A new velocity dependent variable hysteresis-margin-based call handover scheme

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The increase of mobile users compels the uses of picocells in cellular mobile communication and the task of handover becomes critical. Handover response should be faster and also should depend on mobile velocity to avoid unwanted call termination for high velocity mobiles and unnecessary handover for low velocity mobiles. In this paper, a path loss exponent and user-velocity-dependent variable hysteresis-margin-based call handover algorithm is proposed and studied. The handover algorithm is tested and found to give desired response.

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1 Introduction
In mobile cellular communication system, the call handover decisions may be based on measurements such as signal strength, bit error rate, traffic load, carrier-to-interference ratio, etc. Among these, the signal-strength-based handover algorithms are popular because of their simplicity and effectiveness. The handover algorithms based on averaging the signal strength\(^1\) needs a trade off between probability of handover and probability of outage and this may be avoided in the algorithm based on least square estimate of path loss parameters\(^2\). Handover decisions can be taken based on the signal strength values by considering threshold level or hysteresis margin. In the former case, the mobile station (MS) requests for a handover, if the signal strength from serving base transceiver station (BTS) falls below certain pre-designed level (threshold level). In the later case, the MS requests for a handover, if the signal strength from the serving BTS falls below the signal strength from some other BTS by a fixed value called hysteresis margin. Fixed hysteresis margin-based handover suffers from call quality degradation and increase in call termination probability for mobiles with very high velocity, while unnecessary handover for low velocity mobiles. In the proposed scheme the signal strengths from two BTSs have been estimated using least square method and the effect of user velocity on the performance of call handover has been studied. Results show that the call termination probability increases for high velocity mobiles and there are possibilities of unnecessary handover for low velocity mobiles which is in conformity with the expected results. To combat this problem a velocity dependent variable hysteresis-margin-based call handover scheme is proposed and studied.

2 Estimation of signal strength using least square algorithm
To estimate signal strength at MS, a model of cellular mobile communication system with two base transceiver stations BTS\(_0\) and BTS\(_1\) separated by a distance \(D\) is considered where the MS is moving from BTS\(_0\) to BTS\(_1\) with a constant velocity \(V\) as shown in Fig. 1. Mobile station estimates the signal strengths from each BTS and the value of the received signal level is the sum of three parameters, namely, path loss, shadow fading and small scale fading. Small scale fading has much shorter correlation distance compared to shadow fading and is averaged out over the time scale under consideration\(^2\) as well as anti-multipath fading techniques are also available\(^3,4\).
Hence, in a system with anti-multipath technique the effect of small scale fading has insignificant contribution and is not considered in the present work. The signal strengths from two BTSs have been estimated using least square method\textsuperscript{2} for an average cell radius of 250 m. Now, the low velocity mobiles may stop or turn back after the handover execution resulting unnecessary handover, and the high velocity mobiles may penetrate deep into the next cell before the handover execution, resulting call termination. The effects of mobile velocity on handover performance have been studied by many others\textsuperscript{5-7}. It has been shown that probability of handover, average number of handover, call blocking probability and call completion probability change significantly as user velocity changes.

3 Proposed handover scheme

The traffic density in an average urban area generally follows normal distribution\textsuperscript{8}. In India (as collected from the published document of Ministry of Transport, Govt. of West Bengal\textsuperscript{9}), the average speed in four metro cities, e.g. Delhi, Mumbai, Chennai and Kolkata are 30 km/h, 25 km/h, 25 km/h and 22 km/h, respectively. In Japan\textsuperscript{10}, the average national speed is 35 km/h. In London, during peak hours more than 50% vehicle\textsuperscript{10} move at a speed of less than 15 km/h. In highways, an optimum speed is decided on the basis of national loss in compensation and gain through speedy movement of men and material, say 100 km/h before designing highway features\textsuperscript{10}. In England urban area, the travel speed is 30 km/h during peak hours and 40 km/h during off-peak hours\textsuperscript{10}. So, normally traffic speed is considered to vary from 10 km/h to 100 km/h with a mean of 40 km/h and standard deviation 10 km/h as shown in Fig. 2. The cumulative distribution function of traffic is calculated and shown in Fig. 3. From the variation of average number of handover requests\textsuperscript{5-7}, the
distribution of average number of handover is calculated and shown in Fig. 4. Since the velocity distribution has large standard deviation, fixed hysteresis-margin-based algorithm may pose problem of call termination or early handover. These problems may be eliminated, if the hysteresis margin is made variable and velocity dependent. Considering these, a model of velocity dependent call handover algorithm is proposed and described. The signal strength from the BTS decreases as \( \exp (-\gamma d) \), where \( d \) is the distance of the mobile station from BTS and \( \gamma \) is the path loss exponent. In uniform propagation environment, \( \gamma \) can be taken as constant. But, in real environment, due to different density and orientation of obstacles, \( \gamma \) may have different values at different places. The two signals will differ more if the path loss exponent is large. Due to the sensitivity of handover performance to path loss exponent, a variable hysteresis scheme is already in use\(^{11} \), where the hysteresis margin is expressed as a function of path loss exponent and is given by:

\[
h \propto \exp \left[ -\frac{\gamma}{6} \right] \quad \cdots \quad (1)
\]

Handover performance is highly dependent on the MS velocity and the probability of handover (\( P_h \)), average number of handover (\( \eta_h \)) and probability of call dropping (\( P_{\text{drop}} \)) increase as velocity of the mobile station increases. Thus, if the hysteresis margin is changed dynamically in a complimentary fashion with MS velocity, the call termination as well as unnecessary handover may be minimized for high velocity and low velocity mobiles, respectively. Thus, a scheme of variable-hysteresis-margin-based system is proposed which takes care of both path loss exponent and mobile velocity, where the hysteresis is varied as:

\[
h = H \exp \left[ -\frac{\gamma}{6} \right] / \eta_h \quad \cdots \quad (2)
\]

where, \( \eta_h \) is the average number of handover and depends on mobile velocity\(^7 \) and \( H \) is the constant hysteresis margin which is used in fixed hysteresis-margin-based scheme in normal environment. It has been found that a constant hysteresis margin \( H=5 \) dBm would be optimum for avoiding unnecessary handover due to early request and call degradation probability due to delay in request\(^{12} \). Thus, depending on path loss exponent and user velocity, the variable hysteresis margin \( h \) is calculated and the handover request is obtained at the corresponding position.

**4 Results**

The position of handover requests as a function of velocity of MS for different values of path loss exponent has been computed and plotted in Fig. 5. Results show that the distance of handover position from serving BTS decreases as user velocity increases, thus eliminating call termination or call-quality degradation probability for high velocity mobiles and early handover for low velocity mobiles. For the same mobile velocity, the distance of handover position is much lower for high values of path loss exponent, which is desirable. Thus, the present handover request scheme is applicable for very low to very high velocity mobiles. The distribution of average number of handover and the corresponding hysteresis values are plotted in Fig. 6. It may be observed from Fig. 6 that most of the handovers are done at hysteresis values of 2-4 dB,

![Fig. 5—Distance of position of handover requests versus MS velocity](image)

![Fig. 6—Distribution of values of average number of handover versus hysteresis](image)
whereas the smaller and higher values of hysteresis are used for comparatively smaller number of handovers.

5 Conclusions

The present handover initiation strategy avoids both call termination and unnecessary handover for high and low velocity mobiles and thus efficiently utilizes radio channels. Since the algorithm avoids early and unnecessary handover, it also reduces the base station controller (BSC) and mobile switching center (MSC) processor loading. The mobile station would estimate its velocity using the available standard techniques such as level crossing rate, zero crossing rate, etc.13 followed by average number of handover. Then using the algorithm it would decide the position of handover request which will avoid call termination and early handover.

References

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