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A New Handoff Strategy for better Cellular Network Performance

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ABSTRACT

When a mobile station (MS) having two calls, an ongoing call and an on hold call, leaves its base station before handing off its calls, both calls are terminated. In this paper, we propose the handoff scheme Minimum Remaining Time with Largest Number of Calls (MRTLNC) to minimze the number of terminated calls. Our scheme queues the MSs requiring handoff and always serves the MS that has the least remaining time in the cell. Also, when multiple MSs have equal remaining time, the MS with the largest number of calls is served first. The overhead of selecting the corresponding MS is insignificant in comparison to the improvements of the scheme. The results are shown here through extensive simulations.

Keywords: handoff, cellular network, priority, shortest job first queue, on-hold call

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1. Introduction

The cellular communication system (cellular network) is designed to provide communications between either two moving units that are called mobile stations (MSs), or between one mobile unit and one stationary unit, called a land unit. To assure a good QoS, the service providers must be able to locate and track a caller, assign a channel to the call, and transfer the channel from base station (BS) to another when the caller moves out of range. To sipmlify the tracking process, the cellular service area is divided into small regions called cells where every cell is represented by an hexagonal area. Each cell intersects with its neighbours with a small area called the overlap region, that is the area where an MS can receive signal from two cells at the same time (Figure 1).

When an MS starts a new call, the BS should allocate a free channel for it, otherwise its call will be blocked. Once a channel is allocated, the BS is now referred as the serving base station (SBS) of this MS. The MS can use this channel for more than one call, however, only one call should be active and the others are put on-hold. An obstacle in the development of the cellular network involves the problem created when the MS travels from one BS to another during a call. The MS should disconnect from its SBS and connect to another BS, referred as the target base station (TBS). This process is known as handoff. In a practical environment, there is some handoff time delay before that an MS connects to

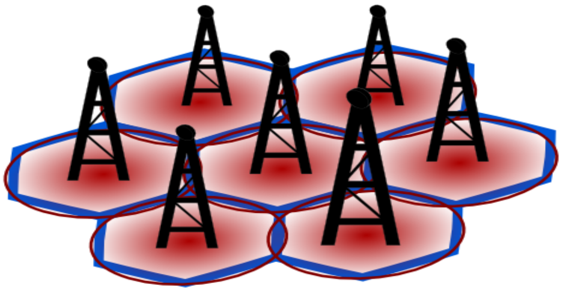

Figure 1: Cellular Network: Approximation of hexagonal areas by circular ones

a TBS. This delay is composed of handoff preparation and handoff execution. It is constrained by a timeout period that when exceeded, the handoff fails and the MS calls are all forced-terminated. Note that an MS could succeed multiple handoffs before its calls are forced-terminated. When MSs are moving with high velocity, the number of handoff attempts dramatically increases. From a user's point of view, it is more annoying to drop an ongoing call than to block a new call. Therefore, handoff calls are given a higher priority to get a channel over new calls. This prioritization rule decreases the handoff failure probability at the expense of an increase in the call blocking probability.

There are two main objectives in cellular network design: maximize the resource utilization and provide a high QoS to users [1]. There exist many schemes in literature that try to accomplish both objectives, however, they improve one of the objectives at the expense of the other. Non-priority schemes provide equal service for all types of traffic, they highly utilize the radio resources but they do not ensure a satisfied level of QoS. Call admission control (CAC) schemes limit the number of call connections into a network, reduce the blocking probabilities of higher priority traffic classes, and optimize the channel utilization [2], [3], [4]. There exist a number of CAC schemes that were proposed by various researchers based on different aspects of the service management. These CAC schemes are of two types: fundamental or conditional. The fundamental CAC schemes can be applicable in any kind of wireless network while the conditional schemes are designed for special purpose systems. Recently, a number of CAC schemes [5],[6],[7] considered an adaptive bandwidth utilization. These schemes overcome the problem of resource utilization, they utilize the maximum radio resources to provide a proper QoS, however they do not provide a priority for special types of traffic. In some other novel CAC schemes, authors proposed some QoS optimization technique based on probabilistic call arrival rate [8], traffic awareness [9], mobility-awareness [10], [11] and cost rate of holding time [12]. However, these categories of CAC schemes are used for special purposes only. The CAC schemes could also be divided into two groups of mechanism. The first group works on the improvement of handoff calls and new calls. In such schemes, the handoff calls have a higher priority over new calls [1], [4], [5]. The second group studies the case where there are multiple services oriented cellular network, i.e when there is a number of service classes with different priorities in the network. Usually, they consider about four to five classes of services [11], [13], [14], and they reserve channels for different classes. However, the priority schemes have some drawbacks, the radio resources in the cellular network are limited, therefore, the reservation of channels will decrease the channel utilization of the system.

The most popular strategies for prioritizing handoff calls are the guarded channel strategy and the handoff queueing strategy [15]. In the guarded channel strategy, a fixed number of channels is reserved exclusively for handoff calls. New calls are not allowed to use these guarded channels for service, while a handoff call can use any channel [16]. Since calls arrive with very high rate at peak hours and with low rate at non-peak hours, the implementation of a fixed guarded band with a number of reserved channels for high priority calls causes unutilised resources at non-peak hours. This problem is solved with a dynamic channel reservation technique. The dynamic channel reservation or dynamic channel allocation technique takes into consideration some statistical calls arrival rate, random calls arrival rate and traffic awareness [17]. The problem with guarded channel strategy is that when all the channels (reserved and non reserved) are busy, the handoff will fail and the call is forced terminated. The handoff queueing strategy cures this problem, it enqueues handoff requests until a channel gets free. Queueing is possible due to the overlap region between neighbour cells where the MS can reach both the SBS and the TBS. Both new calls and handoff calls can be queued [18], however, queuing new calls increases the handoff blocking probability. Therefore when the TBS channels are all busy, it should enqueue only handoff requests while blocking any new incoming call, this will of course increase handoff success at the expense of more blocked calls since new calls will not be served until all the handoff requests in the queue are served first. In [18], a queuing scheme that uses guarded channels is described where both new calls and handoff calls are queued. A number of guarded channels is reserved for handoff calls only. In this scheme, when the new calls are congested, a channel from the guard channels could be used if it is available. This scheme decreases the call blocking probability at the expense of a slight increase in forced termination probability.

More CAC techniques were presented in literature. In [19], a timer based handoff priority scheme is presented. When a channel is released at a BS, a timer starts. If a handoff is requested during some time interval then a channel is assigned to it. However, if the timer expires, then the channel will be assigned to a new or a handoff call depending on the arrival order. Tekinay and Jabbari introduced a new prioritization scheme called Measurement Based Prioritization Scheme (MBSP) in [20]. The handoff calls are queued and the call position in the queue changes dynamically based on the power level it has. That is, the calls with power level closer to the receiver threshold have the highest priorities. This scheme of course provides better results than the first-in first-out (FIFO) queuing scheme where handoff calls are served due their arrival time. The Most Critical First (MCF) policy proposed in [21] assigns a channel to the handoff call that will be first cut off. They used some simple radio measurements to predict the first handoff call to be cut off. However, both articles did not take the MS velocity into consideration. In [22], the Predictive Received Signal Strength (PRSS) studied whether to start a handoff by comparing some quantitative decision values to select a target network. However, this algorithm could not be applied because the MS should know how strong is the PRSS of its neighbors in order to decide an early handoff. Two handoff algorithms were developped in [23] based on the PRSS and the current RSS, they decreased the handoff failure probability but without avoiding the ping-pong effect where a MS keeps switching channels between BSs due to signal fluctuations. Other handoff decision algorithms were proposed based on fuzzy logic to give the best solution for handoff decision [24],[25]. The problem with these algorithms is that they all need to establish some proper rules that require a large memory in databases. The following papers [26],[27],[28] improved handoff decisions by analysing the signal power received by stations, but without taking MS velocity into consideration. Other studies considered the mobility of MSs to decrease handoff failure probabilities [29],[30]. Many other feasible solutions were developed to enhance handoffs by monitoring the MS position [31]. Using the global positioning system (GPS) is one way to get the locations of MS; however, when used in extreme weather conditions, it could suffer from serious interferance problems [32]. The handoff mechanism in [33] considered both the SNR value and the mobility of MSs using geometric analysis. A fast handoff scheme for VoIP was considered in [34], it is based on selective scanning and caching to predict the next cell, but it didn't consider the case where MS is moving with high velocity. A handoff scheme named Shortest Job First-Like Handoff Scheme (SJFLHS) for high velocity MSs was proposed in [35], it always selects to handoff the MS that has the minimum remaining time before leaving the cell which gives more chances to MSs that are moving with high velocity but it didn't consider the case where a MS has on-hold calls. Generally, all of the above proposed schemes reduce the call blocking probability of higher priority traffic, improve the channel utilization and provide the best QoS of a network for specified purposes.

In this article, we consider a cellular network with homogeneous cells where a specific number of channels is assigned to each cell. Specifically, we focus on the handoff process in such networks. The main idea is to increase the handoff success probability of calls by giving a priority to MSs that have on-hold calls while moving with high velocity. The present scheme called Minimum Remaining Time with Largest Number of Calls (MRTLNC) treats each MS individually, and handoffs first the calls of the MS that has the lowest remaining time in the cell and also has the largest number of on-hold calls at the same time. The paper is organized as follows: in section 2 some background about handoffs is provided, our proposed handoff scheme is presented in section 3, simulation of the model and results are shown in section 4, and finally section 5 shows conclusions about the presented scheme.

2. Handoff

Modern communication networks are very complex systems. For a better understanding of their behavior, one has to deal with mathematical models that describe the stochastic service of randomly arriving requests. In a cellular communication system, we assume that the new calls and handoff calls arrive according to a Poisson distribution with parameters λ_n and λ_h respectively. Each station has C channels that can serve C calls in parallel. The time that the MS spends in the system is referred to as the call holding time T and is assumed to be exponentially distributed with parameter μ. Therefore μ is the ongoing calls termination rate and $\frac{1}{C\mu}$ is the average time a call spends in the system.

A. Handoff schemes

There are two types of handoff schemes: Non-priority schemes and priority schemes.

a. Non Priority scheme

Non-priority schemes provide equal service for calls regardless of their types, all C channels are shared by both originating and handoff calls and are assigned in a FCFS basis. That is, if no channel is free, both kinds of requests are blocked equally, which is not desirable in the cellular industry. This is a typical $M/M/C/C$ queueing model. Let E_n be the state that there are n ongoing calls in a cell and P_n be the steady state probability for a cell to be in state E_n. These probabilities are determined by using the Markovian birth-death process shown in the state diagram in Figure 2 and are given in equation (1).

$$P_n = \frac{(\lambda_n + \lambda_h)^n}{n!\mu^n} P_0 \tag{1}$$

Where P_0 is given in equation (2) and found from the equation $P_0 + P_1 + \cdots + P_n = 1$

$$P_0 = \left(\sum_{n=0}^{C} \frac{(\lambda_n + \lambda_h)^n}{n!\mu^n} \right)^{-1} \tag{2}$$

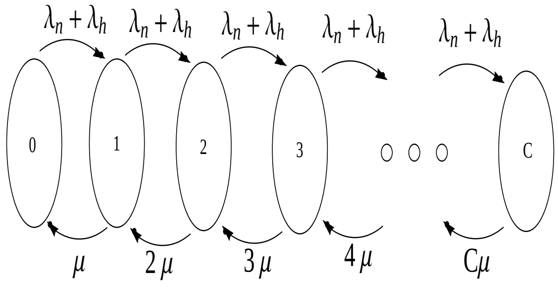

Figure 2: State transition diagram for the non priority scheme.

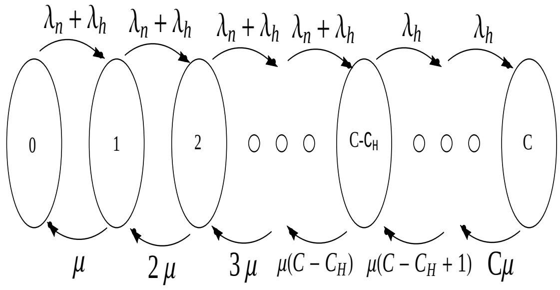

Figure 3: State transition diagram for the guarded channel strategy.

Let P_B represents the call blocking probability and P_{fh} represents the handoff failure probability because no channels are available.

A new call is blocked when all C channels are busy, the blocking probability of new calls is given in equation (3):

$$P_B = P_{n|n=C} = \frac{\frac{(\lambda_n+\lambda_h)^C}{C!\mu^C}}{\sum_{n=0}^{C} \frac{(\lambda_n+\lambda_h)^n}{n!\mu^n}} \tag{3}$$

The handoff of a call fails is there is no availabe channel at the TBS, the handoff call failure probability is given in equation (4):

$$P_{fh} = P_{n|n=C} = \frac{\frac{(\lambda_n+\lambda_h)^C}{C!\mu^C}}{\sum_{n=0}^{C} \frac{(\lambda_n+\lambda_h)^n}{n!\mu^n}} \tag{4}$$

b. Priority Schemes

In order to provide lower forced termination rates, priority schemes assign more channels to handoffs. Many channel assignment strategies with handoff prioritization were proposed, all of them reduce the probability of call forced-termination at the expense of an increase in the call blocking probability. These priority schemes are divided into two categories: guarded channels schemes and queuing schemes [15].

Guarded channels scheme Guarded channels is a handoff priority scheme that increases the probability of succeeding handoffs by reserving a fixed or dynamically adjustable number of channels exclusively for handoffs. The non-reserved channels are used by new and handoff calls. That is, C_H channels among the C channels in the cell are reserved for handoffs only while the remaining $(C - C_H)$ channels could be used by both new calls and handoff calls. A new call is blocked if the number of free channels in a cell is less than $(C - C_H)$ while handoff fails if no channel is free at the TBS. The probability P_n is determined in this case by using the Markovian birth-death process shown in the state diagram in Figure 3 and is given in equation (5):

$$P_n = \begin{cases} \frac{(\lambda_n+\lambda_h)^n}{n!\mu^n} P_0, & n < C - C_H. \\ \frac{(\lambda_n+\lambda_h)^{C-C_H} \lambda_h^{n-\left(C-C_H\right)}}{n!\mu^n} P_0, & C - C_H \leq n \leq C. \end{cases} \tag{5}$$

Where P_0 is given in equation (6) and found from the equation $P_0 + P_1 + \cdots + P_n = 1$

$$P_0 = \sum_{n=0}^{C-C_H} \frac{(\lambda_n + \lambda_h)^n}{n!\mu^n} + \sum_{n=C-C_H+1}^{C} \frac{(\lambda_n + \lambda_h)^{C-C_H} \lambda_h^{n-(C-C_H)}}{n!\mu^n}^{-1} \tag{6}$$

A call is blocked if all the non-guarded channels were busy, threfore P_B is given in equation (7):

$$P_B = \sum_{n=C-C_H}^{C} P_n \tag{7}$$

A handoff fails when all the channels (guarded and non-guarded) are busy, therefore P_{fh} is given in equation (8):

$$P_{fh} = P_{n|n=C} \tag{8}$$

Handoff queueing scheme Handoff queuing prioritization is a handoff priority scheme that queues the handoff calls when all of the channels are occupied in the TBS. If the number of busy channels is less than C then the TBS accepts every incoming call. However, when the C channels are all busy, then the TBS will accept only handoff calls. These handoff calls will wait for their turn in a queue until a channel gets free and then they are treated equally on a FCFS basis. Queuing is possible due to the overlap region between the adjacent cells where an MS is able to communicate with more than one BS. When the TBS is busy, queuing handoff requests delays them instead of terminating them instantly. Once a TBS channel is released, it is assigned to one of the handoffs waiting in the queue. A new call request is assigned a channel only if the queue is empty and if there is at least one available channel in the TBS. The duration that an MS spends in the overlap area is referred as the degradation interval. It depends on system parameters such as cell size, the moving speed and the direction of the MS. When an MS is moving away from its SBS, the RSS decreases. Once the RSS gets lower than a threshold value, the handoff process is initiated.

In the handoff queueing scheme, The first-in-first-out (FIFO) queueing strategy is applied assuming that the queue size at the TBS is infinite. For simplicity reasons, the TBS system is assumed to have:

- C channels that can serve C calls in parallel and its buffer is of infinite waiting room.
- The call holding time T_h is exponentially distributed with parameter μ. Thus, μ is the departure rate for ongoing calls that are ended. Also, $\frac{1}{\mu}$ is the average call holding time.
- The call association time y_i (time that a MS is being served by the SBS in cell i) is exponentially distributed with parameter v. Thus, v is the departure rate for ongoing calls that leave cell i. Also, $\frac{1}{v}$ is the average call association time with cell i. In other words, v is the average moving rate of the MS in a cell.
- The time spent z_i in the non-overlap area is exponentially distributed with parameter ζ. Thus, ζ is the departure rate for ongoing calls that leave the non-overlap area of cell i. Also, $\frac{1}{\zeta}$ is the average time spent in the non-overlap area of cell i.
- The time spent ω_i in the overlap area is exponentially distributed with parameter η. Thus, η is the departure rate for waiting calls in the queue that leave the overlap area of cell i. Also, $\frac{1}{\eta}$ is the average time spent in the overlap area of cell i.
- When the state of the cell is $s\left(k\right), (0 \leq k \leq C)$, (i.e. there are k busy channels), the arrival rate is a constant of $\lambda_n + \lambda_h$ and the service rate is $k\left(\mu + v\right)$.
- When the state of the cell is $s(C + j),\ j \geq 0$, the arrival rate is a constant of λ_h and the service rate is $C\left(\mu + v\right) + j\left(\mu + \eta\right)$.

In [36], authors found that the MS's association time y_i with the SBS in cell i is exponentially distributed with the density function $a\left(y_i\right) = ve^{-vy_i}$. Its expected value is given in equation (9) :

$$\begin{aligned} E\left[y_i\right] &= \frac{1}{v} \\ &= E\left[z_i\right] + E\left[\omega_i\right] \\ &= \frac{\eta + \zeta}{\eta\zeta} \end{aligned} \tag{9}$$

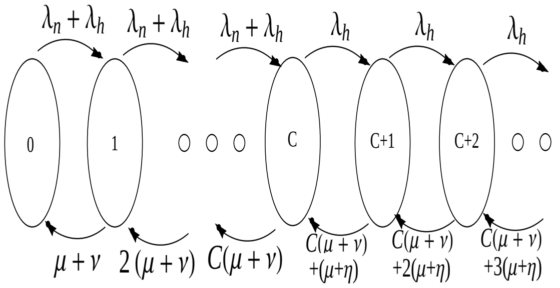

Figure 4: State transition diagram for the queuing strategy.

The network response time needed for a handoff call is composed of a handoff preparation time ϕ and a handoff execution time δ. To compute the expected handoff execution time $E[\delta_i]$, the TBS could be modeled as an M/M/c birth-death process as shown in Figure 4.

Here the steady state probability P_n that there are n ongoing calls in a cell is given in equation (10):

$$P_n = \begin{cases} P_0 \frac{(\lambda_n+\lambda_h)^n}{n!(\mu+v)^n}, & n < C. \\ P_0 \frac{(\lambda_n+\lambda_h)^C \lambda_h^{n-C}}{(C-1)!(\mu+v)^{C-1} \prod_{j=0}^{n-C} [C(\mu+v)+j(\mu+\eta)]}, & n \geq C. \end{cases} \tag{10}$$

Where P_0 is given in equation (11) and found from the equation $P_0 + P_1 + P_2 + \cdots = 1$

$$P_0 = \sum_{n=0}^{c-1} \frac{(\lambda_n + \lambda_h)^n}{n!(\mu + v)^n} + \sum_{n=c}^{\infty} \frac{(\lambda_n + \lambda_h)^C \lambda_h^{n-C}}{(C-1)!(\mu + v)^{C-1} \prod_{j=0}^{n-C} [C(\mu + v) + j(\mu + \eta)]}^{-1} \tag{11}$$

The call blocking probability P_B is given in equation (12):

$$P_B = \sum_{n=c}^{\infty} P_n \tag{12}$$

and, according to [36], the handoff failure probability P_{fh} is given in equation (13):

$$P_{fh} = \sum_{j=0}^{\infty} \frac{\eta\,(j+1)\,P_{c+j}}{C\,(\mu + v) + (j+1)\,(\mu + \eta)} \tag{13}$$

3. Proposed Handoff Scheme

In our scheme, we assume that the velocity (speed and direction) of the MS remains constant during its travel in a cell. However, it changes from cell to cell and its magnitude is uniformly distributed over the interval $[V_{\min}, V_{\max}]$. Our scheme combines both priority schemes (Guarded Channels and Handoff Queuing) and also gives priority to MSs that have the minimum remainig time in the cell τ and MSs that have the largest number of calls. In this scheme, when a new call arrives at a BS, it will check whether there is a free (non-guarded and not reserved by an MS) channel to serve this call, if no channel is free then the call is blocked. As for handoffs, we specify a threshold time τ_h, when an MS has $\tau < \tau_h$, its SBS will make an early reservation for a channel (guarded or not guarded) from the TBS. The TBS will reserve a channel if its has an available one and will allocate it as soon to the MS enters the overlap region. In case there is no currently available channels at the TBS, the SBS will recheck for a channel as long as the MS is still located in the overlap region. If the MS leaves the overlap region before succeeding its handoff, its calls will be forced-terminated. Therefore τ and τ_h are two major factors for succeeding handoffs. In previous studies, handoff is served in a FCFS discipline, which means the MS that requests the handoff first is always served first. However, if we look at the example in Figure 5, two MSs (MS1 and MS2) that are equidistant from a TBS and having $\tau_{MS1} < \tau_{MS2} < \tau_h$ request handoffs. In this case, MS1 has a lower τ than MS2 which means it is moving with higher velocity than MS2 and therefore it is more likely to leave the cell before MS2. The problem with FCFS discipline is that it handoffs the calls of MS2 before MS1 if MS2 requested the handoff first, which could of course lead to the forced-termination of the calls of MS1 if there

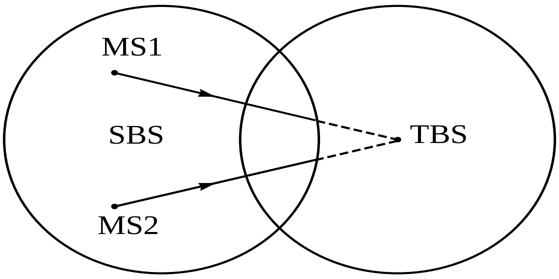

Figure 5: Handoff requests with different priorities.

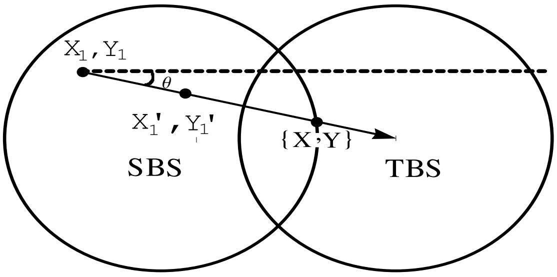

Figure 6: A MS leaving its SBS and moving toward a TBS.

are no more available channels at the TBS. To overcome this problem, the handoffs should not be treated equally, the SBS should select to handoff the call of the MS with the lowest τ first. Our scheme provides this feature, the SBS selects every Δt seconds the MS with the lowest τ and reserves a TBS channel for it. Therefore in the example above, MS1 will be selected before MS2. A special case occurs when τ_{MS1} and τ_{MS2} have close values. In this case, the remaining time is no longer the most important factor to check, more important now is to serve the MS that has the largest number of calls. Let $\Delta\tau$ specifies how close the values of remaining times should be in order to trigger this special case, i.e. this special case will only be triggered when the difference in remaining times between two MSs is lower than $\Delta\tau$. Back to our example, if $\tau_{MS2} - \tau_{MS1} < \Delta\tau$ and MS2 has more on-hold calls than MS1 then MS2 will be selected first for handoff. However, if $\tau_{MS2} - \tau_{MS1} < \Delta\tau$ but MS1 and MS2 have same number of on-hold calls, then the special case is cancelled and the SBS will select MS1 first since it has the lower τ. We should also note that our scheme allows a BS to cancel the reservation of a channel in case an MS has finished its call while being queued, therefore the corresponding reserved channel at the TBS will be released.

A. Calculation of τ

The location of MSs is updated every Δt seconds. If MS1 is located at coordinates (X_1, Y_1), the new location of MS1 depends on its velocity vector $\overrightarrow{V}_{MS1}$, which is constant both in magnitude and angle θ (taken with respect to X-axis) as shown in Figure 6. Note that the magnitude $\left|\overrightarrow{V}_{MS}\right|$ for a MS is uniformly distributed over the interval $[V_{\min}, V_{\max}]$.

The value of θ is given in equation (14):

$$\theta = \tan^{-1}\left(\frac{X_{TBS} - X_1}{Y_{TBS} - Y_1}\right) \tag{14}$$

Where X_{TBS} and Y_{TBS} are the coordinates of the center of the TBS. The new coordinates $\left(X_1^{'}, Y_1^{'}\right)$ of MS1 are given in equation (15):

$$\begin{aligned} X_1^{'} &= X_1 + \Delta t * V \cos\theta \\ Y_1^{'} &= Y_1 + \Delta t * V \sin\theta \end{aligned} \tag{15}$$

MS1 is moving on the straight line $Y = Y_1 + (X - X_1)\tan\theta$, it will leave the SBS once it reaches the point of intersection (X, Y) of this straight line with the coverage area of the SBS, which is a circle of radius R. The remaining time τ_{MS1} for MS1 in the SBS is given in equation (16):

$$\tau_{MS1} = \frac{\sqrt{(Y - Y_{MS1})^2 + (X - X_{MS1})^2}}{\left|\overrightarrow{V}_{MS1}\right|} \tag{16}$$

B. MRTLNC Algorithms

The following algorithm shows how our scheme deals with new call, channel reservation, handoff and handoff cancellation.

Algorithm 1 New Call

```
procedure NEW CALL
    If there is a non guarded channel that is not reserved then allocate the channel
    Else Block the call
end procedure
```

Algorithm 2 Reservation

```
procedure RESERVATION
    Select the MS that has the lowest remaining time with largest number of calls
    If there is a non reserved channel (guarded or non guarded) at the TBS then reserve this channel
    Else Ignore the request
end procedure
```

Algorithm 3 Handoff

```
procedure HANDOFF
    If the MS has an early reservation for a channel then allocate the channel
    Else If there exists a non reserved channel (guarded or non guarded) then allocate the channel
    Else Terminate the Call
end procedure
```

Algorithm 4 Cancellation

```
procedure CANCELLATION
    If a call that reserved a channel has finished then free the reserved channel
end procedure
```

4. Simulation and Results

The new call blocking probability P_B and the handoff failure probability P_{fh} are affected by various parameters such as the new calls arrival rate λ, call service rate μ, number of guarded channels used in a cell, the threshold time τ_h and the velocity (speed and direction) of MSs in the cell. We simulate our model using a C++ program and we show the effect of such parameters on P_B and P_{fh}. The values used in the simulation are shown in Table 1, unless otherwise specified. Next, we compare the results of our scheme MRTLNC with the scheme SJFLHS in [35].

A. Impact of new calls arrival rate on P_B and P_{fh}

The value of λ has a significant impact on the performance of the cellular system. When λ is increased, this will result in more calls arriving at cells and therefore channels will be highly occupied which will lead to a higher P_B and P_{fh}. Figure 7 shows P_B for SJFLHS and MRTLNC versus the new calls arrival rate λ. P_B in MRTLNC is about 11% higher than

Table 1: Values used in simulation

Parameter	**Value**	**Description**
R	3000 m	Radius of a Cell
S	50	Number of Cells
N	100	Number of MSs in a Cell
C	32	Number of Channels in a Cell
GC	2	Guarded Channels in a Cell
$V_{\min}$	1 m/s	Minimum Speed of a MS
$V_{\max}$	30 m/s	Maximum Speed of a MS
λ	1/10 Calls/sec	Call Arrival Rate
μ	1/180 Calls/sec	Call Service Rate
$\Delta\tau$	5 sec	Difference in Remaining Times
τ_h	20 sec	Threshold Time

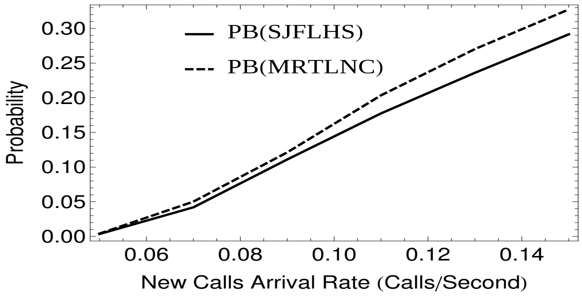

Figure 7: Call Blocking Probability vs. Calls Arrival Rate.

that of the SJFLHS strategy, and this is because the former strategy succeeds the handoffs better than the latter, therefore there are less remaining channels for new calls.

On the other hand, the handhoffs in MRTLNC are served better than in SJFLHS. We can see from Figure 8 that P_{fh} for MRTLNC is about 17% lower than that of SJFLHS when the new calls arrival rate λ increases. MRTLNC gives priority to MSs with largest number of call which leads to more handoffs success.

B. Impact of calls service rate on P_B and P_{fh}

The service rate μ is also a very important factor that affects the performance of the cellular system. As μ increases, the cellular system will have more channels to serve calls and therefore the cells will not be highly occupied anymore which will lead to a lower P_B and P_{fh}. We show in Figure 9 the changes in P_B with the increase in the service rate μ. We notice that P_B in MRTLNC is about 10% higher than that of the SJFLHS scheme.

The increase in μ has a good impact on succeeding handoffs. The handoff failure probability decreases significantly with the increase in μ because higher service rate means more idle channels to serve handoffs. We show the effect of the

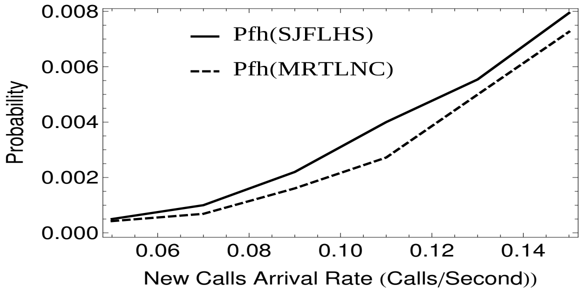

Figure 8: Handoff Failure Probability vs. Calls Arrival Rate.

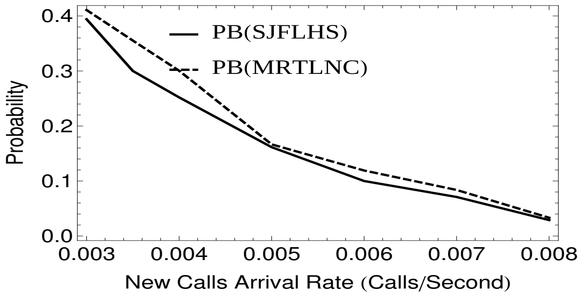

Figure 9: Call Blocking Probability vs. Calls Service Rate.

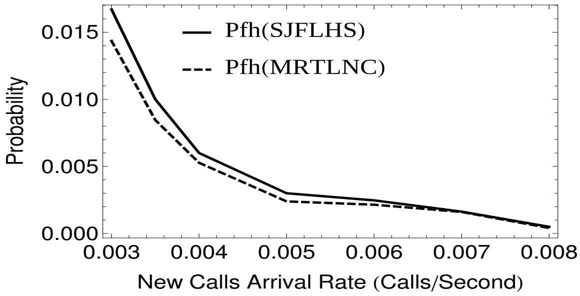

Figure 10: Handoff Failure Probability vs. Calls Service Rate.

service rate on the handoff failure probability P_{fh} in Figure 10, we can see that giving priority to MS with largest number of calls in MRTLNC has resulted in 19% lower values than those of the SJFLHS

C. Impact of guarded channels on P_B and P_{fh}

Specifying the best choice for the number of guarded channels in a cell is a very important issue that should be studied. A large number of guarded channels leads to a very small value of P_{fh}, but it will also lead to a very large value of P_B because more channels are reserved for handoffs which could lead to starvation in new calls. Therefore the increase in the number of guarded channels will result in lower P_{fh} at the expense of higher P_B. Choosing the optimal number of guarded channels is not that easy, one should use the value that optimizes the performance of the cellular network. MRTLNC gives higher priority to on-hold calls which will lead to more handoff successes and of course more blocked calls. We can see from Figure 11 that P_B in MRTLNC is 10% higher than that of SJFLHS scheme.

The increase in the number of guarded channels results in more handoffs success because when there are more guarded channels in a cell, there is a higher chance for handoffs to succeed. We can see in Figure 12 that the strategy of serving the MS with largest number of calls first used in MRTLNC has also lead to values of P_{fh} lower 19% than those of the SJFLHS.

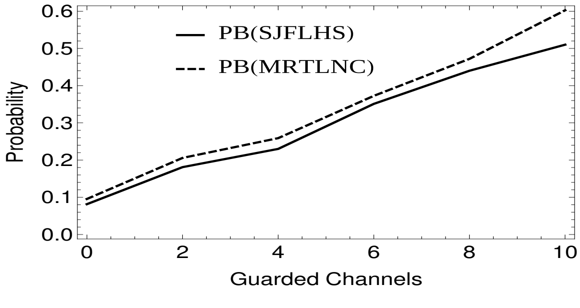

Figure 11: Call Blocking Probability vs. Number Of Guarded Channels.

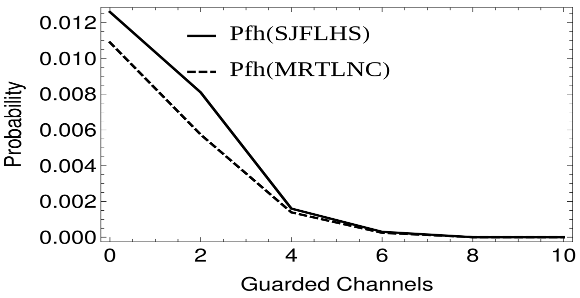

Figure 12: Handoff Failure Probability vs. Number Of Guarded Channels.

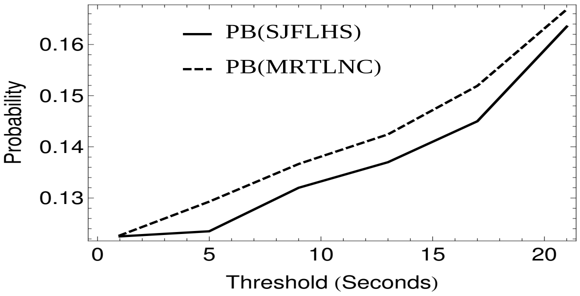

Figure 13: Call Blocking Probability vs. Threshold.

D. Impact of time threshold on P_B and P_{fh}

The time threshold τ_h has also a significant impact on the performance of the system. An increase in τ_h will allow MSs to make earlier reservations which will lead to succeeding handoffs more efficiently. This of course will also lead to high P_B because channels reserved by handoffs will reject new calls. MRTLNC succeeds handoffs more efficiently at the expense of blocking more new calls, we can see from Figure 13 that P_B in MRTLNC is 11% higher than that of the SJFLHS strategy.

As for P_{fh}, when τ_h is large enough, it will give MSs more chance to succeed their handoffs. We can see from Figure 14 that P_{fh} in MRTLNC is 19% lower than that of the SJFLHS and this is of course due to selecting the MSs with largest number of calls to be handed-off first.

E. Impact of MS velocity on P_B and P_{fh}

When a MS is moving with high velocity, it leaves its SBS very quickly and connect to a TBS. However, because of its high velocity, it will leave the new SBS very soon and connect to a new TBS and keeps repeating the process. This of course will result in increasing the total number of handoffs in the system. However, the high velocity gives unsufficient time for MSs to succeed their handoff which will result in a high handoff failure rate. Allowing MSs with largest number of calls to be served first will somehow decrease P_{fh}. We can see from Figure 15 that P_{fh} in MRTLNC is 11% lower than the SJFLHS strategy.

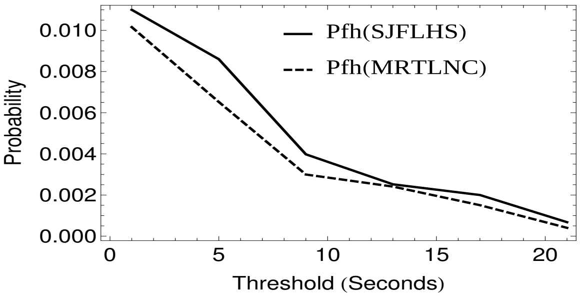

Figure 14: Handoff Failure Probability vs. Threshold.

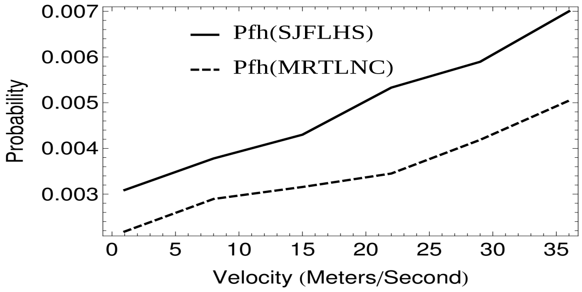

Figure 15: Handoff Failure Probability vs. MSs Velocity.

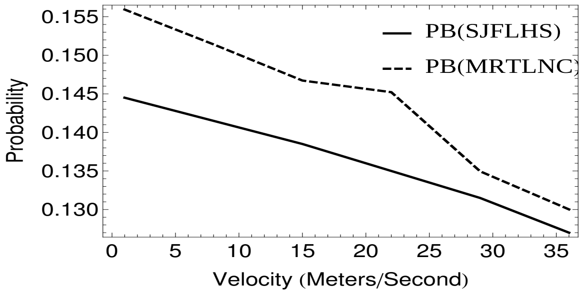

Figure 16: Call Blocking Probability vs. MSs Velocity.

On the other hand, more handoff failures mean more channels for new calls. High velocity will result in less blocked calls, that is P_B decreases with the increase in velocity. We show in Figure 16 that P_B in MRTLNC is 17% higher than that of the SJFLHS strategy.

5. Conclusion

In this paper, we presented a novel cellular handoff scheme particularly suitable for serving MSs that have more than one call and are moving with high velocities. The idea of the scheme is to select for service the MS with minimum remaining time in the cell and that has the largest number of calls. This scheme decreases the likelihood that a MS with more than one call leaves the cell before it handoffs its calls.

The C program used to simulate the proposed scheme has provided us more control than very high level simulation languages and platforms. The simulation results show that the overall performance of the proposed scheme decreases the handoff failure probability with 18% in comparison to SJFLHS. The overhead due to selecting the MS with minimum remaining time and with the largest number of calls is $O(n)$, which is practically a desired property. The simulation shows also that this decrease in the handoff failure probability comes at the expense of an 11% increase in the call blocking probability because a channel reserved for a handoff is basically taken from new calls. However, it is well known in the cellular industry that blocking a new call is more welcome than terminating an ongoing one. As a future work, our scheme could be applied to a more realistic mobility model such as a city model where MSs movements are restricted to some conditions and constraints.

References

[1] V. Pandey, D. Ghosal, B. Mukherjee, and X. Wu. Call admission and handoff control in multi-tier cellular networks: algorithms and analysis. *Wireless Personal Communication*, 43(4):857–878, June 2007.

[2] B. Li, C. Lin, and S. Chanson. Analysis of a hybrid cutoff prioity schemes for multiple classes of traffic in multemedia wireless networks. *Wireless Networks (WINET)*, 4(4):270–290, August 1998.

[3] A. Leelavathi and G.V. Sridhar. Adaptive bandwidth allocation in wireless networks with multiple degradable quality of service. *International Journal of Future Generation Communication and Networking*, 2(4):25–29, October 2012.

[4] M. Cello, G. Gnecco, M. Marchese, and M. Sanguineti. Optimality conditions for coordinate-convex policies in cac with nonlinear feasibility. *ACM Transactions on Networking*, 21(5):1363–1377, October 2013.

[5] F. Richard-Yu, V.W.S. Wong, and V.C.M. Leung. A new qos provisioning method for adaptive multimedia in wireless networks. *IEEE Transactions on Vehicular Technology*, 57(3):1899–1909, June 2008.

[6] N. Nasser. Service adaptability in multimedia wireless networks. *IEEE Transactions on Multimedia*, 11(4):786–793, June 2009.

[7] M.Z. Chowdhury, Y.M. Jang, and Z.J. Haas. Call admission control based on adaptive bandwidth allocation for wireless networks. *Journal of Communications and Networks*, 15(1):15–24, February 2013.

[8] D.G. Stratogiannis, G.I. Tsiropoulos, J.D. Kanellopoulos, and P.G. Cottis. Probabilistic call admission control in wireless multiservice networks. *IEEE Communication Letters*, 13(10):746–748, October 2009.

[9] A. Antonopoulos and C. Verikoukis. Traffic-aware connection admission control scheme for broadband mobile systems. *IEEE Communication Letters*, 14(8):719–721, August 2010.

[10] Y. Kim, H. Ko, S. Pack, W. Lee, and X. Shen. Mobility-aware call admission control algorithm with handoff queuee in mobile hotspots. *IEEE Transactions on Vehicular Technology*, 62(8):404–417, October 2013.

[11] F. Hu and N. Sharma. Priority-determined multiclass handoff scheme with guaranteed mobile qos in wireless multimedia networks. *IEEE Transactions on Vehicular Technology*, 23(4):404–417, January 2006.

[12] W. Ni, W. Li, and M. Alam. Determination of optimal call admission control policy in wireless networks. *IEEE Transactions on Wireless Communication*, 8(2):1038–1044, February 2009.

[13] M.Z. Chowdhury, Y.M. Jang, and Z.J. Haas. Call admission control based on adaptive bandwidth allocation for multi-class services in wireless networks. pages 358–361. International Conference on Information and Communication Technology Convergence, November 2010.

[14] M.Z. Chowdhury, M.S. Uddin, and Y. M. Jang. Dynamic channel allocation for class-based qos provisioning and call admission in visible light communication. *Arabian Journal for Science and Engineering*, 39(2):1007–1016, February 2014.

[15] N.D. Tripathi, J.H. Reed, and H.F. VanLandinoham. Handoff in cellular systems. *IEEE Personal Communications*, 5(6):26–37, December 1998.

[16] D. Hong and S.S. Rappaport. Traffic model and performance analysis for cellular mobile radio telephone systems with prioritized and nonprioritized handoff procedures. *IEEE Trans. on Vehicular Technology*, 35(3):77–92, August 1986.

[17] J. Jiang, T. Lai, and N. Soundarajan. On distributed dynamic channel allocation in mobile cellular networks. *IEEE Transactions on Parallel and Distributed Systems*, 13(10):1024–1037, October 2002.

[18] S. Choi and K. Sohraby. Analysis of a mobile cellular systems with hand-off priority and hysteresis control. pages 217–224. In Proceedings of the Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies, March 2000.

[19] P. Marichamy, S. Chakrabati, and S.L. Maskara. Overview of handoff schemes in cellular mobile networks and their comparative performance evaluation. pages 1486–1490. Vehicular Technology Conference, September 1999.

[20] S. Tekinay and B. Jabbari. Prioritization scheme for handovers in mobile cellular networks. *IEEE Journal on Selected Areas in Communications*, 10(8):1343–1350, October 1992.

[21] P. Agrawal, D. Anvekar, and B. Narendran. Channel management policies for handovers in cellular networks. *Bell Labs Technical Journal*, 1(2):97–110, June 1996.

[22] L. Xia, L. Jiang, H. Chen, and H. Liao. An intelligent vertical handoff algorithm inheterogeneous wireless networks. pages 550–555. IEEE International Conference on Neural Networks and Signal Processing, June 2008.

[23] B.J. Chang and J.F. Chen. Cross-layer-based adaptive vertical handoff with predictive rss in heterogeneous wireless networks. *IEEE Transactions on Vehicular Technology*, 57(6):3679–3692, 2008.

[24] C. Ceken and H. Arslan. An adaptive fuzzy logic based vertical handoff decision algorithm for wireless heterogeneous networks. pages 1–9. IEEE conference on Wireless and Microwave Technology, April 2009.

[25] X. Haibo, T. Hui, and Z. Ping. A novel terminal-controlled handover scheme in heterogeneous wireless networks. *Journal of Computers and Electrical Engineering*, 36(2):269–279, 2010.

[26] A. Rath and S. Panwar. Fast handover in cellular networks with femtocells. pages 2752–2757. IEEE International Conference on Communications (ICC), June 2012.

[27] A. Roy, J. Shin, and N. Saxena. Multi-objective handover in lte macro/femto-cell networks. *IEEE Communications and Networks*, 14(5):578–587, October 2012.

[28] Y. Yu and D. Gu. The cost efficient location management in the lte picocell/macrocell network. *IEEE Commun Lett*, 17(5):904–907, May 2013.

[29] T. Guo, A. Quddus, N. Wang, and R. Tafazolli. Local mobility management for networked femtocells based on x2 traffic forwarding. *IEEE Trans Veh Technol*, 62(1):326–340, August 2013.

[30] J. Astorga, M. Aguado, N. Toledo, and M. Higuero. A high performance link layer mobility management strategy for professional private broadband networks. *Journal of Network and Computer Applications*, 36(4):1152–1163, July 2013.

[31] A.E. Xhafa and O.K. Tonguz. Dynamic priority queueing of handover calls in wireless networks: an analytical framework. *IEEE Journal of Selected Area in Communication*, 22(5):904–916, June 2004.

[32] S. Hong, M.H. Lee, H.H. Chu, S.H. Kwon, and J.L. Speyer. Experimental study on the estimation of lever arm in gps/ins. *IEEE Transactions on Vehicular Technologies*, 55(2):431–448, March 2006.

[33] C. Jenhui, Y. Zhuxiu, and W. Lei. An apropos signal report and adaptive period (asap) scheme for fast handover in the fourth-generation wireless networks. *Journal of Network and Computer Applications*, 45(1):15–26, October 2014.

[34] J. Xiao and F. Liu. A pre-scanning fast handoff scheme for voip in wlans. *International Journal of Future Generation Communication and Networking*, 8(2):343–354, February 2015.

[35] B. Owaidat, R. Kassem, and H. Issa. An efficient handoff scheme using a minimum residual time first scheme. *International Journal of Advanced Research in Computer Engineering and Technology (IJARCET)*, 4(9):3359–3565, September 2015.

[36] Y.B. Lin. and A.C. Pang. Comparing soft and hard handoffs. *IEEE Trans Veh Technol*, 49(3):792–798, May 2000.