# A Measurement-Based Dynamic Guard Channel Scheme for Handover Prioritization in Cellular Networks

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**Abstract.** The introduction of guard channels in a cellular network is a method for giving priority to on-going calls by having channels exclusively reserved for handover purposes. Herein, an adaptive measurement-based dynamic guard channel scheme is introduced. The proposed scheme uses the number of on-going calls in adjacent cells and measurements of handover probabilities to determine the amount of guard channels to allocate in a cell. To improve the efficiency of the scheme, the calls are divided into groups depending upon mobility and latest visited cell, where separate measurements are performed for every single group. Simulations showed that the proposed scheme seems to be very efficient.

## 1 Introduction

The quality of service (QoS) in a cellular network consists among other things of the blocking probability for a new call due to channel occupancy and the probability for a forced call termination. An on-going call may be terminated prematurely due to a handover attempt failure or because of low signal to noise ratio and/or high attenuation. Obviously, it is much more frustrating for a subscriber to have an on-going call dropped than a new call blocked. Since the operator would like to keep the subscribers satisfied, it is a good idea to lower the probability for a forced call termination, which can be achieved by insertion of guard channels. Guard channels are channels exclusively reserved for handover calls, lowering the handover dropping probabilities to the expense of higher blocking probabilities and in most cases reduced throughput.

In the fixed guard channel scheme, a fixed number of guard channels, $N_g$, is allocated in a cell [1]. A new call is accepted if at least $N_g + 1$ channels are available in the cell at the time of the call arrival, while a handover call only needs one available channel to be accepted. The fixed guard channel scheme is quite simple to implement but unfortunately it is not especially efficient due to its poor flexibility. In dynamic guard channel schemes, the number of guard channels allocated in a cell is time varying and dependent upon the momentary network conditions [2,3]. A well-designed dynamic guard channel scheme provides a higher QoS than its fixed counterpart, but the most important advantage

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with the dynamic schemes is the increased flexibility, making it possible to provide a certain average QoS to on-going calls. Unfortunately, the complexity of dynamic guard channel schemes is higher, requiring increased communication between base stations and increased processing load.

In this paper, an adaptive measurement-based dynamic guard channel scheme is introduced. To improve the efficiency of the proposed scheme, the calls are divided into groups depending upon mobility and most recent source cell (latest visited cell), where separate measurements are performed for every single group.

## 2 The Proposed Algorithm

The proposed dynamic guard channel scheme uses measurements to estimate the momentary handover arrival intensity of every single cell. From these intensities, the number of guard channels to be allocated in the cells are derived. All base stations measure the probability for an on-going call residing in its coverage area to make a handover attempt (handover probability) and the probability for a handover attempt to take place to a specific target cell (handover direction probability). To improve the accuracy of the estimations, the calls are divided into groups depending upon most recent source cell, where separate measurements are performed for every single group [4,5]. The introduction of source cell groups is very effective since calls belonging to different groups usually do not have the same movement or mobility patterns, which is especially obvious for a call covering a highway where almost all subscribers follow the same path, namely the road. Obviously, the handover direction probabilities for subscribers traveling in opposite directions on the road differ completely from one another.

The handover probability for calls belonging to source cell group $x$ is denoted $P_h(x)$ and the handover direction probability to target cell $y$ for those calls is denoted $P_{hd}(x, y)$. In formulas (1) and (2), $\zeta$ is the number of adjacent cells to the cell for which the measurements are performed. $H(x, y)$ is the number of handover attempts to adjacent cell $y$ made by calls belonging to source cell group $x$, while $D(x)$ is the number of calls belonging to source cell group $x$ having departed from the cell either through a handover or a call termination.

$$P_h(x) = \frac{\sum_{k=1}^{\zeta} H(x, k)}{D(x)} \tag{1}$$

$$P_{hd}(x, y) = \frac{H(x, y)}{\sum_{k=1}^{\zeta} H(x, k)} \tag{2}$$

In order to make the proposed scheme sensitive towards changes in subscriber behavior, only a limited amount of data is taken into account in the measurements. A data value is considered by the scheme if it is less than $t$ minutes old or if it belongs to the $z$ most recent data values. These parameters have to be set as a compromise between adaptability and accurate measurements. To be able to handle more short-term changes in subscriber behavior, recent data are given a larger influence, which is achieved by weighting the data according to a function with a negative exponential behavior.

Most subscribers are stationary while using their mobiles. Consequently, a large portion of the on-going calls is not moving and will accordingly never perform a handover. When predicting subscriber movements it would be useful if the non-moving calls could be distinguished from the moving calls. By letting the covering base station sample the received signal strength from a mobile and calculate the mean value of the last $v$ samples, a signal strength alteration indicating a changed distance between mobile and base station can be detected. In the proposed scheme, a new call is initially placed in a mobility group for undecided calls. If a call movement is detected, the call is transferred to the moving mobility group and the signal strength measuring stops. Calls belonging to the undecided group are after $w$ seconds transferred to the non-moving mobility group. In this case, the measuring continues and if a call movement eventually is detected, the call is transferred to the moving mobility group.

Obviously, all calls arriving from adjacent cells are moving, which makes the moving and non-moving mobility groups unnecessary. Instead, these calls are divided into low and high mobility groups depending upon channel holding time in the latest visited cell. The channel holding time is defined as the time duration between the time a channel is occupied by a call and the time it is released either through a call termination or a handover. If the channel holding time of a call is larger/smaller than the mean value of calls from the same source cell group with identical target cell, the call is placed in the low/high mobility group.

Separate measurements of $P_h$ and $P_{hd}$ are performed for all mobility groups belonging to a certain source cell group. From these probabilities and the number of on-going calls in each group, $C(k)$, the number of calls in a cell expected to make a handover attempt to adjacent cell $y$, $G(y)$, is derived. There exist $\zeta + 1$ different source cell groups, one for every adjacent cell plus one group for calls with no previous handover. These source cell groups consist of two (low/high) and three mobility groups (moving/non-moving/undecided) respectively. Thus, $2\zeta + 3$ separate measurements are performed for every cell.

$$G(y) = \sum_{k=1}^{2\zeta+3} C(k) P_h(k) P_{hd}(k, y) \tag{3}$$

$G(y)$ is signaled to the base station covering cell $y$ where all received handover expectancy numbers, are summed up. In formula (4), $G_i(y)$ is the number received from adjacent cell $i$. The resulting total handover expectancy number gives an indication of the current handover arrival intensity and can therefore be used to determine the number of guard channels to allocate in the cell. Since all handover calls will not arrive simultaneously, the actual number of guard channels, $N_g$, is significantly smaller than the total handover expectancy number. In the proposed scheme, $N_g$ is equal to the total handover expectancy number multiplied by $\psi$ ($\psi < 1$). Fractional guard channels are used, which means that the number of guard channels in a cell does not have to be an integer.

$$N_g = \psi \sum_{i=1}^{\zeta} G_i(y) \quad (4)$$

In order to provide a guaranteed average QoS to already accepted calls, a requested mean value for the handover dropping probability, $P_{req}$, is set for every cell. By letting $\psi$ be time varying, the handover dropping probability can be held at the requested value. Every single time an on-going call is dropped due to a handover failure, $\psi$ is multiplied by $1 + \kappa$ ($0 < \kappa < 1$), which increases the number of allocated guard channels. When $(1/P_{req}) - 1$ handover attempts have succeeded, $\psi$ is multiplied by $1 - \kappa$ and the counter is set to zero. $\kappa$ has to be set as a compromise between having a robust scheme (small value) and a scheme sensitive towards traffic alterations (large value).

## 3 Simulation Model and Numerical Results

The simulated network consisted of 100 rectangular-shaped cells covering a rectangular street network. All cells had four adjacent cells and were arranged in a 10*10 ring topology with wrapped around edges. Hence, a cell in the $1^{st}$ row with coordinates (x,1) was neighbor with a cell in the $10^{th}$ row, coordinates (x,10). A Manhattan cell architecture was used, meaning that a base station was placed in every intersection and the cell borders were located midway between adjacent intersections.

All cells in the simulated network were identical from a traffic parameter point of view. The number of channels in each cell were set to 50 and the time duration between consecutive new call arrivals and the call lengths were assumed to be exponential distributed with mean values 0.13 and 5 minutes, respectively. The traffic parameter values were chosen to obtain realistic simulation settings and reasonable traffic load. Three different kinds of users were used in the simulations; stationary, slow moving and fast moving. 50 percent of the users were stationary, 17 percent slow moving and 33 percent fast moving. The channel holding time distribution was either exponential or rectangular (uniform) distributed with mean values of 1 minute (fast moving) and 5 minutes (slow moving).

Six variants of the proposed guard channel schemes, briefly described in Table 1, were investigated. Due to simplification reasons, it was assumed that a new call instantly is placed in a moving or non-moving mobility group. This is performed without errors in scheme VI, while 10 percent of the slow moving calls are placed in the non-moving groups in schemes IV and V. In addition, calls with at least one previous handover are placed in a low or high mobility group in schemes V and VI.

Three simulation scenarios with different channel holding time distributions and handover direction probabilities were investigated. In the handover direction probability sets shown in Table 2, $P_1$ is the probability for a user to go

**Table 1.** Investigated guard channel schemes

| *Scheme* | *Description* |
|---|---|
| I | Fixed guard channels |
| II | No source cell or mobility groups |
| III | Source cell groups |
| IV | Source cell and moving/non-moving mobility groups, inserted errors |
| V | Source cell and full mobility groups, inserted errors |
| VI | Source cell and full mobility groups, no inserted errors |

straight ahead at an intersection, $P_2$ the probability for a right turn and $P_3$ the probability for a left turn.

**Table 2.** Simulation scenarios

| *Scenario* | *Distribution* | *Handover direction probabilities* |
|---|---|---|
| I | Exponential | $P_1$=0,5 , $P_2$=0,25 , $P_3$=0,25 |
| II | Exponential | $P_1$=0,67 , $P_2$=0,33 , $P_3$=0 |
| III | Rectangular | $P_1$=0,5 , $P_2$=0,25 , $P_3$=0,25 |

In order to shorten the simulation length, it was decided to perform the simulations without the use of the guaranteed average QoS feature. Instead, the handover dropping probabilities were set to $3 * 10^{-4}$ by manual calibration of $\psi$. This is somewhat unfair towards the fixed guard channel scheme, but this scheme can anyhow be discarded out of flexibility reasons. The blocking probabilities, $P_b$, were used to determine the best scheme in each specific case. In Table 3, 95 percent confidence intervals are given for the blocking probabilities. All schemes were compared to the fixed guard channel scheme, and the *Gain* column, which shows the obtained gain in percent, is calculated from the two closest and two most distant values in the blocking probabilities of the respective schemes.

**Table 3.** Simulation results

| *Scheme* | *Scenario I* | | *Scenario II* | | *Scenario III* | |
|---|---|---|---|---|---|---|
| | $P_b$(%) | *Gain* | $P_b$(%) | *Gain* | $P_b$(%) | *Gain* |
| I | 3,689-3,693 | 0 | 3,690-3,694 | 0 | 3,898-3,902 | 0 |
| II | 3,646-3,650 | 1,1-1,3 | 3,643-3,648 | 1,1-1,4 | 3,835-3,839 | 1,5-1,7 |
| III | 3,594-3,598 | 2,5-2,7 | 3,541-3,546 | 3,9-4,1 | 3,747-3,753 | 3,7-4,0 |
| IV | 3,574-3,579 | 3,0-3,2 | 3,520-3,525 | 4,5-4,7 | 3,711-3,716 | 4,7-4,9 |
| V | 3,573-3,578 | 3,0-3,2 | 3,517-3,522 | 4,6-4,8 | 3,678-3,684 | 5,5-5,7 |
| VI | 3,574-3,578 | 3,0-3,2 | 3,520-3,524 | 4,5-4,7 | 3,675-3,680 | 5,6-5,8 |

The gain obtained by dividing the calls into groups depending upon most recent source cell (scheme III-VI) increased with a larger difference in user behavior between calls from different groups, which can be seen when comparing the simulation results of scenarios I and II. The use of non-moving and moving mobility groups (scheme IV-VI) also led to significant improvements. It was found that the use of high and low mobility groups (scheme V-VI) only was effective for scenario III. In scenarios I and II where an exponential distribution was used, a call with a very long channel holding time in the latest visited cell (low mobility) may out of randomization reasons have a really small channel holding time in the next cell and vice versa. Obviously, this reduces the obtained gain from the prediction-oriented mobility group feature. The removal of the inserted error in the mobility classification procedure (scheme VI) did not have a significant impact on the results.

In general, a large standard deviation for the channel holding time distribution reduces the gain obtained from predictive-oriented features such as source cell and mobility groups because of the larger probability of getting a really small sample value [6]. If a call shortly after arrival in a cell makes a handover attempt, the allocation of guard channels in the adjacent cells may due to channel occupancy not have been fully activated.

## 4 Conclusions

In this paper, an adaptive measurement-based dynamic guard channel scheme was proposed. The scheme uses the number of on-going calls in adjacent cells and their handover probabilities to estimate the handover arrival intensities of every single cell. In order to improve the accuracy of the estimations, the calls are divided into measurement groups depending upon most recent source cell and mobility, where separate measurements are performed for every single group. The channel holding time in the latest visited cell is used to divide the calls into a low or high mobility group, while positioning is used to divide calls with no previous handover into a moving or non-moving mobility group.

The proposed scheme was compared to other similar guard channel schemes and showed better results (lower blocking probabilities) for all investigated simulation scenarios. However, the high complexity of the scheme requires increased communication between base stations and increased processing load, which has not been taken into account.

## References

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