Hierarchical Macro/Femto Cell Networks by using an Efficient Handoff Algorithm

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Abstract—The* best *way to increase the system capacity of a wireless link is by getting the transmitter and receiver closer to each other, which creates the double benefits of higher-quality links and more spatial reuse. In a network with nomadic users, this inevitably involves deploying more infrastructures, typically in the form of microcells, hot spots, distributed antennas, or relays. The use of hierarchical macro/femto cell networks is regarded as the most promising approach. We present an efficient handoff Algorithm to support the inbound mobility from macro cells to femto cells under the consideration of large asymmetry in the Transmit power of the cells. Numerical analysis reveals that the proposed algorithm yields a higher probability that the user will be correctly assigned to the femto cell while maintaining the number of handoffs at the same level.

*Index Term---**Handoff algorithm, handoff criterion, cell selection, hierarchical macro/femto cell networks***

1. INTRODUCTION

The recent development of hierarchical macro/femto cell networks is a realistic way of providing better quality of service to indoor mobile users. Now earlier stage femto cells are very less expensive concept for better coverage, hence it is also called as home base stations, these are data access points installed by home users to get better indoor voice and data coverage.

In these emerging networks, many low-power femto base stations (f-BSs) are implemented within the coverage of macro BSs (m-BSs) that typically use large transmits power for covering a wide geographic area. Onechallenge here is to support the successful inbound mobility that corresponds to the handoff from the m-BS to the f-BS. To achieve this purpose, we are interested in designing an efficient handoff algorithm to be used in the hierarchical macro/femto cell networks.

A variety of handoff algorithms based on received signal strength (RSS) with hysteresis and threshold have been studied. The threshold sets a minimum RSS from a serving BSand the hysteresis adds a margin to the RSS from the serving BS over that from a target BS. Although their efficiency has been verified in many previous works, the performance in the hierarchical macro/femto cell networks was not evaluated. Therefore, we propose a new RSS-based handoff algorithm that is suitable for the hierarchical macro/femto cell networks. The handoff scenario considered in this paper is the inbound mobility from the m-BS to the f-BS. The system model is presented and the proposed algorithm is analyzed.

II.SYSTEM MODEL AND DEFINITIONS

The basic primary method for handoff mechanism in between a macro cell to femtocell is as follows

$$Sm < Smth \text{ and } Sf > Sm + \Delta \quad (1)$$

Where Smth, Sm and Δ represent the minimum RSS level from a serving macro Base Station, and the respective hysteresis values. And Sm and Sf are the received signal powers from macro and femto base stations respectively these can be calculated by the following equations.

$$Sm = Pm, tx - PLm - um$$
$$Sf = Pf,tx - PLf - uf \quad (2)$$

Transmit power from macro cell and femto cell are Pm, tx & Pf, tx and path losses are PLm[k] and PLf [k] from the macro BS and the femto BS. Um[k] and Uf [k] represent the log-normal shadowing with mean zero and variance σ2m and σ2 f, respectively.

We determine short-term femtocell visitors using numerical notations and give a new handoff conclusion method to prevent the unnecessary handoffs. At firstly, we using the threshold time Tth to identify short-term femtocell visitors. Tth can be set differently depending on the organization procedure of each and every femtocell. If any handover subscriber stays in the femtocell for more than Tth, and we assumes that it is appropriates femtocell user . Conversely, if handover subscribers stay in the femtocell less than Tth, it becomes a short-term femtocell visitor hence this is the unnecessary handover. Thus, we defines a new method of macro to femto handover as follows:

$Sf > Sth$ and $Tc > Tth$ (3)

Where

Sf - received signal strength,

Sth - the predefined threshold value,

Tc - cell residence time of user.

Our main theme is to expects to Tc using future mobility prediction scheme so that we can perform selective macro to femto handover not to accept temporary femtocell visitor.

UE speed is a most important factor in handoff process. The UEspeed should be stayed inside the femtocell at least for certain large amount of time. Because generally the use of femtocell is not for very high speed mobile users. This minimum amount of time UE needs to stay for handoff is called time to trigger (TTT).So hense now condition for handoff is

$Sf > Sm + \Delta$ for TTT (4)

And for femtocell to femtocell handoff is

$Sf1 > Sf2 + \Delta$ for TTT (5)

If we know the speed of the user, we can estimate the time it will resides in the femtocell. Then it would be easy to make decision for handoff. To prevent the RSS from varying abruptly, the exponential window function $w[k] = (1/d1) \exp(-kds/d1)$, where ds and d1 represent the distance between two adjacent measurement locations and the window length, respectively, is applied to Sm[k] and Sf [k]. This operation can be expressed as follows:

$Sm[k]=w[k] * sm[k]$ and $s\bar{f}[k] = w[k] * sf[k]$ (6)

Then, the variance of the shadowing, in which the correlated shadowing and the window function are considered, becomes

$\sigma 2mw = (d0\sigma 2m)/(d0 + d1)$ and $\sigma 2fw = (d0\sigma 2f)/(d0 + d1)$, (7)

and the correlation coefficient ρc between two RSS samples can be written as follows

$\rho c = \{d0 \exp(-ds/d0) - d1 \exp(-ds/d1)\} /(d0 - d1)$ (8)

Given these representations of the received signals, we now clarify the problem of a conventional handoff algorithm. The most general form is the RSS comparison using hysteresis and threshold [2]. If this criterion is used for inbound mobility, the criterion for handoff can be expressed as follows:

$s\bar{m}[k] < sm,th$ and $s\bar{f}[k] > s\bar{m}[k]+\Delta$ (9)

Where sm,th and Δ denote the minimum RSS level from them-BS and the value of hysteresis, respectively. Since there is large difference in the transmit power of them-BS (≈ 46 dBm) and the f-BS (≈ 20 dBm) [1], the criterion for handoff in (4) is difficult to satisfy. Especially when the f-BS is located in the inner region of the macro cell, the m-BS easily has the first priority as a target BS for handoff, although the RSS from the f-BS is high enough. It may cause undesired congestion in the m-BS and low utilization in the f-BS.

III. PROPOSED ALGORITHM

To overcome the above mentioned drawback of a conventional algorithm and derive a reasonable criterion for handoff, we propose a new RSS-based handoff algorithm. The main idea is to combine the RSSs from both a serving m-BS and target f-BS through following process.

1. Criterion for handoff in proposed algorithm

If $Sf > Sf,th$ and $Sfmod > Sm + \Delta$

or if $Sf < Sf,th$ and $Sf > Sm + \Delta$ (10)

Then connect to femto BS

If $Sf > Sf, th$ and $Sfmod < Sm + \Delta$

or if $Sf < Sf,th$ and $Sf < Sm + \Delta$ (11)

Then connect to macro Base Station (BS)

The procedure just described has several remarkable properties. First, the combination process in (5) may be interpreted as the generation of an adaptive offset that is determined by the RSS from the m-BS and the combination factor, so that a more reasonable comparison can be performed. In addition, the combination process is applied when the RSS from the f-BS exceeds a threshold Sf,th. By carefully controlling the threshold, it is possible to choose a better connection with them-BS or the f-BS to guarantee a certain level of QOS during handoff.

Note that the hysteresis Δ is still needed to avoid the unnecessary trials of handoff and each condition is marked byF1, F2, M1 and M2 in Fig. 1.The most important step in the proposed algorithm is to determine a proper value for the combination factor.

If it is unnecessarily high, the criterion for handoff is always satisfied, even when the RSS from the f-BS is low. If it is unnecessarily low, the proposed algorithm converges to the conventional algorithm. A method for determining an optimal value for the combination factor is suggested as follows subject to

Pcm[k0] = Pr{M(k0) and s $\bar{f}$ [k0] > Sf,th} < ε (12)

Where Pm[k] and Pf [k] denote the probability that an MS will be assigned to the m-BS and the f-BS at k, and M(k)and F(k) indicate the corresponding events, respectively. In addition, k0 and k1 represent the indexes corresponding to the femto cell boundary and the marginal distance, which are used to measure how fast the handoff is performed. Thus yields

2. Mathematics of the algorithm.

Let the distance between macro cell and femto cell be D km. Femto cell radius is rf which is taken as 10m.

Macro cell transmit power = 46 dBm

Femto cell transmit power = 10 dBm

Macro cell path loss = 128 + 37.6 log10d (km)

Femtocell path loss(simplified) =42 + 28log10d(m)

Therefore at femtocell boundary, received signal strength from femtocell should not be less than that of macro cell.

Sf = [10-(42+28log10d(m))]

Sm= 46- [128+37.6 log10(D-d)(km)]

Now replacing d= rf = 10m at boundary, we get

Sf = [10-(42+28log1010)] = -60dBm

Sm= -82-37.6 log10(D-0.01) dBm

Sdiff = Sf – Sm = 22+37.6 log10(D-0.01)

And α = 1+(Sdiff/Sf)

3. Performance Analysis

Pm[k] and Pf [k] denote the probabilities that the MS will be assigned to the macro BS and the femto BS at time k, respectively, and M(k) and F(k) indicate the corresponding events and the probability of handoff at k, denoted by Pho[k], can be expressed as follows

Pm[k] = Pm[k − 1](1 − Pf|m[k]) + Pf [k − 1]Pm|f [k]

Pf [k] = Pm[k − 1]Pf|m[k] + Pf [k − 1](1 − Pm|f [k])

Pho[k] = Pm [k − 1]Pf|m[k] + Pf [k − 1]Pm|f [k] (13)

Where, Pf|m[k] represents the probability of handoff from a macro cell to a femtocell at k, and vice versa for Pm|f [k]. Then, Pf|m[k] can be calculated by using the concept of conditional Probability as follows:

Pf|m[k] = ( ) ( )

Then, the total number of handoffs Nho can be obtained by summing the probability of handoff for all k, that is,

Nho = Σk Pho[k].

IV RESULTS AND DISCUSSION.

We observe a single MS moving straight from a macro BS to a femto BS with the speed of 1 m/s. Then, the MS measures RSS's from both BSs at an interval of 1 second and a proposed handoff decision algorithm is operated based solely on the measured values of the RSS's.

1. Optimum multiplication factor vs. different positions of femto BS.

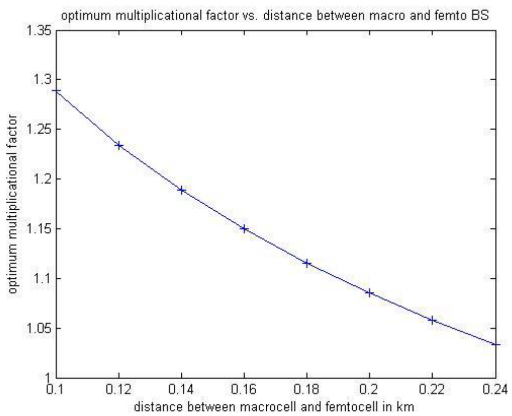

Fig.1. Optimal multiplying factor vs. distance of femto-macro BS

As distance between macro and femto BS increases, α decreases. After 250 meter there is no need of α. That means α is more needed when FBS is closer to MBS.

2. Femtocell assignment probability with distance between femto cell and macro cell.

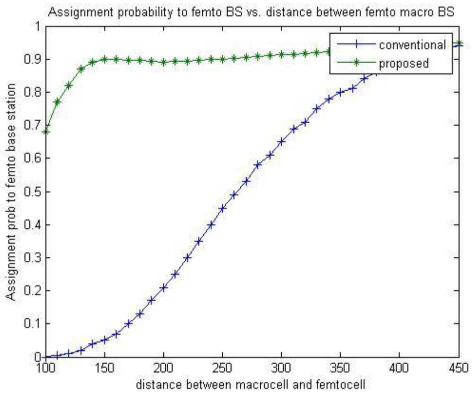

Fig.2. Assignment probability to femto BS vs. distance of macro-femto BS

When the femto BS is closely located to the macro BS, proposed algorithm has much higher assignment probability to femto BS compared to conventional algorithm. It is to be noted that each value is measured at the location separated by 10 m from the femto BS.

3. No. of handoffs with distance between femto and macro cell.

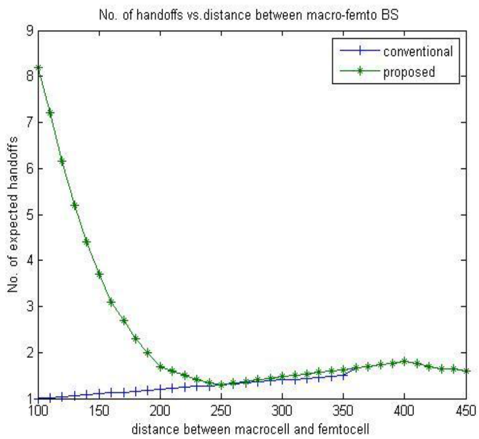

Fig.3. Number of handoffs vs. distance of macro-femto BS

It can be seen that when femto and macro BS are closely located, no. of handoffs are also increased. So a trade-off exists between assignment prob. to femto BS and no. of handoffs. It should also be noted that when the distance is greater than 200 m, the number of handoffs has the same level for both the conventional and proposed algorithms while the proposed algorithm still has the gain in the assignment probability to the femto BS. Therefore, it is possible to use the proposed algorithm with adaptive hysteresis that is decided by the RSS from the macro BS.

In order to evaluate the performance of a proposed algorithm, we use the same path loss and shadowing model, as represented in [1], and set the transmit power Pm,tx = 43dBm for an m-BS and Pf,tx = 21.5 dBm for an f-BS. In addition, we set the filter period to d0=20 m, the correlation distance to d1 = 30 m, and the sampling distance to ds =1m. The combination process is triggered when the RSS from the f-BS exceeds Sf,th = −72 dBm. Also, the femto cell boundary k0 = 30 m, the marginal distance k1 = 10 m, and the constraint ε = 0.05 imposed on Pcm[k0] in (6) were used. We first observe an optimal combination factor that satisfies(6) for different positions of the f-BS, as shown in Fig. 2.When the m-BS and the f-BS are close to each other, less than200 m apart, its value has nearly 1. Therefore, we can notice that the combination process is actively utilized, in particular, when the f-BS is located in the inner region of the macro cell or the RSS from the m-BS is strong.

Fig. 1 illustrates the cell assignment probabilities Pf [k] and Pcm[k] that are used in (6). These probabilities are obtained in the situation where the f-BS is located 200 m away from the m-BS. When a conventional algorithm is used, Pf [k] is below 0.1 and Pcm[k] is about 0.5 at the femto cell boundary = 170. This means that a conventional criterion for handoff is hardly satisfied, because of the large RSS from the m-BS. However, when the proposed algorithm is used with the optimal combination factor α∗ = 0.96, Pf [k] iabout0.5andPcm[k] is below 0.1 at the boundary. Such improvement can be obtained by the combination process that generates an adaptive offset according to the RSS from the m-BS and the combination factor. Thus, the proposed algorithm can support both successful and quick handoff from the m-BS to the f-BS.

Fig. 2 and Fig. 3 show the assignment probability Pf [k]measured at 10 m inside from its boundary and the number of handoffs as a function of the distance between the m-BS and the f-BS, respectively. When the f-BS is located close to the m-BS, the proposed algorithm yields a much higher value for Pf [k] than the conventional algorithm. However, the number of handoffs is also increased. Thus, there clearly exists a trade-off between the number of handoffs and the probability that the MS will be assigned to the f-BS. In order to reduce the number of handoffs, we suggest using an adaptive hysteresis, which is denoted by Δ, according to the RSS from the m-BS. For example, Δ=0.5 can be applied when the distance is smaller than 140 m. Then, the number of handoffs can be effectively reduced while keeping the gain in the probability that the MS will be assigned to the f-BS.

V. CONCLUSION

As future works, system performance, such as utilization of femtocells and user throughput, may be investigated when the proposed handoff decision algorithm is used. Then, the derivation of optimal handoff location and the corresponding application of the proposed algorithm can be examined. With more extensive analysis and study, we are expecting that the proposed algorithm will give the desirable effects on the improvement of the hierarchical macro/femto cell networks.

Also in real time scenario, using signal estimation, it can be examined how this algorithm works and what the exact effect on handoff probability, assignment probability to femto cell and number of handoffs are occurring.

We have proposed a new RSS-based handoff algorithm that is suitable for the hierarchical macro/femto cell networks with respect to providing successful handoff from an m-BS to an f-BS. The proposed algorithm reflects large asymmetry in the transmit power of the cells and its performance is analyzed by using the statistical properties of RSSs.

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