modelled as wide sense stationary uncorrelated scattering process, where the time variability is independent of that of frequency variability. Traditional handover practice chooses the strongest candidate after satisfying equation (7). However, handover is not completed until the hysteresis margin (HM) test is passed as presented in [6];

$$P_{av}^{Tar}>P_{av}^{Ser}+HM \qquad (1)$$

But assigning threshold values of HM does not consider the user's position in the cell. This practice assumes constant channel power profile leading to erroneous triggering or dropping of the call. Further the adaptation of HM proposed in [4] is also not realistic as the cell radius of the cell and the instantaneous distance from the cell is not known. The best alternative is to introduce the handover delay time (HDT) as proposed in [5].

$$P_{av}^{Tar}>P_{av}^{Ser}\,|\,t\in t_{ho},t_{ho}+HDT \qquad (1)$$

The actual value of HDT should is estimated as;

$$HDT=\max\left\{HDT_{max}\,x\left(1-10^{\frac{CINR_{act}-CINR_{min}}{CINR_{min}-CINR_{max}}}\right)^4;0\right\} \qquad (1)$$

In [10] the faraway target femtocell is chosen after condition (8) is met and the velocity is below 15 km/h otherwise the macrocell is taken. The authors in [10] do not show how the faraway cell will be selected if more than three femtocells have been visited. To avoid this weakness, the time records of the visited cells are used in this work to select the faraway cell. Hence, when condition in (8) is met and velocity is below 15 km/h, the farthest femtocell with minimum power is selected in Set 1 with recent time record. The time records selected should not be more than 40seconds old. The received power selection criteria will be:

$$P_{av}^{T}=\left\{\min\left(P_{av,i}^{T}\right)\geq P_{th}\right\},i\in\{0,1,2,\ldots..N\} \qquad (1)$$

The algorithm in Table 1 summarizes the proposed seamless femtocell to femtocell handover algorithm ideal for highly changing channels.

Table 1. Proposed femtocell-femtocell handover algorithm

1. Initialize: RSS values from available femtocells
   UE is connected to the first femtocell

   Start
2. Measure and record RSS and time values of nearby femtocells storing them in Set 1.
3. Handover is triggered if $P_r^S < P_{th}$
4. Handover process initiated by comparing $P_{r,av}^T > P_{r,av}^S$. The average values are estimated as $\frac{\sum_{i=1}^{WS} P_{r,i}^T}{WS} > \frac{\sum_{i=1}^{WS} P_{r,i}^S}{WS}$ and window size estimated as

$$WS = \max\left\{ WS_{\max}\, x \left(1 - 10^{\frac{CINR_{act} - CINR_{min}}{CINR_{min} - CINR_{max}}} \right)^4 ; 0 \right\}$$

5. Handover Delay Time (HDT) is set:

$$HDT = \max\left\{ HDT_{max}\, x \left(1 - 10^{\frac{CINR_{act} - CINR_{min}}{CINR_{min} - CINR_{max}}} \right)^4 \right\}$$

6. Handover is not implemented until HDT check is implemented to avoid short channel changes: $P_r^S < P_r^{Tar} \mid t \in \left(t_{HO}, t_{HO} + HDT \right)$
7. When $t_{HO} + HDT$ elapses AND condition (4) holds then handover is made.
8. Velocity of the user is examined, if $v \geq 15\, km/hr$, the user is handed over to macrocel.
9. Step (2) is repeated and Set 1 is updated.
10. If the RSS value from Set 1 is minimum (equal to threshold or just above; $P_{tar} \geq P_{th}$) and the time label is current, the selected femtocell is the target.
11. **End**

If neither of the conditions in step (8) through (10) are not met and serving received power is below threshold, the user is handed over to macrocell.

Fig 2 shows the flow chart illustrating the flow which was carried out during the algorithm development.

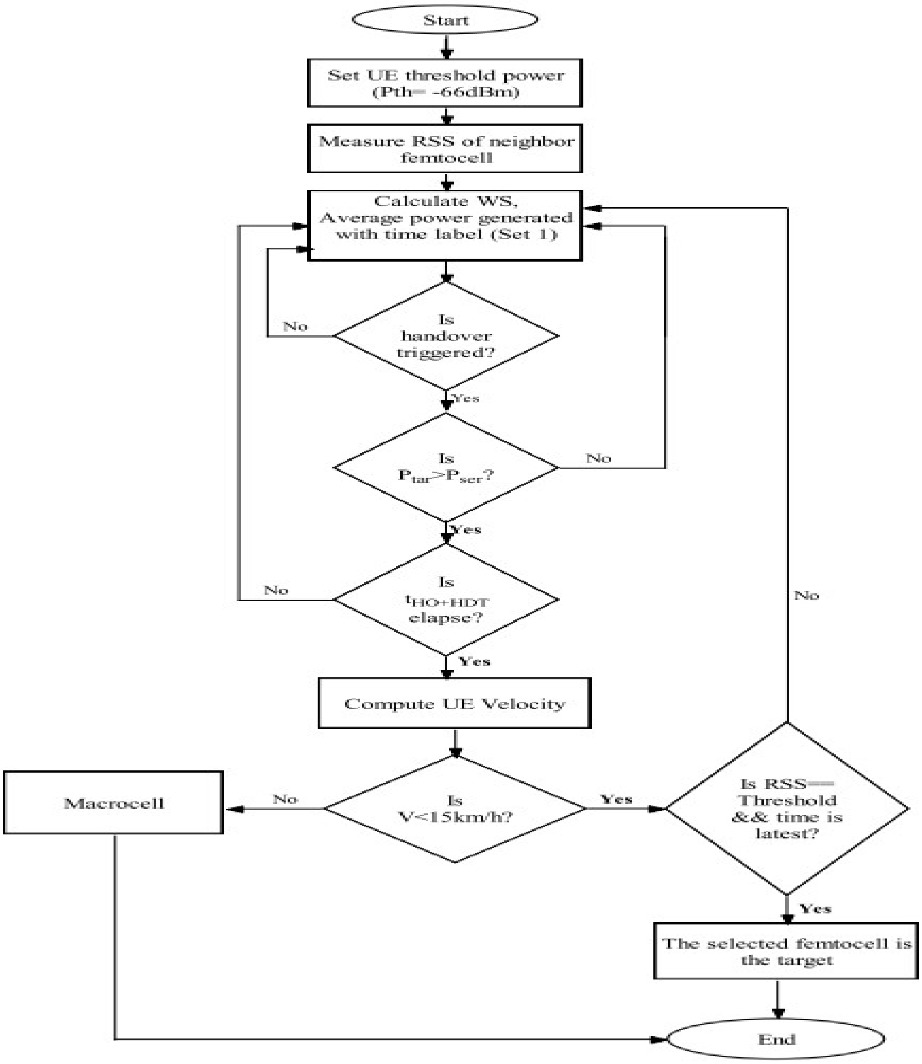

Fig.2. Flow Chart of Developed Algorithm

3 Simulation Results

In this section, the performance of the proposed algorithm is evaluated based on the setup shown in Fig 1. The proposed seamless handover algorithm is simulated using

MATLAB software. It is carried out with the support of LTE Simulink. LTE Simulink provides different functions like MCS, bandwidth, selection of macrocell and femtocell, transmit power, transmit antenna port and number of downlink RB. Therefore, simulation is done by selecting the appropriate parameters as provided in MATLAB LTE Simulink. The simulation parameters are summarized in Table 2. During simulation process, results are gathered and all important data collected after averaging 100 simulation runs for each experiment. Results for all performance parameters are collected and presented in plot forms. It is assumed that the user moves with an initial speed v along the straight street shown in Fig.1 and all handovers are performed successfully.

Table 1. Simulation parameters for handover setting in Fig 1

Parameter	Assumption/Value
Femtocell Transmit Power	20dBm
Macrocell Transmit Power	48dBm
Velocity of the UE	1km/h -15km/h
Window size	5
Frequency	2GHz
Handover Delay Time	65ms
Initial distance	15m
Threshold power (P_{th})	-66dBm
Femtocell coverage (Radius)	30m
Macrocell coverage radius	1km

In Fig.3, the effect of speed is examined on the received power profile of the first three femtocells in the direction of the user. When the user crosses the first femtocell the power profile starts to increase, the UE attains its maximum power for the second femtocell at t=14.2 seconds, at a distance of 30 m from the peak of the first femtocell. Also UE attains its maximum power at t=21.2 seconds at a distance of 30m from the second femtocell and 60m from the first femtocell. Once the user is moving away from femtocell one, the power profile starts to decrease, the same apply to femtocell 2 and femtocell 3. These closely time spaced handovers are termed as frequent handovers due to their close proximity. Employing the proposed algorithm which is the improved version of the work done in [10], reduces the frequency of the handovers as observed in Fig. 4. The assumption for Fig. 4 is that the first serving femtocell is the same for both proposed and existing algorithms. The first handover is initiated at 14.4 seconds for both the proposed and the existing algorithm, this is shown by black circles with blue face color for proposed and black circles with red face color for the existing. After performing the first handover, the proposed algorithm selects the farthest femtocell (femtocell with minimum threshold) and also implementing HDT and WS to avoid instantaneous variations, it takes 11.1 seconds to trigger for next handover at 25.5 second with minimum RSS of -65.1dBm nearly the threshold value. The existing algorithm takes 6.6 seconds to trigger the next handover at 21 second with RSS value of -62.2dBm. Thus, for the proposed algorithm the UE stays in the serving femtocell coverage area for longer duration before triggering for the next handover. The proposed algorithm allows the UE to stay longer duration by extending time to trigger handover while the existing algorithm takes shorter time, hence proposed algorithm reduce redundant handovers by 1.7 times compared to existing ones.

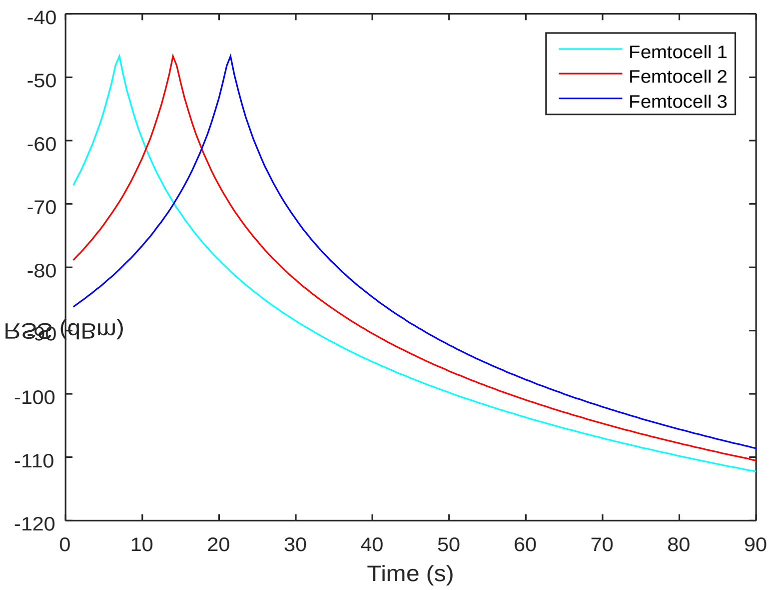

Fig. 3. Received power profile for user moving at 15 km/hr

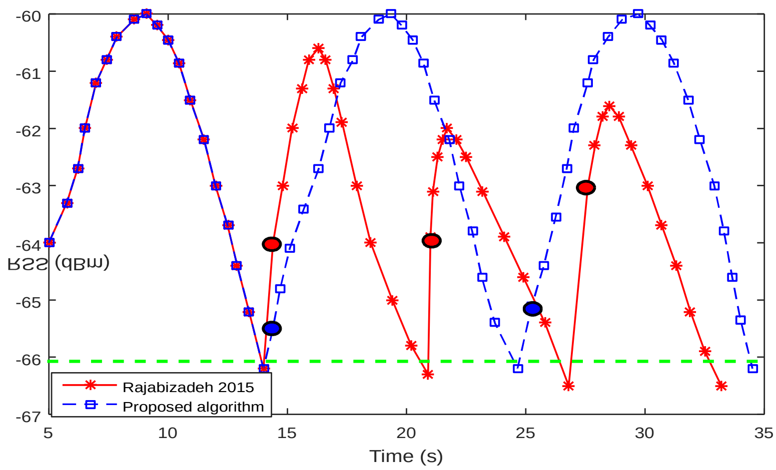

Fig. 4. The received power profile for serving femtocell versus time

In Fig. 5, throughput efficiency is examined as the user moves at a speed of 11 km/hr. The throughput is measured as the number of packets transmitted successfully per unit time. The defined time indicates the time elapsing after handover has been initiated. When the handover is initiated the UE is connected to the farthest serving femtocell and throughput is observed, as the user is moving towards the femtocell, throughput starts to increase to its maximum value. It takes 6 seconds for the UE to attain its maximum value of 0.959Mbps for the proposed algorithm as the UE is closest to the femtocell but the existing algorithm takes longer time to converge at 8 seconds for 0.788Mbps, that shows 17% throughput improvement. It takes 3 seconds after throughput has reached its maximum value to deteriorate for the proposed algorithm and 1 second for the existing system, as the user is approaching the edges of the cell coverage and expecting another handover to take place.

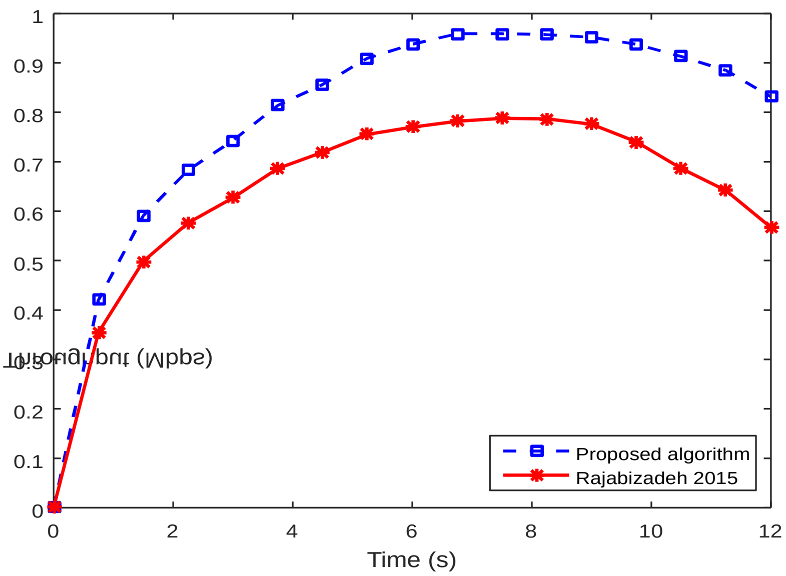

Fig. 5. Throughput performance with user speed of 11 km/hr

4 Conclusion

In this paper, the problem of frequent femtocell to femtocell handover in LTE network is addressed. The setup consisted of one macrocell and several femtocell in an open access mode. The seamless handover algorithm is proposed whose decision is based on the velocity, time, RSS value, window size, hysteresis margin and the set HDT. This is an improvement made on the works of [10]. Simulation results show that proposed algorithm reduces the unnecessary handovers by increasing the time intervals 1.7 times compared to existing one. It also improves throughput performance by 17% compared to existing algorithm when the user moves at a speed of 11km/hr. The proposed system reduces handover in femtocells when a UE is moving at a speed less than or equal to 15km/h, this is because the coverage area of femtocell is very small that makes a UE to stay in a femtocell for a very short time. The future work will be focused on reducing handover for very high speed users at a speed greater than 15km/h in order to increase performance and efficiency of the system.

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