Modified LP-DDCA for Integrated Service over Cellular System

Prepared by Yi-Hung Hsieh

Directed by Prof. Po-Ning Chen

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Department of Communication Engineering

National Chiao Tung University

Hsinchu, Taiwan 300, R.O.C.

E-mail: u8713520@cc.nctu.edu.tw

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Abstract

In this thesis, we consider a hierarchical cellular system (HCS) with two tiers where macrcells in the high tier provide broad radio coverage and microcells in the low tier support system capacity, and both jointly serve users of different mobility. One important issue in the system is how best a channel assignment scheme can be designed to reduce the probability of new call blocking as well as handoff call forced termination. As expected, this issue becomes more complex when both voice calls and data-packet calls are considered. To stem on this issue, we focus on the Local Packing Distributed Dynamic Channel Assignment (LP-DDCA) scheme and Guard Channel scheme, which are developed to smooth the handoff calls. Specifically, we propose to combine the two schemes (with some modifications) to reduce the probability of handoff call forced termination for both voice and data-packet call services, subject to a satisfactory level of new call (including voice and packet-data calls) blocking rates. We conclude from our simulations that in order to have an acceptable handoff call forced termination rate, the packet-data calls, although they are often armed with re-transmission, also need to be protected for their handoff.

Acknowledgements

I would like to thank Dr. Po-Ning Chen for his encouragement and guidance. This work would not have been possible without his advises and commitments. I would also like to thank all the people who have helped me, especially the members of network technology laboratory at Department of Communication Engineering, National Chiao Tung University.

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Chapter 1

Introduction

Provision of ubiquitous access and seamless wireless mobile telecommunications is a feature of the third generation wireless communication systems. This nevertheless involves the fundamental issue that the system needs to satisfy the requirement of a tremendously growing population of subscribers in a limited available spectrum [1, 2]. Recently, mobile telecommunication market is rapidly expanding, not only due to the increasing number of new subscribers but also the increased usage of new mobile services such as mobile Internet and high speed data transfer, among which packet data transfer is getting more and more important. It is expected that in the near future, the capacity demand cannot be fulfilled by traditional macrocellular networks. Technologies of multiple access based on TDMA and CDMA have been studied extensively for the third generation systems [6]. It is without doubt that some new techniques will have to be used, ranging from concepts as microcells and frequency hopping in GSM, to fundamentally new techniques, such as Smart Antenna and Dynamic Channel Allocation (DCA).

By the approach to micro-cellular systems, the capacity per unit coverage area can be significantly increased. However, the mobile crossing rate at cell boundaries is also increased, inducing a higher call forced termination probability which deteriorates the service quality of high mobility users [3, 4, 5, 17]. In order to provide high system capacity as well as to

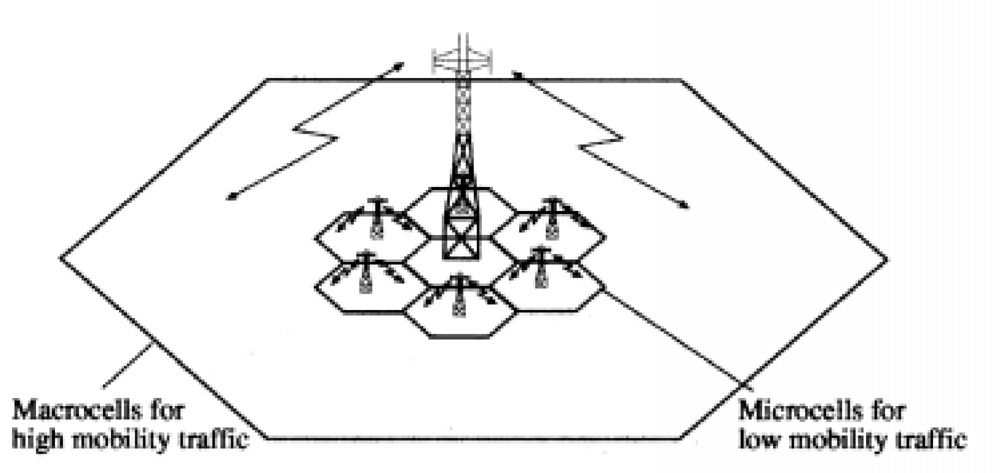


Figure 1.1: Microcell and macrocell systems.

support different user mobility, systems with Hierarchical Cellular Structure (HCS), where microcell and macrocell systems coexist, were proposed as shown in Fig. 1.1.

To satisfy the large demand of mobile telephone services, channels need to be re-used in different non-interfering cells. How channels are assigned for simultaneous usage in different cells directly affects the throughput of such systems.

There are different channel assignment schemes, and each of them provide different capacity. They can be roughly classified into three types: fixed channel assignment (FCA), dynamic channel assignment (DCA) and hybrid channel assignment (HCA). In FCA, a set of nominal channels is permanently assigned to each cell, and the same set of channels is re-used some distance away. That distance is called the co-channel reuse distance, and is usually assumed to be three cell units. According to the FCA strategy, an arriving call can only be served by those nominally assigned channels. If all nominal channels have been allocated, new calls are blocked. Most of the other strategies are variations of the FCA strategy with different channel borrowing methods. In HCA, the set of nominal channels assigned to each cell is divided into two subsets: A and B. Subset A channels are only used in the local cell, while subset B channels can be lent to the neighboring cells. The ratio of A against B (A and B now denote the number of elements in subsets A and B, respectively) is set as a priori. It was found that the optimum ratio depends on the traffic load [14].

The DCA enables a system to adapt to spatial and temporal variation of traffic statistics. It has been proven that TDMA (and FDMA) systems have a better performance using DCA than FCA, especially at low and moderate traffic load. It is widely adopted in most mobile phone standards that the new call blocking probability should be less that 2 percent even in an environment where most of cells have coverage areas severely deformed, which further makes the DCA a better choice than FCA [7, 8, 15]. In view of the above, it appears necessary to develop a novel DCA scheme to improve the performance of HCS in TDMA systems.

Recently, a CE-DCA (Co-Existence DCB) scheme for HCS based on Local Packing Distributed DCA (LP-DDCA) was proposed to preclude the inter-tier interference by appropriate selection of exclusion set [9, 10]. Their results show that CE-DCA can improve the system capacity subject to an upper-bounded blocking probability at the expense of message exchanges among base stations.

Since from the users' viewpoint, call termination as a result of handoff failure is considerably less desirable than the blocking of a new call, a prioritized handoff scheme is essential for microcellular systems where the mobile cell boundary crossing rate is high [11, 12]. Therefore, an efficient DCA should give higher priority to handoff calls. It is anticipated in the future that in addition to voice services, packet-data services should be provided, which apparently occupy more time than normal voice calls. Whether or not the packet-data calls need handoff protection, when an in-process packet-data call is served during cell boundary crossing, becomes a new research issue. As mentioned earlier, packet-data calls take more time than normal voice calls, so their handoff probabilities should be larger.

In this thesis, we will re-visit typical LP-DDCAs in a single layer system in Chapter 2, where handoffs handling scheme is described. In Chapter 3, we introduce our proposed *modified LP-DDCA* with single and double thresholds. Chapter 4 presents our simulation results on modified LP-DDCA in HCS under different handoff rates. We conclude this thesis in Chapter 5.

Chapter 2

General Background for LP-DDCA and Guard Channel Schemes

In this chapter, we introduce the schemes which had already been proposed in the literature. We will modify and combine these schemes to adapt to integrated services in the next chapter.

I Dynamic channel assignment

One major factor in determining the number of channels that can be used for a wireless spectrum is the level of received signal quality that can be achieved. The underlying concept of channel assignment schemes for cellular systems is based on the idea of physical separation and power control [15, 19]. In DCA, a channel is eligible for use in any cell, provided that the CIR(min) constraint is satisfied in that cell. In general, more than one channel might be available at a cell. The main idea of DCA schemes is to evaluate the cost function of using each candidate channel, and select the one with the minimum cost. The cost function is usually chosen in a way that the DCA scheme is able to exploit certain characteristics, such as interference adaptation, traffic adaptation, and channel re-usability [16].

DCA schemes, based on the type of control fashion, can be divided into two categories: centralized and distributed. The centralized scheme employes a centralized controller which is responsible for selecting and assigning one of the available channels to a user for temporary usage. It can usually produce near-optimum channel allocation at the expense of a high centralized overhead. Yet, it is not suitable for high-density microcell systems, where propagation characteristics are less predictable, which may introduce more intense network controls.

The distributed scheme uses, in each cell, an assignment algorithm which is usually much simpler than the centralized schemes. It is therefore more attractive in its implementation, especially for systems with a large number of microcells and highly time-varying local traffic. Distributed schemes can be either cell-based control where each base station keeps information about the current available channels in its vicinity; or autonomous mobile-based control where the mobile chooses a channel based on its local CIR measurements without the involvement of a central assignment entity. The latter has lower complexity at the cost of lower efficiency. Handoff procedures, particularly in microcell systems, have significant impact on the call forced termination probability. This is also another important consideration of using DCA schemes instead of FCA schemes. The following two subsections will be respectively devoted to the LP-DDCA scheme and the Guard channel handoff scheme.

II Local packing distributed DCA

Local Packing Distributed Dynamic Channel Allocation (LP-DDCA) uses at each base station an Augmented Channel Occupancy (ACO) table for channel assignment [9]. The ACO table is a matrix that contains necessary and sufficient local information for the base station to select a channel. Let M be the total number of available channels in the system, and let k_i be the number of neighboring cells to cell i within co-channel interference constraint.

The ACO matrix at base station i, as shown in Fig. 2.1, has $M+1$ columns and k_i+1 rows. The first M columns correspond to the M channels, and the last column records

	Channel number										
Cellsite	1	2	3	4	5	6	7	8	$\cdots$	M	# of free channels
i		x			x						0
i_1	x			x			x				0
i_2			x					x		x	2
i_3	x						x		$\cdots$		0
i_4			x			x				x	5
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
i_{k_i}			x					x			4

Figure 2.1: An example of Augmented Channel Occupancy table at cellsite i.

the number of free channels currently available at each neighboring cell. The first row indicates the channel occupancy in cell i, and the remaining k_i rows indicate the channel occupancy pattern in the neighboring cells of cell i, obtained from neighboring base stations. In side ACO table, an empty content indicates that the channel is not being used in the corresponding neighboring cell, while an "X" mark means that the channel is now being assigned to a user by the respective neighboring base station.

When a call requests call service to cell i, its base station searches the ACO table for a completely empty column for an available channel. If there is any, it will assigns the available channel to the call. If, however, the ACO table contains no empty column, the base station looks for a column with a single check mark, which is not located at the first row. If found, it checks to see whether the cell that uses the channel has additional channels available. If the answer is affirmative, it sends a message to the corresponding cell to see if the base station could re-assign the call currently using the channel to a new one. In case a positive response is received, base station i then assign the channel to the requested call.

The content of the ACO matrix is updated by collecting channel occupancy information, exchanged among interfering cells.

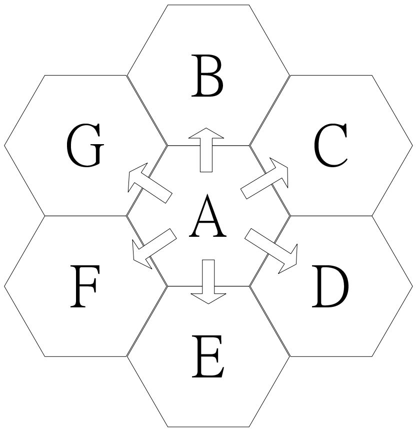


Figure 2.2: Mobile handoff to neighbors.

LP-DDCA with adjacent channel constraints is a variation of LP-DDCA scheme for wireless applications. The aforementioned LP-DDCA scheme is modified to limit the adjacent channel interference (ACI) [13]. Specifically, if the required separation between channels to avoid ACI is N_{adj}, then the $N_{adj} - 1$ channels to the left and right of that channel should have empty entries in the first row of the ACO matrix. The new LP-DDCA scheme takes this ACI constraint into account in searching and/or re-assigning channels as is done by the LP-DDCA.

III Guard channel handoff scheme

As shown in Fig. 2.2, calls in cell A may move to cells B, C, D, E, F, or G; so handoffs happen. To limit the probability of call forced termination due to handoff, the system must reduce the chances of unsuccessful handoffs by reserving some channels explicitly for handoff calls. Handoff prioritizing schemes improve performance at the expense of a reduction in the total admitted traffic and an increase in the blocking probability of new calls.

Guard Channel Scheme (cutoff priority scheme) improves the probability of successful handoffs by simply reserving a number of channel exclusively for handoffs in each cell. The remaining channels are shared equally between handoff calls and new calls. The penalty is a reduction in the total carried traffic. This advantage may be bypassed by allowing queuing of new calls.

Handoff Queueing Scheme [12] supports queuing of handoff requests, with or without employing guard channels. In the scheme no new call is granted a channel before the handoff requests in the queue are served. When the power level received in the base station reaches a certain handoff threshold, the call is queued for service by a neighboring cell. The call remains queued until either an available channel in the new cell is found or the power by the base station in the current cell drops below a receiver threshold. If the call reaches the receiver threshold and a new channel has not been found, the call is terminated. Queuing handoff requests is made possible by the existence of the time interval that mobile station spends between the two thresholds. The performance of this scheme can be further improved by modifying the queuing discipline.

New Call Queueing Scheme [14] is based on the consideration that it is more feasible to queue new call attempts, instead of handoff attempts because of the delay insensitivity of new call.

IV Definition of packet handoff

We now give some notations and definitions that will be used throughout the thesis.

By packet handoff, we mean that the mobile is transferring packets at the boundary of cells. In other words, when a mobile is not transferring packet while crossing the cell boundary, no packet handoff occurs (cf. Fig. 2.3).

We also define *packet-on* as the time a mobile desiring to transfer a packet during a

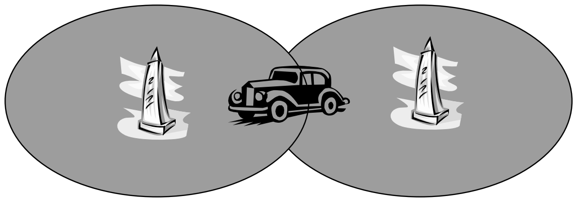


Figure 2.3: Mobile packet handoff.

network session. In such case, a channel will be temporarily to the mobile and will be returned at the end of the packet transfer.

According to above definitions, we further define five performance indices used in this thesis:

$$handoff\ forced\ termination\ rate\ (for\ voice\ call) = \frac{blocked\ handoff\ (voice)\ calls}{total\ handoff\ (voice)\ calls}.$$

$$new\ call\ blocking\ rate\ (for\ voice\ call) = \frac{blocked\ new\ (voice)\ calls}{total\ new\ (voice)\ calls}.$$

$$packet\ handoff\ forced\ termination\ rate = \frac{blocked\ packet\ handoff\ calls}{total\ packet\ handoff\ calls}.$$

Note that a packet call may consist of several packet-on requests, before it is over. We therefore also define:

$$packet - on\ blocking\ rate = \frac{blocked\ packet - on\ requests}{total\ packet - on\ requests}.$$

We also define a new packet-call as the first packet-on request for a call session.

$$new\ packet - call\ blocking\ rate = \frac{blocked\ newpacket - calls}{total\ packet\ calls}.$$

Chapter 3

Modified LP-DDCA with Double-Threshold Guard Channel Scheme

In this chapter,we will introduce the proposed modified LP-DDCA with double-threshold guard channel scheme. We begin with an introduction of its simplified version, i.e., a single-threshold analog.

I The single threshold scheme

Since call termination due to handoff failure, when compared to the blocking of a new call, is considerably less desirable from the user's viewpoint, a prioritized handoff scheme is essential especially for microcellular systems where the boundary crossing rate is high.

We propose a method which allows LP-DDCA to preserve channels for handoff calls, and assign channels according to certain priorities. In this scheme, we define the *guardChannelThreshold* as the number of channels which are specifically reserved for handoff calls in a cell. When a call arrives, channel is assigned according to the following rules.

Let the number of nominal channels in a cell be m. Assume that a packet-on request will retry (at least) 5 times when it is blocked. Then:

1. If there are more than one call arrives at the same time, these calls are prioritized as: voice calls have higher priority than packet calls, and handoff calls have higher priority than new calls. Calls with the same priority will be ordered in a random fashion. Put all these call in a list. (Of course, the ACO table will be updated first, if any call is terminated to free its channel.)

2. Extract the top call from the list. Check if the cell has more free channels than guardChannelThreshold, according to LP-DDCA ACO table. If not, only voice handoff calls are allowed to be served, and block all other kinds of calls. In case there are no free channels in the cell, block all calls.

3. Assign a channel using LP-DDCA scheme, and update the ACO tables for the cell, and its neighboring cells.

4. Repeat step 2 and 3 until the list is exhausted.

In our simulations, when a packet-on request (which may be a new packet call or a follow-up packet-on request in a packet call session) is blocked, it will be automatically re-tried at the next round (where each round is one-second in duration). However, no retry will be performed automatically for voice calls. The main reason for the presumed scenario is based on the following observation. In most packet transfer protocols, when the physical layer in a mobile reports a channel failure to its upper layer protocol stack, the upper layer will automatically issue a retry to the physical layer usually without the intervention of the user. Yet, the retry of a voice call often requires the user to press a button on its phone. We thus assume that a packet-on request will be automatically re-tried 5 times after failure.

Note that the above strategy only provides protection for voice handoff calls. After simulations, we observe that indeed, the packet handoff call does have high probability to request channel at the cell boundary; and hence, it may also need *protection* to preserve its smoothness. We therefore propose the double-threshold scheme which will be introduced in the next section.

The flow chart of the single threshold scheme is also provided in Figure 3.1.

II The double-threshold shceme

We define a new threshold to protect packet handoff calls. We therefore name the new scheme, *modified LP-DDCA with double-threshold guard channel scheme*, which is described below.

Let the number of nominal channels in a cell be m. Denote by *LowThreshold* and *HighThreshold* as the number of channels reserved for both voice handoff calls and packet handoff calls, and the number of channels reserved only for voice handoff calls, respectively. Then:

1. If there are more than one call arrives at the same time, these calls are prioritized as: voice calls have higher priority than packet calls, and handoff calls have higher priority than new calls. Calls with the same priority will be ordered in a random fashion. Put all these call in a list. (Of course, the ACO table will be updated first, if any call is terminated to free its channel.)

2. Extract the top call from the list. If there is no free channels, block the call. Else if the number of free channels is greater than $LowThreshold + HighThreshold$, assign a channel to the call according to LP-DDCA. Else if the number of free channels is (only) greater than *HighThreshold*, only assign a channel to handoff calls. Else only assign a channel to voice handoff call.

3. Update ACO tables for the cell, and its neighboring cells.

4. Repeat step 2 and 3 until the list is exhausted.

From simulations, the double-threshold scheme does decrease the force termination rate of packet handoff call.

The flow chart of the modified LP-DDCA with double-threshold guard channel scheme is provided in Figure 3.2.

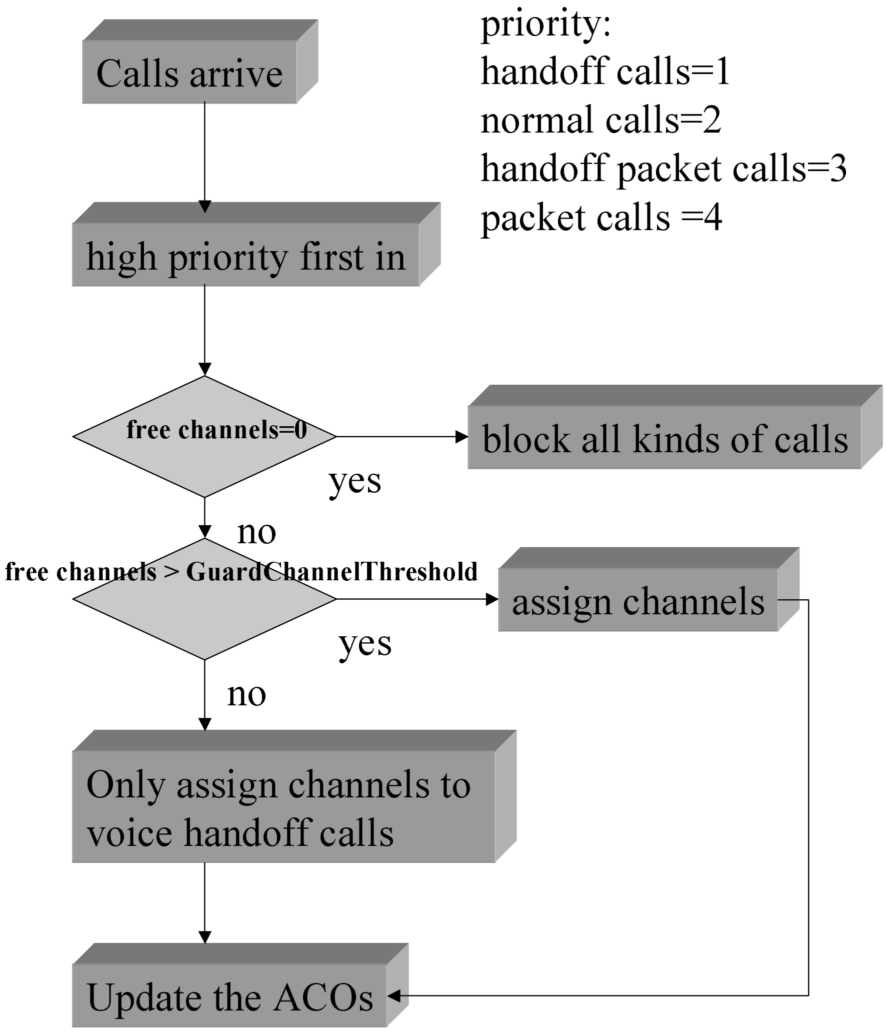


Figure 3.1: Flow chart of the modified LP-DDCA with single-threshold guard channel scheme.

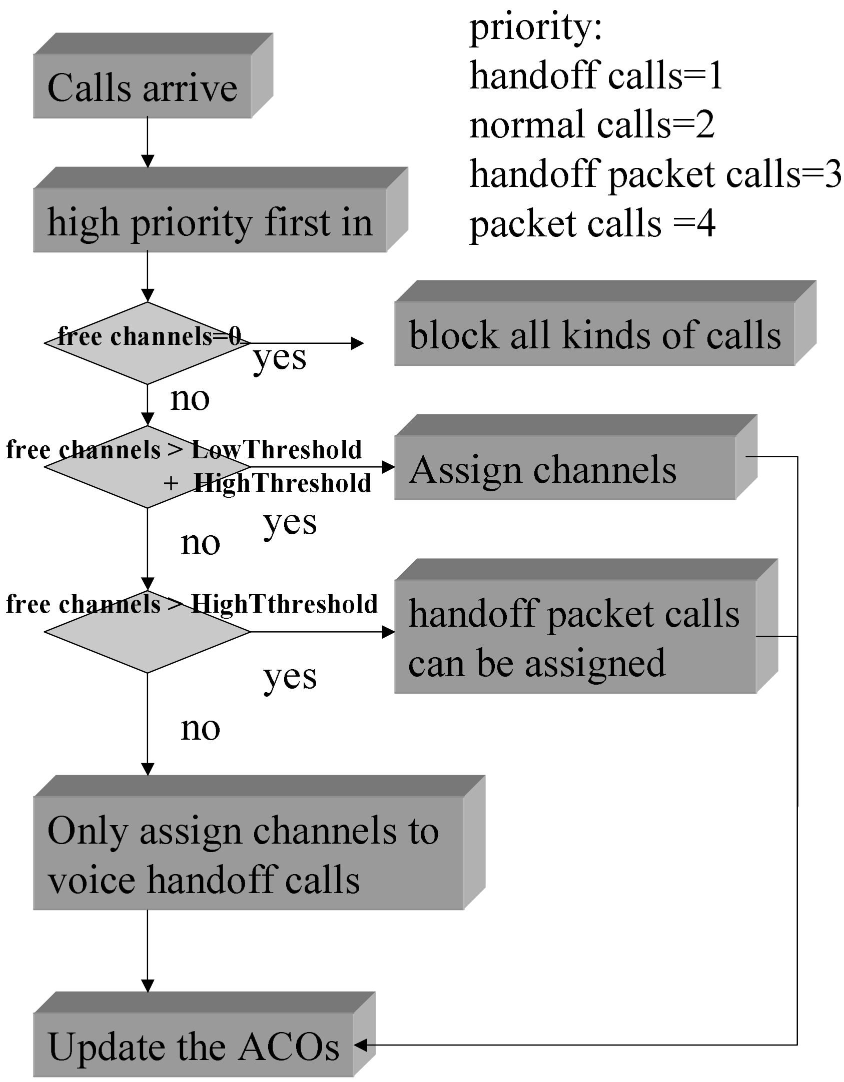


Figure 3.2: Flow chart of the modified LP-DDCA with double-threshold guard channel scheme.

Chapter 4

Simulation Model and Results

I The simulation model

The simulated cellular system contains 16×16 hexagonal cells as shown in Fig. 4.1. This topology is similar to that adopted in [18]. We use two integers, x and y ($0 \leq x, y \leq 15$), to index the cell locations.

We assume that there are total 70 channels in this system. Also assume that the arrival of voice calls is a Poisson process with exponentially distributed call duration with mean = three minutes.

When the voice call duration is larger than a pre-specified time threshold, a handoff is resulted. Similar situation applies to packet call as well. Three cases will be simulated, which corresponds to the probability of voice call handoffs are 1/10, 1/20 and almost zero. These three cases actually are achieved by taken different time thresholds.

Note that it is possible that a call in a cell with location index $(0, y)$ or $(15, y)$ or $(x, 0)$ or $(x, 15)$ is handoffed to a cell outside the 16×16 region. In such case, no wrap-around is considered. In other words, we assume that the call is no longer required services (or is served by another cellular company), and hence, the channel used by the call can be taken back.

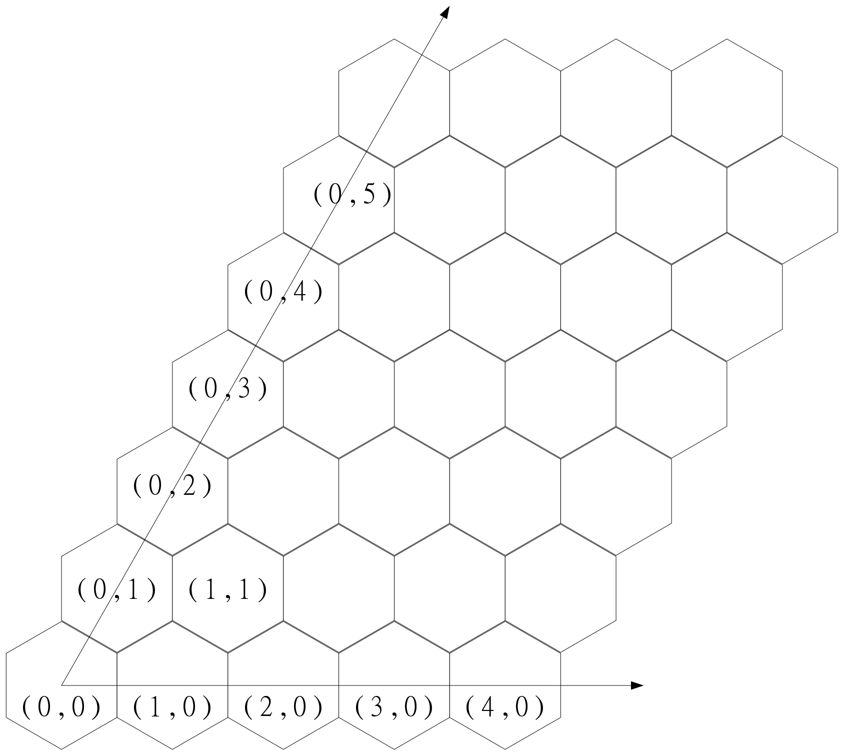
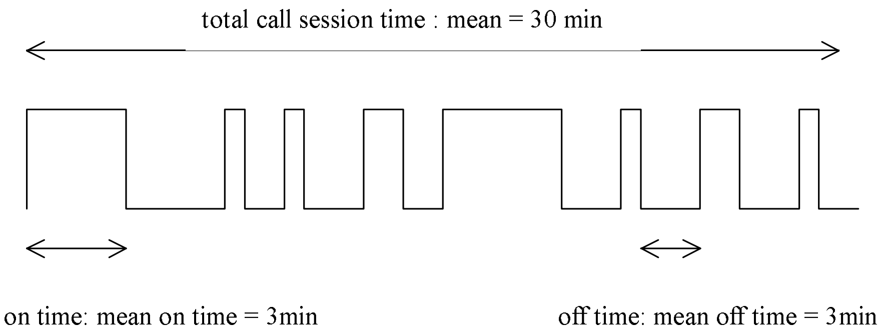


Figure 4.1: Cellular system layout with uniform traffic.

We also assume the Poisson model for the packet call arrivals. However, the call session duration is exponentially distributed with mean = 30 minutes. In addition, within an active packet call session, the packet-on-time and packet-off-time are also exponentially distributed with mean= 3 minutes. An example of a packet call sesstion is depicted in Fig. 4.2

We use LP-DDCA to assign channels. Usually, there are two channel-reuse situations considered in the literature: channels can be re-used outside the first tiers, and channels can be re-used outside the second tiers [20], as shown in Figure 4.3. In our thesis, only the results for the latter channel-reuse situations will be presented.

Finally, we assume that packet call mean arrival rate is one tenth of the voice call mean arrival rate.



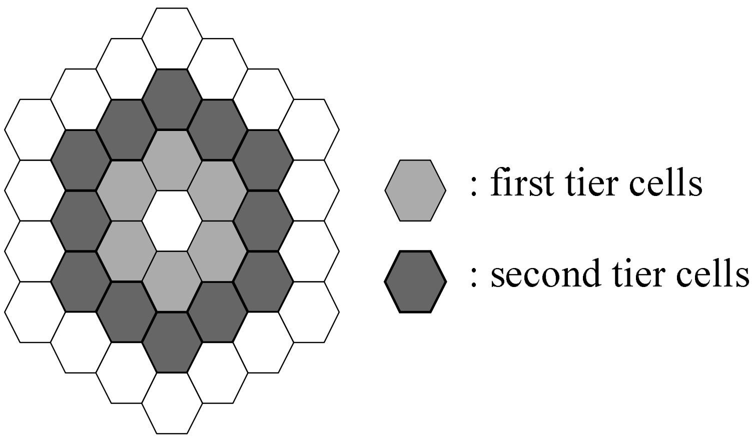


Figure 4.3: First tier and second tier channel reuse patterns.

II Simulation Results

We distinguish the simulation results into three subsections according to different probabilities of voice call handoffs. In each figure, we plot the average call block probability, as well as call forced termination probability, as a function of the overall traffic load (x-axis), including voice calls and packet calls, with measuring unit *(voice)calls/cell/hour*. For example, if the cell experiences 80 voice-call/cell/hour and 8 packet-call/cell/hour, then we first derive

$$8\,\frac{\text{packet-call}}{\text{cell hour}} \times 0.5\,\text{hour} \times \frac{1}{2} \quad = \quad 40\,\frac{\text{voice-call}}{\text{cell hour}} \times \frac{1}{20}\,\text{hour}$$

where 0.5 hour and 1/20 are respectively the mean holding times of a packet call and a voice call, and a packet call in average only consists of 1/2 packet-on time. We then conclude that 8 packet-call/cell/hour is equivalent to 40 voice-call/cell/hour. Therefore, the traffic load of 80 voice-call/cell/hour and 8 packet-call/cell/hour equals to 120 voice-call/cell/hour.

II.1 1/10 voice call handoff ratio

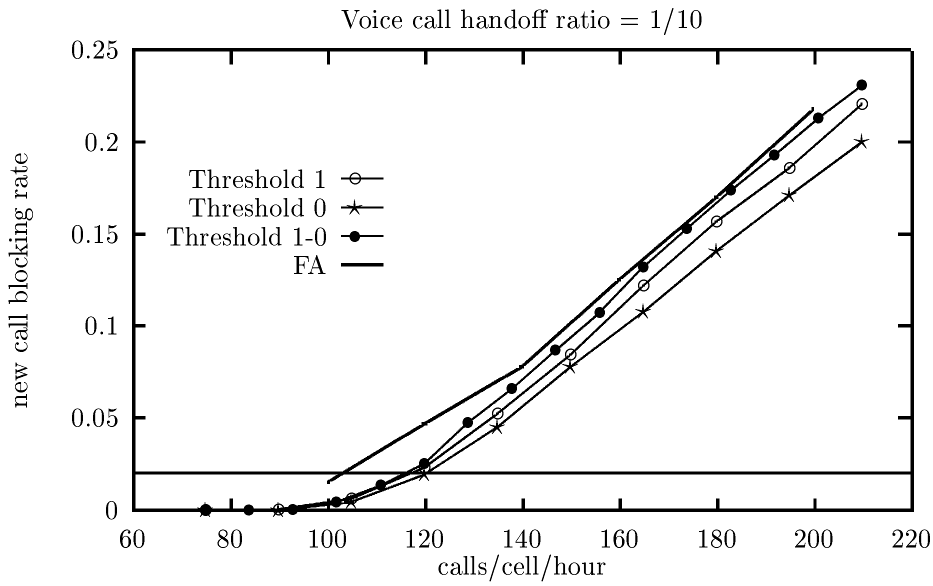


Figure 4.4: The new voice call blocking rate under 1/10 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0. FA = fixed channel assignment scheme.

Figure 4.4 shows that the original LP-DDCA actually has the smallest new call blocking rate. However, with our single-threshold and double-threshold modified scheme, the new call blocking rate only slightly increases. All the LP-DDCA family performs better than FA in new call blocking rate.

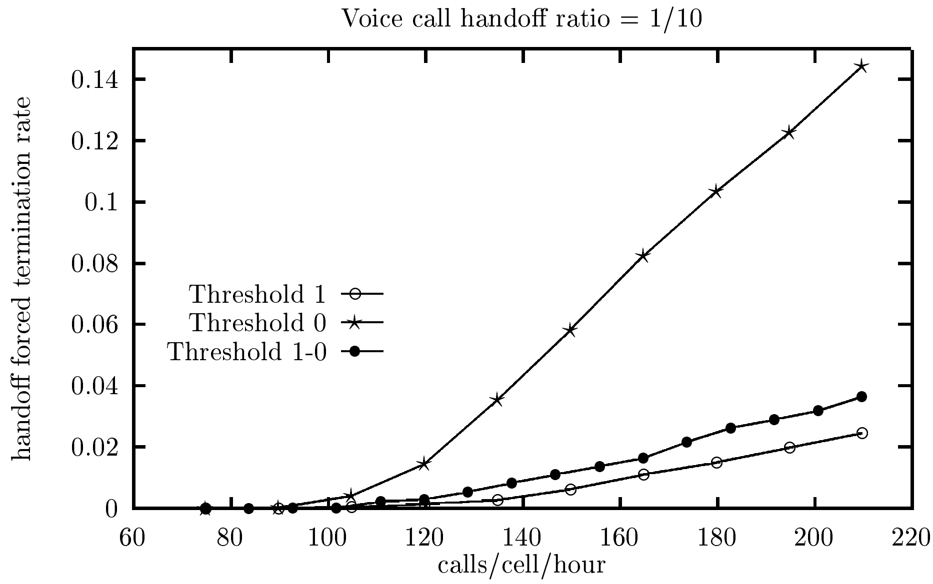


Figure 4.5: The call forced termination rate for voice call under 1/10 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

Figure 4.5 shows that the modified LP-DDCA with single threshold being equal to 1 gives the lowest call forced termination rate. The modified LP-DDCA with double threshold is the second smallest one. However, both modified LP-DDCA schemes significantly improve the call forced termination rate of the original LP-DDCA scheme.

Figure 4.6 shows that when we reserve one channel only for voice handoff call, the packet handoff forced termination rate remains high. However, when the reserved one channel is shared among all voice and packet handoff calls (Threshold 1-0 scheme), the packet handoff forced termination rate is significantly decreasd.

Figure 4.7 shows that all LP-DDCA family has similar performance in packet-on blocking ratio due to re-try, among which the original LP-DDCA scheme gives the smallest packet-on

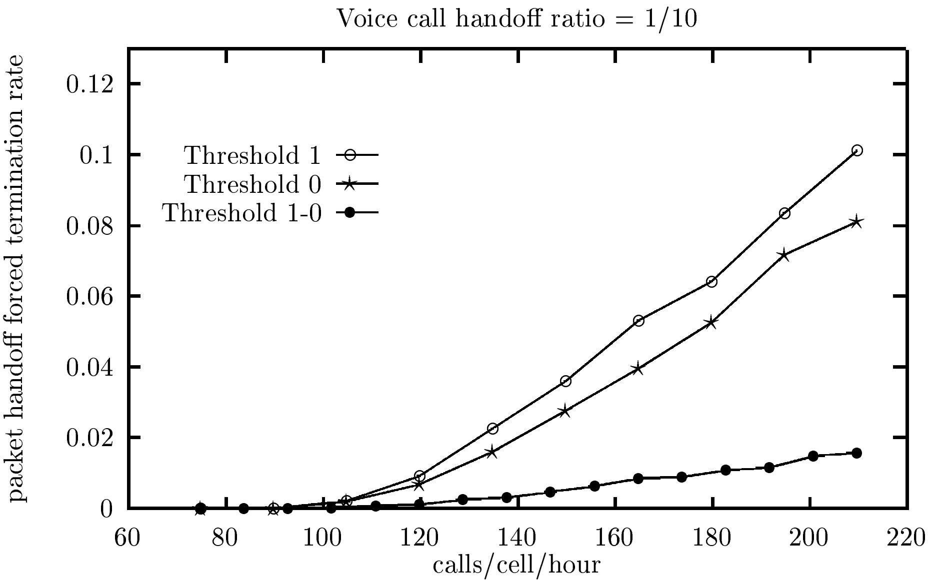


Figure 4.6: The call forced termination rate for packet call under 1/10 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

blocking ratio.

Figure 4.8 shows that the original LP-DDCA gives the smallest new packet call blocking rate, and the single-threshold modified LP-DDCA is the second lowest. It is interesting to note that the new packet call blocking rate is prohibitively high, even if packet calls will be retried five times when failure. This is because a call session is considered *blocked* when any packet-on request in the call session is rejected.

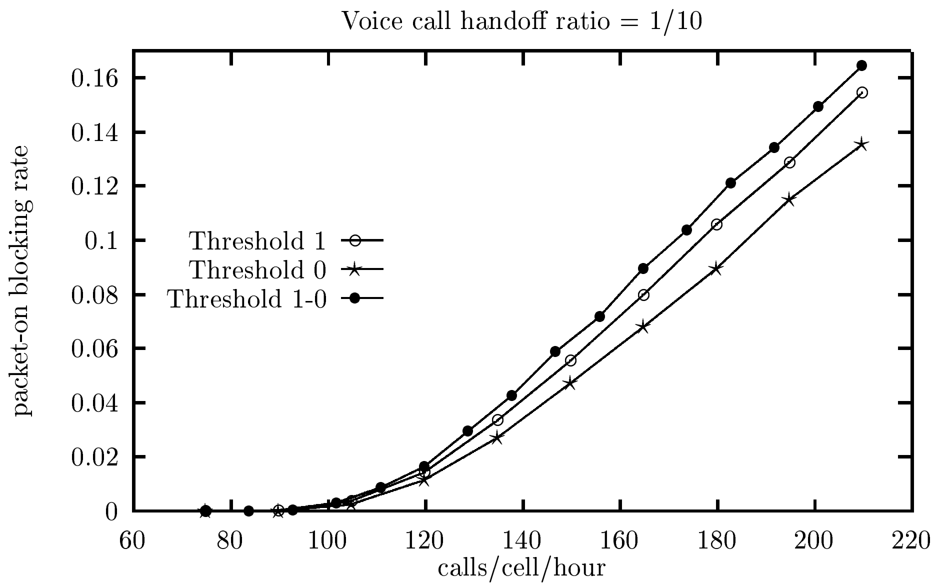


Figure 4.7: The packet-on blocking rate under 1/10 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

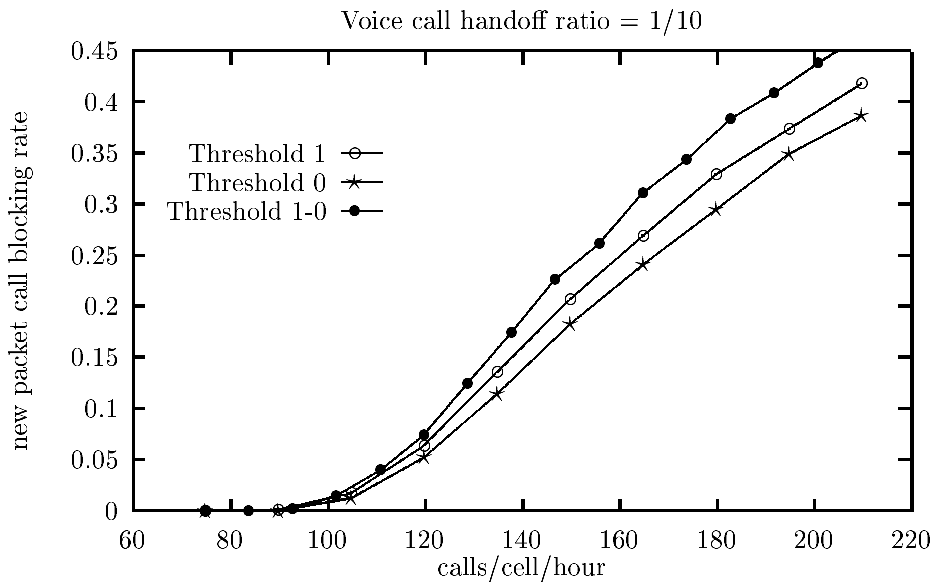


Figure 4.8: The new packet-call blocking rate under 1/10 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

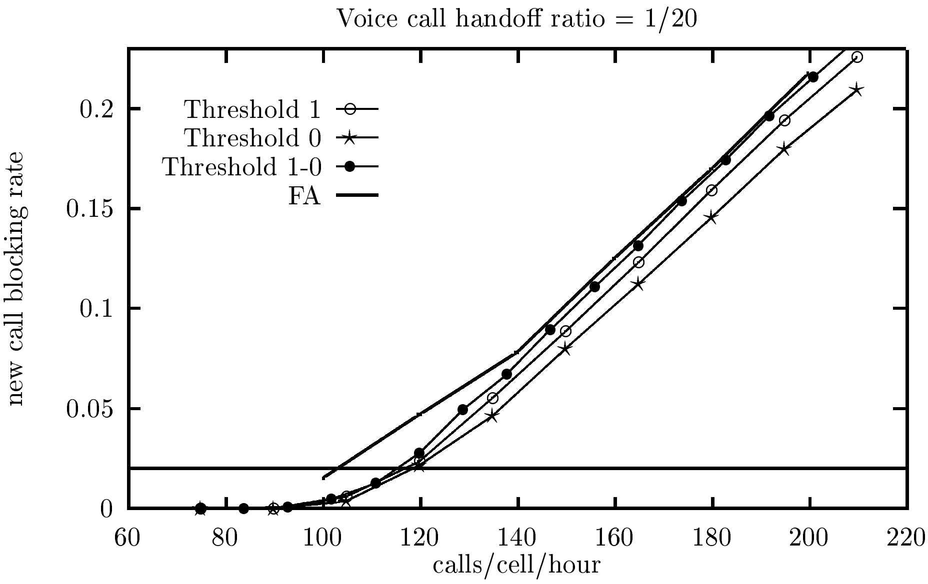


Figure 4.9: The new voice call blocking rate under 1/20 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0. FA = fixed channel assignment scheme.

II.2 1/20 voice call handoff ratio

The conclusions from Figures 4.9, 4.10, 4.11, 4.12 and 4.13 are basically the same as Figures 4.4, 4.5, 4.6, 4.7 and 4.8, respectively; and hence, we omit them.

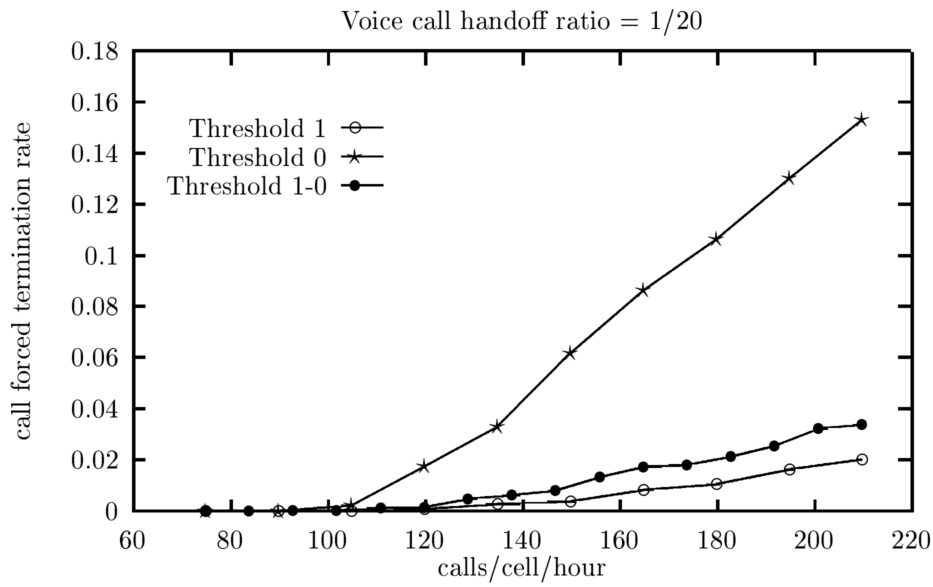


Figure 4.10: The call forced termination rate under 1/20 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

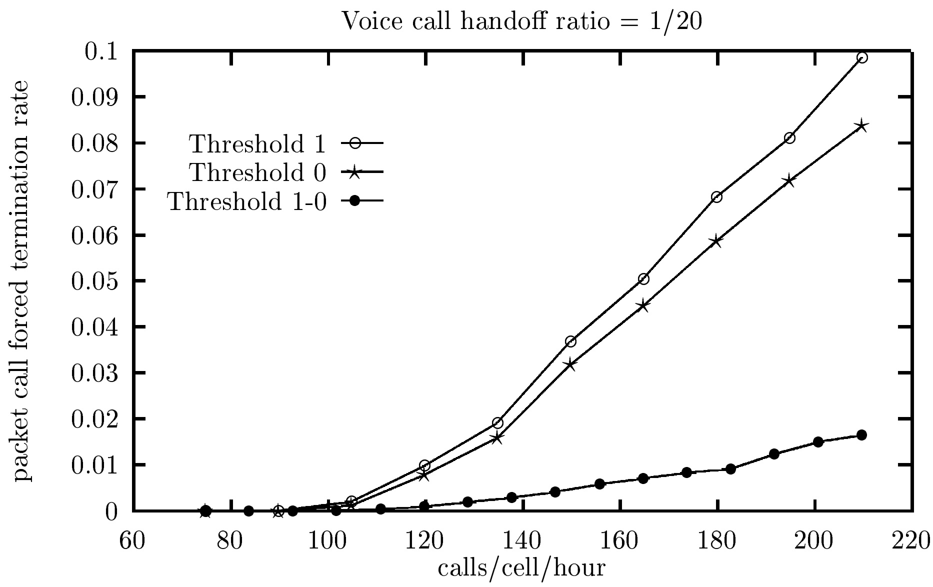


Figure 4.11: The packet call forced termination rate under 1/20 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

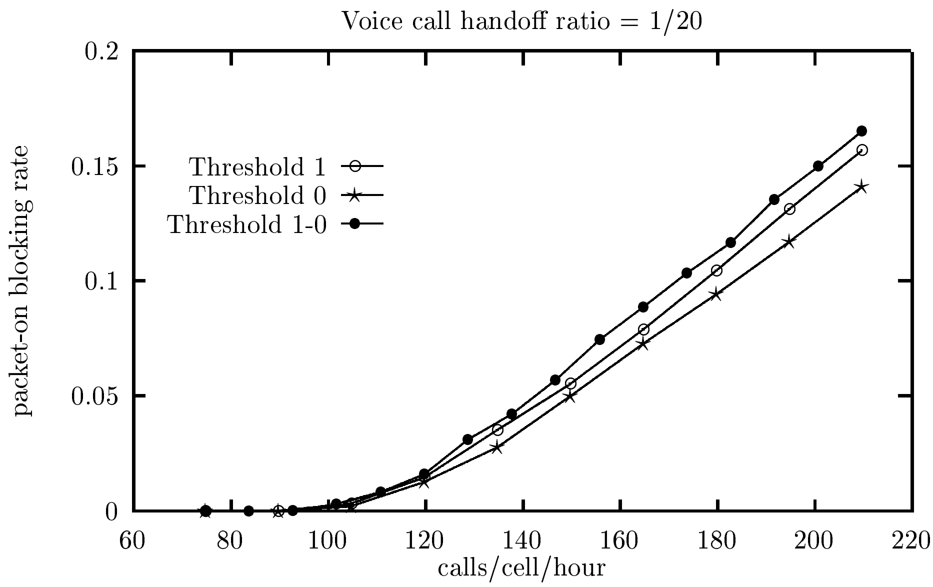


Figure 4.12: The packet-on blocking rate under 1/20 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

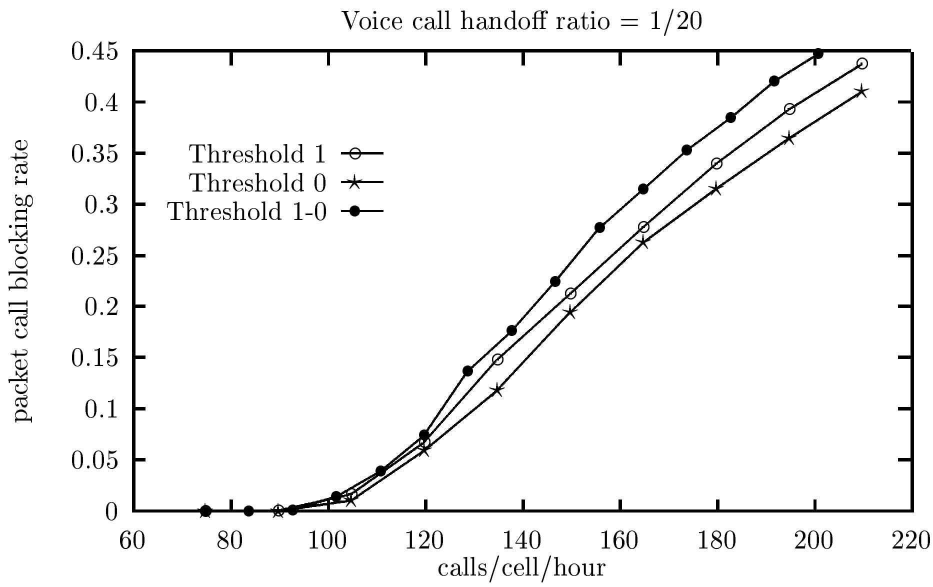


Figure 4.13: The new packet-call blocking rate under 1/20 voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

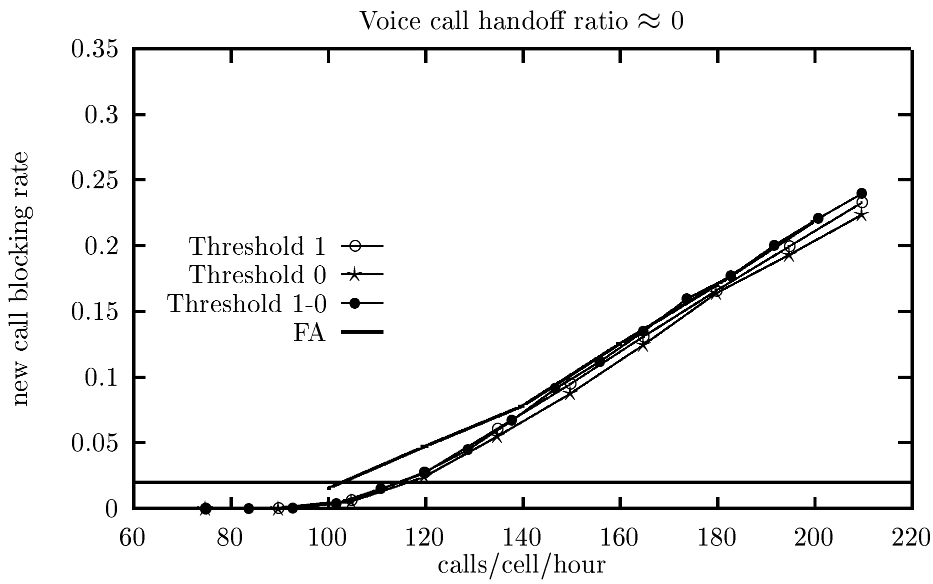


Figure 4.14: The new voice call blocking rate under nearly zero voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0. FA = fixed channel assignment scheme.

II.3 Nearly zero voice call handoff ratio

The conclusions from Figures 4.14, 4.15, 4.16, 4.17 and 4.18 are basically the same as Figures 4.4, 4.5, 4.6, 4.7 and 4.8, respectively; and hence, we omit them.

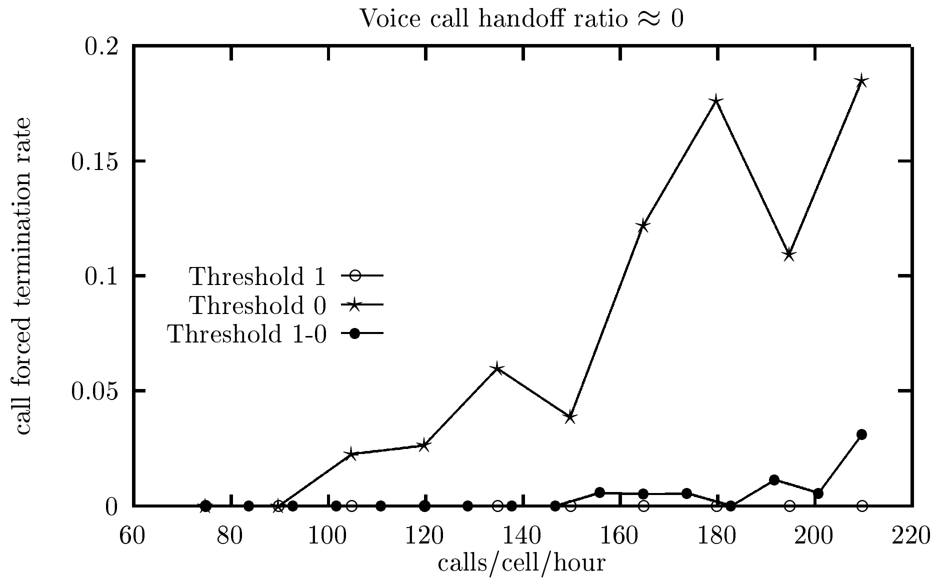


Figure 4.15: The call forced termination rate for voice call under nearly zero voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

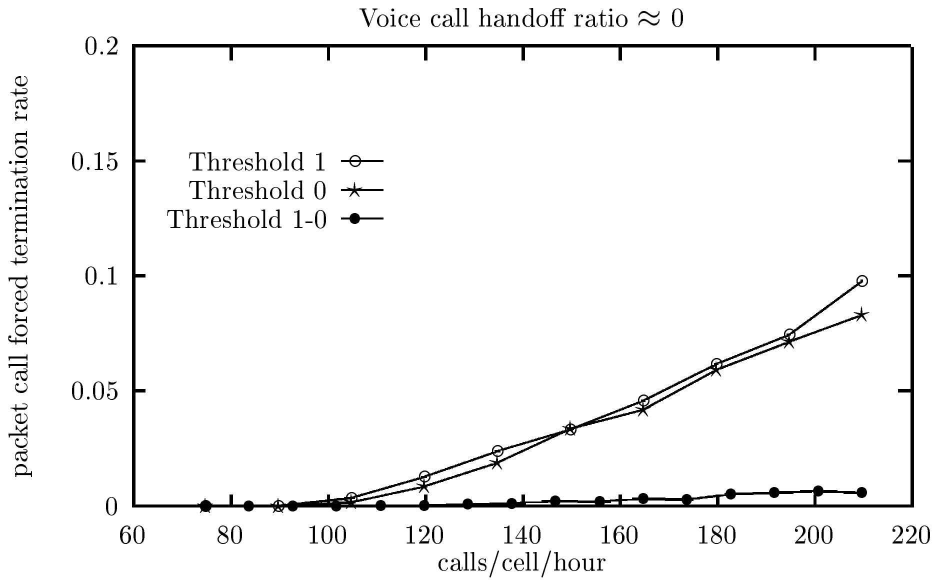


Figure 4.16: The call forced termination rate for packet call under nearly zero voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

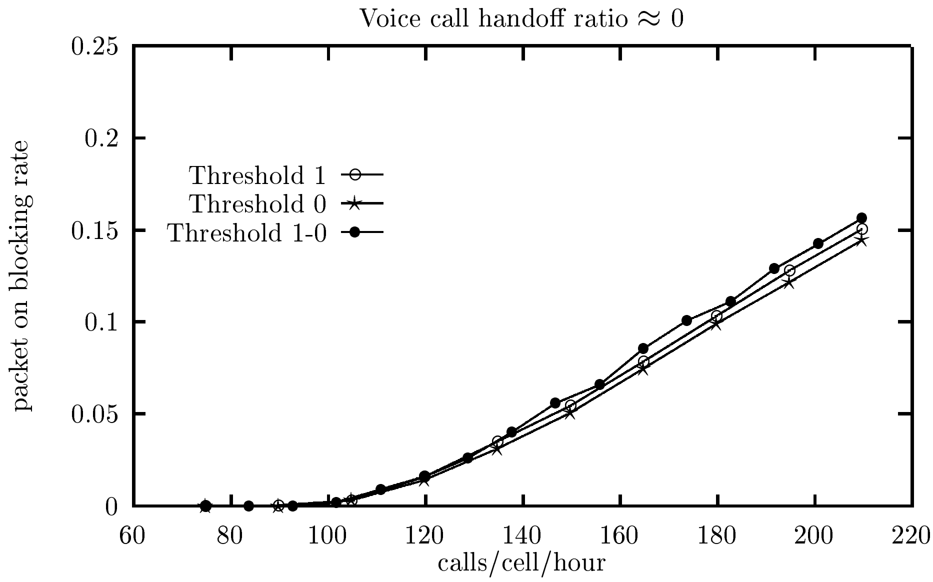


Figure 4.17: The packet-on blocking rate under nearly zero voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

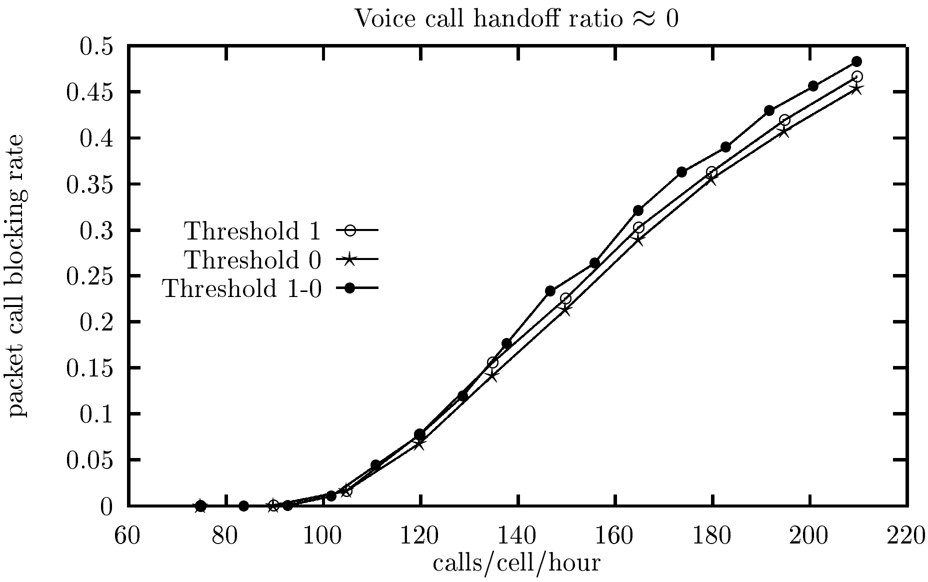


Figure 4.18: The new packet-call blocking rate under nearly zero voice call handoff ratio and channel re-use distance being two. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

III Simulations under frequency-reuse distance being one

The figures presented in this section are generated under the premise that the re-use distance is only one. Basically, we observe almost the same behaviors from these curves as those results from re-use distance being two. The major difference is that a smaller re-use distance results in larger capacity. Specifically, the resultant capacity is almost twice of the capacity presented in the previous session. For example, in Figure 4.19, the LP-DDCA with single threshold has a capacity of 291 calls/hour/cell, the LP-DDCA with double threshold has a capacity of 291 calls/hour/cell and the pure LP-DDCA has a capacity of 300 calls/hour/cell; however, From Figure 4.4, we obtain that the LP-DDCA with single threshold = 1 has a capacity of 118.5 calls/hour/cell, the LP-DDCA with double threshold = 1,0 has a capacity of 118 calls/hour/cell, and the original LP-DDCA has a capacity of 120 calls/hours/cell.

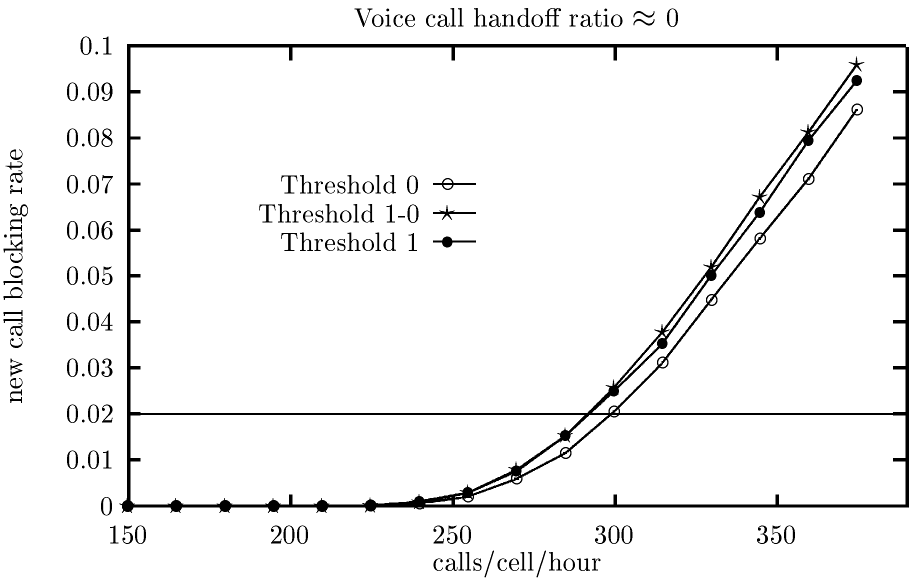


Figure 4.19: The new voice call blocking rate under nearly zero voice call handoff ratio and channel re-use distance being one. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

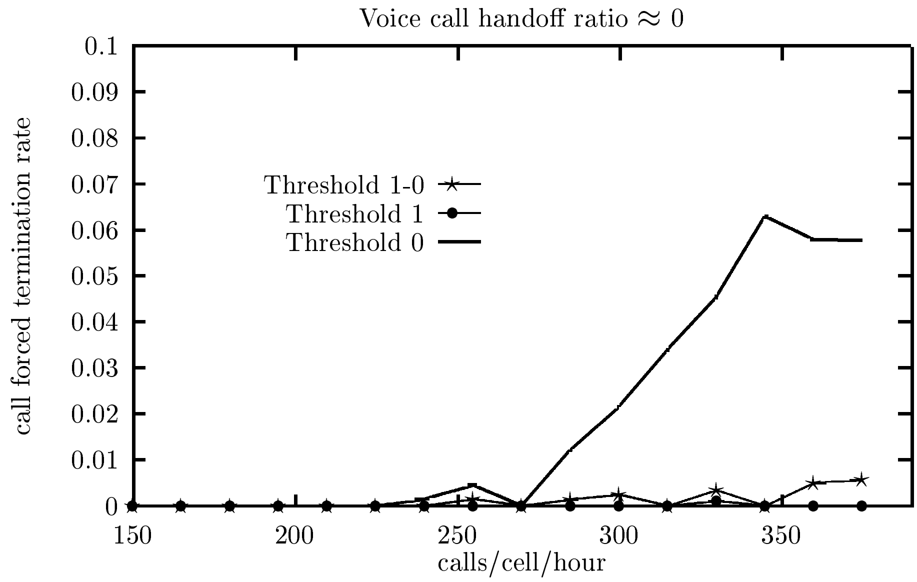


Figure 4.20: The call forced termination rate for voice call under nearly zero voice call handoff ratio and channel re-use distance being one. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

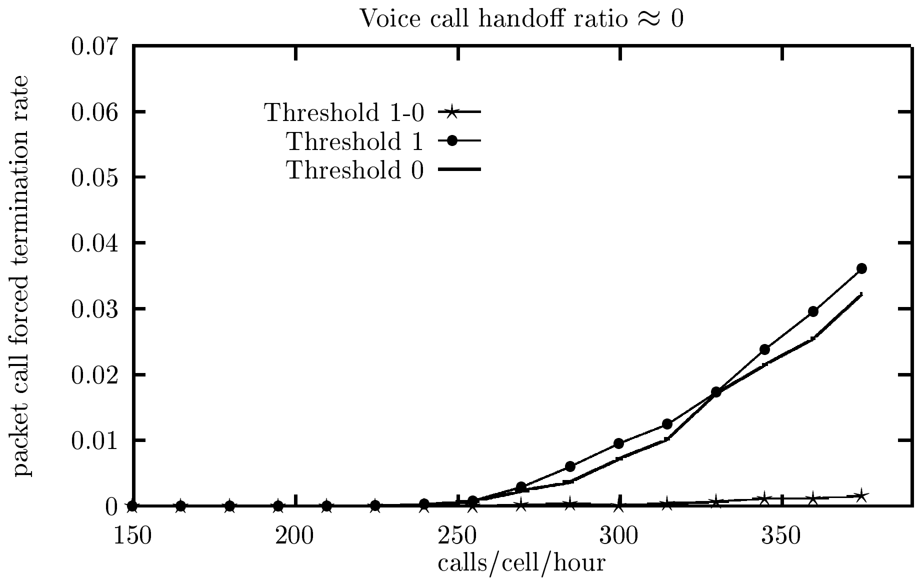


Figure 4.21: The call forced termination rate for packet call under nearly zero voice call handoff ratio and channel re-use distance being one. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

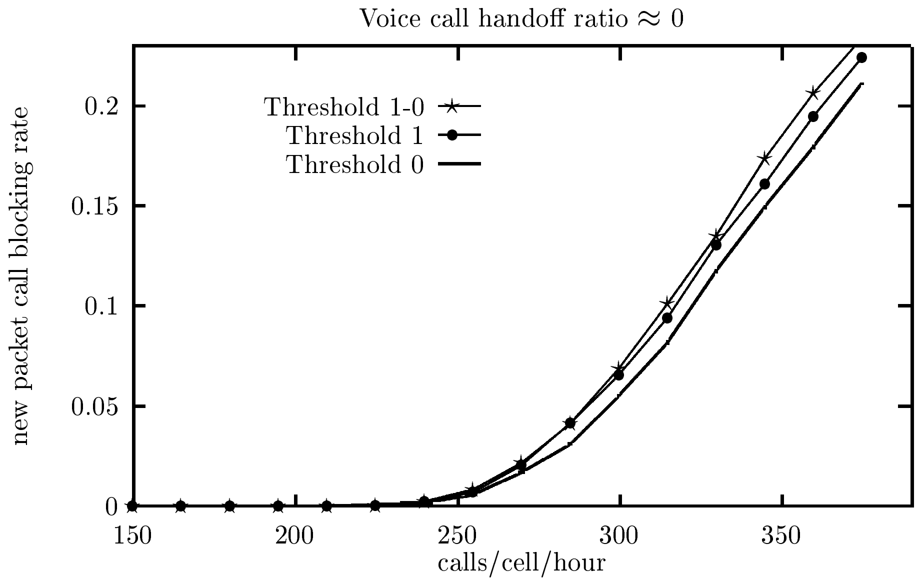


Figure 4.22: The new packet-call blocking rate under nearly zero voice call handoff ratio and channel re-use distance being one. Threshold 1 = modified LP-DDCA with single threshold being equal to 1; Threshold 0 = modified LP-DDCA with single threshold being equal to 0 (i.e., the original LP-DDCA); Threshold 1-0 = modified LP-DDCA with double thresholds for which HighThreshold = 1 and LowThreshold = 0.

Chapter 5

Conclusions

I General remarks

Local Packing Distributed Dynamic Channel Assignment is an adaptable dynamic channel assignment scheme to spatial variable traffic. As the cell size decreases, which results in a higher probability of call handoff, a DCA must give priority to handoff calls in order to maintain call smoothness. We therefore propose a modified LP-DDCA with double thresholds guard channel scheme.

From our simulations, we found that by only reserving one channel for both voice and packet calls, our scheme can significantly reduce the handoff call forced termination rate at the expense of a slightly increasing new call blocking rates. Also, by the simulation results regarding one-threshold scheme, we note that protection on packet call is necessary even if most packet protocols are enforced with re-try mechanism. Note that the packet call handoff probability is prohibitively higher than the voice call handoff probability due to its longer call duration, although the packet call session only periodically enters the packet-on status under which a channel must be granted.

We conclude that in the future, the cell size is expected to be getting smaller, and packet service become a trend for cellular systems, it is our hope that our results can provide a guide to the cellular service providers for their system planning.

II Future work

In our thesis, due to its simplicity, we only consider the case that a channel can only serve one call, which is different from most of the existing cellular systems, such as GSM. Hence, an immediate future work is to modify the scheme so that it can be used at a cellular system enforced with a single-channel-multi-call support, or specifically, TDMA support. In addition, how to give priorities to voice and packet calls in order to adapt to different demands or traffic patterns is another interesting future work.

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