QUALITY OF SERVICE PROVISIONING USING MULTICRITERIA HANDOVER STRATEGY IN OVERLAID NETWORKS

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ABSTRACT

The poor coverage problem inside the buildings and the existence of disparate wireless technologies have led to the development of integrated macro femtocellular networks. Correct and efficient vertical handover decision is of utmost importance in such integrated macro femtocellular networks. Initially, Received Signal Strength (RSS) used to be the sole criterion for taking a decision for vertical handover. Such decision leads to inaccurate results and therefore unnecessary handovers. In this paper, a multicriteria vertical handover strategy based on received signal strength, user velocity, number of users in a cell and data rate of the cell is proposed. This proposed strategy and the traditional algorithm are simulated and the results are analyzed quantitatively for different QoS parameters namely ping pong rate, packet loss ratio, throughput, packet delay, jitter and signalling cost. The results show significant improvement in the QoS parameters when the proposed strategy is used as compared to traditional algorithm.

Keywords: Macrocells, Femtocells, Handovers, Packet loss ratio, Throughput, Jitter, Delay, Signalling cost

1.0 INTRODUCTION

The data traffic and consequently the communication networks are growing rapidly. With the exponential increase in the number of mobile users and fast growing data traffic, the cellular network providers are facing with the problem to accommodate all the mobile users and provide good Quality of Service (QoS) at the same time. These mobile users have different needs and requirements, which are difficult to be fulfilled by the present network capacity. The node density of macrocells needs to be increased to improve the network capacity [1]. Deploying more macrocell base stations (BS) in already dense deployment increases the interference to a great level. The low power BS can solve this problem to a great extent. A variety of networks are available today which can be integrated with the existing cellular network. One such alternative is femtocells, which have emerged out as a good solution to increase the coverage and to offload macrocells in the recent past. A femtocell is a low cost, low power device which operates in licensed spectrum, supports a very small number of users and can be easily plugged in by the user inside a building [2]. The femtocells provide improved coverage indoors, offload macrocell, provide enhanced QoS to user and significant savings in mobile phone’s battery. Mobility management has always been an important point of concern in such integrated macro femtocelluar networks. When a user leaves a network and comes within the range of another, it must be seamlessly handed over to the new network. This process is referred to as vertical handover. Whenever a user comes within the range of a femtocell, a vertical handover from macrocell to femtocell is performed. The vertical handover reduces the load on the macrocell and solves the poor coverage problem inside a building. However, the presence of large number of femtocells within a macrocell complicates the handover procedure as there are numerous options to choose from. In addition, it gives rise to increase in number of unnecessary handovers as large number of femtocells lead to handover trigger even before one handover is complete.

To mitigate the above mentioned effects of deploying a large number of femtocells, the decision to perform handover should be such that it improves the overall utilization of resources at one hand and reduces the unnecessary handovers at the same time. This paper presents a vertical handover algorithm based on multiple criteria namely, Received Signal Strength (RSS), user velocity, number of users in a cell and cell data rate. The proposed algorithm takes into account all the three types of handovers i.e. macrocell to femtocell, femtocell to femtocell and femtocell to macrocell. The handover function is evaluated depending upon the weights assigned to each parameter based on its importance in handover decision. The use of multiple criteria for handover decision ensures reduction in unnecessary handovers. The proposed strategy outperforms the traditional strategy on various QoS parameters namely packet loss ratio, throughput, ping pong rate, packet delay, jitter and signalling cost. The improvement in the QoS parameters validates the fact that the proposed handover strategy improves the call quality and provides better coverage for medium as well as high velocity users.

The remaining part of the paper is structured as follows: Section 2 presents the work related to handover algorithms in integrated macro femtocellular networks. Section 3 explains the details of the proposed handover algorithm. The results are presented in section 4 and detailed analysis of the results in terms of QoS parameters is discussed in section 5. Finally, Section 6 gives the conclusion of the work.

2.0 RELATED WORK

The vertical handover problem in integrated macro femtocellular networks has gained the interests of various researchers in the past few years. This section presents a study of the various vertical handover algorithms proposed in integrated macro femtocellular networks. A classification of vertical handover techniques has been presented in [3] where the schemes are classified on the basis of decision parameters and techniques employed for handover. The classifications are namely: (i) RSS based Schemes; (ii) QoS based Schemes; (iii) Decision Function based Schemes; (iv) Network Intelligence based Schemes; and (v) Context based Schemes. In [4], the schemes are based on: (i) Received Signal Strength (RSS); (ii) Speed; (iii) Interference aware; (iv) Cost function; and (v) Energy efficient. RSS based algorithm is the traditional algorithm which uses RSS for performing handover. A handover margin is further added to optimize the results [5][6]. The RSS based handover is the least complex method but does not provide accuracy and optimized results. The handover solution for LTE cellular system proposed in [7] considers RSS and available bandwidth for the selection of destination cell. The solution improves the handover success rate but does not consider velocity of the users. The high velocity users tend to have many unnecessary handovers. The handover algorithm given in [8] is based on the mobility prediction of the user and is an enhancement to the traditional algorithm. The mobility prediction method predicts the position where the user is heading and then selects the suitable target femtocell. However, the results show a linear increase in the number of handovers as the number of femtocells increased. The issue of energy saving in 5G heterogeneous networks has been discussed in [9]. A study by [10] proposes an energy centric handover decision policy which reduces the power consumption of mobile terminal but leads to a moderate increase in the number of handovers. Another study by [11] presents a handover strategy based on speed and application type of the user. A high speed user using a real time application is not allowed to handover to femtocell while a handover is allowed for slow moving user using a non real time application. This helps to reduce the unnecessary handovers and is suitable for high speed users. A context aware handover decision algorithm is proposed in [12] which use multiple criteria for handover and takes intelligent handover decision to obtain multiple objective outcome of maximizing bandwidth, low power consumption and low bit error rate. However, the scenario considered in [12] consists of a single macrocell and single femtocell and it fails to provide the simulation results. In the current scenario, multiple femtocells are deployed in a single macrocell. Using multicriteria method for handover decision provides a quantitative and efficient calculation for choosing among several candidates. The multicriteria methods of Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Multiplicative Exponent Weighting (MEW), Grey Relational Analysis (GRA) and Analytic Hierarchy Process (AHP) are discussed in [13]. A comparison of mobile priority, network priority and equal priority multicriteria vertical handover techniques has been done in [14]. The parameters used in the technique are RSS, network occupancy, traffic class and speed of the mobile. A multicriteria handover technique presented in [15] has shown to work better than the traditional algorithm using single criteria in terms of blocking probability, load balance index and reduced number of handovers in heterogeneous wireless networks.

3.0 PROPOSED ALGORITHM

In this section, the traditional RSS based handover algorithm and the proposed algorithm are discussed.

3.1 Traditional Algorithm for Handover Decision

The traditional algorithm as given in [5], considers the received signal strength of candidate cells for handover. Whenever the RSS from the source cell falls below a threshold value and the RSS from the target cell is greater than the source, the mobile device is handed over to the target cell. Additionally, handover margin is added to reduce the unnecessary handovers. The handover decision is evaluated for each of the candidate base station as shown in equation (1):

$$(RSS_s < RSS_{ths})\ and\ (RSS_t > (RSS_s + \delta)) \quad (1)$$

where RSS_s, RSS_t, RSS_{ths} are the received signal strengths of source, target and source threshold respectively and δ is the handover margin.

The base station with RSS value higher than the source base station by certain handover margin is chosen. The δ value is fixed here. The algorithm leads to more number of handovers if δ is small because even though the RSS from the target is higher by a small amount, the handover is performed. This causes the deterioration in RSS after a short interval and again a target cell is searched for handover leading to ping pong effect. A large value of δ can reduce the number of unnecessary handovers but would lead to packets being lost.

3.2 Proposed Algorithm for Handover Decision

Current and future generation heterogeneous networks require more optimized and dynamic approach for handover decision. The traditional scheme does not provide an optimized solution for such heterogeneous networks. For example, in an integrated macro femtocellular network, a fast moving user should be connected to macrocell while a slow user should be preferably connected to femtocell. The high velocity leads to frequent handovers and consequently disconnection of services and packet loss [16]. On the other hand, triggering handover to a femtocell which already has sufficient number of users would result in unnecessary handovers. Moreover, considering a fixed value of handover margin is not justified for all users as users near to the source base station need a greater handover margin as compared to the users who are far away from the source base station. Therefore, a handover algorithm which considers more than one criterion for handover decision and calculates dynamic handover margin would provide an efficient solution in such types of networks.

The proposed decision function algorithm overcomes the above mentioned limitations of traditional algorithm by:

a) Considering four parameters namely RSS, User Velocity (V), Number of users (U) and Cell data rate (DR) to calculate the value of decision function.
b) Calculating a function based on above mentioned parameters.
c) Considering a dynamic value of handover margin.

3.2.1 Input Parameters

To provide an efficient solution both from network and user point of view, a combination of network and user parameters is chosen. The input parameters are as shown in Table 1.

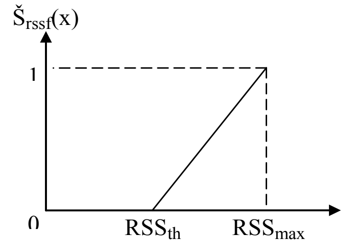
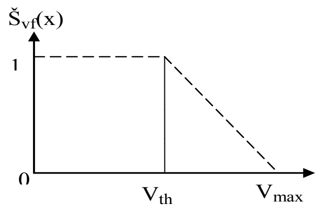
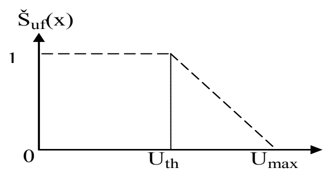
Table 1 : Input Parameters

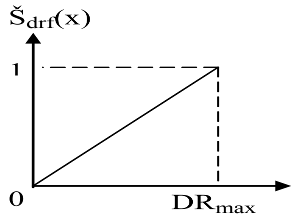
S.No.	Input Parameter	Short Term	Remarks
1.	Received Signal Strength	RSS	This is the signal strength received by the user from the femtocell. The user measures the signal strength received from the Femto BS to initiate handover.
2.	User Velocity	V	This is the velocity with which the user is moving. For slow moving vehicles, femtocell is preferred while macrocell is preferred for fast moving vehicles due to large coverage area.
3.	Users	U	This is the number of users connected to a femto BS. A limited number of users can be connected to femto BS, as the number of users increases, the resources available with femto BS decrease and consequently the probability of connecting new users to femto BS also decreases.
4.	Data Rate	DR	This is the data rate offered by a femto BS. It takes care of interference in the network. More interference lowers the data rate and thus discourages a user to get connected to femto BS.

3.2.2 Scaled Input Parameters for Vertical Handover Algorithm

This section explains the calculation of scaled value and weight factor of the four parameters considered for handover decision. Table 2 shows the method for calculating scaled value for input parameters and their graphical representation. The scaled value of input parameters received signal strength, user velocity, number of users and data rate are symbolized as $\check{S}_{rssf}$, $\check{S}_{vf}$, $\check{S}_{uf}$ and $\check{S}_{drf}$ respectively. The scaled value of input parameters ranges between 0 and 1.

Table 2 : Scaled Value of Input Parameters

Input Parameter	**Scaled Value of IP**	**Graphical Representation**
Received Signal Strength (RSS)	$\check{S}_{rssf} = \begin{cases} 0 & RSS_x < RSS_{th} \\ \frac{RSS_x - RSS_{th}}{RSS_{max} - RSS_{th}} & RSSx \geq RSS_{th} \end{cases}$ RSS_{max} - the maximum power received from a femto BS The value of RSS_{max} is chosen to be -75 dBm, which is calculated at the nearest distance in line of sight environment from the femtocell.	 As the value of received signal strength from the base station goes above the threshold value and goes towards *RSS_{max}*, the contribution of RSS to the handover decision function value increases.
User Velocity (V)	$\check{S}_{vf} = \begin{cases} 1 & V_x \leq \\ 1 - \frac{V_x}{V_{max}} & V_{th} < V_x < V_{max} \\ 0 & V_x \geq V_{max} \end{cases}$ V_x - the velocity of the user V_{th} - the threshold value of velocity of user in femtocell V_{max} - the maximum velocity of the user V_{th} is chosen as 30 kmph because femtocells support slow moving users. The value of V_{max} is chosen as 150 kmph to signify high velocity vehicles.	 When a user moves below the threshold velocity, it has high probability of being connected to femtocell and thus scaled function is assigned value 1. As the velocity increases and reaches towards maximum, the contribution of velocity in making handover decision to connect to femtocell goes on decreasing because high velocity vehicles should be connected to macrocell.
Users (U)	$\check{S}_{uf} = \begin{cases} 1 & U_x \leq U_{th} \\ 1 - \frac{U_x}{U_{th}} & U_{th} < U_x \leq U_{max} \\ 0 & U_{max} > 0 \end{cases}$ U_x - the number of users currently present in the target cell U_{th} is the threshold value for a user in a femtocell U_{max} - the maximum number of users in a	 A very less number of users can be connected to femtocells [17]. When $U_x \leq U_{th}$, a new user is more likely to get connected to femtocell. As the number of users in a femtocell

	femtocell. The value of U_{max} is chosen as 8 [17] and the value of U_{th} is 4. This is because the interference increases as the number of users increase.	approaches to maximum, the handover decision criterion does not consider it as the candidate cell for handover.
Data Rate (DR)	$\check{S}_{drf} = \frac{DR_x}{DR_{max}}$ $\check{S}_{drf}$ - the scaled value of data rate DR_{max} is the maximum data rate provided by femtocell. DR_x - the current data rate provided by femtocell and is calculated using the Shannon capacity formula [18] given by $DR_x = Bandwidth * log_2 * (1+SINR)$ where SINR is the Signal to Interference Noise Ratio. The value of DR_{max} is chosen as 3 Mbps. The value is derived by taking an average of downlink speeds in the network after running a speed test for 10 times at different locations.	 The data rate of candidate cells is calculated to determine if enough capacity is available in the target cell to support the additional user. When a femtocell gives higher data rate, the user is more likely to get connected to this femtocell. As DR_x approaches towards DR_{max} the contribution of this parameter in making handover decision goes on increasing.

3.2.3 Dynamic Handover Margin

The dynamic handover margin is based on the distance of mobile device from the source base station. A device which is very far from the base station receives very weak signal strength. Therefore it needs a very small margin to perform handover to a neighboring base station. This would help to achieve good packet delivery ratio. On the other hand, a close by device should need a high handover margin since it is already getting good signal strength from the current base station. This would reduce the unnecessary handovers.

The margin, δ given in [19] is calculated as shown in equation (2):

$$\delta = \max\left\{\delta_{max}\left\{1 - \left(\frac{Distance}{Radius}\right)^4\right\}, 0\right\} \quad (2)$$

where Radius is the radius of current cell and Distance is the distance between mobile device and base station to which mobile device is currently connected. δ_{max} is the maximum value of handover margin, which is calculated by taking the difference between power received at the boundary of a cell and at a position closest to the base station.

3.2.4 Weight Vector of the candidate Base Stations

Analytic Hierarchy process (AHP) is used to calculate the value of decision function. The AHP process decomposes the network selection problem into a hierarchy of smaller problems, distinguishes the various criteria according to their priorities and helps to take a decision in an organized way [20][21]. It has good computational accuracy as it performs the pair wise comparisons of metrics using scales from 1 to 9 [22].

After determining the scaled values of each parameter, the weight factor of each parameter is calculated so that the f_{ho} for each femto BS can be achieved. The f_{ho} value decides whether handover to the candidate base station can be performed or not. The weight factor is calculated using the Analytic Hierarchy Process (AHP) method. According to AHP, the parameters are ranked from 1 to 9 based on their importance in the network. Table 3 shows the comparison of various parameters and the reasons for their ranking.

Table 3 : Pairwise judgement matrix of parameters for Macrocell

Pairwise Judgement		Remarks
RSS	Velocity	RSS is the most important factor as it is the primary condition for handover and if the required signal is not available, other parameters hold little value. Therefore, RSS is given the top most priority followed by velocity, users and data rate.
	Users	
	Data Rate	
Velocity	User	To offload macrocell, slow users are the best option to connect to femtocell. Therefore, velocity is given higher rank as compared to number of users and data rate.
	Data Rate	
User	Data Rate	As only a limited number of users can be connected to femtocell, the number of users gets higher rank as compared to data rate.

Table 4 depicts the weight matrix for the femtocell. It shows the ranking of various parameters taken in this paper. The four parameters RSS, Velocity, Number of Users and Data Rate are ranked as 1,2,3,4 in order of their importance of being a valuable parameter for taking handover decision.

Table 4 : Weight Matrix of parameters for Femtocell

Femtocell	RSS	Velocity	Users	Data Rate
RSS	1	2	5	7
Velocity	1/2	1	3	5
Users	1/5	1/3	1	3
Data Rate	1/7	1/5	1/3	1

Weight Factor, W_i is calculated by dividing the fourth root of unity of the values in each row by their addition.

Table 5 : Weight Factor Calculation

Parameters	Fourth roots to Unity of weight vector	Weight Factor (W_i)
RSS	2.89250	0.523198
Velocity	1.65487	0.299334
Users	0.66874	0.120963
Data Rate	0.31239	0.056505
Total	5.52850	1.000000

With these weight factor values, the input parameters are assigned discrete values according to the priority of each input parameter and their sum always equals to one. The weight matrix helps to calculate the weight factor, W_i of each parameter as shown in Table 5.

3.2.5 Handover Function

To determine a base station to handover is performed, handover function, f_{ho} is calculated for all the candidate base stations. A handover to a base station is performed if the handover function value for that base station is greater than 0.5. It is calculated by multiplying the weight of the parameter as determined in Table 5 and the scaled value of the parameter which is dependent on the corresponding base station as determined in Table 2.

For any base station k, the handover function value, f_{ho} is calculated as shown in equation (3):

$$f_{\text{ho}} = \sum_{i=1}^{n} w_i * \check{S}_i \quad (3)$$

where w_i is the weight of the parameter and $\check{S}_i$ is the scaled value of the parameter in the corresponding base station.

3.2.6 Vertical Handover Decision Algorithm

This section presents handover strategy which makes use of multicriteria technique to take handover decision. The strategy is composed of two tiers. At the first tier, it prepares a list of all neighboring candidate cells which have RSS more than the RSS from the current base station by a certain margin. At the next level, the handover function f_{ho} based on RSS, V, U and DR is determined for all the candidate cells short listed in the first level. The value of these parameters is scaled depending on the threshold value for the parameter within a femtocell. The reason for the handover decision to be dependent on two tiers is to reduce the overall complexity of algorithm and to save time consumed to take the decision. The measurement of handover parameters from a large number of neighboring candidate cells is a time consuming process, makes the decision process complex and eventually leads to battery drain. Therefore, the list of candidate cells is reduced at first hand by comparing the RSS.

Two possible situations during the movement of user within a network are explained in Fig. 1. As can be seen in Fig. 1, in both cases the preference is always given to the femtocell for connection. This is done to offload macrocell whenever possible. Moreover, when a user is connected to femto BS and its received signal strength diminishes beyond threshold value and no other suitable femtocell is found; it is handed over to macrocell. This is due to the fact that macrocells are overlaid with femtocells and macrocell coverage is available in the region of femtocells also.

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Pseudocode for the proposed Decision function Handover algorithm

i = current station & j = target station
Case 1 : User is connected initially to Macro BS:
From all the i femto BSs
    Find a femto BS such that (RSS_i ≥ RSS_thf ) and (RSS_i > (RSS_m + δ))
    Add femto BS to list_i of candidate cells
    From list_i find a femto BS j such that
        f_hoj ≥ 0.5
    if such a femto BS,j found then
        Handover to j
    else
        remain connected to macro BS
    endif
Case 2 : User is initially connected to femto BS:
if RSS_i < RSS_thf
{
    from all the remaining k femto BSs
    find a femto BS such that (RSS_k ≥ RSS_thf ) and (RSS_k > (RSS_i + δ))
    add femto BS to list_i of candidate cells
    from list_i find a femto BS j such that
        f_hoj ≥ 0.5
    if such a femto BS,j found then
        Handover to j
    else
        Handover to macro BS
    endif
}
```

Fig. 1 : Pseudocode for the proposed algorithm

The algorithm works for all the scenarios for handover in an integrated macro femtocellular network i.e. (i) Macrocell to femtocell Handover, (ii) Femtocell to femtocell handover and (iii) Femtocell to macrocell Handover. Of all the three scenarios mentioned, (i) and (ii) require an efficient and correct decision to select a target cell as there are numerous options to choose from. The macrocell to macrocell handover is not considered in the paper as only one macrocell is considered keeping in view the coverage area of macrocell. The accurate decision at this stage would help to reduce unnecessary handovers and ping pong effect. The value of f_{ho} helps to choose the most appropriate femtocell which optimizes the results.

The possible cases for the handover are:
Case I : Mobile device is connected to macrocell. When a mobile device is connected to macrocell, it continuously monitors the RSS from femtocells. Whenever the RSS from a femtocell is greater than RSS_{thf} , a list of all such femtocells is created. When such a femtocell is found, the decision for handover is taken based on the handover function. The handover function, f_{ho} based on (7) is calculated for all such femtocells and a handover is performed to a femtocell if $f_{ho} \geq 0.5$. The mobile device remains connected to macrocell if no such femtocell is found.

Case II : Mobile device is connected to femtocell. When a mobile device is roaming in a femtocell coverage area which is overlaid by macrocell, the handover to macrocell or femtocell takes place when RSS falls below RSS_{thf}. The selection depends on handover decision function value where if RSS received from a nearby femtocell is greater than the threshold value RSS_{thf}. If no femtocell is found then mobile device is handed over to macrocell. The flowchart for the algorithm is shown in Fig. 2. Choosing the appropriate value of RSS_{thf} is very important here. A very low value for RSS_{thf} would result in frequent handovers, and performance loss whereas a high RSS_{thf} would force the mobile device to be in macrocell for most of the time, thus macrocell would not be offloaded.

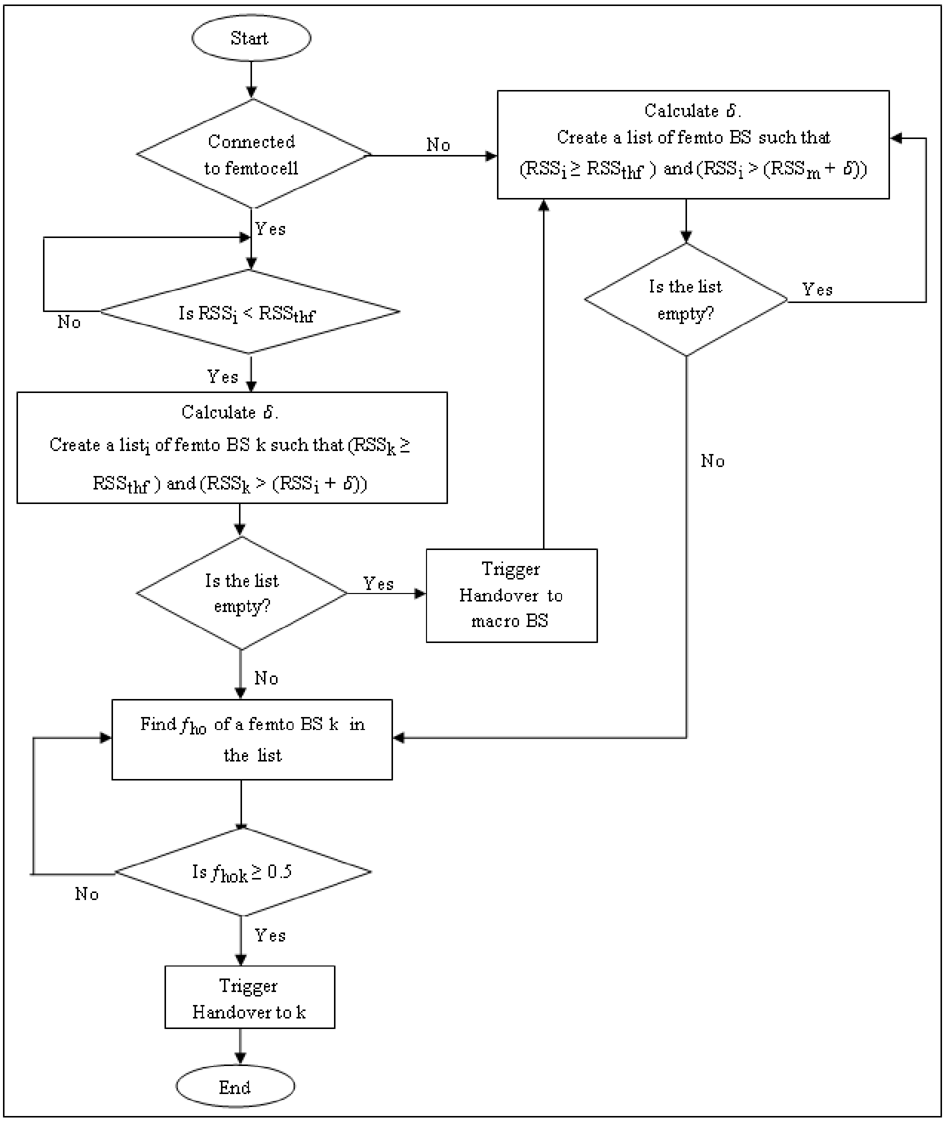


Fig. 2 : Flowchart of the proposed algorithm

4.0 RESULTS AND ANALYSIS

In the integrated macro femtocellular networks, the number of handovers from macro to femto and femto to femto increase as more femtocells are deployed within a macrocell because there are more possibilities to choose from due to vast deployment. In such a scenario, if handover decision is based on RSS only, frequent handovers will be performed. Many of these frequent handovers will be unnecessary which cause only overhead in the system consuming system resources and not contributing to useful work. Fig. 3 shows the total handovers for the three types of handovers when number of femtocells increase in a macrocell.

As shown in Fig. 3, the probability of a mobile device being handed over to femtocell keeps on increasing as more femtocells are deployed in the macrocell. A significant increase can be seen in femtocell to femtocell and macrocell to femtocell handovers. These large numbers of handovers should be reduced in such a way so that network performance can be preserved.

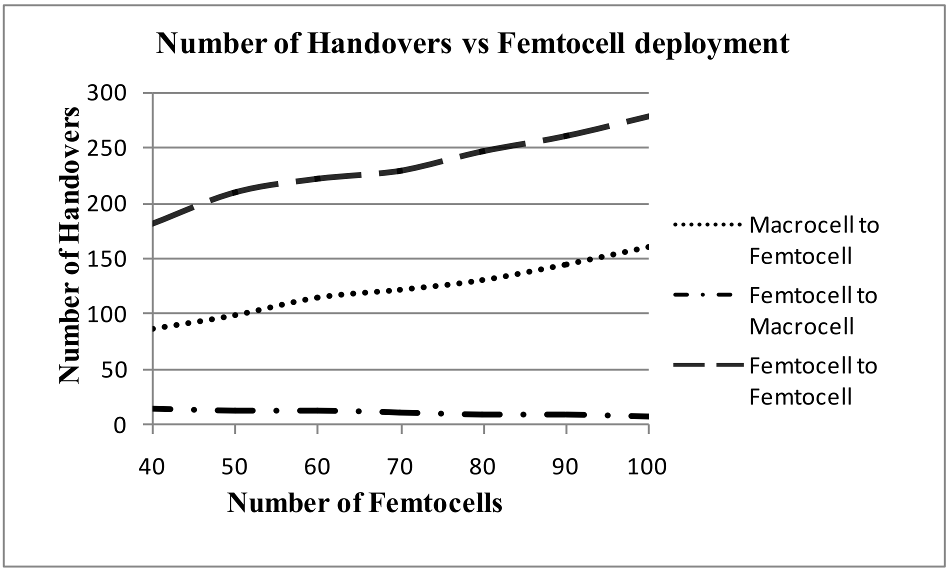


Fig. 3 : Handover Probability vs Femtocell deployment

The proposed algorithm with accurate handover decision manages the handovers properly without the loss of performance. The performance of the proposed algorithm was compared with the traditional RSS based handover algorithm. The handover decision is based on equation (1) in traditional algorithm and equation (3) in the proposed algorithm. Whenever a mobile device moves in an integrated network, the RSS is continuously monitored by the device.

4.1 Simulation Model

The proposed algorithm is implemented in LTE-Sim, an open source simulator [23]. It supports handover management, QoS management and single cell environment as well as multicell environment. The simulation scenario consists of one macrocell and 40 femtocells randomly deployed inside the macrocell. The users are randomly placed and are continuously moving in the network. The network topology for the overlaid simulation scenario is shown in Fig. 4.

The simulation is first run for the traditional algorithm by taking three different values of 2, 6 and 10 dBm for fixed handover margin for handover and later for proposed algorithm with a dynamic handover margin, δ. The simulation is carried out for both slow moving and fast moving vehicles. The simulation parameters are shown in Table 6. The comparison is made between traditional approach with different static values for handover margin and proposed algorithm with dynamic handover margin by varying the number of users and the velocity of the users for both.

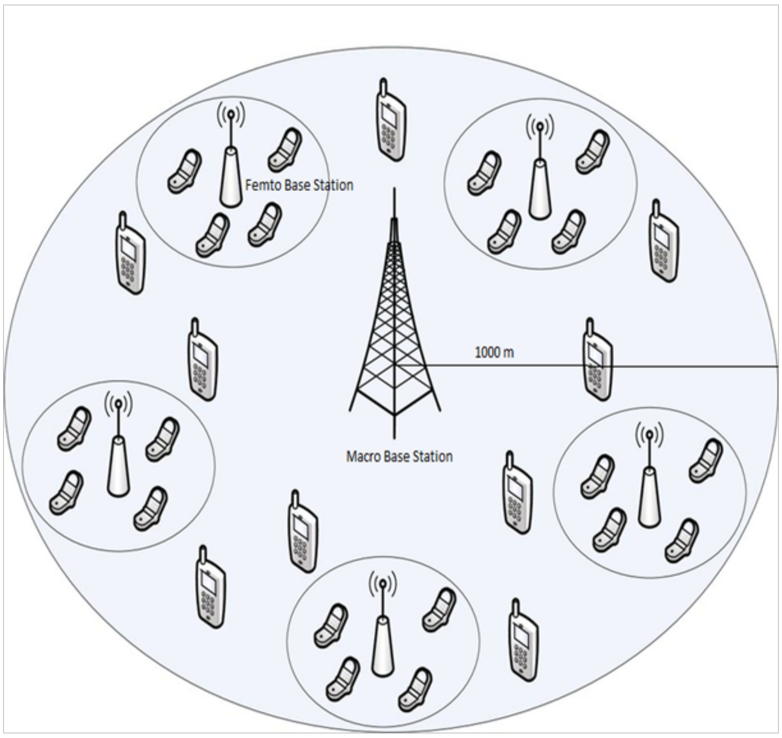


Fig. 4 : Network Topology for Macrocell and Femtocells

Table 6: Simulation Parameters

Parameter	Macrocell	Femtocell
Radius	1 Km	30 m
Transmission power	43 dBm	20 dBm
Threshold power	-110 dBm	-90 dBm
Path loss Model	128.1+(37.6*log10(distance*0.001))	20*log10(distance)+46.4+20log10(2/5)
Number of cells	1	40
Bandwidth	20 MHz	
Number of users	50-100	
Simulation time	180s	
Velocity of users	30kmph, 120kmph	
Handover Margin, δ for traditional algorithm	2, 6, 10 dBm	

4.2 Number of Handovers

The variation in number of handovers with increase in number of users at different velocities of 30 kmph and 120 kmph is shown in Fig. 5a and Fig. 5b. From the figures, we found that as the handover margin is increased, the number of handovers is reduced. Therefore, increasing handover margin reduces the unnecessary handovers. In the proposed algorithm, the dynamic handover margin is used. The handover margin is increased to maximum when the user is near to the base station and decreased to minimum when the user is near to the boundary. This helps to reduce the unnecessary handovers on one hand and reduced packet loss on the other hand. The proposed algorithm performs better for both the velocities. At a very high velocity, the mobile device suffers from frequent handovers and thus results in a degraded performance. The proposed algorithm shows a considerable decrease in unnecessary handovers.

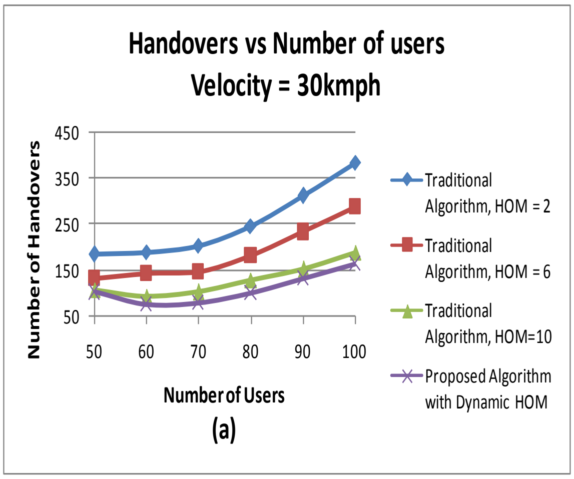


Fig. 5a : Number of Handovers vs Number of users at 30kmph

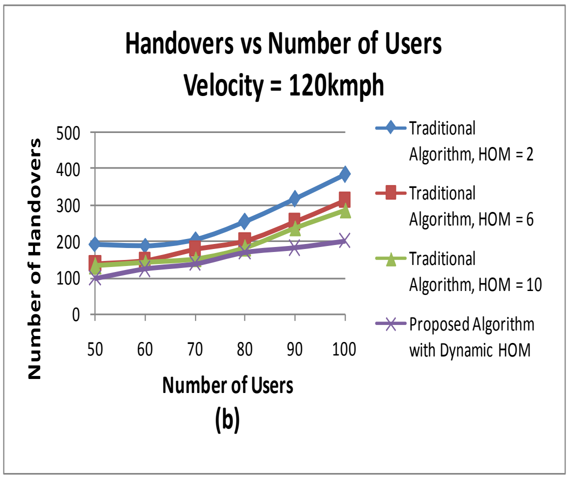


Fig. 5b : Number of Handovers vs Number of users at 120kmph

Considering Fig. 5a and Fig. 5b, the mean number of handovers per user is calculated as follows :

$$\textit{Mean Handovers per user } (\overline{HO}) = \textit{Total Handovers / Total users} \quad (4)$$

Table 7 shows the mean handovers per user for the different values of handover margin for traditional algorithm and the proposed algorithm.

Table 7 : Mean Handovers per user ($\overline{HO}$)

Velocity	Traditional Algorithm			Proposed Algorithm
	$\overline{HO}_{HOM=2}$	$\overline{HO}_{HOM=6}$	$\overline{HO}_{HOM=10}$	$\overline{HO}_{Proposed}$
At 30 kmph	3.386	2.51	1.728	1.477
At 120 kmph	3.431	2.748	2.524	2.035

The above values show that the mean number of handovers per user in the proposed algorithm is 56.37%, 41.15%, and 14.5% less than the traditional algorithm with a handover margin of 2, 6 and 10 dBm respectively at a velocity of 30 kmph. Similarly, mean number of handovers per user in the proposed algorithm is 40.68%, 25.94%, and 19.37% less than the traditional algorithm with a handover margin of 2, 6 and 10 dBm respectively at a velocity of 120 kmph. The number of handovers is decreased because handover decision is not based on RSS alone and multiple criteria are included to make a handover decision. It ensures that the mobile device handed over to a femto base station will be retained in the femtocell for a considerable time. The decrease in number of handovers shows that all the resources of network are efficiently utilized, therefore network efficiency is increased.

4.3 Packets Lost

The variation in packets lost with increase in number of users at different velocities of 30 kmph and 120 kmph is shown in Fig. 6a and Fig. 6b. The figures show that as the handover margin is increased the number of packets lost is reduced. In the proposed algorithm, the dynamic handover margin is used. As the handover margin is increased, more number of packets is lost during transmission. The reason for increase in the number of packets lost is that a mobile device is not getting enough signal strength from the current base station and is also not handed over to the new base station because of high value of handover margin. However, in the proposed algorithm, handover margin has a high value when the user is near to the base station and frequent handovers are not performed, thus reduce the packet loss. The proposed algorithm performs better for both the velocities. Considering Fig. 6a and Fig. 6b, the mean number of handovers per user is calculated as follow:

$$\text{Mean Packet loss per user } (\overline{PL}) = \text{Total Packets lost / Total users} \quad (5)$$

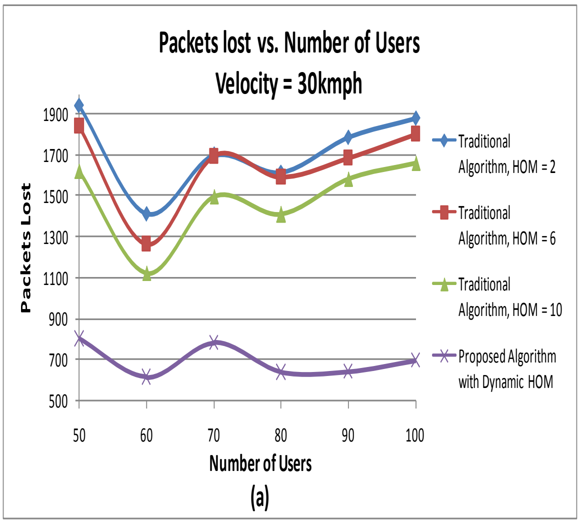


Fig. 6a : Number of Packets lost vs Number of users at 30kmph

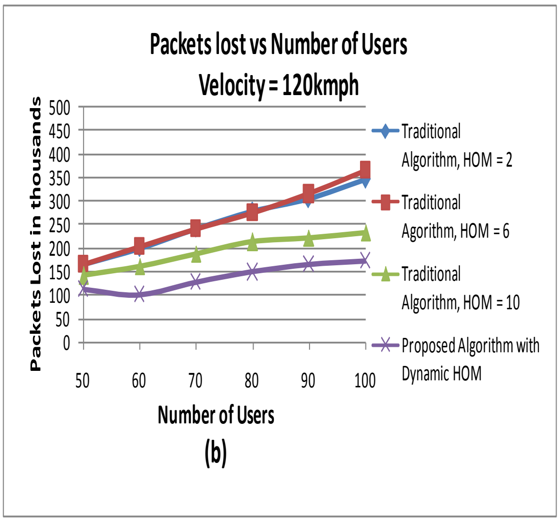


Fig. 6b : Number of Packets lost vs Number of users at 120kmph

The mean packets lost per user for different values of handover margin for traditional algorithm and the proposed algorithm is shown in Table 8.

Table 8 : Mean packets lost per user ($\overline{PL}$)

Velocity	Traditional Algorithm $\overline{PL}_{HOM=2}$	$\overline{PL}_{HOM=6}$	$\overline{PL}_{HOM=10}$	Proposed Algorithm $\overline{PL}_{Proposed}$
At 30 kmph	22.99	21.97	19.78	9.3
At 120 kmph	34.06	34.82	25.77	18.48

The above values show that the mean number of packets lost per user in the proposed algorithm are 59.54%, 57.66%, and 52.9% less than the traditional algorithm with a handover margin of 2, 6 and 10 dBm respectively at a velocity of 30 kmph. Similarly, mean number of handovers per user in the proposed algorithm are 45.74%, 46.92%, and 28.28% less than the traditional algorithm with a handover margin of 2, 6 and 10 dBm respectively at a velocity of 120 kmph.

5.0 QUALITY OF SERVICE

The results obtained from the simulations help to analyze some important factors in improving the Quality of Service (QoS) provided by the network. QoS is the capability of network operator to provide good service to user in terms of voice quality, minimum call blocking and dropping and good signal strength [24][25]. The various QoS parameters considered in this paper are categorized as shown in Fig. 7. The QoS parameters have been categorized as network related and end user related. The network related QoS parameters are Ping pong rate, throughput achieved by the network and signaling cost while end user related parameters are Packet Loss Ratio (PLR), Packet Delay and jitter.

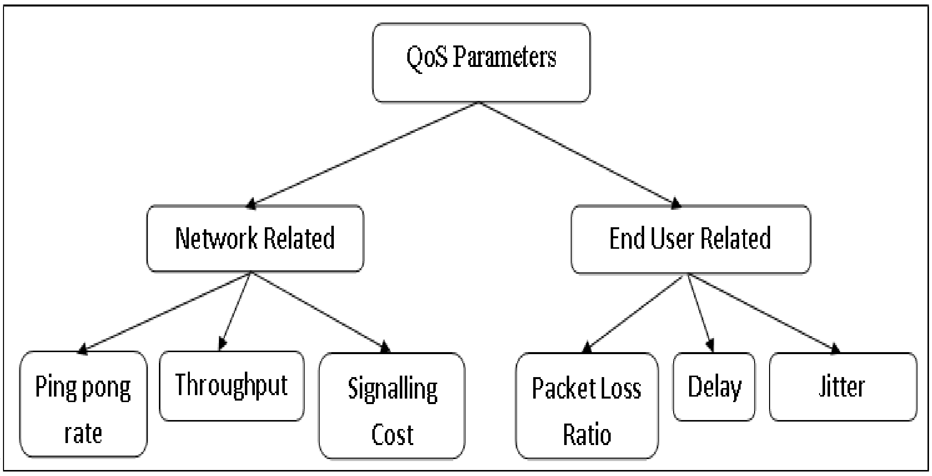


Fig. 7 : QoS parameters

This section explains the various QoS parameters and their analysis for the traditional and the proposed algorithm.

5.1 Ping pong Rate

Sometimes, a mobile device handed over to a base station is handed back to the original base station within a very short time interval. These types of handovers are called ping pong handovers. Such type of handovers should be avoided in a network because the to and fro movement of mobile device leads to inefficient utilization of resources and puts heavy handover processing load on the network. The ping pong rate is defined as the ratio of ping pong handovers to the total number of handovers [26] which can be represented as equation (6).

$$Ping\text{-}pong\ rate = N_{ping\text{-}pong\ HO} / N_{total} \tag{6}$$

where $N_{ping\text{-}pong\ HO}$ is the total ping pong handovers in the simulation and N_{total} is the total number of handovers.

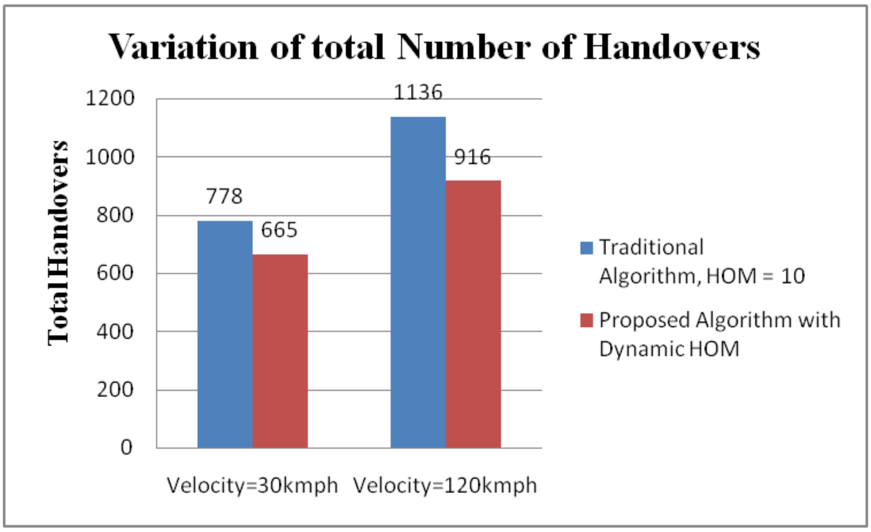


Fig. 8 : Total Handovers in traditional and Proposed algorithms

The total number of handovers is used to calculate the ping pong rate. Ping pong handovers are the unnecessary handovers which do not contribute towards the task being performed in the network. Since, the same task is performed by 665 handovers in the proposed algorithm for a velocity of 30 kmph, therefore 778-665=113 are the unnecessary or ping pong handovers for the traditional algorithm. Assuming that there is one ping pong handover in the proposed algorithm, the ping pong rate for each algorithm is calculated using equation (6) as shown in Table 9.

Table 9 : Ping pong rate

Velocity	**Traditional Algorithm**			**Proposed Algorithm**
	$Pingpong_{HOM=2}$	**$Pingpong_{HOM=6}$**	**$Pingpong_{HOM=10}$**	**$Pingpong_{Proposed}$**
30 kmph	0.5636	0.4130	0.1452	0.00150
120 kmph	0.5693	0.4624	0.4146	0.2740

To find the improvement in QoS, the handover quality indicator, HO_{qi}, is calculated using the following equation (7) [26]:

$$HO_{qi} = k * (1 - Ping\text{-}pong\text{-}rate) \quad (7)$$

where k is the proportionality constant dependent on calls dropped and blocked.

Using the above equation, the handover quality indicator, HO_{qi} for both algorithms is shown in Table 10.

Table 10 : Handover Quality Indicator

Velocity	Traditional Algorithm			Proposed Algorithm
	$Pingpong_{HOM=2}$	$Pingpong_{HOM=6}$	$Pingpong_{HOM=10}$	$Pingpong_{Proposed}$
30 kmph	0.4364k	0.587k	0.8548k	0.9985k
120 kmph	0.4307k	0.5376k	0.8064k	0.9989k

The reduction in ping pong rate improves the QoS provided to user. The reduction in ping pong rate is due to multiple criterions involved to take handover decision. The multiple parameters involved in the decision ensure that the connection after the handover would be stable for a sufficient period of time.

5.2 Throughput

Throughput (Th) is defined as the total number of bits transferred over a network per second. The total number of packets received at the destination helps to calculate the throughput of the network. It is a positive indicator for QoS provided by the network. Throughput is calculated using equation (8) as follows:

$$\text{Throughput (Th)} = \left(\left(\sum_{i=1}^{n} P_i * S_i\right) * 8\right) / T_s \quad (8)$$

where P_i and S_i is the number and size of each packet in bytes and T_s is the simulation time.

As shown in Fig. 9a and Fig. 9b, the network throughput increases when the proposed algorithm is used. The increase is visible at the velocity of 30 kmph but is significant at 120 kmph. The reason is that velocity is taken as a criterion for deciding whether handover is to be performed or not.

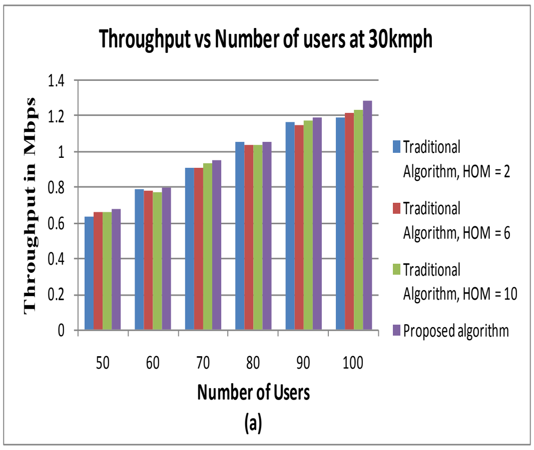


Fig. 9a : Network throughput against number of users at 30 kmph

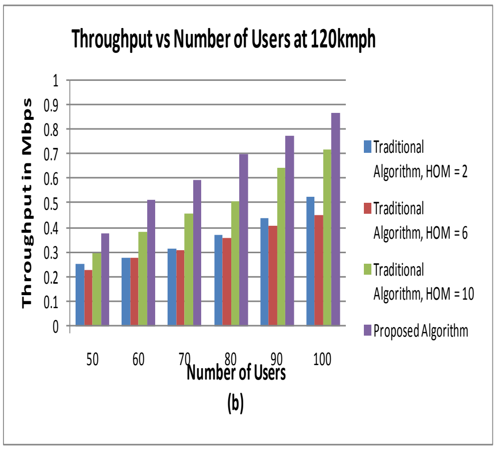


Fig. 9b : Network throughput against number of users at 120 kmph

The percentage gain in the overall throughput is calculated by finding the mean throughput. The network throughput for both the algorithms is shown in Table 11.

Table 11 : Throughput in Mbps

	Traditional Algorithm			**Proposed Algorithm**
Velocity	**$Th_{HOM=2}$**	**$Th_{HOM=6}$**	**$Th_{HOM=10}$**	**$Th_{Proposed}$**
30 kmph	0.95865	0.96029	0.96957	0.99525
120 kmph	0.36612	0.34027	0.50455	0.64010

The table indicates that using the same simulation time, more number of bits are transferred over the network in the proposed algorithm than in the traditional algorithm.

5.3 Signalling Cost

Signalling cost of a handover in a network depends on the number of messages exchanged between the source and target base stations during the handover process. The handovers in overlaid macro femtocellular networks as explained in sub section 3.2.6 are categorized as inter cell and intra cell handover as shown in Fig. 10a and Fig. 10b. Inter cell handover is the handover from macrocell to femtocell or from femtocell to macrocell where the request for handover is processed by the core network. Intra cell handover is the handover from femtocell to femtocell where the core network is only informed about the handover of device to target femtocell. Equation (9) is used to calculate the signalling cost, $Cost_{Signalling}$:

$$\mathrm{Cost}_{\mathrm{Signalling}} = \sum_{I=1}^{3} HO_i * S_i \quad (9)$$

where HO_i is the number of handovers of each type i.e. macro BS to femto BS, femto BS to macro BS and femto BS to femto BS. S_i is the signalling cost of each handover in dB and is calculated using the following equation:

$$S_i = 10\log\left(\frac{S_n}{S_{min}}\right) \quad (10)$$

where S_n is the number of messages in the current handover obtained from Fig. 10a and Fig. 10b. S_{min} is the number of minimum messages required for a handover. In this case the number of messages in intra handover is considered as S_{min}.

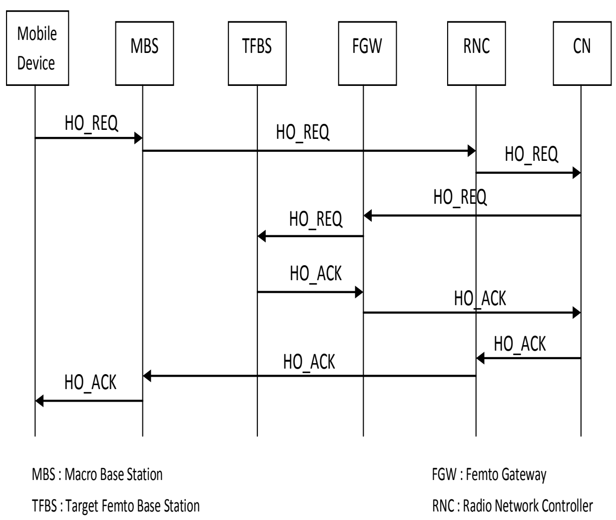
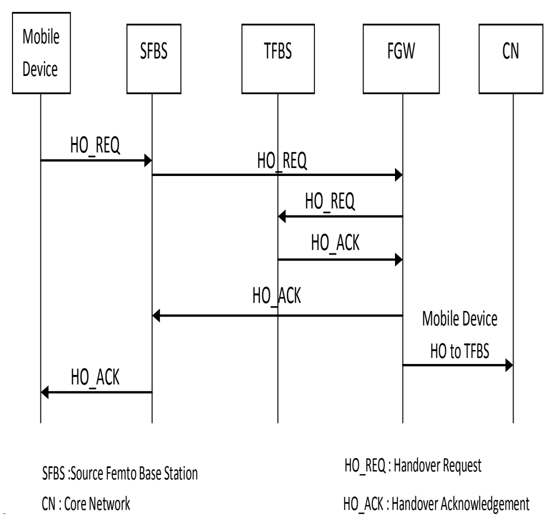


Fig. 10a : Handover triggering procedure for inter cell handover



cell handover

Considering the handover triggering procedure shown in Fig. 10a and Fig. 10b and equations (9) and (10), the signalling cost is evaluated and is shown in Table 12.

Table 12 : Signalling Cost Evaluation

Handover Type	Signalling Messages, S_n	Signalling Cost in dB, S_i
femto to femto (intra handover)	6	0
femto to macro (inter handover)	10	2.218
macro to femto (inter handover)	10	2.218

The Signalling cost calculated according to equation (10) is plotted against the number of users in Fig. 11a and Fig. 11b for the velocities of 30 kmph and 120 kmph.

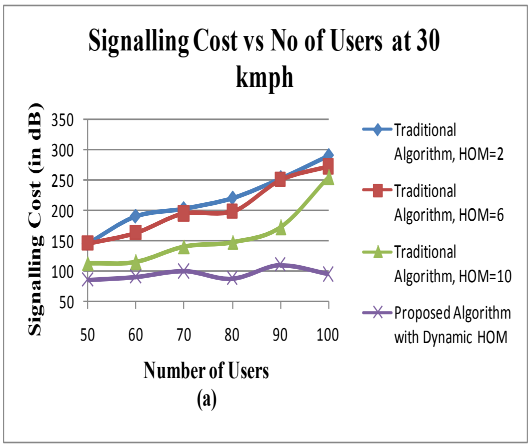


Fig. 11a : Signalling Cost vs Number of users at 30kmph

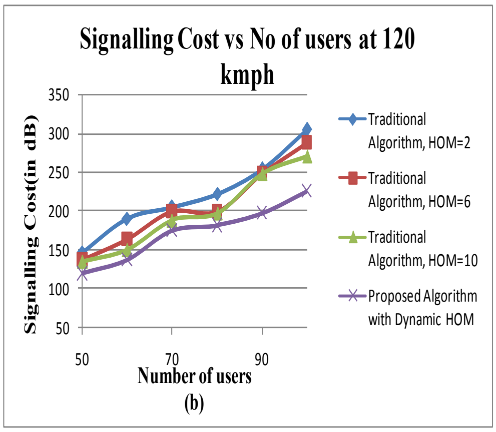


Fig. 11b : Signalling Cost vs Number of users at 120kmph

As shown in Fig. 11a and Fig. 11b, the signalling cost is less in the proposed algorithm than the traditional algorithm for both the values of velocities. The reduction in the signalling cost is because of the fact that it is dependent on the number of handovers as shown in equation (9).

The mean signalling cost per user for traditional algorithm and proposed algorithm is evaluated and is shown in Table 13.

Table 13 : Mean Signalling Cost in dB

Velocity	Traditional Algorithm			Proposed Algorithm
	$Cost_{Signalling\ HOM=2}$	$Cost_{Signalling\ HOM=6}$	$Cost_{Signalling\ HOM=10}$	$Cost_{Signalling\ \mathbf{Proposed}}$
30 kmph	2.903	2.730	2.104	1.271
120 kmph	2.932	2.750	2.646	2.306

The mean signalling cost per user is less in the proposed algorithm than the traditional algorithm. This shows that the signalling overhead is not increasing with the increase in number of users.

5.4 Packet Loss Ratio

When a packet travels from source to destination, it may be lost on its way due to congestion in the network. Packet Loss Ratio (PLR) is an estimation of total packets lost in the network. It is ratio of packets lost to the total packets sent. A low value of PLR indicates that fewer packets were lost on the way to destination in network and thus is an indicator that the user is provided with good QoS.

PLR should always be minimized. It is calculated as given in equation (11):

$$PLR = (TX - RX)/\,TX \qquad (11)$$

where TX is the total number of packets sent and RX is the total number of packets received.

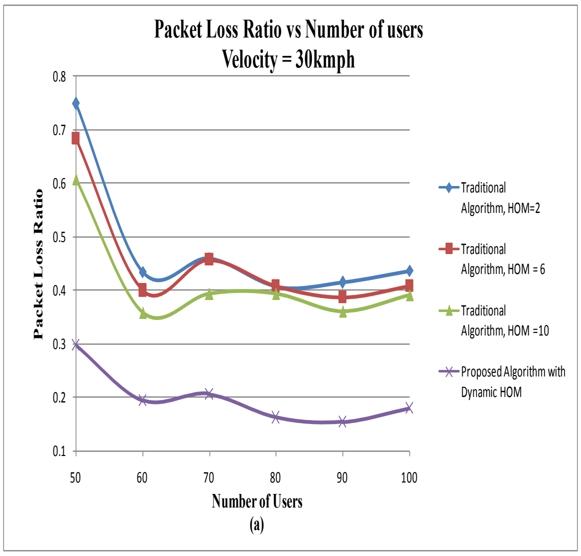


Fig. 12a : Packet Loss Ratio vs Number of users for Velocity of 30 kmph

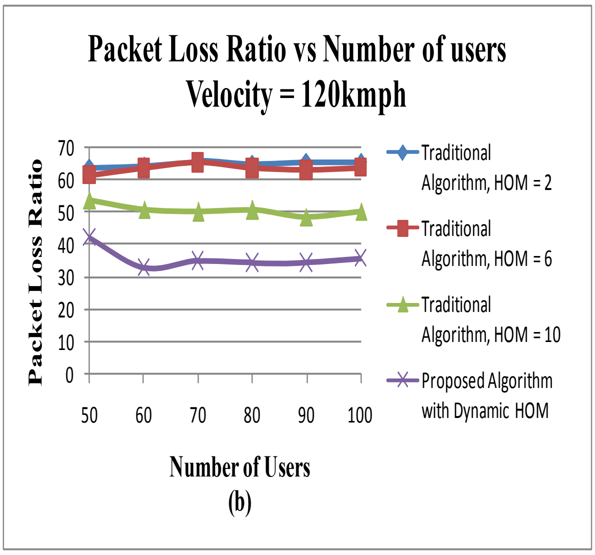


Fig. 12b : Packet Loss Ratio vs Number of users for Velocity of 120 kmph

Fig. 12a and Fig. 12b present the variation in the PLR with increasing number of users at 30 kmph and 120 kmph respectively. Fig. 12a and 12b show that PLR is much less in the proposed algorithm than that of traditional algorithm with different handover margins for both the velocities. To calculate the improvement in QoS, mean PLR is calculated for both the velocities and the result is as shown in Table 14.

Table 14 : Mean Packet Loss Ratio

Velocity	Traditional Algorithm			Proposed Algorithm
	$\overline{PLR}_{HOM=2}$	$\overline{PLR}_{HOM=6}$	$\overline{PLR}_{HOM=10}$	$\overline{PLR}_{Proposed}$
30 kmph	0.48305	0.45683	0.41781	0.19896
120 kmph	65.0267	63.5464	50.8604	35.8746

As the number of unnecessary handovers is reduced significantly by the proposed algorithm, the mobile device is connected to femto base station for a longer period of time. The correct and stable handover decision helps in receiving more packets and thus reduces packet loss.

5.5 Packet Delay

Packet delay is an important parameter for deciding the QoS. Average packet delay is defined as the time taken by a packet to reach from source to destination within a network. Since today's networks are all IP networks, therefore even the voice is transmitted over the network in the form of packets. The flow of these packets affects the user's experience of QoS. When the packets flow smoothly with minimum time between their sending and receiving, good QoS is indicated, while packets arriving with large delays signify degradation in the service. To calculate the total packet delay, the retransmission of the lost packets is also considered. The packets which are lost need to be resent. It is assumed that the retransmission of lost packets will require at least twice the average packet delay, if round trip time from source to destination is considered.

The total packet delay is calculated as shown in equation (12):

$$\text{Total Delay} = ((\Sigma P_{received} * \text{Average Delay}) + (\Sigma P_{lost} * 2 * \text{Average Delay})) / \Sigma P_{sent} \quad (12)$$

where ΣP_{sent} , $\Sigma P_{received}$ and ΣP_{lost} are the total packets sent, received and lost during the simulation time.

The total delay is calculated in this manner at 30 kmph and 120 kmph as shown in Fig. 13a and Fig. 13b respectively.

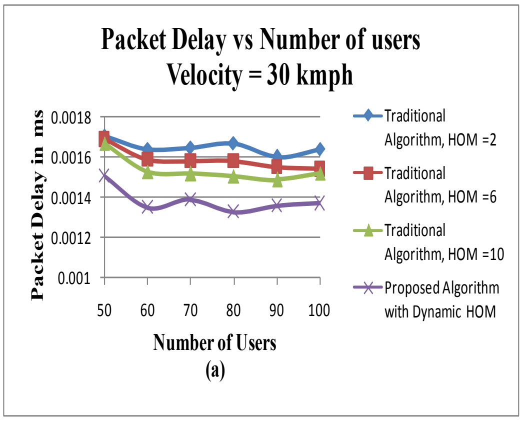


Fig. 13a : Packet Delay vs No of users at 30kmph

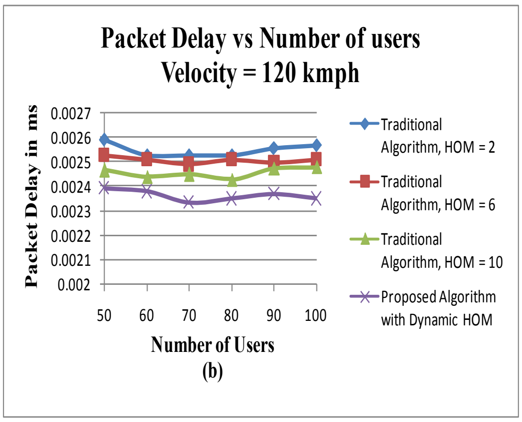


Fig. 13b : Packet Delay vs No of users at 120kmph

As shown in Fig. 13a and Fig. 13b, the total packet delay is reduced when proposed algorithm is used for both the velocities. The reason for reduction in the total delay is that due to the reduction in unnecessary handovers, the connectivity of the mobile device to the base station is maintained for a longer period of time. The packet sent can flow easily to the destination instead of searching for the suitable connection to a base station frequently. Moreover, the retransmission of packets also increases the total delay in traditional algorithm as the number of packets lost is more in traditional algorithm as compared to proposed algorithm. To quantitatively show the reduction in total packet delay and find the improvement in QoS, mean packet delay is calculated and is shown in Table 15.

Table 15 : Mean Packet Delay

Velocity	Traditional Algorithm $\overline{\text{Delay}}_{HOM=2}$	$\overline{\text{Delay}}_{HOM=6}$	$\overline{\text{Delay}}_{HOM=10}$	Proposed Algorithm $\overline{\text{Delay}}_{Proposed}$
30 kmph	0.001652	0.001588	0.001541	0.001384
120 kmph	0.002552	0.002508	0.002457	0.002363

The table shows that packet delay is less in proposed algorithm as compared to the traditional algorithm for both the velocities

5.6 Jitter

Jitter is an indicator of QoS for VoIP calls. It is defined as the variation in the delay of packets received at the destination. The packets sent as a continuous stream may have a varied delay when received at the destination due to network congestion or improper queue and it appears as a distortion in voice quality at the receiver's end. When the packets are not received in the same order as they were sent, the receiver experiences some gaps. Jitter is calculated by taking the mean difference between the delays of two consecutive packets to estimate the variation. It is shown in Fig. 14a and Fig. 14b for velocities of 30 kmph and 120 kmph.

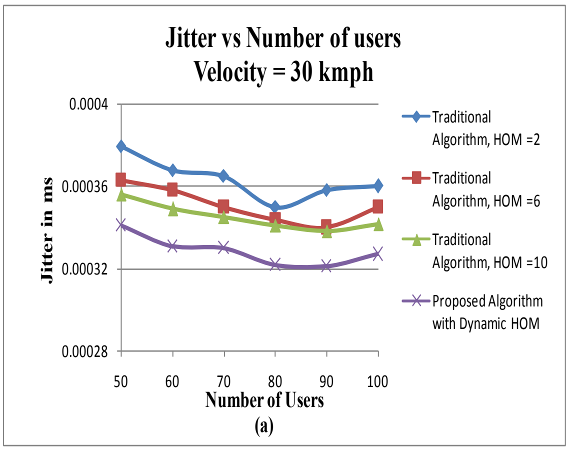


Fig. 14a : Jitter vs Number of users at 30kmph

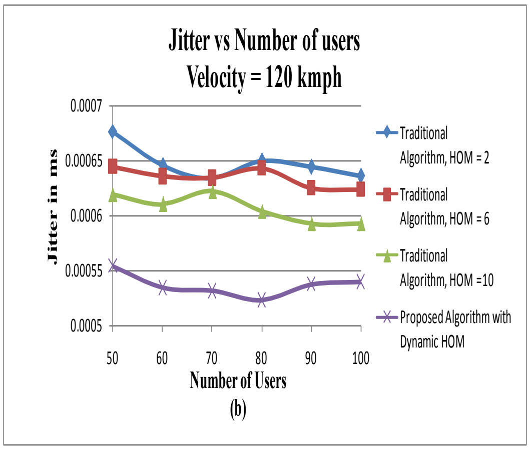


Fig. 14b : Jitter vs Number of users at 120kmph

To show the reduction in jitter and improvement in QoS, the mean values of jitter for traditional algorithm and the proposed algorithm are calculated and the analysis is shown in Table 16.

Table 16 : Mean Jitter in ms

Velocity	**Traditional Algorithm** $\overline{Jitter}_{HOM=2}$	$\overline{Jitter}_{HOM=6}$	$\overline{Jitter}_{HOM=10}$	**Proposed Algorithm** $\overline{Jitter}_{\textbf{Proposed}}$
30 kmph	0.000363	0.000351	0.000345	0.000329
120 kmph	0.000647	0.000634	0.000607	0.000536

5.7 QoS Verification

The percentage improvement in QoS parameters when the proposed algorithm with dynamic handover margin was used is shown in Table 17. The proposed algorithm performs better than the traditional algorithm for all the three values of handover margin as presented in Table 17.

Table 17 : Comparison of QoS parameters in proposed algorithm with traditional algorithm

QoS Parameters	**Improvement in the QoS parameters in Proposed Algorithm w.r.t. Traditional Algorithm for different values of Handover margin at a velocity of**					
	30 kmph			**120 kmph**		
	HOM = 2 dBm	HOM = 6 dBm	HOM = 10 dBm	HOM = 2 dBm	HOM = 6 dBm	HOM = 10 dBm
Handover Quality improved(due to reduction in ping pong rate) by	56.2%	41.2%	14.3%	56.8%	46.1%	19.2%
Throughput increased by	3.8%	3.6%	2.6%	74.8%	88.1%	26.8%
PLR reduced by	58.8%	56.4%	52.3%	44.8%	43.5%	29.4%
Packet Delay reduced by	16.2%	12.4%	10.1%	7.4%	5.7%	3.8%
Jitter reduced by	9.3%	6.0%	4.6%	17.1%	15.4%	11.6%
Signalling Cost reduced by	56%	53.4%	39.5%	21.3%	16.1%	12.8%

6.0 CONCLUSION

In integrated macrocell femtocell networks, efficient handover is important to achieve a considerable system performance. A multicriteria decision function handover strategy has been proposed in this paper. The traditional RSS based and the proposed multicriteria based handover algorithms have been discussed, compared and analyzed. The traditional RSS based approach for handover decision is very simple but has many limitations, such as high ping pong rate, increased unnecessary handovers etc. In the proposed algorithm, four parameters are used to take the decision for handover. The use of four parameters reduces the simplicity of algorithm but helps to attain the required QoS by the user. The simulation results show that at a handover margin of 10 dBm, the mean packet loss ratio, mean packet delay, mean jitter and mean signalling cost are reduced by 52.3%, 10.1%, 4.6% and 39.5% respectively and throughput and handover quality due to reduction in ping pong rate is improved by 2.6% and 14.3%, when users move at a velocity of 30 kmph. At 120 kmph the mean packet loss ratio, mean packet delay, mean jitter and mean signalling cost are reduced by 29.4%, 3.82%, 11.69% and 12.8% respectively and throughput and handover quality due to reduction in ping pong rate is improved by 26.8% and 19.2%. The improvement can also be seen at the handover margin of 2 dBm and 6 dBm. Improvement in the QoS indicators show that resources of the network are efficiently utilized and better connectivity is provided.

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