Handover with Consideration of Connection Cost in Femtocell Networks

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Abstract – **One of the most important benefits of femtocells is possibility to offload macrocells. Therefore, an interest of operators is to prolong a time spent by users connected to the femtocells. However, the longer time in the femtocell can brings lower quality of service due to lower quality of communication channel. Hence, the operators should compensate the drop in quality to users. A way of prolongation of time in femtocells is to initiate handover to the femtocell as soon as possible and postpone handover from the femtocell. This paper analyzes impact of modified hysteresis on several handover decision strategies. For this purpose, the handover decision phase is adjusted to prolong the time spent by users in the femtocells. This way, macrocells can be offloaded. The time spent in femtocells is prolonged according to customers' willingness to tolerate worse quality of connection in exchange for lower cost of connection provided by the femtocell.**

Keywords - femtocell, handover, hysteresis, connection cost, outage probability

I. INTRODUCTION

Increasing requirements on throughput of wireless networks led to development of concept of home base stations, so called femtocells [1]. The femtocell is small home base station represented by a Femtocell Access Point (FAP), which is supposed to be deployed especially indoor (e.g., in households, in offices, or in shopping centers). The FAP is connected to an operator's backbone via a wired line such as xDSL or optical fiber. The main purpose of the FAPs is to improve signal quality indoor or in shadowed areas, to increase throughput in areas with high density of users, and to offload the Macrocell Base Stations (MBSs).

The FAP can provide three modes of user's access: open access, closed access, and hybrid access. The FAP with open access can serve all User Equipments (UEs) if they passing near to the FAP. On the other hand, the FAP with closed access allows the connection only for users that are included in so-called Closed Subscriber Group (CSG). The hybrid access combines both open and closed accesses. The FAP in hybrid access dedicates a part of resources for the CSG users and the rest of resources are available for non-CSG users.

In case of the closed FAP, only few members of the CSG can exploit the FAP's resources. All other non-CSG UEs suffer from interference introduced by this FAP. Therefore, a control algorithm of FAP's transmitting power must be implemented to minimize the interference [2], [3]. In case of the open access, a level of interference increases as well. Nevertheless, the UE can attach to the FAP and thus reduce the impact of interference comparing to the closed access. On the other hand, frequent switching among the MBS and neighboring results in a high amount of signaling overhead for controlling handover procedure. Moreover, it decreases user's quality of service due to handover interruption.

The goal of this paper is to analyze possibilities of a prolongation of a time spent by the UE in the FAP. This requires an adjustment of the hysteresis according to the users' connection quality. The longer time in FAP shortens the time in MBS and thus, it leads to the offloading of the MBS. On the other hand, the prolongation of the time in the FAP can decrease the connection quality of users. Keeping users at the FAP for a longer time introduces a benefit for the operator (MBS offloading) while users suffer a loss in quality. Therefore, we propose to compensate this potential decrease in the quality to users by lower expenditures of users.

The rest of the paper is divided into following sections. In the next section, the state of the art of handover decisions is described. In Section III, the system model for evaluation is presented. Section IV describes a principle of the hysteresis adjustment according to the user's requirements. Evaluation of several conventional handover algorithms from the time in FAP point of view is also presented in Section IV. The last section gives our conclusions and future work plans.

II. RELATED WORK

The most of research papers dealing with the handover in femtocell network are aimed especially on reduction of redundant handovers incurred due to deployment of open access FAPs or on mitigation of interference.

The papers [4], [5] and [6] focus on the reduction of amount of unnecessary handovers and signaling overhead. For these purposes, users are classified according to their mobility state. It means if the user is too fast, the handover is not

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performed. In [5], a simple handover optimization is introduced. Handover decision is based on a speed of users and on a signal level. A proposal presented in [4] takes several parameters, such as Quality of Service (QoS), required bandwidth, and a type of application into account. The results of both papers show that the higher ratio of fast users lowers the signaling overhead for the proposed handover while the conventional algorithm increases the signaling overhead. The paper [6] focuses on efficient handover execution. In this approach, the QoS criteria for determining a target cell are introduced. The handover is performed in case if no mobility of user is detected and if an offloading of MBS is necessary.

A handover procedure is proposed also in [7] and further elaborated in [8]. This algorithm eliminates handovers if the FAP and the MBS are near to each other. The decision on handover is performed based on a combination of received signal levels from the serving MBS and the target FAP. Large asymmetry in transmit power of the MBS and the FAP is taken into account.

The suppression of a number of handover, as investigated in the most of the proposals, leads to the fact that the capacity of FAPs is not fully exploited and the MBS offloading by FAPs is limited.

A proposal focused on the saving of users' expenditures and on offloading of the MBS, is described in [9]. This proposal deals with the vertical handover between IEEE 802.16e WiMAX and Wireless Local Area Network (WLAN). The authors propose to deliver data belonging to delay-tolerant applications over the WLAN. As the result, there is a cost saving on the user's side. Nevertheless, the vertical handover to WLAN leads to significant handover interruption [10]. Moreover, QoS for voice services can be also impaired since QoS support in WLANs may not be implemented.

None of above-mentioned proposals considers the cost of connection provided via the FAP as a parameter for handover decision. In our paper, we propose to incorporate potential lower cost of connection via the FAP to handover decision algorithm. A potential to prolongation of the time in FAP by three existing handover decision algorithms is analyzed.

III. System Model

An area with twenty-five blocks of flats with square shape is used for simulation of users' movement. The blocks of flat are arranged according Fig. 1. Size of each block is 100 x 100 meters and contains 64 apartments with size of 10 x 10 meters. The apartments are located in two rows around the perimeter. A street between blocks is 10 meters wide. Three FAPs are deployed per a block. Each FAP is placed in random position in random flat and operate in open access mode. The MBS is located in distance of approximately 50 meters from the closest block in the right top corner of the simulation area.

Thirty users move along the streets according to Manhattan mobility model. The speed of each user is 1 m/s. Each UE passes 3000 m during the simulation. Indoor users are not included in simulation as we assume sufficient coverage of a flat by FAP signal and thus a movement within the flat does not cause handover.

The quality of signal received by the UE from the FAP is determined according to ITU-R P.1238 path loss model [11]. The signal between UE and the MBS is derived by Okumura-Hata for outdoor to outdoor communication [12]. Wall losses are considered for both models.

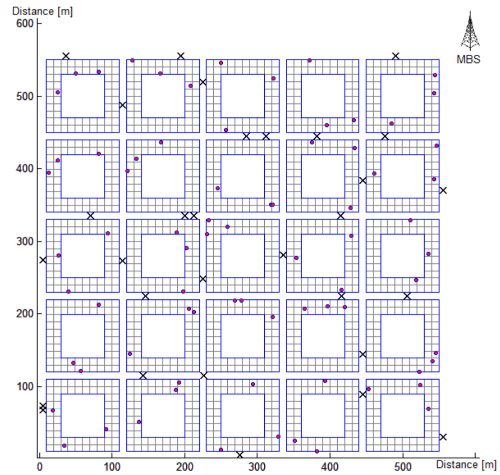

Figure 1. Example of random simulation deployment.

The major system and simulation parameters are summarized in Table 1.

TABLE I. PARAMETERS OF SIMULATION

Parameter	Value
Frequency	2 GHz
Channel bandwidth	20 MHz
Transmiting power of MBS / FAP	46 / 15 dBm
Height of MBS / FAP / UE	32 / 1 / 1.5 m
External / internal wall loss	10 / 5 dBm
Simulation real-time	3 000 s

In the simulations, three algorithms are compared: algorithm based on comparison of Carrier to Interference and Noise Ratio (CINR), algorithm based on comparison of Received Signal Strength Indication (RSSI) and Moon's algorithm. The algorithm denoted as CINR is a conventional handover decision based on comparison of CINR levels of a serving cell and a target cell. The handover is performed, if the CINR level of the target cell is higher than the CINR level of the serving cell. The RSSI based algorithm is analogical to the conventional CINR based handover. However, instead of CINR, the decision is based on comparison of the RSSI levels. The algorithm denoted as Moon is proposed in [7] and further specified in [8]. According to this algorithm, the handover is initiated based on a combination of the received signal levels from the serving MBS and the target FAP. The level of the received signal from the FAP is compared with the absolute threshold level of –72 dB. Moreover, the signal level of the MBS is confronted with a combination of the signal levels from the MBS and the FAP. The handover to the FAP is performed if the FAP offers signal level above the threshold and simultaneously the FAP is deployed at sufficient distance from the MBS. If the conditions are not fulfilled the handover is performed according to the conventional handover scheme.

IV. HANDOVER BASED ON CONNECTION COST

This section first describes handover decision for maximization of the time in FAP. Then, the time in FAP is evaluated for three selected handover algorithms. At the end, the algorithm for selection of hysteresis according to users' requirements on QoS is presented.

A. *Maximization of the time in FAP*

Prolongation of the time spent in the FAP allows offloading of neighboring MBS. On the other hand, the long stay in the FAP if the UE is moving out of the FAP's coverage area can cause a degradation of quality of user's connection. We investigate the possibility of prolongation of the time spent in the FAP by the user (t_{FAP}) and compensation of potential drop in quality by lower cost of connection. An extension of the t_{FAP} is adjusted by the hysteresis used if the user is leaving the FAP. This hysteresis is denoted as hand-out hysteresis. The lower connection cost provided via FAP, the higher hand-out hysteresis can be applied and vice versa.

When a user is moving from a MBS to a FAP or from one FAP to another FAP, no hysteresis is considered since this hysteresis shortens the t_{FAP}. Handover is performed immediately after the monitored parameter of the target FAP exceeds the same parameter of the serving MBS and if the target FAP can offer sufficient QoS to serve the UE. This mechanism further prolongs the t_{FAP}. The early handover might lead to significant degradation of the quality of services, an increase in the outage probability, or an increase in the number of redundant handovers due to selection of inappropriate target cell. Exclusion of the hysteresis could increase amount of redundant handovers due to ping-pong effect (i.e., frequent handover between two neighboring cells). Therefore, a one-second long timer between two handovers is considered. When the handover between two MBSs is performed, the level of hysteresis is set according to the conventional macrocell network criteria.

The principle of the handover decision for prolongation of t_{FAP} is depicted in Fig. 2.

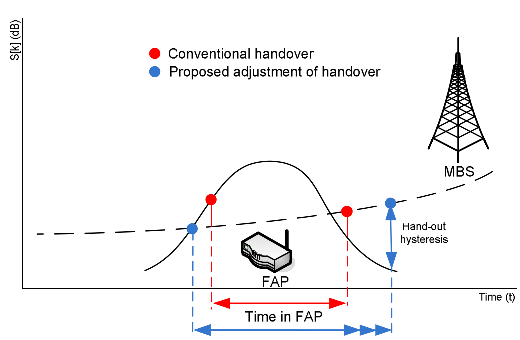

Figure 2. Handover decision for maximization of the time in FAP.

B. *Evaluation of the time in FAP and outage probability*

Evaluation is performed for algorithms based on CINR, RSSI and for Moon's algorithm. As can be seen in Fig. 3, the t_{FAP} rises almost linearly with the hand-out hysteresis for all three handover strategies. The steepest rise is observed for the handover based on RSSI. The growth is approximately 1.9 s/dB. For no hand-out hysteresis, the similar result is achieved also by CINR based handover. However, the rise in t_{FAP} is roughly 1.25 s/dB for the CINR based handover. The shortest time spent by the UE in the FAP is reached by the Moon's algorithm. For no hand-out hysteresis and Moon's algorithm, the t_{FAP} is significantly shorter than for another two handovers (25.2 s). The t_{FAP} for Moon rises with 1.35 s/dB. Dependence of the t_{FAP} on the hand-out hysteresis can be expressed by using the formula for a straight line:

$$t_{FAP}(\Delta_{HM}) = t_{FAP}(\Delta_{HM} = 0) + tp * \Delta_{HM}$$

where Δ_{HM} is the hand-out hysteresis and tp is the time prolongation in s/dB. The tp is 1.9 s/dB, 1.25 s/dB, and 1.35 s/dB for RSSI, CINR and Moon's handover respectively. Then the equations for all three algorithms are as follows:

$$t_{FAP,\ RSSI}(\Delta_{HM}) = 32.6 + 1.9 * \Delta_{HM}$$

$$t_{FAP,\ CINR}(\Delta_{HM}) = 32.1 + 1.25 * \Delta_{HM}$$

$$t_{FAP,\ Moon}(\Delta_{HM}) = 25.2 + 1.35 * \Delta_{HM}$$

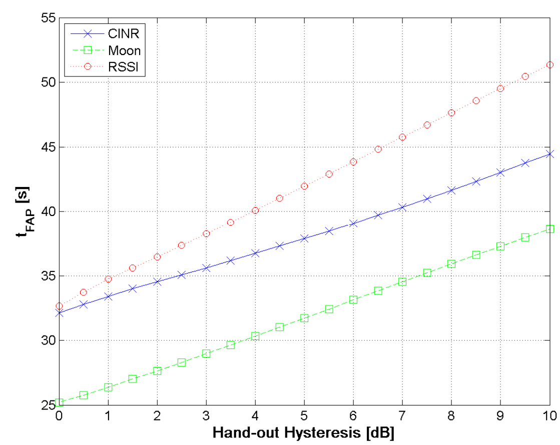

Figure 3. Average time spent in the FAP over hand-out hysteresis.

Higher hand-out hysteresis and increase in t_{FAP} lead to a degradation of the received signal quality due to decreasing level of the FAP's signal and increasing interference from cells in the UE's vicinity. It may results in a lower quality of service or drop of the connection especially for UEs close to the cell edge. The quality of service can be represented by an outage probability. The outage probability is understood as the ratio of t_{FAP} when the CINR level of the FAP is under an outage limit to the overall time of the simulation run. The outage limit, denoted as $CINR_{OL}$, is the level of CINR, under which the transmission rate and the quality of user's channel is not fully guaranteed. According to [13] and [14], the $CINR_{OL}$ is set to –3 dB in this paper.

The average outage probability over hand-out hysteresis for all three handover algorithms is depicted in Fig. 4. As the figure shows, the highest outage probability for each level of hand-out hysteresis is reached by the Moon's algorithm. The outage probability is roughly 2.2 % for no hand-out hysteresis if Moon's algorithm is used. The outage probability for no hand-out hysteresis and for both CINR and RSSI based algorithms is approximately 0.2 % and 0.8 % respectively. The outage probability rises the most rapidly for the Moon's algorithm. For hand-out hysteresis of 10 dB, the outage for Moon's algorithm is roughly 26.5 % while only 5 % and 14 % outage is observed for CINR and RSSI based handovers respectively.

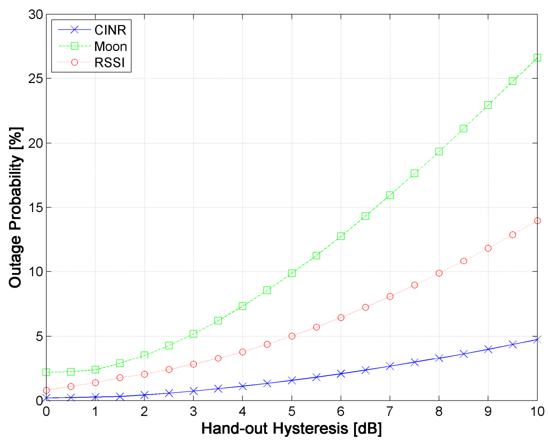

Figure 4. Outage probability of UE over hand-out hysteresis.

From the comparison of all three handover algorithms can be seen that Moon's algorithm is worse than both conventional algorithms in both the average t_{FAP} and the outage probability. The handover algorithms based on CINR and based on RSSI show better results in outage probability and in the average t_{FAP} respectively. For CINR and RSSI based handovers, there is a trade-off between t_{FAP} and outage.

C. Determination of hand-out hysteresis over quality required by users

As shown in Fig. 3 and Fig. 4, t_{FAP} increases with hand-out hysteresis. However, it is at the cost of higher outage probability. Therefore, a compensation of the higher outage probability for the users is necessary. Otherwise, no user will accept such degradation. In our proposal, we consider a benefit for users who are willing to tolerate higher outage probability. Nevertheless, each user is willing to retreat from its demands on quality of service for different level of benefit. Therefore, two illustrative types of users are defined for evaluation of the proposal.

The first one, denoted as *User A*, prefers the quality regardless the connection cost. An example of *User A* can be someone, who requires the highest quality of voice services. This user insists on the high quality disregarding lower cost of the connection. An opposite of the *User A* is a user focused on the lowering the connection cost regardless a temporary degradation of the connection quality. In this paper, this user is denoted as *User B*. The *User B* can be someone, who uses the services with low requirements on delay such as instant messaging or e-mail.

The benefit can be represented by a reduction of the users' expenditures. The save in user's expenditures is related to the cost of the connections via the FAP and the MBS. Therefore, we define a Cost Ratio. It expresses the ratio of the cost of data transmitted via the FAP to the cost via the MBS. The ratio "1/1" means the same cost of the connection through the MBS and the FAP. The ratio "0/1" implies that the connection provided via the FAP is for free. The values of cost ratio are associated with an increase in outage probability, which are individual users willing to accept (see examples for individual users in Fig. 5).

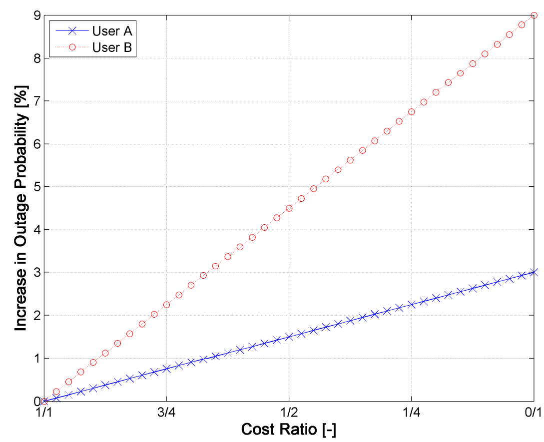

Figure 5. Examples of requirements on outage probability for two types of users.

According to the acceptable increase in outage probability (Fig. 5), Fig. 6 depicts a level of hand-out hysteresis determined for individual types of users and for different handover algorithms in dependence on the connection cost ratio. It means the outage probability shown in Fig. 4 is recalculated according to the requirements of users defined in Fig. 5.

The highest acceptable hand-out hysteresis is reached for the *User B* employing handover based on CINR. This is due to the following: i) the handover based on CINR shows the lower outage probability, and ii) the *User B* has the lower requirements on the reduction of connection cost. On the contrary, the results of hand-out hysteresis based on the connection cost show the lowest acceptable hand-out hysteresis reached by *User A* and Moon's algorithm.

The level of acceptable hand-out hysteresis does not show how the t_{FAP} is prolonged by the hand-out hysteresis. Therefore, t_{FAP} is derived from hand-out hysteresis over the ratio of the connection cost (presented in Fig. 6) and from the t_{FAP} over hand-out hysteresis (shown in Fig. 3). The t_{FAP} over the ratio of the connection cost is then depicted in Fig. 7.

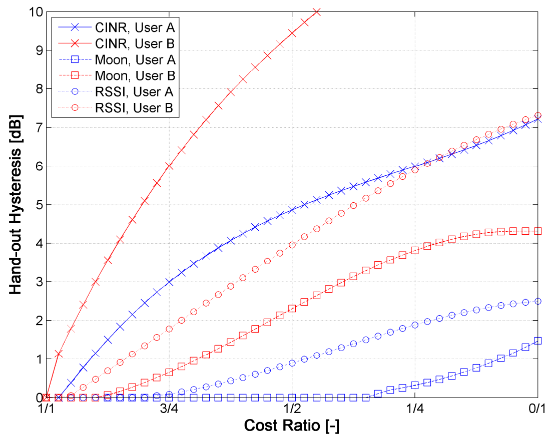

Figure 6. Hand-out hysteresis based on the connection cost.

Fig. 7 shows how the increase in difference between the connections cost via the FAP and the MBS influences the time for individual types of users using the different handover strategies. From Fig. 7 can be observed that the Moon's algorithm is not suitable for prolongation of the t_{FAP}. The *User B* using Moon's algorithm for the lowest cost of connection through the FAP (ratio *0/1* on *x-axis*) achieves even lower t_{FAP} than others handover algorithms with the same cost of connection via the FAP and the MBS (ratio *1/1* on *x-axis*).

On the contrary, as the most appropriate algorithm for prolongation of t_{FAP} is handover based on CINR. This algorithm increases the t_{FAP} with hand-out hysteresis most rapidly, while the outage probability remains the lowest. If the connection cost via the FAP is reduced to the half, t_{FAP} is extended by using CINR handover for *User A* and *User B* by 18 % and 36 % respectively. If the connection via the FAP is free, t_{FAP} is prolonged by 27 % and 65 % for *User A* and *User B* respectively. The results show that the most suitable algorithm for extending the t_{FAP} is handover based on CINR.

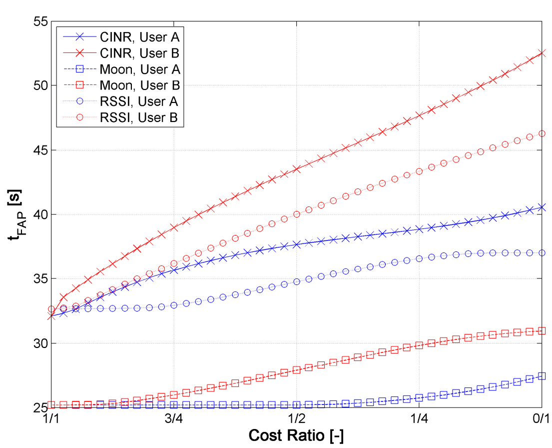

Figure 7. Time spent in the FAP based on the connection cost.

The proposed prolongation of the t_{FAP} by hand-out hysteresis in exchange for a reduction of FAP connection cost can be implemented in a real network in several ways.

From the network operator point of view, one of the reasons for using hand-out hysteresis adjustment can be the offload of the MBSs. In the first step, the operator determines the ratios of the outage probability to the reduction of connection cost. It means the slope of the line in the Fig. 5. The slope of the line depends on the willingness of the operator to motivate customers to extend the t_{FAP} (Fig. 7). The customers then select tolerated outage probability (*y-axis* in Fig. 5) or demand on reduction of connection cost provided via the FAP (*x-axis* in Fig. 5). The hand-out hysteresis is determined according to the cross-point, which is selected in Fig. 5 and recalculated on the curve in Fig. 6. As can be seen from Fig. 5, the lower cost preferred by the customer results in setting of the higher hand-out hysteresis. The higher hand-out hysteresis is associated with longer t_{FAP} and more significant offload of the MBSs.

The request of the customers to provide the lower connection cost via FAPs can also lead to a use of the proposed hand-out hysteresis adjustment. The operator can offer several types of user's classes (e.g., *User A* or *User B*) to customers. It means, the customer choose among several slopes of lines in the Fig. 5. For each type of users, individual reduction of the connection cost is defined. The customer belonging to the type *User B* will be able to get more significant reduction of the connection cost than the customer who choose type *User A*. From the offload point of view, the *Users A* does not enable a significant offload since it accepts only low level of quality degradation. A number of types of users are not limited and it depends on the operator's business model.

V. Conclusions

In this paper, three different handover decision strategies are compared to show their impact on the time in FAPs. The results show the most appropriate algorithm for the prolongation of t_{FAP} is the conventional handover decision based on CINR.

Additionally, maximization of t_{FAP} by adjustment of the handover algorithm is proposed. It considers willingness of users to stay connected to the FAP for a longer time if the cost of connection provided via FAPs is lower than via the MBS. The longer t_{FAP} is associated with the shorter time in MBS and thus with offloading of the MBSs.

The concept of connection cost based handover will be further extended and modified in order to increase t_{FAP} together with minimization of impairment of the connection quality.

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