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A New Approach for the Minimization of Packet Losses in LTE Networks

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Abstract - This research work presents a new approach for minimization of packet losses in Long Term Evolution (LTE) networks. A prominent design feature for vertical handover decision algorithm is to ensure seamless handover process between different wireless access technologies without compromising the Quality of Service (QoS) and Quality of Experience (QoE) of the users. There are scenarios in handover schemes, where due to poor handover process, frequent handover occur leading to packet losses and subsequent dissatisfaction of the users. A handover decision algorithm that incorporates the user's changing speed into a proximity model prediction technique (PMPT) in order to minimize packet losses during handover process between macrocell and femtocell networks is presented in this paper. The developed algorithm is designed to make appropriate prediction based on the established communication link to either the macrocell or femtocell network as the User Vehicle (UV) speed changes. Results obtained using MATLAB R2015b shows that the developed vertical handover algorithm (DVHA) attained a 77.07% reduction in packet loss ratio over the existing vertical handover algorithm (EVHA).

Keywords: Macrocell, Femtocell, QoS, QoE, LTE, PMPT, DVHA.

Introduction

The Long Term Evolution (LTE) network is a wireless communication standard specified for high speed data, of which the macro base stations are derived from (Deswal & Singhrova, 2017). In spite of the fact that macro base stations provide high data rates due to its operation at high bandwidth, complete coverage at indoor environment is not provided for, by the macro base stations (Chuang *et al*., 2015). As a result, femtocells are deployed to provide total network coverage. Femtocells operate within a licensed spectrum and are low powered, less expensive device with a limited range of 30 meters (Godor *et al*., 2015). Femtocells link mobile devices to the core network via the broadband connection, and improve network coverage as well as capacity (Zhang & Roche, 2010). However, only few users can be granted access simultaneously in an indoor environment (Shbat *et al*, 2012).

Users' movement between the different access networks is still a challenging issue in vertical handover process (Seth, 2013). This is due to the unpredictable nature of the user movement pattern. The conventional method of using Received Signal Strength (RSS) measurements has been deployed in the design of vertical handover algorithm to address this challenge. The results obtained, shows that there is still room for improvement in order to ensure seamless vertical handover process. The absence of a seamless vertical handover process and its resultant interruptions result in packet losses, which in turn degrades the user's call quality (Becvar & Mach, 2013).

Figure 1 shows a typical handover scenario in Long Term Evolution (LTE) networks (Wu, 2011). The handover between a macrocell and femtocell should be smooth and seamless (Wu, 2011).This can only be achieved by ensuring that the users' active voice and data sessions are maintained during the changing process of the BS (Base Station). Traditionally, handover can be of two types: Hard and soft handover. In hard handover scenario, the channel is made available at the serving BS after which the channel is engaged at the target BS, whereas for the soft handover, the channel is held at the serving BS for a certain period while been used simultaneously with the channel at the target BS. In an LTE multi-tier network, there are three handover scenarios (Gódor *et al*., 2015):

(i) **Hand-in:** A handover that occurs as the UE moves from a macrocell BS to a femtocell BS.
(ii) **Hand-out:** A handover that takes place when the UE moves from a femtocell coverage area into a macrocell zone.
(iii) **Inter-HeNB:** This is the movement of the UE from one femtocell to the other femtocell.

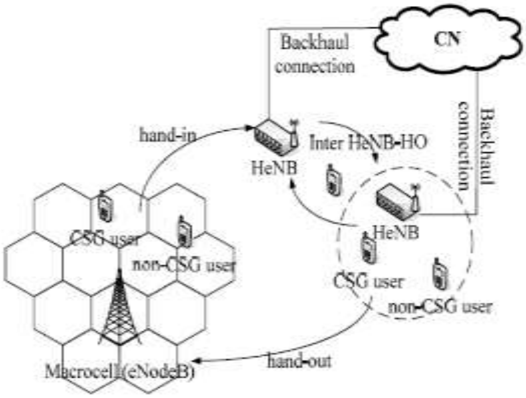


Figure 1: Handover Scenario in LTE Network (Wu, 2011)

This paper proposes a New Approach for the Minimization of Packet Losses in LTE Network. This approach introduces the concept of incorporating the changing speed of the users into a prediction technique in order to efficiently reduce the rate at which packets are lost in LTE networks. The first section of this work contains the introduction and the second section is the review of related works which gives an insight on the state of act of works done on LTE networks. The third section highlights the methodology applied in the minimization of packet losses. The fourth section shows the parameters used for the simulation. And the fifth section discusses the validation and comparison of the developed work.

2. Review of Related Work:

(Ben Cheikh et al, 2013) proposed an optimized handover algorithm with an efficient call admission control. The proposed algorithm was basically designed to reduce the number of unnecessary handovers and to maintain the communication quality during the handover. In the authors approach, the choice of the target femtocell took into account the direction of the mobile user, its velocity, and the quality of the signal in terms of Signal-to-Interference Ratio (SINR). The results showed that the proposed algorithm minimized the number of hand-in and drop rate handovers when compared to the traditional handover procedure which considered only signal strength. However the changing speed of the user was not considered in the design of the algorithm, as this could have improved the results obtained in terms of reducing the packet losses.

(Kalbkhani et al, 2014) developed a handover decision algorithm that relied on the prediction of the Received Signal Strength (RSS) in order to have a better throughput and also minimize the ping pong handover encountered by the users. In the proposed work, base stations that fulfilled the conditions of having a higher RSS than the set threshold as well as also been greater than the RSS of the serving base station with a hysteresis margin were known. The future RSS samples of the known base station and the serving base station were predicted using adaptive Recursive Least Square (RLS) algorithm. These approximated samples were used for future SINR samples. In conclusion, the candidate base stations list were reduced on the basis of the approximated SINR and predicted RSS, after which the base station with the highest throughput was selected. The proposed algorithm was validated based on the performance metrics of: Ping Pong Rate (PPR), number of handover (NHO), throughput, Outage Probability (OP) of the UE, and error due to the RSS prediction. The major drawback of the work was that the authors did not consider the varying speed of the User Equipment (UE) towards the mobile stations, which could have improved the throughput thereby leading in an enhanced result.

(Al-Shahin, 2015) presented an inter-femtocell handover scheme for dense femtocell networks. In the proposed work, two parameters namely; the movement direction of the mobile user and the location of the neighbor FAPs were considered in the minimization of the neighbor cell list for the purpose of reducing the need to scan a large cell list . Two algorithms were used to address the movement direction of the user; the first was used to predict the user mobility pattern, while the other was for generating mobility rules. To determine the location of the FAPs, a user mobility analysis server was used. Results obtained showed that as the mobile user direction was predicted towards (west-south) direction, 65% reduction in the FAPs list was achieved and an 85% reduction was obtained when the prediction was made in the (east-south) direction. The problem with the handover scheme was that no parameter was set to aid in the selection of a suitable FAP for handover which could result in increased dropped packets and eventual degradation of the user's QoS.

(Habibzadeh et al, 2015) analyzed a handover decision algorithm that was based on received signal strength and channel holding time. In their work, the UE connects to the femtocell when the mean signal power from the macrocell was less than the set threshold and the mean signal power from the femtocell was higher by a fixed hysteresis margin. Furthermore, connection to the femtocell was made when the time spent in the femtocell was greater than the holding time. This was done to obtain an increased rate of handover to the femtocell while also reducing the number of unnecessary handover. The major challenge of the work was the delay that could occur as a result of the algorithm, when applied in a highly mobile environment which would result in signaling overhead during the process of selecting the target base station and this could be a major limitation of the work.

Xenakis *et al.*, (2016) designed a novel handover decision algorithm which utilizes measurement from candidate cells to optimize two Handover Hysteresis Margins (HHMs). The first HHM is used to avoid cells that can compromise service continuity, while the second HHM is used to identify the cell with the minimum required UE transmit power. When the handover event is triggered, the serving cell acquires the maximum transmit power, the cell interference and the downlink RS transmit power for all candidate cells by using the private mechanism for non-standard use. The two adaptive HHMs are subsequently evaluated for all candidate cells and the subset of cells that sustain service continuity is identified. The cell that requires the minimum UE transmit power is subsequently selected and the handover execution phase is initiated. However, in using the candidate cell list as an input to the algorithm, there are delays associated with the handover decision since the list is not optimized.

Alhabo & Zhang (2017) proposed a handover decision algorithm that makes use of the actual distance between the UE and the SCs (small cells) and the UE angle of movement, for the purpose of creating a shortened candidate list which assisted in minimizing the energy resource that would have been dissipated in the process of scanning for the candidate cells (macrocell or small cells), thereby reducing the number of unnecessary HOs (Handovers) while increasing the network throughput of the system. By the introduction of the shortened SC list, the performance of the algorithm was improved upon, as the number of unnecessary HOs were avoided because less number of target SCs were selected and the cell with the highest SNR (Signal to Noise Ratio) was selected as a candidate HO target. However, the delay that could eventually arise from the scanning process could affect the performance of the HO process, especially in a scenario where the UE moves at varying speeds.

Khan *et al.*, (2017) presented a handover algorithm for hand-in procedure. In the work, a multi-step handover scheme was used for the purpose of reducing the number of unnecessary handover, while also selecting the appropriate femtocell access point (FAP) for the incoming UE. Three filtering phases were proposed to achieve it. The first of the filtering phases for the proposed scheme was to measure the power of the available candidate femtocells. The next phase was to filter out the femtocells which cannot support an unregistered UE. The final filtering phase was to determine whether the UE was registered in the closed subscriber group (CSG) or not. All three phases in the proposed scheme were set as input parameters to make the handover decision, for the purpose of minimizing unnecessary handover and improving the throughput of the UE. The proposed handover algorithm showed better performance than already existing hand-in algorithms. However the work did not consider the delays that could arise from having to check, select and measure for the available and target femtocell, which could lead to degradation of the UE’s QoS.

(Deswal & Singhrova, 2017) designed a handover decision algorithm for an integrated macrocell and femtocell network in which the macrocell network was overlayed by several femtocell networks using equivalent received signal strength (RSS_{eq}) and a dynamic hysteresis margin. In the proposed work, the RSS_{eq} was calculated by normalizing the unequal transmit powers of the femtocell and macrocell with respect to the distance of their respective base stations. The distance was to ensure that the UV (User Vehicle) performs handover to a femtocell whenever a femtocell was in the boundary of a macrocell as this guarantees successful packet delivery. The major problem of the work was that the changing speeds of the users were not considered as input parameters for deciding where and when to perform the handover, since both networks have dissimilar wireless access technologies. This could lead to degradation in quality of service. Also, no mobility prediction technique was used in order to accurately describe the user’s movement towards the target cell, which could have improved the results obtained.

From the literatures reviewed, degradation of the user’s quality of service caused by frequent handovers has been a major drawback in achieving a seamless handover process. This proposed work improved on the work of Deswal & Singhrova, (2017) where the scenario of the changing speed of the UV was not considered in deciding where and when to handover, as this could result in degradation in both QoS and QoE. A developed vertical handover decision algorithm (DVHA) that incorporates the changing speed of users into a proximity model is proposed in this paper.

3. Improved Algorithm: Dvha

This work proposes a new approach for minimizing packet losses in LTE networks. To address the issue of packet losses especially as the users speed changes, a mobility prediction technique that considers the changing speed of the user is presented. The following steps were used in the development of the DVHA.

1. For simulation purpose, an LTE macrocell-femtocell network architecture made up of one macrocell and 60 femtocells was used.
2. The Received Signal Strength (RSS) of macrocell and femtocell at all UV positions was obtained.
3. Random movement mobility model to model the movement pattern of the UV at varying speed was obtained.
4. Path loss between the UV and the FAPs was generated. The proximity prediction technique was used to mitigate the occurrence of packet losses during the handover process.
5. The conditions considered for the generation of the RSS for both the macrocell and femtocell are given as (Deswal & Singhrova, 2017):

   NCL = ($RSS_f \geq RSS_{fth}$) or ($RSS_{fe} \geq (RSS_m + \delta)$) and NCL = ($RSS_f \leq RSS_{fth}$) and ($RSS_m \geq (RSS_{fe} + \delta)$)

   Where: NCL= Neighbor Cell List

   RSS_f = Received Signal Strength of the femtocell

   RSS_{fth}= Received Signal Strength of the threshold femtocell

   RSS_{fe} = Equivalent Received Signal Strength

   RSS_m= Received Signal Strength of the macrocell

   δ = Hysteresis margin

6. The packet loss ratio is now calculated using equation 1(Deswal & Singhrova,

$$PLR = \frac{\left(\sum_{i=1}^{n} P_{r_i} - \sum_{i=1}^{n} P_{s_i}\right)}{\sum_{i=1}^{n} P_{s_i}} \qquad (1)$$

The equation used to describe the rate of handover during the packet delivery process is given as (Singh et al, 2005):

$$\lambda_H(h) = \frac{KD}{320}\left(1 - exp\left(-\frac{b}{h^a}\right)\right) \qquad (2)$$

The variables in the equation 2 are defined as follows:

K = adaptive parameter

D = base station separation

h = hysteresis margin

a = ratio of the path loss exponent (γ) to the standard deviation (σ) b = ratio of the correlation distance (d_o) to the averaging distance (d_{av})

The total link availability of the Proximity model is given as (McDonald & Znati, 1999). thus:

$$A^T_{m,n}(t) = [A^i_{m,n}(t)]S_{uv} \qquad (3)$$

The variables in the equation 3 are defined as follows:

$A^T_{m,n}(t)$ = Total link availability between two nodes m and n

$A^i_{m,n}(t)$ = Link availability when the mobility is random

S_{uv} = Speed of the user vehicle

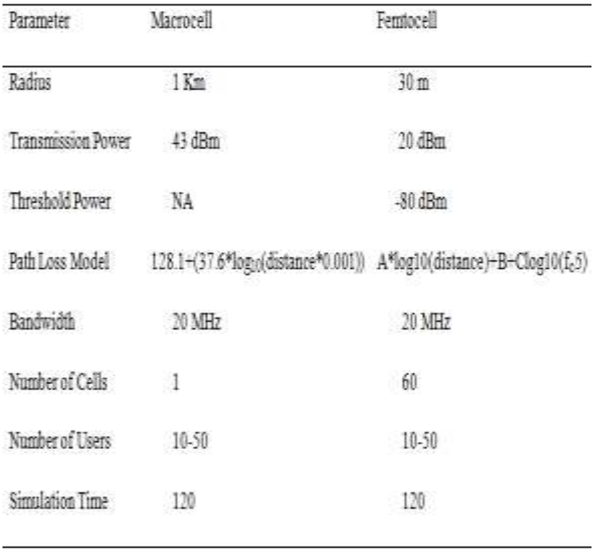
m = node of the UV

n = node of the target femtocell or macrocell

4. Simulation Environment

MATLAB R2015b version was used in the simulation of this work. MATLAB R2015b was used to compare the performance of the Improved Vertical Handover Algorithm (IVHA) and the Existing Vertical Handover Algorithm (EVHA). The simulation parameters used in this work is as shown in table 1

Table 1: Simulation Parameters



Parameter	Macrocell	Femtocell
Radius	1 Km	30 m
Transmission Power	43 dBm	20 dBm
Threshold Power	NA	-80 dBm
Path Loss Model	128.1+(37.6*$\log_{10}$(distance*0.001))	A*log10(distance)+B+Clog10(f$_c$5)
Bandwidth	20 MHz	20 MHz
Number of Cells	1	60
Number of Users	10-50	10-50
Simulation Time	120	120

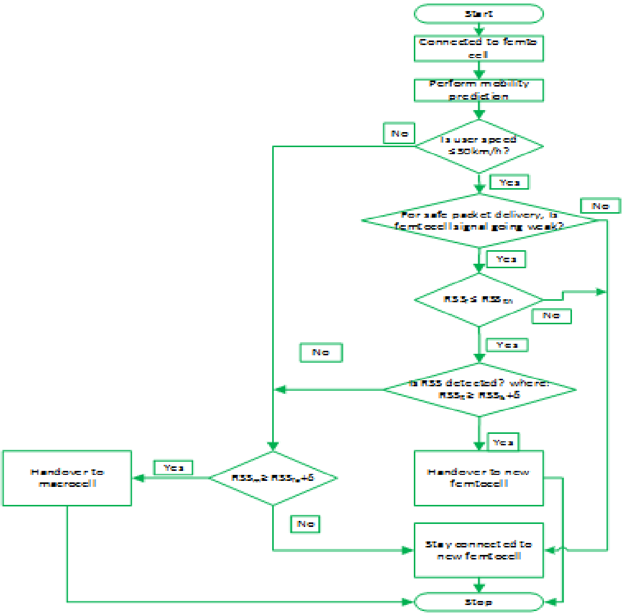


fig 2: Flowchart of the Ivha when the users were connected to Femtocell.

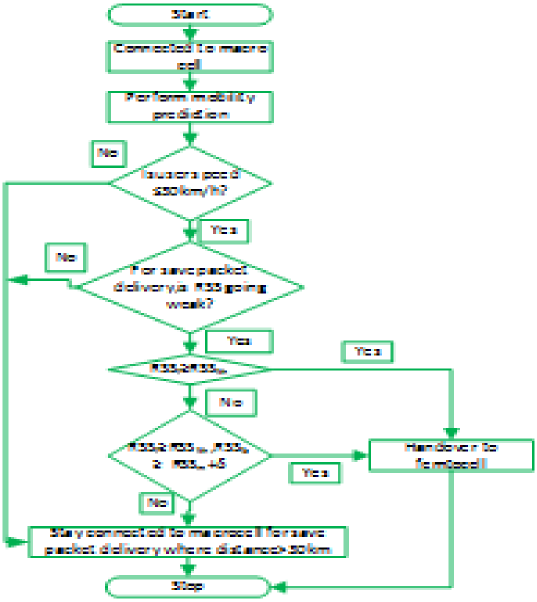


Figure 3: Flowchart of the DVHA when the users were connected to Macrocell

5. Results and Discussion

Figure 4 shows the result of the performance of EVHA and DVHA. The packet loss ratio is calculated using equation 1. The packet loss was simulated for both low and high speed users ranging from 30-120kmph. A Markovian model for random motion was used for the network simulation. From the plot, it can be observed that the developed vertical handover scheme displayed less packet loss ratio count when compared to the existing vertical handover scheme. This was achieved as a result of the effect of the mobility prediction scheme deployed, as well as the dwell time that was incorporated. Furthermore, the fluctuations as evident in the plot are due to the varying speed of the users as they move towards either the femtocell or macrocell.

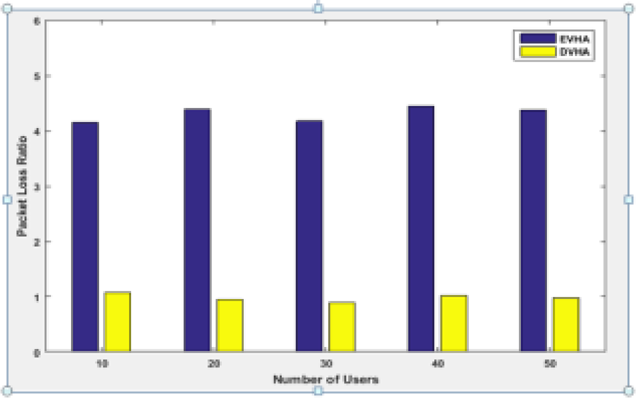


Fig 4: Plot of Packet Loss Ratio to number of Users

6. Conclusion

This paper presents the development of a new approach for the minimization of packet losses in LTE networks. After simulation, the performance of the DVHA was shown to perform better than the EVHA. The DVHA achieved this by using a PM prediction technique that incorporates the changing speed of the UV. The DVHA reduced the packet loss ratio by 77.07% with respect to the number of users over the EVHA.

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