# A Novel Handoff Prioritization Scheme Based on Propagation and Traffic Criteria

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## Abstract

In this paper, in order to modify and improve the handoff process, which contains initiation and execution phases, three new prioritization schemes have been investigated. These new schemes prioritize handoff requests considering both traffic and propagation conditions. According to suggested schemes, priority of different candidate base-stations is based on three measurements in a joint state. These measurements are received power at mobile unit, power variation rates, and the number of free traffic channels of adjacent base-stations. Simulation results show that considering similar conditions, i.e. equal number of handoffs, lower call dropping (outage) and smaller delay distance will be achieved by new prioritization schemes rather than previous works. It means access to lower forced termination probability and interference and hence better QoS (Quality of Service). Finally, due to the best trade offs between propagation and traffic criteria, simulation results introduce SPBPS3 as optimum scheme.

## Keywords

Mobile, Cellular, Handoff, Base-station, Outage

## 1. Introduction

Cellular mobile communication systems divide their radio coverage area to sub-areas, which are known as cells. Each cell can be covered by an individual base-station. One of the main key elements in second generation of cellular mobile communication systems as well as third generation is handoff (handover) process. It is the process of changing the current engaged radio channel to a new free radio channel. In accordance with multiple access technique, radio channel may be frequency, time slot or code. Handoff process mainly takes place due to movement of mobile unit and deterioration of received signal quality inside an individual cell or near to cell boundaries. It has to have no effect on active calls. First and second generations of mobile communication systems apply hard handoff and CDMA-based systems utilize soft handoff [1-3]. In this investigation, hard handoff has been considered and power-based methods have been simulated.

Handoff process includes two major steps:

- Handoff initiation;
- Handoff execution

In initiation phase, the received signal quality is investigated according to radio propagation based methods and if necessary, a new base-station will be chosen. In execution phase, based on traffic control policies and traffic priority schemes, a new radio channel will be assigned. It is necessary that the handoff process should be unrecognizable for the user. Both reliable handoff decision-making and quick execution of handoff process play major roles in preserving communication quality and reducing interference as well as operational load of the network. The design of reliable and fast handoff algorithm is crucial to the operation of a cellular communication system. It is especially important in microcellular systems, where the mobile unit may traverse several cells during a call. Therefore, Modified versions should be used for data communications in third generation of mobile communication systems and real time applications [3-5].

Handoff decision can be based on three main measurements:

- Received power;
- Bit Error Rate (BER);
- Estimated distance between mobile unit and base-station

Power-based handoff initiation algorithms basically utilize previous and present values of received power. In the presented simulation these values belong to down-link which offers a more realistic picture rather than up-link. Simulation results of handoff initiation methods show that the received

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power can not be considered as a precise and perfect measure for performing handoff process. Also, it does not appropriately represent received power variations [6].

In order to improve the handoff initiation algorithms, joint reduction of mean number of handoffs, outage and delay distance should be achieved. Additionally, one must consider the simplicity of the algorithm and utilization of existing measures. So in this investigation, the effect of power variation rates due to different base-stations has been made use off. As a new idea the number of free traffic channels of candidate base-stations has been considered. Final list of candidate base-stations has been derived in accordance with propagation and traffic conditions in a joint state. According to this idea, three handoff schemes which proposed in reference [7] have been modified and simulation results show better performance metrics.

This paper is structured as follows. Section II presents a review of handoff initiation algorithms and most important conclusions of previous researches about non-predictive algorithms. Cellular structure, simulation assumptions same as propagation model and formulas, and considered performance metrics are discussed in section III. Section IV evaluates the sensitivity of slope of power based algorithms to traffic conditions of target base-station. Section V proposes three new handoff priority schemes. Simulation results and comparison of these algorithms are shown in the other sections.

## 2. Power-Based Handoff Algorithms

Handoff process should be accomplished whenever the received signal quality deteriorates inside a cell or between two adjacent cells. First phase of hard handoff, initiation phase, is defined as monitoring the radio link, taking a decision to commence handoff process and select a new base-station. Handoff decision methods are usually based on received power from the base station. It means the mobile unit is connected to the base-station whose power at the mobile unit location is the strongest.

The basic non-predictive handoff initiation algorithms are as follows:

- *MPH (Maximum Power Handoff)*

In this simple method, the mobile unit connects to the base-station from which receives the maximum power. When the mobile unit moves near the cell boundary, more unnecessary handoffs and ping-pong effect will be occurred.

- *AV (Relative Averaged Received Power)*

If the average of W recent samples of received power from target (candidate) base-station is greater than the average of W recent samples of received power from reference (current) base-station, then the handoff process to target base-station will take place. Averaging decreases the effect of fast fading.

- *HYS (Relative Received Power with Hysteresis)*

The handoff process will occur on the assumption that the received power from target base-station is effectively greater, in order of hysteresis margin, than the received power from reference base-station.

- *TB (Absolute Received Power with Threshold)*

The handoff process will take place if the joint conditions of received power in mobile unit due to reference base-station less than handoff threshold level and received power in mobile unit due to target base-station greater than handoff threshold level are met.

- *RTB (Relative Received Power with Threshold)*

In this algorithm, when the received power from reference base-station is sufficiently small (less than handoff threshold level), if one or two following conditions are met, then handoff will happen:

1. The received power from target base-station becomes large enough (greater than handoff threshold level);
2. Received power due to target base-station is greater than received power from reference base-station

- *MPHT (Maximum Power Handoff with Timer)*

Here if the received power due to target base-station in *n*th sampling instance is greater than the received power from reference base-station, then a delay will be exerted. Afterwards handoff will occur if the similar power conditions are dominant [5,6,8,9].

In MPH method, where the variation of received power from base-stations is very fast, repeated handoffs will take place. In spite of receiving adequate power from reference base-station, nevertheless many unnecessary handoffs will be occurred. In AV, HYS and MPHT methods, increasing W, H and $t_d$ respectively, cause the mean number of handoffs to be decreased and the outage and delay distance to actual boundary to be increased. It can be seen that in RTB method, decreasing the handoff threshold level is the reason for decreasing the mean number of handoffs and decreasing delay distance. Variation of outage in different handoff threshold levels can be ignored. In similar conditions, all above mentioned handoff initiation algorithms with their related control parameters reduce the mean number of unnecessary and repeated handoffs. In the other hand all of them introduce greater delay distance and higher outage rather than MPH method [10-11].

One of the most important problems related to handoff is the effect of delay time due to completion of handoff process. Hence handoff initiation methods should be modified by considering this effect. In order to increase mean number of candidate base-stations, modified versions of handoff initiation algorithms suggested. Enhanced version of each method causes lower forced termination probability rather than simple one. In the enhanced versions, a power priority list includes adequate target base-stations will be considered. Highest priority of this list belongs to similar base-station of simple method.

Looking through the simulation results of major power-based handoff initiation algorithms and in order to access to successful handoff process, combined forms are suggested as follows:

- *Simple HTB*

It hands a user over to a new base-station only if two conditions are met in a joint state:

1. The received power from current base-station drops below handoff threshold level;
2. The received power from target base-station is stronger than the current one by hysteresis margin.

- *HTB-AND*

This algorithm hands a user over to a new base-station only if three following conditions are met:

1. The current received power drops below handoff threshold level of current base-station
2. The received power from target base-station is stronger than the current one by a given hysteresis margin;
3. The received power from target base-station is above or equal to handoff threshold level.

- *HTB-OR*

This algorithm hands a user over to a new base-station only if the current received power drops below handoff threshold level of current base-station and the received power from target base-station is stronger than the current one by a given hysteresis margin or received power from target base-station is above or equal to handoff threshold level of target base-station.

These combined forms have two adjustable control parameters (hysteresis margin and handoff threshold level). Simulation results have shown that most appropriate combined form regarding all performance metrics is HTB-OR [11-12]. HTB-OR is the main kernel of references [7], [13] and this research. In this investigation we renamed it to Power Based Priority Scheme (PBPS).

In references [7] and [13] slope of power is a criterion for:

1. Selection of adequate target base-stations;
2. Prioritizing them;
3. Deciding about handoff execution or not.

For convenient new schemes named as Slope of Power Based Priority Scheme (SPBPS). In three SPBPSs all base-stations, which satisfy power conditions of PBPS algorithm, will be determined. Afterwards suggested schemes will be presented as follow:

*SPBPS1:* First list of selected base-stations will be sorted in terms of received power value. Final list includes that base-stations of first list, which their slopes of powers are not negative and is greater than reference base-station. In final list adequate target base-stations will be sorted by slope of power.

*SPBPS2:* Final list of candidate target base-stations, determined by PBPS, will be sorted by slope of power. In this method, slope of power is a tool for sorting the base-stations. Execution of handoff depends on existence of target base-station in list.

*SPBPS3:* Final list of those base-stations, which satisfy power conditions of PBPS, will be sorted according to a new criterion. This criterion is defined as multiplication of received power value and slope of power.

According to references [7] and [13], simulation results of these schemes show that:

- SPBPSs can reduce mean number of handoffs as well as delay distance. SPBPS3 can reduce outage in comparison to usual power based methods and better than SPBPS1 and SPBPS2.
- Lower sensitivity to delay times can be achieved by SPBPSs.
- SPBPS3 offers an appropriate estimation of next sampling point. It means a suitable trade off between the performance metrics of both initiation and execution phases.

## 3. Simulation Assumptions

In the simulations, mobile unit is moving from one base-station toward another one along direct path between them. The distance between two adjacent base-stations is set equal to 2000 meters. In order to evaluate the effect of adjacent cells, Figure 1 has been considered.

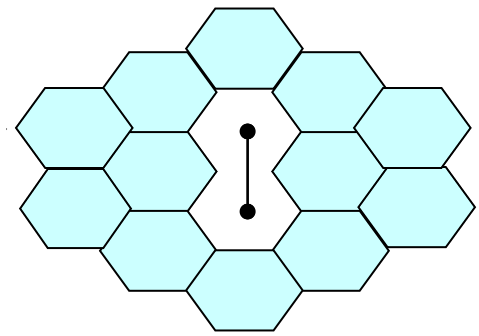

**Fig. 1 Cellular structure.**

Received power in cellular mobile communications is affected by three phenomena:

1. Path loss (can be evaluated by means of Lee's model with propagation constant $\gamma$)

2. Slow fading (Lognormal distribution)
3. Fast fading (Rayleigh distribution)

For all power-based handoff initiation methods the major value is the averaged received power at mobile unit or different base-stations. Standard deviation of fast fading phenomenon can be reduced effectively by averaging the measured power, so that it can be ignored comparing to slow fading effect. The effect of averaging window on slow fading and path loss components must be neglected. For the validity of this presumption, sampling interval has to be between 18 and 36 times larger than the wavelength. By considering the mobile unit velocity equal to 45 Km/h and sampling rate equal to 480 ms (according to GSM standard), the fast fading can be averaged out and averaging window has no considerable effect on slow fading and path loss components of received power. In this research, window length is 6 meters.

### 3.1. Input Data

- Effective Power of transmitter = 15 dBm
- $\gamma$ (Lee's model constant) = 3.5
- T (Sampling rate) = 480 ms
- V (Average velocity) = 45 Km/ h
- $\sigma_s$ (Standard deviation of fading) = 6 dB
- $d_0$ (Correlation distance of fading) = 30 m
- Receiver threshold level = - 98 dBm
- Signal wavelength = 1/3 m
- Cell Radius = 1000 m

### 3.2. Performance Metrics

- *HO*: Mean number of handoffs in a single displacement through a defined path.
- *OUT*: Mean outage in a single displacement through a defined path.
- *Delay*: Difference between actual boundary and the value of boundary obtained from handoff algorithm.
- *$N_S$*: Mean number of adequate candidate base-stations.

### 3.3. Formulas

$$P_{r_i} = P_t - 10.\gamma.\log(d_i) + f_i(d_i) \quad (1)$$

Received power due to *i*th base-station located at distance of $d_i$ from mobile unit according to Lee's model and considering the effect of slow fading (shadowing).

$$f_i(n) = X_i(n) + a.f_i(n-1) \quad (2)$$

Recursive expression for generating slow fading as a AR1 model.

$$X_i = N(0, \sigma) \quad (3)$$

Gaussian distribution with zero mean and standard deviation of σ.

$$\sigma = \sqrt{1-a^2}\sigma_s \quad (4)$$

Effective standard deviation of slow fading.

$$a = e^{-\frac{V.T}{d_0}} \quad (5)$$

## 4. Sensitivity of SPBPSs to Traffic

All researches about handoff initiation algorithms find a target base-station. They suppose this station has at least one free channel that will be assigned to handoff request. It should be noted that the best handoff initiation strategy and fast decision making does not guarantee successful handoff process because may be no free channel in target selected base-station. This fact leads us to consider the traffic effect of target base-stations. In actual model we suppose that if there is at least one free traffic channel, handoff will be completed. Otherwise request will be terminated. C is defined as a random variable with uniform distribution in the interval [0, 1]. $P_F$ is existence probability of free channel in target base-station. If C Є [0, 1-$P_F$], all channels of candidate base-station will be engaged. Otherwise, if C Є [1-$P_F$, 1], there is at least one free channel in target candidate base-station. $P_F$ =0 equals to no free channel and $P_F$=1 equals to at least one free channel.

For evaluating sensitivity of handoff initiation algorithms (PBPS and SPBPSs) to different values of $P_F$ we supposed that just highest base-station of priority list can be involved. If there is no free channel for this candidate station, handoff will be cancelled.

Presented simulations have been performed by considering -94 dBm for handoff threshold level and 4dB for hysteresis margin. Variations of performance metrics, HO, OUT, Delay and $N_S$ relating to changing $P_F$ are shown in Figure 2. As depicted in this figure, decreasing $P_F$ causes decreasing HO whereas OUT, Delay and $N_S$ to be increased. Figure 3 shows that the best (HO, OUT) and (HO, Delay) couples for different $P_F$ values belongs to SPBPS3. In the view of $N_S$, PBPS is better than the others but SPBPS3 has no visible changes.

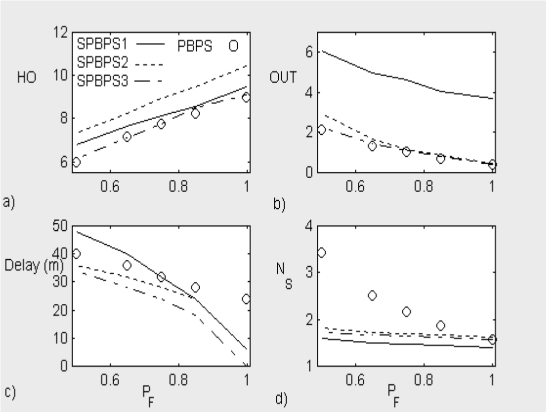


**Fig. 2 Variations of performance metrics vs. $P_F$**

**a) HO vs. $P_F$, b) OUT vs. $P_F$, c) Delay vs. $P_F$, d)$N_S$ vs. $P_F$.**

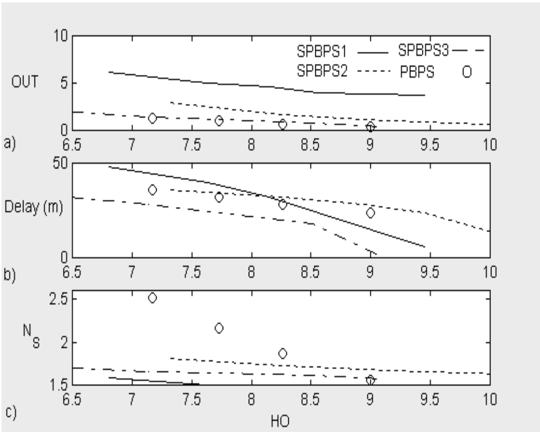


**Fig. 3 Variations of performance metrics vs. HO in terms of different $P_F$.**

**a) OUT vs. HO, b) Delay vs. HO, c) $N_S$ vs. HO**

## 5. New Prioritization Schemes

Previous section leads us to improve handoff initiation algorithms by considering number of free channels in each candidate base-station. For PBPS and SPBPS1, 2 & 3 we suggest final prioritization in terms of the number of free traffic channels. For convenience, in this investigation we supposed two types of candidate base-stations. First candidate base-stations have free channel and second ones have no free channel. According to this fact, final list includes those candidate base-stations that contain at least one free channel. Handoff will be done if final list has one element at least. Highest element of this list should be involved in handoff process.

Figure 4 shows simulation results for PBPS in two cases, with and without traffic prioritization. According to this figure, performance of new PBPS related to no-traffic priority PBPS, will be decreased.

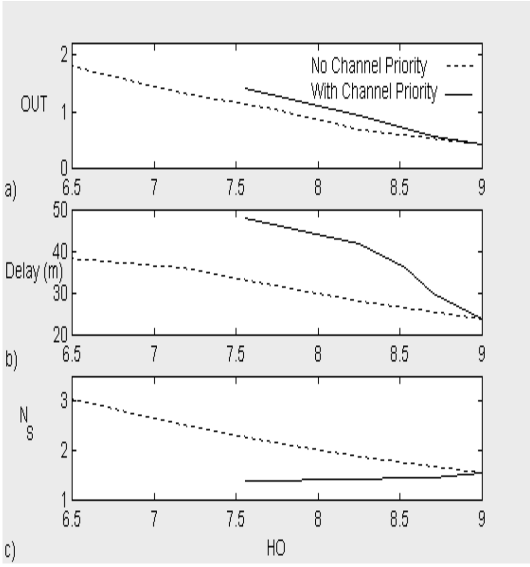


**Fig. 4 Variations of Performance Metrics of PBPS vs. HO in terms of different $P_F$.**

**(With and without channel priority)**

**a) OUT vs. HO, b) Delay vs. HO, c) $N_S$ vs. HO**

In Figures 5 and 6 simulation results of SPBPS1 and SPBPS2 for with and without traffic prioritization plotted. It can be seen that two algorithms SPBPS1 and SPBPS2 with channel priority have lower OUT and Delay.

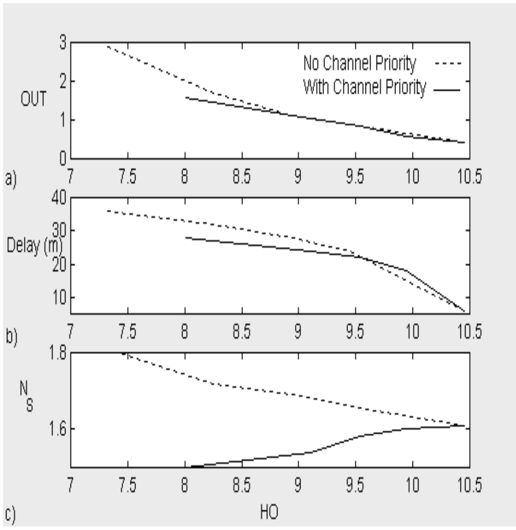


**Fig. 5 Variations of Performance Metrics of SPBPS1 vs. HO in terms of different $P_F$.**

**(With and without channel priority)**

**a) OUT vs. HO, b) Delay vs. HO, c) $N_S$ vs. HO**

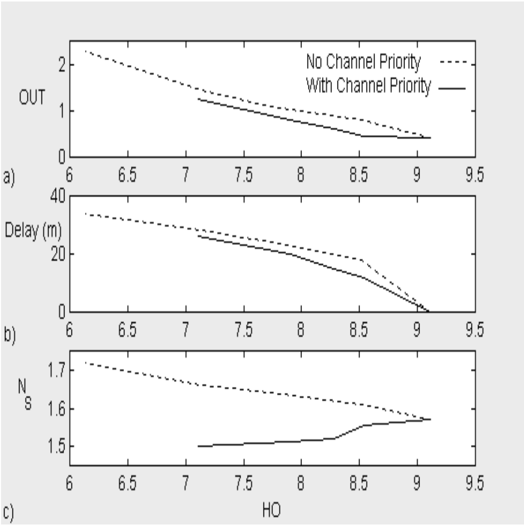


**Fig. 6 Variations of Performance Metrics of SPBPS2 vs. HO in terms of different $P_F$.**

**(With and without channel priority)**

**a) OUT vs. HO, b) Delay vs. HO, c) $N_S$ vs. HO**

Simulation result diagrams of SPBPS3 with and without traffic channel priority are shown in Figure 7. Similar situations for OUT and Delay have been derived same as SPBPS1 and SPBPS2.

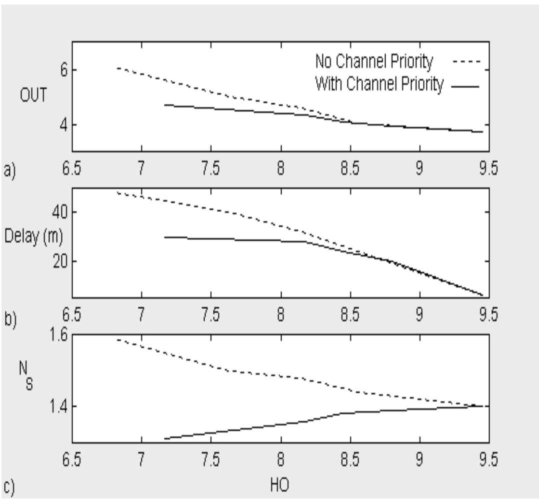


**Fig. 7 Variations of Performance Metrics of SPBPS3 versus HO in terms of different $P_F$.**

**(With and without channel priority)**

**a) OUT vs. HO, b) Delay vs. HO, c)$N_S$ vs. HO**

In accordance with simulations and referring to figures 5 to 7, following results can be summarized:

- If $P_F$ equals to 1, proposed algorithms with channel priority and usual SPBPSs have the same performance metrics.
- With channel priority OUT, Delay and number of candidate base-stations will be decreased. Decreasing of $N_S$ is about 6%. This degradation in comparison to decreasing OUT and Delay can be ignored.
- SPBPS3 has better (OUT, HO), (Delay, HO) and ($N_S$, HO) couples rather than two other SPBPSs and PBPS.

## 6. Conclusions

Most of recent researches considered traffic and propagation conditions separately. It is obvious that actual model is a model with higher relation between these conditions and considering the effect of these two in a joint state. In this research by suggesting a new prioritization scheme for handoff process in macro-cellular structure, better trade off between performance metrics has been achieved. This fact has been shown according to comparing the simulation results of this new method to previous works. Simulation of proposed scheme and comparison to previous works show that:

1. In the view of number of handoffs, outage, delay distance and the number of candidate base-stations, appropriate power-based handoff initiation algorithm should have three control parameters. These adjustable parameters, averaging window length, hysteresis margin and HO threshold level introduce a combined algorithm.

2. According to received power prioritization and finding candidate base-stations that satisfy decision making power algorithm criteria, mobile unit mobility area can be estimated.

3. In the suggested traffic-based priority schemes, forced termination probability will be decreased. This improvement is due to handoff to a base-station which has appropriate received power and includes maximum number of free traffic channels.

4. The main advantages of traffic and power-based priority algorithms are as follows:

   - Decreasing of both call dropping and forced termination probabilities.
   - Neglected variation of call blocking probability because there is no priority policy for traffic channels.

Proposed traffic-based scheme can be considered and implemented to soft handoff process but it should be noted that hard handoff is more sensible to time delay and degradation of signal quality. Prioritization based on number of free traffic channels introduce a list of appropriate base-stations which help us to find base-stations that can be involved in soft handoff process.

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