Modelling and Analysis of a Dynamic Guard Channel Handover Scheme with Heterogeneous Call Arrival Processes

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Abstract. This chapter presents a detailed review of existing handover schemes and focuses on an analytical model developed for a Dynamic Guard Channel Scheme (DGCS), which manages adaptively the channels reserved for handover calls depending on the current status of the handover queue. The Poisson process and Markov-Modulated-Poisson-Process (MMPP) are used to model the arrival processes of new and handover calls, respectively. The accuracy of this model is demonstrated through the extensive comparisons of the analytical results against those obtained from discrete-event simulation experiments. Moreover, the analytical model is used to assess the effects of the number of channels originally reserved for handover calls, the number of dynamic channels and the burstiness of handover calls on the performance of the DGCS scheme.

Keywords: Wireless Cellular Networks, Handover, Guard Channel Scheme, Performance Modelling, Markov-Modulate-Poisson-Process (MMPP).

1 Introduction

In communication industry, wireless networks have undergone the fastest growth in the past decades. Mobile cellular systems have evolved from the first generation analogue system, e.g. Advanced Mobile Phone System (AMPS) and European Total Access Cellular System (ETACS), to the second generation digital systems, e.g. Global System for Mobile (GSM) and IS-95 cdmaOne. The increasing demands for parallel, rapid internet-based services drives the development of third generation mobile systems (3G). With the deployment of increasing wireless applications and access constraints, a tremendous development to improve the efficient usage of the limited radio spectrum resources in academic and industry fields is required. The reason for the cellular network topology is to enable frequency reuse.

Cellular networks deploy smaller cells in order to achieve high system capacity due to the limited spectrum. The frequency band is divided into smaller bands which are reused in non interfering cells [1-3]. Smaller cells cause an active mobile station (MS) to cross several cells during an ongoing conversation. This active call should be transferred from one cell to another in order to achieve call continuation during boundary crossing.

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Handover represents a process of changing the channel associated with the current connection while a call is in progress. Handover is an essential component of cellular communication systems since it enables two adjacent base stations (BS) to guarantee the continuity of a conversation. A well designed handover scheme should minimize the probability of dropped handover calls because forced termination of new calls is more favoured than termination of handover calls in the point view of mobile users. Therefore, the design of an efficient handover scheme requires to minimize the handoff call blocking probability as well as to maintain the new call blocking probability and the utilisation of precious wireless resources at acceptable levels.

Prioritizing handover calls is an effective strategy towards these goals. There are two popular schemes for handover prioritization: Guard Channel Scheme (GCS) and Handover Queueing Scheme (HQS) [1]. The basic idea behind GCS is to give high priority to handover calls by exclusively reserving a number of dedicated (or, guard) channels. In HQS, the forced termination probability of handover calls can be reduced by allowing handover requests to be queued temporarily. Both schemes can reduce the handover call dropping probability effectively in wireless mobile networks [4].

The existing GCS and HQS schemes often reduce the blocking probability of handover calls at the expense of increasing the blocking probability of new calls and the delay of handover calls. With the aim of reducing the deteriorating effects of GCS and HQS on the blocking probability of new calls and the delay of handover calls, this chapter firstly presents an efficient handover scheme, referred to as Dynamic GCS (DGCS) which can dynamically manage the channels reserved for handover calls depending on the current status of the handover queue. Secondly, a three-dimensional Markov model is developed for performance analysis of this dynamic handover scheme. The new and handover call arrivals are modelled by the non-bursty Poisson process and bursty Markov-Modulate-Poisson-Process (MMPP), respectively. Moreover, the effects of users' mobility are taken into consideration by modelling the dwell times of both calls spent in a cell by an exponential distribution. Thirdly, the analytical mode is used to investigate the effects of the number of channels originally reserved for handover calls, the number of dynamic channels, and burstiness of handover calls on the performance of the DGCS scheme.

The rest of the chapter is organized as follows. Section 2 provides a review of handover schemes. Section 3 presents the analytical model and derives the expressions of the performance measures including the mean number of calls in the system, aggregate response time, aggregate call blocking probability, handover call blocking probability, new call blocking probability and handover delay. Section 4 validates the model and conducts extensive performance evaluation. Finally, conclusions are drawn in Section 5.

2 Review of Handover Schemes

Handover presents a process of changing channels associated with an existing connection which is always initiated either by a worse quality of received signal on the current channel or by crossing a cell boundary [1-4]. A detailed and comprehensive overview of handover is presented in this section.

2.1 Handover Type

Handovers can be categorized as hard and soft handovers according to the number of connections [5]. In the process of hard handover, a radio link is established to the new base station and the radio link of the old base station is released. This means that a mobile node is only allowed to maintain connection to one base station at one time. The handover is initiated based on a hysteresis imposed on the current link. Based on the link measurements, the target BS is selected and executes the handover, and the active connection is transferred to the target BS instantly. The connection experiences a brief interruption during the actual transfer because MS can only connect to one BS at a time. Hard handover does not have advantage of diversity gain opportunity during the process of handover where the signals from two or more BSs arrive at comparable strengths. However, it is a simple and inexpensive way to implement handover.

On the contrary, a soft handover enables a mobile node to maintain radio connections with more than two base stations simultaneously while it does not release any radio links unless the signal strength drops below a specified threshold value [5]. Soft handover completes when the MS selects the best available candidate BS as the target cell. Soft handover is a type of mobile assisted handover. The disadvantage of soft handover is that it is complex and expensive to implement. Moreover, forward interference actually increases since several BSs are used in soft handover simultaneously to connect the MS. The increase in forward interference can become a problem if the handover region is large such that there are many MSs in soft handover mode.

2.2 Channel Assignment

Channel assignment is a key phase of handover process and consists of the allocation of resources to calls in the new base station. When a call is admitted to access the network, in order to, make a decision of acceptance or rejection by a call admission control (CAC) algorithm, several characters including QoS of the existing connection, and the amount of available resource versus QoS requirements [7] should be considered. The success of handover process is also affected by the radio technology of the channel assignment process. Various channel assignment strategies (e.g. non-prioritized scheme, the guard channel scheme, and queuing priority scheme) have been proposed to reduce the forced termination of calls at the expense of increasing the number of dropped or blocked calls.

Channel assignment strategy can either be fixed or dynamic. Fixed channel assignment strategy allows each cell to contain a specific and fixed number of channels. New arriving calls are served by unused channels in that cell. If all the channels are in use, any new arriving calls will be blocked. Several variations of the fixed assignment strategies are available. One approach, referred to as channel borrowing strategy, allows a cell to borrow channels from a neighbouring cell if all of its own channels are in use. The MSC controls the borrowing procedures and ensures that this procedure does not disrupt or interfere with services in the donor cell.

Dynamic channel assignment strategy does not assign channels to any cells permanently. Instead, when a call arrives, the serving BS requests a channel from the MS. The MS then allocates that channel to the cell and uses an algorithm to calculate the likelihood of future blocking within the cell, the reuse distance of the channel, and other cost functions. The MS only assigns a channel if that channel is not in use in the cell or any other cells which falls within the minimum restricted distance of channel reuse to avoid co-channel interference [8]. Dynamic channel assignment strategies decrease the likelihood of blocking and increase the trunking capacity of the system. Dynamic channel assignment strategy requires the MS to collect real time data on channel occupancy, traffic distribution, and radio signal strength indications (RSSI) of all channels on a continuous basis. This increases the storage and computational loads on the system but increases the channel utilization and decreases the blocking probability of calls.

2.3 Handover Schemes

Since ongoing communications are very sensitive to interruption, the handover dropping probability must be minimized. In what follow, two well-known prioritization schemes [9] are presented.

Guard Channel Scheme. GCS is the most popular way of assigning priority to handover calls by reserving a fixed number of channels out of the total number of available channels for handover calls [6, 10-15]. The high priority is assigned to handover calls over calls originated from the serving cell in GCS, e.g. h channels are assigned to handover calls only from a total of N channels in a cell. New calls and handover calls share the remaining $n=N-h$ channels together. If the number of available channels in the cell is less than or equal to h, any arrivals of new calls are rejected/blocked because the remaining idle channels are used by handover calls exclusively. A handover call is blocked if there is no channel available in the cell at all. The flowchart for GCS is show in Fig. 1.

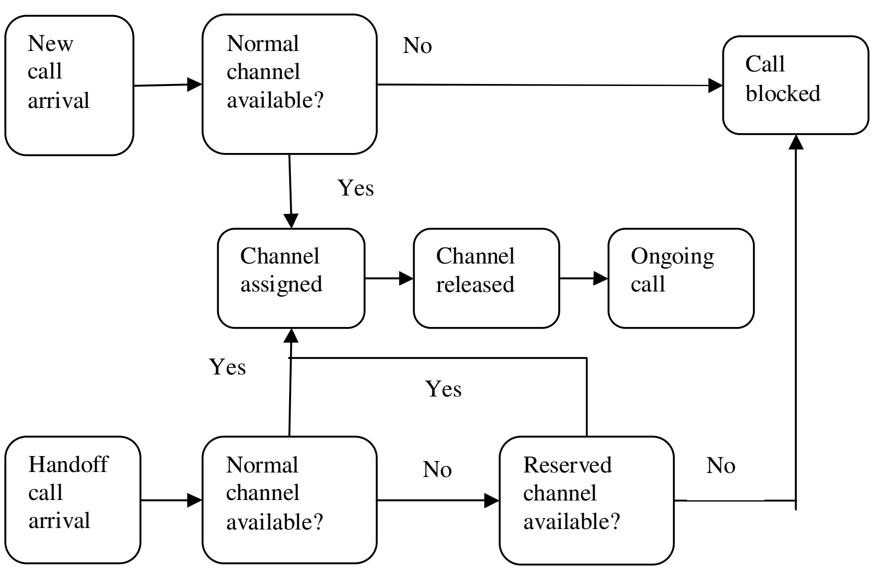

Fig. 1. Flowchart of Guard Channel Scheme

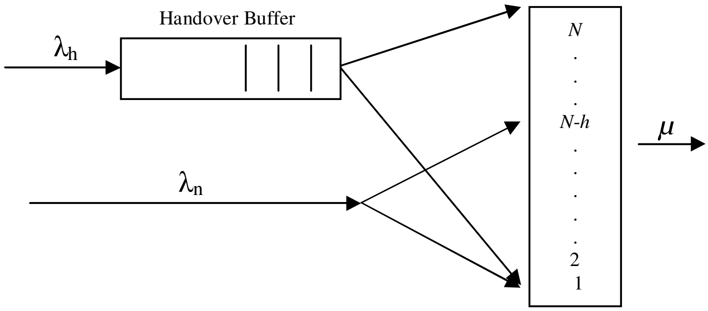

Fig. 2. System Model with Priority and Handover Queueing Scheme

Handover Queueing Scheme. In the queuing handover calls prioritization scheme, if all of the channels are occupied in a cell, arrival handover calls are stored in a queue [9, 16-20]. The handover calls stored in the queue can be served whenever a channel becomes idle. In order to decrease the blocking probability of new calls, queuing scheme can also be applied to new calls. Fig. 2 shows the queuing scheme that store newly arriving handover calls when all channels are not available.

2.4 Existing Analytical Models of Handover Schemes

One of the earliest analytical frameworks for GCS has been developed by Guerin in [21]. Zhang, Soong and Ma [22] have proposed a novel approximation approach using a simplified one-dimensional Markovian model to evaluate the performance of a guard channel scheme. Vazuqez-Avila, Cruz-Perez and Ortigoza-Guerrero [23] have developed a Markovian model for Fractional Guard Channel (FGC) which accepts an arriving new call with a probability calculated on the base of the number of busy channels but accepts an arriving handover call unless there are no channels available. Ogbonmwan and Li [24] have extended GCS to support voice traffic by using three dynamic thresholds to, respectively, provide priority to handover data calls, new voice calls and handover voice calls. They have developed a two-dimensional Markov chain to analyze this new bandwidth allocation scheme, namely, multi-threshold bandwidth reservation scheme.

In addition to the fixed channel allocation schemes, GCS and its variants have also been analyzed with the dynamic allocation schemes in [25]. Moreover, several recent studies [26-29] have investigated the performance of GCS with a First-In-First-Out (FIFO) queue of handover calls via simulation or analytical modelling. Louvros, Pylarinos and Kotsopoulos [30] have proposed a multiple queue model for handover in microcellular networks with a dedicated queue for each transceiver in the cell. Xhafa and Tonguz [14] have presented an analytical framework which employs two queues for the two priority classes of handover calls and incorporates a priority transition between handover calls in the queue. However, the arrivals of both new calls and handover calls were modelled by the traditional non-bursty Poisson process in the aforementioned references. Only a few studies [10, 31] have adopted the Markov-Modulated-Poisson-Process (MMPP) [32] to capture the bursty properties of handover call arrivals.

3 Analytical Model

3.1 System Description

The dynamic handover scheme, DGCS, is illustrated in Fig. 3. An FIFO finite capacity queue is adopted to accommodate handover calls waiting for a free channel. Let N be the total number of channels available in a cell and k be the buffer capacity. When the buffer is empty, as shown in Fig. 3(a), the maximum number of channels, which can be used to transmit new calls, is n $(n \leq N)$. Consequently, all remaining channels, h ($h = N - n$), are reserved for handover calls. In the dynamic handover scheme, the number of channels allocated to handover calls, h, changes according to the queue status. Specifically, when the buffer of handover calls is not empty, t more channels are allocated to handover calls in order to reduce the delay and loss probability of handover calls. In this case, the maximum numbers of channels which can be used for new calls and handover calls are changed to $n' = (n - t)$ and $h' = (h + t)$, respectively, as shown in Fig. 3(b).

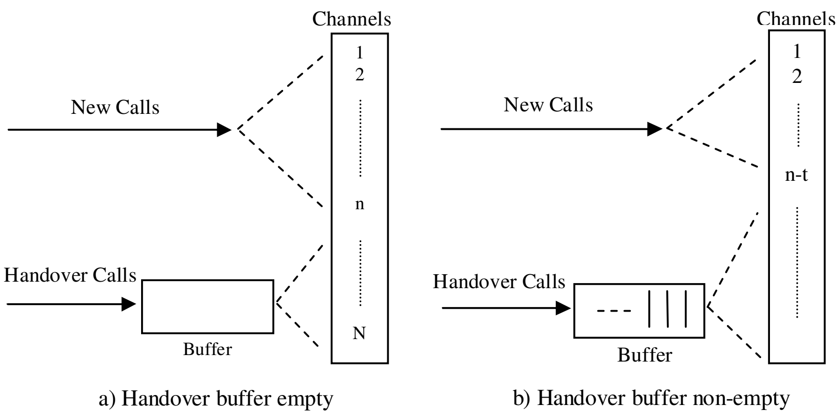

Fig. 3. The dynamic guard channel scheme

The arrivals of new calls follow a Poisson process with average arrival rate λ. The arrivals of handover calls are modelled by a two-state MMPP with the infinitesimal generator $\mathbf{Q} = \begin{bmatrix} -\delta_1 & \delta_1 \\ \delta_2 & -\delta_2 \end{bmatrix}$ and rate matrix $\mathbf{\Lambda} = \begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix}$, respectively, where λ_m $(m = 1, 2)$ is the arrival rate when the MMPP is at state m and δ_m is the intensity of transition from state m to the other. The call duration time, which is the amount of time that the call remains in progress without forced termination, is assumed to be exponentially distributed with mean μ_{du}^{-1}. Moreover, the cell dwell time, i.e., the time duration that a mobile user resides in the cell before crossing the cell boundary, follows an exponential distribution with mean μ_{dw}^{-1}. Therefore, the channel holding time defined as the time spent in a cell follows an exponential distribution with mean $\mu^{-1} = (\mu_{du} + \mu_{dw})^{-1}$. Furthermore, a handover call waiting in the queue is forced to terminate if the mobile station moves out of the radio coverage of the handover area. The corresponding handover dwell time is exponentially distributed with mean d^{-1}.

3.2 System State Transition Diagram

This section presents the state transition diagram of the system with the dynamic handover scheme. As shown in Figure 4, the three-dimensional Markov chain is constructed from two 2-dimensional Markov chains with one in the front layer and the other in the back (shaded) layer. The transition between the corresponding states from one layer to the other represents the change between the two states of the MMPP.

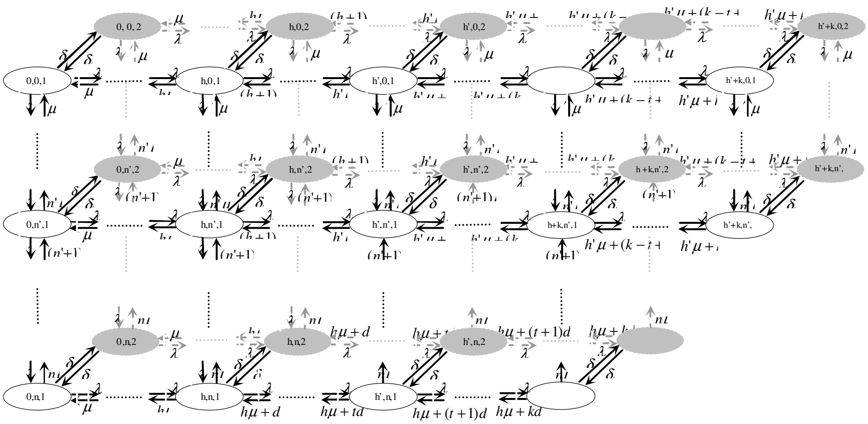

Fig. 4. State transition diagram of a three dimensional Markov chain for modelling the handover scheme

Each state (i, j, m) in the three-dimensional Markov chain corresponds to the case where there are i, $(0 \le i \le (h'+k))$, handover calls and j, $(0 \le j \le n)$, new calls in the system and the two-state MMPP is at state m, $(m = 1, 2)$. The transitions from state (i, j, m) to $(i+1, j, m)$, $(0 \le i < h'+k,\ \ 0 \le j \le n, m = 1,2)$, and from state (i, j, m) to $(i, j+1, m)$, $(0 \le i \le h'+k,\ 0 \le j < n, m = 1, 2)$ imply that a handover call and a new call enters into the system, respectively. Therefore, the transition rates out of state (i, j, m) to $(i+1, j, m)$ and to $(i, j+1, m)$ are λ_m and λ, respectively. On the other hand, the transitions from state (i, j, m) to $(i-1, j, m)$, $(1 \le i \le h'+k,\ 0 \le j \le n,\ m = 1,2)$, and from state (i, j, m) to $(i, j-1, m)$, $(0 \le i \le h'+k,\ 1 \le j \le n, m = 1,2)$ represents that a handover call and a new call departs from the system, respectively. Therefore, the transition rate out of state (i, j, m) to $(i, j-1, m)$ is $j \times \mu$. If a state (i, j, m) indicates that the buffer is empty (i.e., $i \le h'$ and $i + j \le N$), the transition rate from (i, j, m) to $(i-1, j, m)$ is $i \times \mu$. Otherwise, the transition rate is $(N-j)\times\mu + (i-N+j)\times d$ and $h'\mu + (i-h')d$ when $n' \le j \le n$ and $j < n'$, respectively.

Let p_{ijm} denote the joint probability of state (i, j, m) in the three-dimensional Markov chain. Let $\mathbf{P}$ be the steady-state probability vector of this Markov chain, $\mathbf{P} = (p_{001}, \cdots, p_{0n1}, \cdots, p_{(h'+k)01}, \cdots, p_{(h'+k)n'1}, \cdots, p_{002}, \cdots, p_{0n2}, \cdots)$. The infinitesimal generator matrix, $\mathbf{Z}$, of this Markov chain is of size $(2\times((h'+k+1)\times(n+1)-t(t+1)/2))\times$ $(2\times((h'+k+1)\times(n+1)-t(t+1)/2))$ and can be given according to the state transition rates of the Markov chain presented in the previous paragraph. The steady-state probability vector, $\mathbf{P}$, satisfies the following equations.

$$\begin{cases} \mathbf{PZ} = \mathbf{0} \\ \mathbf{Pe} = 1 \end{cases}. \tag{1}$$

where $\mathbf{e} = (1, 1, \cdots, 1)^T$ is a unit column vector of length $(2\times((h'+k+1)\times(n+1)-t(t+1)/2))$. Solving Equation (1) using the approach presented in [32-34] yields the steady-state probability vector, $\mathbf{P}$, as

$$\mathbf{P} = \boldsymbol{\alpha}(\mathbf{I} - \mathbf{X} + \mathbf{e}\boldsymbol{\alpha})^{-1}. \tag{2}$$

where matrix $\mathbf{X} = \mathbf{I} + \mathbf{Q}/\beta$, $\beta \le \min\{\mathbf{Q}_{ii}\}$ and $\boldsymbol{\alpha}$ is an arbitrary row vector of $\mathbf{X}$.

The aggregate and marginal state probabilities, p_x and p_x^q, that there are x calls in the system and in the queue, respectively, can be calculated based on the joint state probability p_{ijm}. The probabilities p_x and p_x^q can be written as.

$$p_x = \begin{cases} \sum_{j=0}^{x} \sum_{m=1}^{2} p_{(x-j)jm} & 0 \le x \le n \\ \sum_{j=0}^{n} \sum_{m=1}^{2} p_{(x-j)jm} & n < x \le h'+k \\ \sum_{j=x-h'-k}^{n} \sum_{m=1}^{2} p_{(x-j)jm} & h'+k < x \le N+k \end{cases}. \tag{3}$$

$$p_x^q = \begin{cases} \sum_{m=1}^{2} (\sum_{i=0}^{h} \sum_{j=0}^{n} p_{ijm} + \sum_{i=h+1}^{h'} \sum_{j=0}^{N-i} p_{ijm}) & x = 0 \\ \sum_{m=1}^{2} (\sum_{j=0}^{n'} p_{(h'+x)jm} + \sum_{j=n'+1}^{n} p_{(N-j+1)jm}) & 1 \le x \le k \end{cases}. \tag{4}$$

The probabilities, p_x and p_x^q, are essential for the derivation of the aggregate and marginal performance metrics below.

3.3 Derivation of Performance Metrics

Analytical expressions are derived to evaluate the mean number of calls in the system $\overline{L}$, aggregate response time $\overline{R}$, aggregate call blocking probability $\overline{CLP}$, handover call blocking probability $\overline{CLP_H}$, handover delay $\overline{D}$ and new call blocking probability $\overline{CLP_N}$.

The mean number of calls in the system $\overline{L}$ can be calculated as follows

$$\overline{L} = \sum_{x=0}^{N+k}(x \times p_x)\,. \tag{5}$$

The expressions for the mean aggregate response time can be derived using Little's Law [35].

$$\overline{R} = \frac{\overline{L}}{\overline{T}}\,. \tag{6}$$

where $\overline{T}$ is the aggregate throughput and is equal to the sum of the throughput of handover calls and new calls, $\overline{T_H}$ and $\overline{T_N}$. Due to the equilibrium of the rates of incoming flows and outgoing flows in the steady state, the mean marginal throughputs $\overline{T_H}$ and $\overline{T_N}$ are equal to the corresponding arrival rate multiplied by the probability that a handover or new call are not lost.

$$\overline{T} = \overline{T_N} + \overline{T_H}\,. \tag{7}$$

$$\overline{T_H} = \sum_{m=1}^{2} \lambda_m \Big(\sum_{i=0}^{h'+k-1} \sum_{j=0}^{n'} p_{ijm} + \sum_{j=n'+1}^{n} \sum_{i=0}^{N-j+k-1} p_{ijm} \Big)\,. \tag{8}$$

$$\overline{T_N} = \lambda \sum_{m=1}^{2} \Big(\sum_{i=0}^{h} \sum_{j=0}^{n-1} p_{ijm} + \sum_{i=h+1}^{h'} \sum_{j=0}^{N-i-1} p_{ijm} + \sum_{i=h'+1}^{h'+k} \sum_{j=0}^{n'-1} p_{ijm} \Big)\,. \tag{9}$$

As a blocked call does not contribute to the throughput, the call blocking probability is calculated by

$$\overline{CLP} = \frac{\overline{\lambda_H} + \lambda - \overline{T}}{\overline{\lambda_H} + \lambda}\,. \tag{10}$$

The average arrival rate, $\overline{\lambda_H}$, of handover calls, modelled by an MMPP-2 can be given by

$$\overline{\lambda_H} = \frac{\lambda_1 \delta_2 + \lambda_2 \delta_1}{\delta_1 + \delta_2}\,. \tag{11}$$

Similarly, the handover call blocking probability and new call blocking probability can be written as

$$\overline{CLP_H} = \frac{\overline{\lambda_H} - \overline{T_H}}{\overline{\lambda_H}} . \tag{12}$$

$$\overline{CLP_N} = \frac{\lambda - \overline{T_N}}{\lambda} . \tag{13}$$

Moreover, the expression for the handover delay $\overline{D}$ can also be derived using Little's Law and is given by [35].

$$\overline{D} = \frac{\overline{L_q}}{\overline{T_H}} . \tag{14}$$

Finally, the mean number of handover calls in the queue can be easily calculated using the probability p_x^q

$$\overline{L_q} = \sum_{x=0}^{k} (i \times p_x^q) . \tag{15}$$

4 Model Validation and Performance Analysis

To investigate the accuracy of the above developed performance model, a discrete-event simulator has been developed for the dynamic handover scheme using JAVA programming language. Extensive numerical experiments have been performed for several combinations of different degrees of burstiness of handover calls, various numbers of channels (h) originally reserved for handover calls and numbers of dynamic channels (t). The figures presented below in this section reveal that the simulation results closely match those predicted by the analytical model. Moreover, we investigate the effects of the number of channels originally reserved to handover calls, the number of dynamic channels and the burstiness of handover calls on the system performance.

Figs. 5-10 illustrate, respectively, the mean number of calls in the system, aggregate response time, aggregate call blocking probability, handover call blocking probability, handover delay and new call blocking probability against the number of dynamic channels t with different degrees of burstiness of handover calls and the original number of channel reserved for handoff calls $h = 10, 15$. Performance results depicted in Figs. 5-10 are presented for the following cases: The total number of available channels in the cell is $N = 30$. The buffer capacity, k, is set to be 10. Additionally, the call duration time, cell dwell time and handover dwell time are exponentially distributed with mean μ_{du}^{-1} = 0.67, μ_{dw}^{-1} = 10, and d^{-1} = 100, respectively. The mean arrival rate of new calls λ is set to be 20. Furthermore, handover calls with high burstiness is generated using the infinitesimal generator matrix $\mathbf{Q}=\begin{bmatrix}-0.001 & 0.001\\ 0.001 & -0.001\end{bmatrix}$ and the rate matrix $\boldsymbol{\lambda}=\begin{bmatrix}1 & 0\\ 0 & 30\end{bmatrix}$. In addition, handover calls with low burstiness is generated using the infinitesimal generator matrix $\mathbf{Q}=\begin{bmatrix}-0.97 & 0.97\\ 0.97 & -0.97\end{bmatrix}$ and the rate matrix $\boldsymbol{\lambda}=\begin{bmatrix}1 & 0\\ 0 & 30\end{bmatrix}$. The burstiness of 2-state MMPP which is characterized by the infinitesimal generator $\mathbf{Q}=\begin{pmatrix}-\delta_1 & \delta_1\\ \delta_2 & -\delta_2\end{pmatrix}$ and rate matrix $\boldsymbol{\Lambda}=\begin{pmatrix}\lambda_1 & 0\\ 0 & \lambda_2\end{pmatrix}$ is given by Equation (16).

$$c^2=1+\frac{2\delta_1\delta_2(\lambda_1-\lambda_2)^2}{(\delta_1+\delta_2)^2(\lambda_1\lambda_2+\lambda_2\delta_1+\lambda_1\delta_2)}. \tag{16}$$

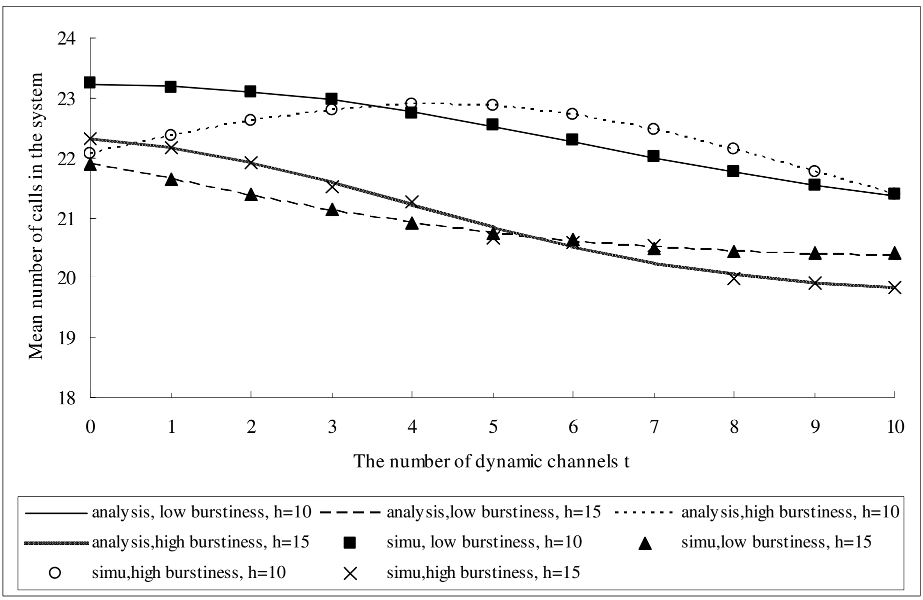

Fig. 5. Mean number of calls in the system vs. the number of dynamic channels t with the number of channels reserved for handover calls $h=10, 15$ and different burstiness of handover calls

As the number of dynamic channels (t) increases, more and more handover calls are accepted whilst more and more new calls are denied. The decrease in the mean number of calls in the system, on condition that the burstiness of handoff calls is low

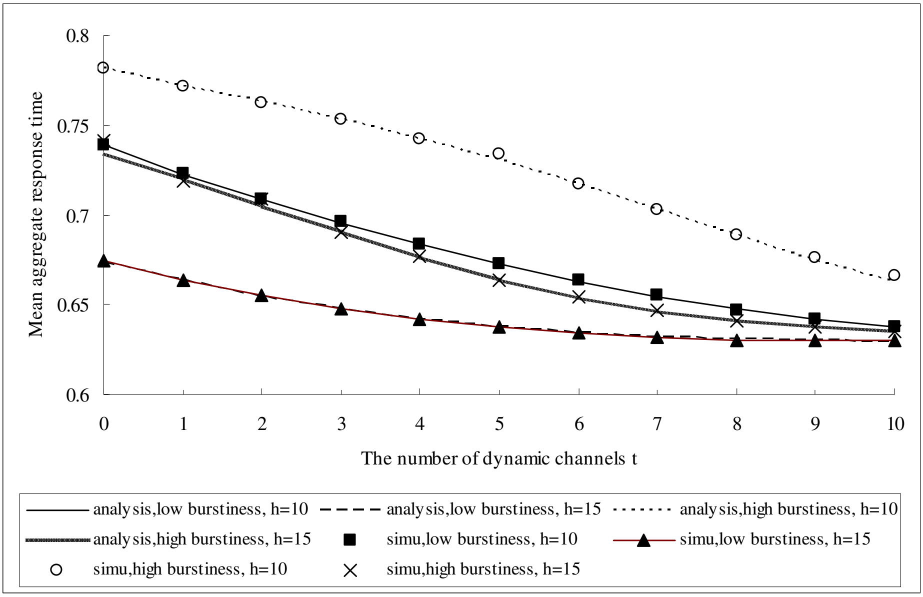

Fig. 6. Mean aggregate response time vs. the number of dynamic channels t with the number of channels reserved for handover calls $h=10,15$ and different burstiness of handover calls

or on condition that h is small (i.e., $h=10$) and the burstiness of handover calls is high, indicates that the decrease of the number of new call arrivals holds the leading position in affecting the aggregate number of calls in the system. However, Fig. 5 depicts that when the burstiness of handover calls and h are high (i.e., $h=10$), the mean number of calls that can be accommodated in the system tends to increase before it reaches a maximum value as t increases. This trend represents that the system accepts more handover calls although the number of accepted new calls decreases. When the number of calls in the system reaches its maximum value, the number of handover calls in the system is at the saturation point and the decrease of the number of new call arrivals consequently holds the leading position in affecting the aggregate number of calls in the system.

Furthermore, Fig. 5 shows the negative effect of high burstiness of handover calls, for instance, when h is fixed as 10, high burstiness results in an increased mean aggregate number of calls in the system if t is smaller than 4. Once the number of dynamic channels t exceeds 4 the decrease in the number of new calls plays more important role than burstiness in affecting the aggregate number of calls in the system. Moreover, the mean aggregate number of calls in the system when the h is small (i.e., $h=10$) is larger than that when h is big (i.e., $h=15$).

Figs. 6-9 reveal that, respectively, the increase of t remarkably reduces the mean aggregate response time, aggregate call blocking probability, handover call blocking probability and handover delay, in particular, with high burstiness and less number of channels originally reserved for handover calls (i.e., $h=10$), in that more channels

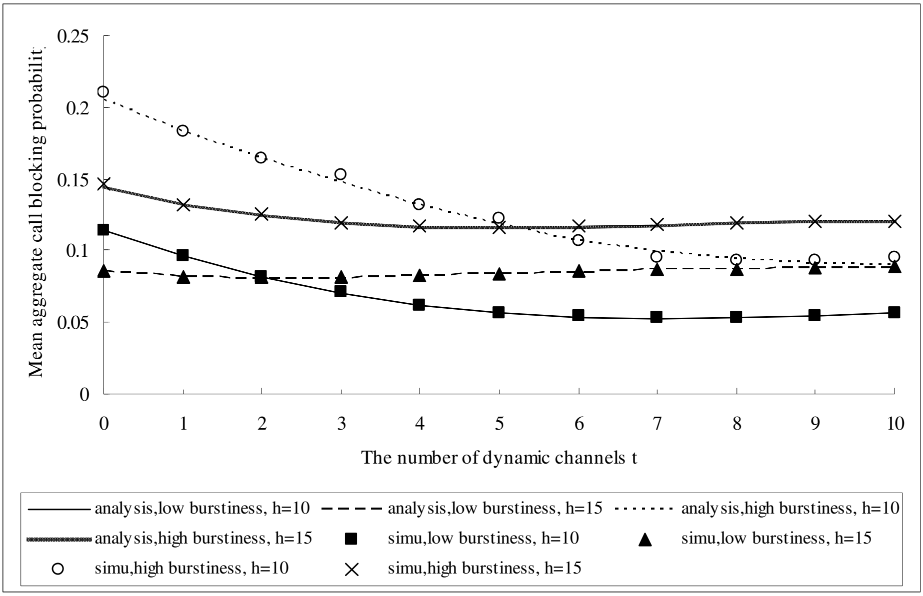

Fig. 7. Mean aggregate call blocking probability vs. the number of dynamic channels t with the number of channels reserved for handover calls $h = 10, 15$ and different burstiness of handover calls

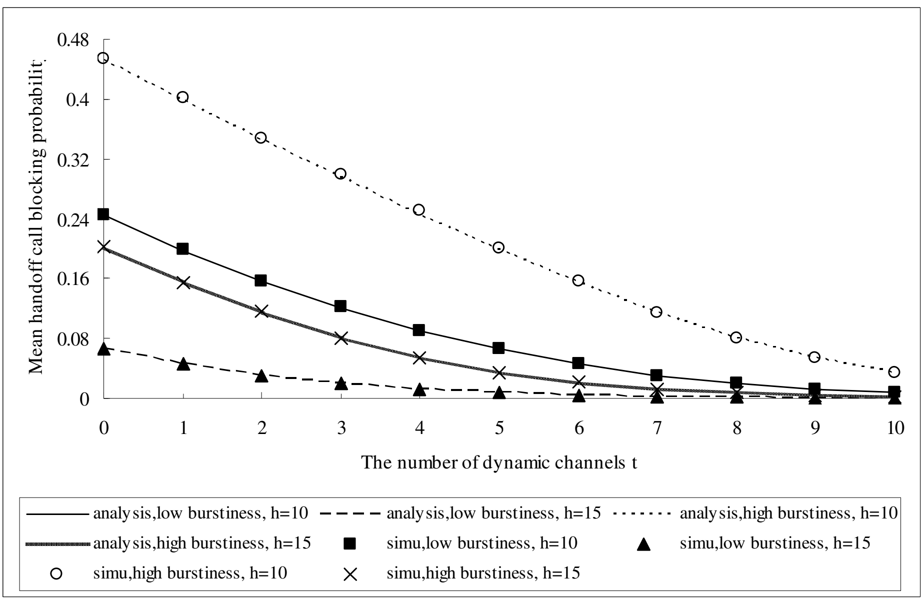

Fig. 8. Mean handover call blocking probability vs. the number of dynamic channels t with the number of channels reserved for handover calls $h = 10, 15$ and different burstiness of handover calls

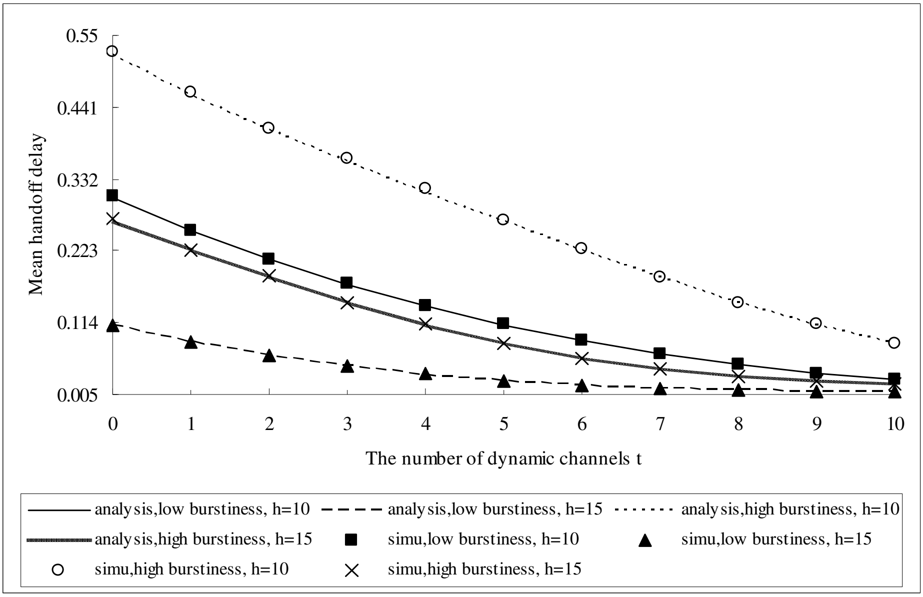

Fig. 9. Mean handover delay vs. the number of dynamic channels t with the number of channels reserved for handover calls $h = 10, 15$ and different burstiness of handover calls

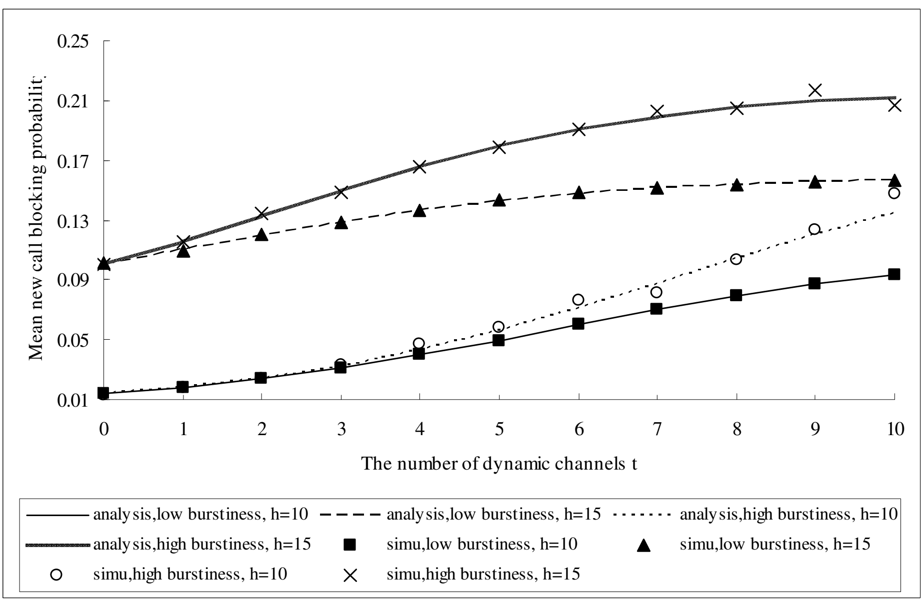

Fig. 10. Mean new call blocking probability vs. the number of dynamic channels t with the number of channels reserved for handover calls $h = 10, 15$ and different burstiness of handover calls

are allocated to handover calls. In addition, long aggregate response time, high aggregate call blocking probability, high handover call blocking probability and long handover delay are demonstrated in Figs. 6-9, respectively, as a result of increasing the burstiness of handover calls. On the other hand, it is easily understandable that the increase of h reduces the number of handover calls in the buffer, consequently decreases the aggregate response time, handover call blocking probability and handover delay. Meanwhile, Fig. 7 denotes that, when t is small (i.e., $t \le 2$ under low burstiness, $t \le 5$ under high burstiness), the aggregate call blocking probability increases as h grows. However, for a large t, the aggregate call blocking probability with a big h (i.e., $h = 15$) is higher than that with small one (i.e., $h = 10$).

As more and more handover calls are accepted, Fig. 10 illustrates that the new call blocking probability increases as t rises. High burstiness results in the growth of new call blocking probability. Such a trend becomes remarkable as t increases. Finally, as shown in Fig. 10, if more channels is originally reserved for handover calls (i.e., $h = 15$), new call blocking probability, the number of channels used for new call transmission decreases and consequently, more arriving new calls are to be blocked.

5 Conclusions

This chapter presented a detailed review of existing handover schemes for wireless communication networks. Particular emphasis was given to a proposed handover scheme DGCS, which can assign dynamically the reserved channels in order to reduce both the handover call blocking probability and mean handover delay. In this context, an analytical model was devised to assess the performance of this handover scheme and the MMPP was used to capture the impact of bursty and correlated arrival patterns of handover calls. The credibility of the model was illustrated by comparing favourably the analytic results against those obtained through extensive simulation experiments. Moreover, it was shown that the proposed handover scheme can effectively reduce the handover blocking probability and mean handover delay.

The analytical model can be employed to obtain a desirable number of dynamic channels in order to establish an optimal trade-off amongst the blocking probabilities of new calls and handover calls as well as the aggregate blocking probability of all calls.

References

1. Tekinay, S., Jabbari, B.: Handover and Channel Assignment in Mobile Cellular Networks. IEEE Comm. Mag. 29(11), 42–46 (1991)
2. Pollioni, G.P.: Trends in Handover Design. IEEE Comm. Mag. 34(3), 82–90 (1996)
3. Marichamy, P., Chakrabarti, S., Maskara, S.L.: Overview of Handoff Schemes in Cellular Mobile Networks and Their Comparative Performance Evaluation. In: 50th IEEE Vehicular Technology Conference Fall, pp. 1486–1490. IEEE Press, Amsterdam (1999)
4. Chaudhary, V., Tripathi, R., Shukla, N.K., Nasser, N.: A New Channel Allocation Scheme for Real-Time Traffic in Wireless Cellular Networks. In: IEEE Performance, Computing, and Communications Conference, pp. 551–555. IEEE International, New Orleans (2007)

5. Nasser, N., Hasswa, A., Hassanein, H.: Handoffs in Fourth Generation Heterogeneous Networks. IEEE Comm. Mag. 44(10), 96–103 (2006)
6. Yavuz, E.A., Leung, V.C.M.: Computationally Efficient Method to Evaluate the Performance of Guard-Channel-Based Call Admission Control in Cellular Networks. IEEE Trans. Veh. Tech. 55(4), 1412–1424 (2006)
7. Nasser, N., Hassanein, H.: Adaptive Call Admission Control for Multimedia Wireless Networks with QoS Provisioning. In: International Conference on Parallel Processing Workshops, Canada, pp. 30–37 (2004)
8. Rappaport, T.: Wireless Communications: Principles and Practice, 2nd edn. Prentice-Hall, Englewood Cliffs (2002)
9. Ekiz, N., Salih, T., Kucukoner, S., Fidanboylu, K.: An Overview of Handoff Techniques in Cellular Networks. International J. Information Technology 2(2) (2005)
10. Niyato, D., Hossain, E., Alfa, A.S.: Performance Analysis of Multi-service Wireless Cellular Networks with MMPP Call Arrival Patterns. In: IEEE GLOBECOM, pp. 3078–3082 (2004)
11. Louvros, S., Pylarinos, J., Kotsopoulos, S.: Mean Waiting Time Analysis in Finite Storage Queues for Wireless Cellular Networks. J. Wireless Personal Communications 40(2), 145–155 (2007)
12. Ye, Z., Law, L.K., Krishnamurthy, S.V., Xu, Z., Dhirakaosal, S., Trpathi, S.K., Molle, M.: Predictive Channel Reservation for Handoff Prioritization in Wireless Cellular Networks. J. Computer and Telecommunications Networking 51(3), 798–822 (2007)
13. Tung, D., Wong, C., Kong, P.: Wireless Broadband Networks. John Wiley & Sons, Inc., Chichester (2009)
14. Xhafa, A.E., Tonguz, O.K.: Dynamic Priority Queueing of Handover Calls in Wireless Networks: an Analytical Framework. IEEE J. on Selected Areas in Communications 22(5), 904–916 (2004)
15. Pati, H.K.: A Distributed Adaptive Guard Channel Reservation Scheme for Cellular Networks. Int. J. Commun. Syst. 20(9), 1037–1058 (2007)
16. Stojmenovi, I.: Handbook of Wireless Networks and Mobile Computing. John Wiley & Sons, Inc., Chichester (2002)
17. Akyildiz, I.F., McNair, J., Ho, J.S.M., Uzunalioglu, H., Wang, W.: Mobility Management in Next-Generation Wireless Systems. Proceedings of the IEEE 87(8), 1347–1384 (1999)
18. Znati, T.F., Kim, S.J.: Adaptive Channel Management Schemes for Wireless Communication Systems. International Journal of Communication Systems 13(6), 435–460 (2009)
19. Xhafa, A.E., Tonguz, O.K.: Dynamic Priority Queueing of Handoff Requests in PCS. In: IEEE International Conference on Communications, Finland, pp. 341–345 (2001)
20. Pandey, V., Ghosal, D., Mukherjee, B., Wu, X.: Call Admission and Handoff Control in Multi-Tier Cellular Networks: Algorithms and Analysis. Wireless Personal Communications 43(3), 857–878 (2007)
21. Guerin, R.: Queuing Blocking System with Two Arrival Streams and Guard Channels. IEEE Trans. Communications 36(2), 153–163 (1988)
22. Zhang, Y., Soong, B., Ma, M.: Approximation Approach on Performance Evaluation for Guard Channel Scheme. Electronics Letters 39(5), 465–467 (2003)
23. Vazuqez-Avila, J.L., Cruz-Perez, F.A., Ortigoza-Guerrero, L.: Performance Analysis of Fractional Guard Channel Policies in Mobile Cellular Networks. IEEE Trans. Wireless Communications 5(2), 301–305 (2006)
24. Ogbonmwan, S., Li, W.: Multi-Threshold Bandwidth Reservation Scheme of An Integrated Voice/Data Wireless Network. J. Computer Communications 29(9), 1504–1515 (2006)

25. Zheng, J., Regentova, E.: QoS-Based Dynamic Channel Allocation for GSM/GPRS Networks. In: Jin, H., Reed, D., Jiang, W. (eds.) NPC 2005. LNCS, vol. 3779, pp. 285–294. Springer, Heidelberg (2005)
26. Hong, D., Rapaport, S.: Traffic Model and Perfromance Analysis for Cellular Mobile Radio Telephone Systems with Prioritized and Nonprioritized Handoff Procedures. IEEE Trans. Vehicular Technology 35(3), 77–92 (1986)
27. Du, W., Lin, L., Jia, W., Wang, G.: Modeling and Performance Evaluation of Handover Service in Wireless Networks. In: Lu, X., Zhao, W. (eds.) ICCNMC 2005. LNCS, vol. 3619, pp. 229–238. Springer, Heidelberg (2005)
28. Wang, Z., Mathiopoulos, P.: On the Performance Analysis of Dynamic Channel Allocation with FIFO Handover Queuing in LEO-MSS. IEEE Trans. Communications 53(9), 1443–1446 (2005)
29. Ma, X., Cao, Y., Liu, Y., Trivedi, K.S.: Modeling and Performance Analysis for Soft Handoff Schemes in CDMA Cellular Systems. IEEE Trans. Vehicular Technology 55(2), 670–680 (2005)
30. Louvros, S., Pylarinos, J., Kotsopoulos, S.: Handoff Multiple Queue Model in Microcellular Networks. Computer Communications 30(2), 396–403 (2007)
31. Farahani, M.A., Guizani, M.: Markov Modulated Poisson Process Model for Hand-off Calls in Cellular Systems. In: Proc. IEEE Wireless Communications and Networking Conference, pp. 1113–1118 (2000)
32. Fischer, W., Meier-Hellstern, K.: The Markov-modulated Poisson Process (MMPP) Cookbook. Performance Evaluation 18(2), 149–171 (1993)
33. Paige, C.C., Styan, G.P.H., Wachter, P.G.: Computation of the Stationary Distribution of A Markov Chain. J. Statist. Comput. Simulation. 4, 173–186 (1975)
34. Min, G., Ould-Khaoua, M.: A Performance Model for Wormhole-switched Interconnection Networks under Self-similar Traffic. IEEE Transactions on Computers 53(5), 601–613 (2004)
35. Kleinrock, L.: Queueing Systems: Compute Applications, vol. 1. John Wiley & Sons, New York (1975)