The CSI Journal on
Computer Science and Engineering
Vol. 9, No. 2 & 4 (b), 2011
Pages 1-10
Regular Paper

Performance Analysis in Double Layer Cellular Network with New Call Bounding Scheme and Directed Retry

Madhu Jain[1] Ragini Mittal[2]

[1]Department of Mathematics, IIT Roorkee, Roorkee, India
[2]Department of Mathematics, St. John's College, Agra, India

Abstract

Overlapping coverage area of nearby base stations can be utilized by the mobile users to access channels from more than one base station. This facility of the cellular system improves the performance of teletraffic systems. In the present study, we develop an analytical model for evaluating the blocking probabilities in the double layer cellular network. The double layer cellular architecture is dedicated to micro cell and macro cell layers. These two layers deal with two different types of terminals i.e. high speed moving terminals (HSMTs) and low speed moving terminals (LSMTs). The concept of new call bounding scheme is proposed in the micro cell layer along with subrating scheme to admit more handoff attempts. In case when all the channels are busy, the low speed handoff attempts may retry for a channel in the neighboring base station. By using iterative algorithm, we calculate the rate by which attempts are made to retrying for the service. Various performance indices are obtained in terms of steady state probabilities. Numerical illustration is provided to demonstrate the tractability and validity of the analytical model for real time system.

Keywords: Cellular Network, Multi-Layer Architecture, Channel Assignment Scheme, Handoff Calls, Guard-Channel, Sub Rating, Directed Retry, Blocking.

1. Introduction

Wireless/cellular communication networks have now-a-days become the integral part of individuals of our society. Over the past decade with the advances in the technology, the dependency on wireless technology has increased. By using some sort of portable device such as cell phone, smart phone, tablet, laptop etc., someone can not only communicate with family/friends and can browse the web, but can also do high performance computing for their business and studies. In the past decade, the wireless communication market has experienced tremendous growth and this growth is likely to continue in near future. The limited radio frequency cannot fulfill the increasing demand and the required quality of service (QoS) as such it is very much essential to utilize the available frequency resources optimally.

In this paper, we suggest a channel assignment scheme for a two-tier cellular network to reduce the blocking of calls and to achieve a good quality of service. In a cellular mobile system, a new channel is assigned by the base station to a new call which originates in the area of the cell. The available channels of the base station also provide the continuation of ongoing calls as the users of neighboring cell enters in the service area of that cell; this process is called the handoff. For the traffic management of wireless/cellular network, it is important that handoff should occur smoothly, without gaps in communications links. To maintain the grade of service (GoS), the priority will be given to handoff calls instead of new originating calls. The handoff is an essential phenomenon of cellular communication; the prediction of the blocking probability of handoff is a key performance factor which plays an important role in finding ways, by which carried load of the handoff calls can be minimized. To achieve the maximum utilization of the system and to minimize the handoff failures, various handover prioritized schemes have been suggested by many researchers [1-4]. A mobility based channel reservation (MBCR) and new call bounding (NCB) schemes were analyzed by hou and Fang [5] to provide the QoS guarantee for a mobile wireless network. To reduce the dropping probability of voice/data handoff calls and to improve the performance of wireless/cellular network, various prioritized channel allocation schemes were developed by many researchers in different contexts [6-9]. To transparently avoid the service interruptions during horizontal and vertical handoffs, a noble middleware called mobile agent ubiquitous multimedia middleware (MUM) was proposed by Khan et al. [10]. A handoff scheme with wireless access points (WAP) was studied by shet et al. [11]. This scheme uses WAP as the ad-hoc routing station, to connect to the base stations.

In cellular architecture, the radio coverage is represented by hexagonal shaped cell structure. The irregular shape of the radio coverage area is due to the interference of various objects like building, mountains, uneven terrains etc. By exploiting the coverage of overlapping area, the user may be able to establish the best communication link quality. To improve the teletraffic performance of cellular network, directed retry scheme in different manners has been widely employed [12-14]. By considering the density of the base station and the speed of the mobiles for cellular radio network, the effects of directed retry on the call blocking were analyzed by verdone and zanella [15, 16]. To optimize the performance of wireless cellular network in case of network congestion resource/channel reservation and call admission control schemes were extensively used by many authors [17, 18]. A dynamically adaptive channel reservation scheme was suggested by salamah and lababidi [19]. According to this scheme, the reserved channels can also be assigned to new calls depending upon the locality principle, in which the base station with the help of location estimation algorithms in the mobile location centre predicts the position of mobile terminal. The subrating channel assignment scheme in which the reserved channels (guard channels) are divided into two half rate channels to serve the more prioritized calls present in the network, can be used to improve the performance of handoff voice attempts in cellular network [20,21]. A novel time-frequency resource allocation mechanism using fractional frequency reuse (FFR) for a macro-femto overlay cellular network was proposed by Oh et al. [22].

To improve the handoff performance in a cellular network, the overlay architecture plays a vital role. The macro cell/micro cell overlay architecture provides a balance between maximizing the number of users per unit area and minimizing the network control load associated with handoff. In order to increase the network capacity, the multi-tier network architecture can be used [23-27]. Two channel sharing strategies (i) vertical channel sharing and (ii) vertical-horizontal channel sharing for a two-tier cellular network with overlapping in service area was proposed by Lin et al. [28]. The Markov models for two-tier hierarchical cellular network to control the admission of new and handoff calls were developed in [29-31]. Many concepts including interference modelling and spectrum allocation issues in two-tier networks were discussed by Quek et al. in their book [32].

The consideration of macro/micro cells i.e. overlay architecture of cellular network provides flexibility to manage the traffic load inside the network more efficiently in comparison to a single layer architecture. The consideration of different speeds of handoff calls is quite realistic in the present scenario because it is necessary to design any communication network in such a way that it can handle the different types of users according to their mobility status. In the present investigation, we are dealing with the two types of handoff calls i.e. high speed and low speed handoff calls. We propose a two-tier cellular network to deal with different traffic conditions at different places and speed. According to the density of the subscribers, the two layers i.e. (i) macro layer and (ii) micro layer are taken into consideration for modeling purpose. The macro layer covers the area which is less congested such as the area beyond a city centre or outside the main street of the city whereas micro cell covers the area with high traffic density (called hot spot) such as an airport, a railway station or a parking lot. The cells in the lower tier are called micro cells and their radii are smaller than those cells of the macro layer. Upper layer cells i.e. macro cells cover the area of few kilometers whereas micro cells cover the area of few hundred meters. Two classes of mobile terminals (i) high speed moving terminal (HSMT) and (ii) low speed moving terminal (LSMT) are taken into consideration. The HSMT class represents the mobile terminals that are used in cars and other vehicles whereas LSMT class is made up of the users that are preliminary pedestrians. During the peak hours of the traffic, new call bounding scheme seems to reasonably good to control the admission of the new calls which can be further improved by giving the priority to the handoff calls with the provision of guard channels. The channel subrating in the micro cell can play a significant role in reducing the dropping of the calls. In the present investigation, we have employed the subrating scheme for low speed handoff voice calls.

The finite buffer provisioning is done in the macro cell to admit more calls in the system. The directed retry scheme is also proposed by considering the overlapping area of the neighboring cells; this scheme is quite helpful in reducing the blocking probabilities of handoff calls to certain extend. The concept of directed retry incorporated makes our model versatile to deal with real time system. The rest of the paper is organized as follows. The traffic model description by stating the requisite assumptions and notations being used in the formulation of the mathematical model is presented in section 2. The analysis is carried out in section 3. In section 4, various performance indices are discussed. An iterative algorithm is suggested to compute the rate of directed retry traffic. In section 5, the sensitivity analysis has been performed to examine the effect of various parameters on the system performance. Finally, concluding remarks for future scope of our study are given in section 6.

2. Model Description

We develop a double layer cellular network consisting of a group of hexagonal shaped micro cells overlaid by a macro cell. The macro cell layer which is the outer layer of the network, also known as umbrella layer, receives the HSMT type handoff calls. The micro cell layer is the inner layer of the network and deals with the LSMT traffic (both new and handoff calls) along with only new calls of HSMT type. A macro cell has i (i= 1, 2, …, K) group of micro cells. These micro cells are overlapped with each other to provide the full coverage area. Figure 1 shows the cluster of seven micro cells overlaid by a macro cell. There are C channels allocated in a macro cell whereas each micro cell has c channels to communicate with the subscribers. To support more low speed handoff voice attempts, c channels can be split into two half rate channels; this splitting process is known as subrating. To deal with heavy traffic conditions, the new call bounding scheme is used in micro cell layer for both new LSMT and HSMT attempts, according to which the new attempts are admitted up to a certain threshold level and after that all new attempts are rejected. We also incorporate the concept of directed retry in the micro cell layer for LSMT type handoff calls. It is clear from figure 1, that ith cell is overlapped with the coverage area of the neighboring j cells (j =1, 2, …, K-1).

The fraction of total area of ith cell is given by f_i, which is overlapped with the neighboring cells. S_i denotes the set of neighboring cells of the ith cell. Whenever a new call is initiated in the ith cell, a channel is assigned to the call. In case if there is no channel available to serve the call then the call is directed to retry for the service in the neighboring cells; this process is known as directed retry. All types of attempts are assumed to arrive in Poisson fashion whereas the call holding time is exponentially distributed with mean rate μ_n and μ_h for new and handoff attempts, respectively.

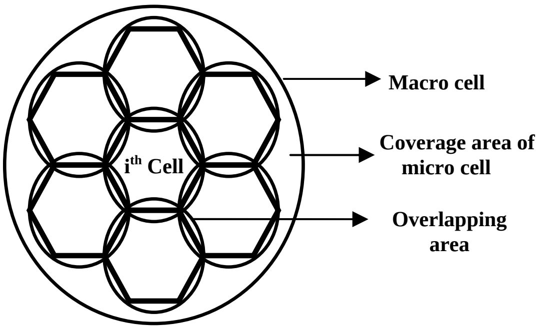


Figure 1. The geometry assumed for overlapping area (hexagonal cell side, circular coverage area)

Now we list the notations, which are used to construct the model mathematically as follows:

$\lambda_{i,Ln}(\lambda_{i,Hn})$	Arrival rates of new calls for LSMT (HSMT) at the ith (i=1, 2, …, K) cell.
$\lambda_{i,Lh}(\lambda_{i,Hh})$	Arrival rates of handoff calls of LSMT (HSMT) at the ith (i=1, 2, …, K) cell.
$\lambda_{i,n}$	Arrival rate of new calls so that $\lambda_{i,n} = \lambda_{i,Ln} + \lambda_{i,Hn}$ at the ith (i=1, 2, …, K) cell.
$\lambda_{i,h}$	Arrival rate of new calls so that $\lambda_{i,h} = \lambda_{i,Lh} + \lambda_{i,Hh}$ at the ith (i=1, 2, …, K) cell.
λ_i	Aggregate arrival rate of calls at the ith (i=1, 2, …, K) cell so that $\lambda_i = \lambda_{i,n} + \lambda_{i,h}$
$1/\mu_n\ (1/\mu_h)$	The call holding time for new (handoff) calls.
$\sigma_{i,Lh}$	Rate of directed retry by neighboring cells for low speed handoff calls.
$P_{(0,0)}$	Steady state probability that there is no call in the microcell.
$P_{(l,m)}$	The steady-state probabilities that *l* channels are occupied by new calls and m channels are occupied by the low speed handoff calls in a microcell
$B_{i,n}$	Blocking probability of new calls in microcell i, (i=1, 2, …, K).
$b_{i,Lh}$	Blocking probability of handoff calls at LSMT in microcell i, (i=1, 2, …, K).
$B_{i,Lh}$	Overall blocking probability of handoff calls at LSMT in microcell i, (i=1, 2, …, K).
B_{Hh}	Blocking probability of handoff calls at HSMT in macrocell.
q_s	The steady state probabilities that s channels are busy with handoff calls of HSMT in macro cell.
Q	The buffer size for handoff calls at HSMT in macrocell.
B_o	Overall blocking probability.
CL	Carried Load.

The traffic intensities of new calls for LSMTs and HSMTs at ith (i = 1, 2, …, K) micro cell are $\rho_{i,Ln} = \frac{\lambda_{i,Ln}}{\mu_n}$, $\rho_{i,Hn} = \frac{\lambda_{i,Hn}}{\mu_n}$.

The traffic intensities of handoff calls for LSMTs and HSMTs are $\rho_{i,Lh} = \frac{\lambda_{i,Lh} + \sigma_{i,Lh}}{\mu_h}$, $\rho_{i,Hh} = \frac{\lambda_{i,Hh}}{\mu_h}$.

Also, $\rho_{i,n} = \rho_{i,Ln} + \rho_{i,Hn}$, $\rho_{i,h} = \rho_{i,Lh} + \rho_{i,Hh}$.

3. Traffic Analysis

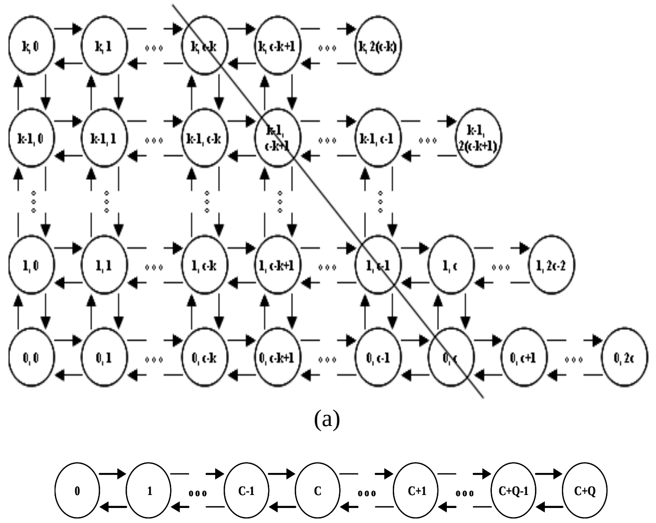
For the new call bounding scheme we consider that new attempts are admitted up to the threshold limit k. If the number of new calls in the cell exceeds k, the new call will be blocked. The handoff call is rejected only when all channels in the cell are used up. Figure 2(a) shows the state transition diagram for this scheme. The diagram forms two dimensional Markov chain with the state space:

$$S = \{(l, m) \mid 0 \le l \le k,\quad 0 \le m \le c,\quad l + m \le 2c - l\}$$

Where *l* denotes the number of new calls admitted in the micro cell and m is the number of low speed handoff calls initiated in a micro cell. The transition flow rates for this scheme are given in the table 1.

We obtain the steady state probability $P_{(l,m)}$ in each micro cell by using product type solution in two dimensions as [33]:

$$P_{(l,m)} = \frac{\rho_n^l}{l!}\frac{\rho_{Lh}^m}{m!}P_{(0,0)}\,; \qquad 0 \le l \le k, \quad l+m \le 2c-l, \quad m \ge 0 \tag{1}$$



(a)

(b)

Figure 2. (a) Two-dimensional state transition diagram for new call bounding scheme in micro cell. (b) State transition diagram for macro cell

Table 1. Transition flow rates

States		Transition Rate	Range
To	**From**		
(l, m)	(l -1, m)	$l\mu$	$0 \le l \le k, \quad 0 \le m \le c,$ $l+m \le 2c-l$
(l, m)	(l+1, m)	λ_n	$0 \le l \le k, \quad 0 \le m < c,$ $l+m \le 2c-l$
(l, m)	(l, m-1)	$m\mu_h$	$0 \le l \le k, \quad 0 < m \le c,$ $l+m \le 2c-l$
(l, m)	(l, m+1)	λ_{Lh}	$0 \le l \le k, \quad 0 \le m < c,$ $l+m \le 2c-l$

Using normalizing condition, we obtain

$$P_{(0,0)} = \left[\sum_{l=0}^{k}\sum_{m=0}^{2(c-l)}\frac{\rho_n^l}{l!}\frac{\rho_{Lh}^m}{m!}\right]^{-1} \tag{2}$$

For the macro cell consisting of i (i =1, 2,…,K) number of micro cells, the stationary probability that s channels are occupied can be derived using state transition rates shown in figure 2(b) as follows:

$$q_s = \begin{cases} \left(\dfrac{(K.\rho_{Hh})^s}{s!}\right)q_0, & s = 1,2,\ldots\ldots,C \\ \left(\dfrac{(K.\rho_{Hh})^s}{C!C^{s-C}}\right)q_0, & s = C+1, C+2,\ldots\ldots,C+Q \end{cases} \tag{3}$$

Where

$$q_0 = \left[\sum_{s=0}^{C}\frac{(K.\rho_{Hh})^s}{s!} + \sum_{s=C+1}^{C+Q}\frac{(K.\rho_{Hh})^s}{C!C^{s-C}}\right]^{-1} \tag{4}$$

4. Performance Measures

This section provides the results for blocking probabilities of new calls, low speed handoff calls in a micro cell, blocking probability of high speed handoff calls along with expected number of busy channels in a macro cell and the overall blocking probability of low speed handoff calls, etc.

4.1. Performance Indices for Micro Cell

In this section, we establish the explicit formula for the blocking probabilities and some other indices for micro cell as follows:

The blocking probabilities of new LSMT and HSMT calls are given by

$$B_{i,n} = B_{i,Ln} = B_{i,Hn} \quad \frac{\sum_{m=0}^{c-k}\frac{\rho_n^k}{k!}\frac{\rho_{Lh}^m}{m!} + \sum_{l=0}^{k-1}\frac{\rho_n^l}{l!}\frac{\rho_{Lh}^{2(c-l)}}{2(c-l)!}}{\sum_{l=0}^{k}\sum_{m=0}^{2(c-l)}\frac{\rho_n^l}{l!}\frac{\rho_{Lh}^m}{m!}} \tag{5}$$

The blocking probability of handoffs of LSMT is obtained as

$$b_{i,Lh} = \frac{\sum_{l=0}^{k}\frac{\rho_n^l}{l!}\frac{\rho_{Lh}^{2(c-l)}}{2(c-l)!}}{\sum_{l=0}^{k}\sum_{m=0}^{2(c-l)}\frac{\rho_n^l}{l!}\frac{\rho_{Lh}^m}{m!}} \tag{6}$$

The expected number of busy channels in a micro cell is determined by using

$$E[n_{micro}] = \sum_{l=0}^{k}\sum_{m=0}^{2c}(l+m)P_{l,m} \tag{7}$$

The number of subrated channels in a micro cell is given by

$$E[n_s] = \sum_{\substack{l=0 \\ c \le l+m \le 2c}}^{k-1}\;\sum_{m=0}^{2c}2(l+m-c)P_{l,m} \tag{8}$$

The degradation of voice quality of low speed handoff voice calls is calculated as

$$E[D] = E\left[\frac{n_s}{n_{micro}}\right] = \sum_{\substack{l=0 \\ c \le l+m \le 2c}}^{k-1}\;\sum_{m=0}^{2c}\frac{2(l+m-c)}{l+m}P_{l,m} \tag{9}$$

4.2. Performance Indices for Macro Cell

Here, we establish two performance measures for HSMT handoff calls in a macro cell given as follows:

The handoff call blocking probability for HSMT is obtained as

$$B_{Hh} = \frac{(K.\rho_{Hh})^{(C+Q)}}{(C+Q)!} \tag{10}$$

The expected number of busy channels in a macro cell is

$$E[n_{macro}] = \sum_{0 \le n \le C} nP_n \tag{11}$$

4.3. Overall Blocking Probability for Low Speed Handoff Terminal

The overall blocking probability in a cell can be obtained by considering the origination of the calls. According to the previous assumptions, a cluster of K hexagonal micro cells is considered where f_i is the fraction of the total area of the i^{th} cell which is overlapped by the neighboring cells.

The overall blocking probability of LSMT type handoff calls in the i^{th} cell is given by $B_{i,Lh}$ = (non-overlapping area) × Prob. (cell i is blocked for handoff call at LSMT) + overlapping area Prob. (cell i is blocked for handoff call at ×LSMT)× $\sum_j$ Prob. (cell j is blocked for handoff call at LSMT).

Hence, we have

$$B_{i,Lh} = (1 - f_i) b_{i,Lh} + f_i b_{i,Lh} \sum_j b_{i,Lh} \tag{12}$$

For the notational convenience, we omit the suffix i and obtain the blocking probability in an individual micro cell as follows:

$$B_o = \frac{\lambda_n B_n + \lambda_{Lh} B_{Lh} + \lambda_{Hh} B_{Hh}}{\lambda} \tag{13}$$

The carried load is given by

$$CL = \frac{\lambda_n (1 - B_n) + \lambda_{Lh} (1 - B_{Lh}) + \lambda_{Hh} (1 - B_{Hh})}{\lambda} \tag{14}$$

4.4. Computation of Directed Retry Traffic

Here, we provide a procedure for calculating the arrival rates due to directed retry. Now we obtain the traffic due to directed retry as follows [12]:

$\sigma_{i,Lh} = \sum_j \lambda_{j,Lh}$ Prob. (cell j is blocked and cell i is not blocked for new LSMT calls) × Prob. (a new call is directed to cell i given that cell j is blocked and cell i is not blocked for new LSMT calls)

$$= \sum_j \lambda_{j,Lh} b_{j,Lh} (1 - b_{i,Lh}) \frac{f_i}{|S_j|} \tag{15}$$

Since the expressions of blocking probabilities include the arrival rates due to directed retry, we adopt an iterative procedure for calculating the blocking probabilities as follows:

Iterative Algorithm

```
1. Initialize $\sigma_{i,Lh}$ = 0, $\delta$ = 1, $\varepsilon$ = 0.00001.
2. While | $\delta$ |> $\varepsilon$, repeat the following steps:
    2.1 Calculate $P_{l,m}$ using (1) and all the blocking
        probabilities using (5), (6), (10) and (12).
    2.2 Compute $\sigma_{i,Lh}$ using (15).
    2.3 Calculate $\delta$ as the difference between
        The old $\sigma_{i,Lh}$ and new $\sigma_{i,Lh}$.
        $\delta = \left| \frac{old\ \lambda_{Lh} - new\lambda_{Lh}}{new\lambda_{Lh}} \right|$
3. Compute $B_o$ and CL by using (13) and (14), respectively.
```

5. Sensitivity Analysis

In order to explore the effect of different sensitive parameters on various performance measures such as blocking probability of new calls (B_n), overall blocking probability of low speed handoff calls (B_{Lh}), blocking probability of high speed handoff calls (B_{Hh}), overall blocking probability of calls (B_o), carried load (CL) and expected number of busy channels in micro cell ($E[n_{micro}]$), we provide numerical results by taking an illustration. The coding of computer program has been done in MATLAB software. The numerical results for various performance indices are summarized in tables 2-3. The graphical representation of blocking probabilities has also been done in figures 3-5. For illustration purpose, we set default parameters as C=70, c=10, K=7, k=6, Q=5, λ_{Ln}=0.1, λ_{Hn}=0.2, μ_n=0.1, μ_h=0.2, λ_{Lh}=0.010 and λ_{Hh}=0.05.

In table 2, a comparative study has been done for various performance indices on the basis of retry and without retry schemes. From table 2, we observe that overall blocking probability of low speed handoff calls (B_{Lh}) and overall blocking probability (B_o) decrease in case when the calls are directed to retry in comparison to without retry scheme. On the other hand, the carried load (CL) increases significantly in case of retry scheme in comparison to without retry scheme. It is clear from both the results that the overall blocking probability of low speed handoff calls and overall blocking probability of calls can be reduced remarkably by using the directed retry scheme. It is noticed that there is no change in blocking probability of new calls (B_n) in both the cases (i.e. with retry and without retry) which is as per our expectation because the directed retry scheme is applied only for low speed handoff terminal. The blocking probabilities B_n, B_{Lh} and B_o increase on increasing the arrival rate of low speed handoff terminal (λ_{Lh}) whereas CL decreases with the increase in λ_{Lh}. It is observed that the trend of numerical results are quite close to real-time situation for any cellular network as the arrival rate of incoming calls inside the network increases, the blocking probabilities increase significantly. It is also clear that B_n and B_o decrease sharply on increasing the value of threshold parameter for new call bounding scheme (k), whereas the reverse effect is seen for both B_{Lh} and CL which increase with the increasing value of k. The reason for decreasing trend of B_n is quite obvious because the new call bounding scheme is applied to render service of only k new incoming calls, hence whenever this threshold parameter ‘k’ increases, the blocking probability of new calls decreases significantly.

Table 3 displays the effect of λ_{Hh} on different performance indices. In table 3, we see the increasing trend of blocking probability of high speed handoff calls (B_{Hh}), overall blocking probability of calls (B_o) and expected number of busy channels in macro cell ($E[n_{macro}]$) for increasing values of the arrival rate of high speed handoff calls (λ_{Hh}). The decreasing pattern for carried load (CL) on increasing λ_{Hh} is also noted. The trends seem to be reasonably correct because if the arrival rate of high speed handoff calls in a macro cell increases, the blocking probability of high speed handoff calls and the overall blocking probability of the network increases accordingly. Here, B_n and B_{Lh} attain constant values by varying the value of λ_{Hh}, which is quite obvious as B_n and B_{Lh} both are considered for the micro cell and the high speed handoff calls are served in the macro cell.

Figure 3(a-c) show the effect of arrival rate of low speed handoff calls (λ_{Lh}) on the blocking probability of new calls (B_n), overall blocking probability (B_o) and carried load (CL) for different values of the threshold parameter ‘k’of new call bounding scheme. From figures 3(a-b), we notice that B_n and B_o gradually increase on increasing λ_{Lh} whereas decrease sharply with the increase in k. Figure 3(c) shows that CL decreases moderately with the increase in λ_{Lh} whereas increases sharply on increasing k. The effect of arrival rate of low speed handoff calls on B_n, B_o and CL is quite matching with the realistic congestion situation for any cellular communication network as with the increasing arrival rate of calls, the blocking probabilities of calls increase significantly whereas carried load of the network decreases moderately.

The trend of B_n, B_o and CL with the variation in threshold parameter of new call bounding scheme ‘k’ are same what we expect; by increasing the value of k, the blocking probability of new call and overall blocking probability decrease remarkably whereas the carried load increases significantly.

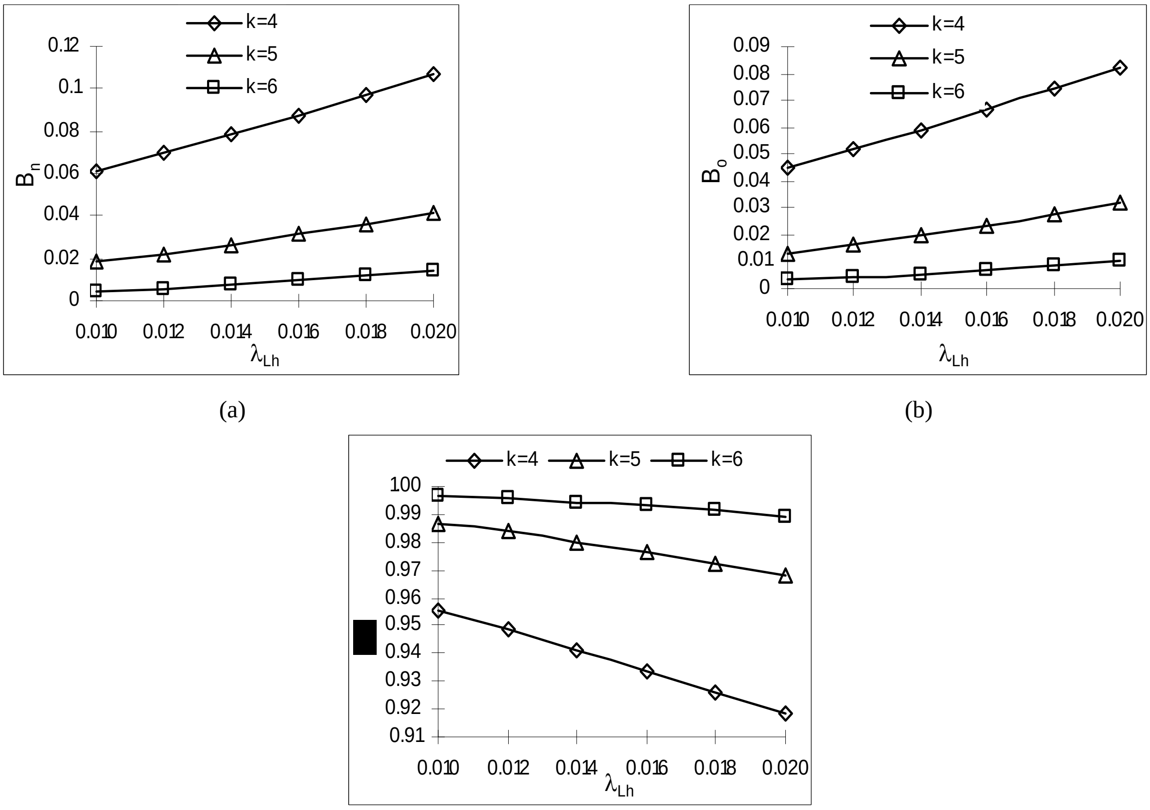
Figures 4(a-c) reveal the effect of arrival rate of low speed handoff calls (λ_{Lh}) on the overall blocking probability of low speed handoff calls (B_{Lh}) for different values of threshold parameter of new call bounding scheme (k), number of channels in a micro cell (c) and fraction (f) of overlapping area with neighboring cell, respectively. From figure 4(a), it is noticed that B_{Lh} sharply increases on increasing λ_{Lh} and k.

Table 2. Performance indices for different values of λ_{Hh} and K

	λ_{Lh}	**B_n**		**B_{Lh}**		**B_o**		**CL**	
		without retry	**with retry**	**without retry**	**with retry**	**without retry**	**with retry**	**without retry**	**with retry**
	0.010	0.060934	0.060934	4.79E-18	4.31E-18	0.044589	0.044586	0.955412	0.955415
	0.012	0.069605	0.069605	2.98E-17	2.68E-17	0.051563	0.051559	0.948440	0.948441
	0.014	0.078553	0.078553	1.42E-16	1.28E-16	0.058831	0.058829	0.941169	0.941172
k=4	0.016	0.087710	0.087710	5.52E-16	4.97E-16	0.066339	0.066336	0.933661	0.933664
	0.018	0.097008	0.097008	1.84E-15	1.66E-15	0.074034	0.074022	0.925977	0.925978
	0.020	0.106383	0.106383	5.43E-15	4.88E-15	0.081839	0.081833	0.918165	0.918167
	0.010	0.018197	0.018197	1.07E-14	9.66E-15	0.013322	0.013315	0.986683	0.986685
	0.012	0.022142	0.022142	4.94E-14	4.45E-14	0.016408	0.016401	0.983569	0.983572
	0.014	0.026508	0.026508	1.83E-13	1.65E-13	0.019859	0.019851	0.980146	0.980148
k=5	0.016	0.031279	0.031279	5.77E-13	5.19E-13	0.023668	0.023657	0.976342	0.976343
	0.018	0.036438	0.036438	1.60E-12	1.44E-12	0.027815	0.027804	0.972194	0.972195
	0.020	0.041958	0.041958	4.02E-12	3.61E-12	0.032279	0.032271	0.967724	0.967726
	0.010	0.004545	0.004545	1.29E-11	1.16E-11	0.003787	0.003345	0.996666	0.996673
	0.012	0.005897	0.005897	4.39E-11	3.95E-11	0.004379	0.004368	0.995629	0.995631
	0.014	0.007497	0.007497	1.27E-10	1.14E-10	0.005619	0.005614	0.994385	0.994384
k=6	0.016	0.009361	0.009361	3.24E-10	2.92E-10	0.007089	0.007080	0.992918	0.992919
	0.018	0.011503	0.011503	7.49E-10	6.75E-10	0.008787	0.008777	0.991220	0.991222
	0.020	0.013930	0.013930	1.60E-09	1.44E-09	0.010722	0.010716	0.989281	0.989283

Table 3. Various performance indices by varying λ_{Hh} for C=70 and Q=5

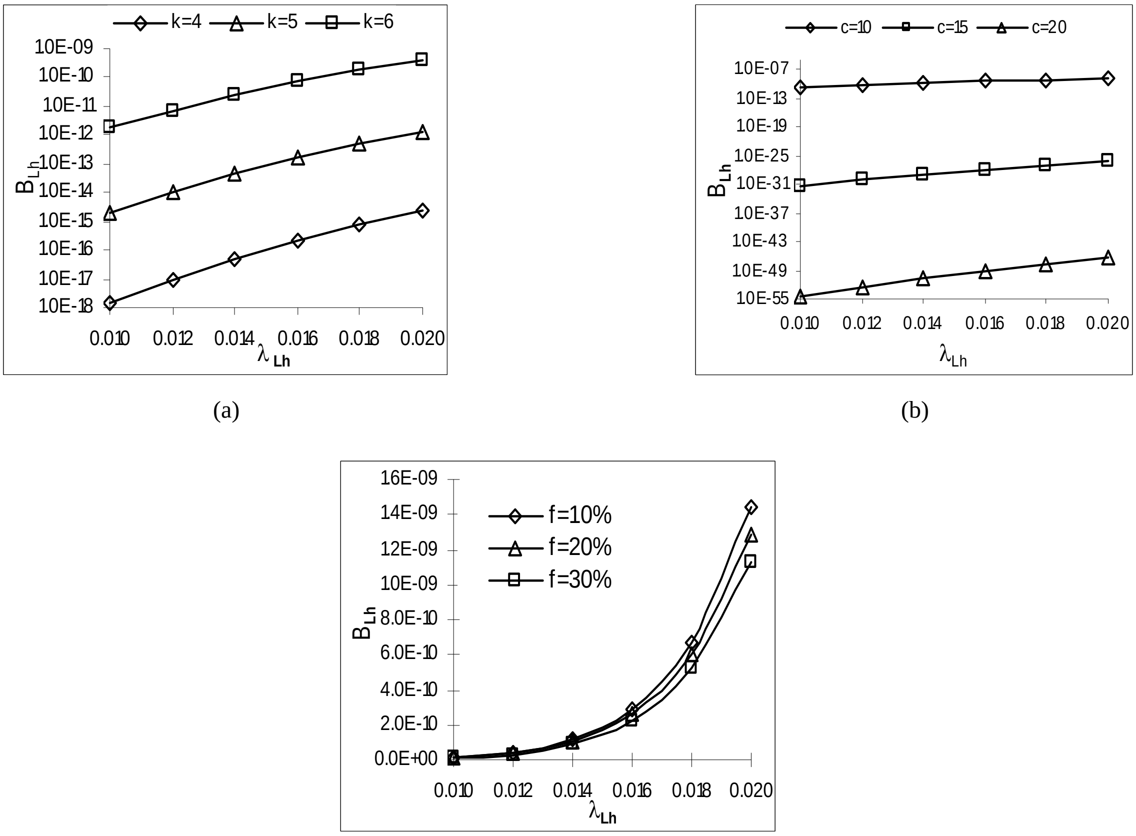
λ_{Hh}	**B_n**	**B_{Lh}**	**B_{Hh}**	**B_o**	**CL**	**$E(n_{macro})$**
0.10	0.053724	1.79E-12	9.72E-47	0.045400	0.954599	3.608982
0.12	0.053724	1.79E-12	8.44E-41	0.068948	0.931051	4.263940
0.14	0.053724	1.79E-12	8.86E-36	0.094292	0.905707	4.936762
0.16	0.053724	1.79E-12	1.98E-31	0.119433	0.880566	5.620785
0.18	0.053724	1.79E-12	1.36E-27	0.142898	0.857101	6.311590
0.20	0.053724	1.79E-12	3.67E-24	0.163809	0.836191	7.006389



(a) (b)

(C)

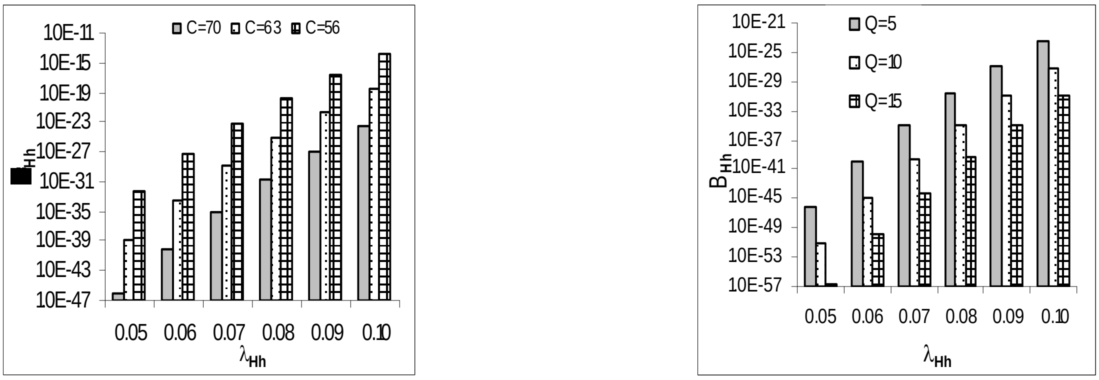
Figure 3. (a) Effect of λ_{Lh} on B_n for different values 'k'. (b) Effect of λ_{Lh} on B_o for different values of 'k'. (c) Effect of λ_{Lh} on CL for different values of 'k'



(a) (b)

(c)

Figure 4. (a) Effect of λ_{Lh} on B_{Lh} for different values of 'k'. (b) Effect of λ_{Lh} on B_{Lh} for different values of 'c'. (c) Effect of λ_{Lh} on B_{Lh} for different values of 'f'



(a) (b)

Figure 5. (a) Effect of λ_{Hh} on B_{Hh} for different values of 'C'. (b) Effect of λ_{Hh} on B_{Hh} for different values of 'Q'

Figure 4(b) reveals that on increasing λ_{Lh}, blocking B_{Lh} increases moderately whereas a remarkable decreasing pattern of B_{Lh} is seen on increasing the value of c; the effects of λ_{Lh} and c are same what we expect. From figure 4(c) it is clear that on increasing λ_{Lh}, B_{Lh} first increases slowly for the lower values of λ_{Lh}; after that a remarkable increasing trend of B_{Lh} is seen for higher values of λ_{Lh}. Also, on increasing f, we see that B_{Lh} decreases slowly; this is due to the fact that by increasing the fraction of overlapping area (f) with neighboring cell, more calls are directed to retry their service in the overlapping area, hence the blocking probability decreases.

Figures 5(a-b) show the graphs for blocking probability of high speed handoff calls (B_{Hh}) by varying the arrival rate of high speed handoff calls (λ_{Hh}), for different values of total number of channels (C) in macro cell and buffer size (Q) for high speed handoff calls in macro cell, respectively. In these figures, we notice that B_{Hh} increases sharply with the increase in λ_{Hh}, which is quite obvious. We observe in figure 5(a) that B_{Hh} decreases on increasing the value of C. This can be physically explained as by providing the service to the incoming calls at faster rate, the blocking probability reduces significantly. From figure 5(b), it is clear that on increasing the buffer size (Q), B_{Hh} decreases sharply, which is same as what we expected.

Overall, we conclude that the blocking probabilities of high speed moving terminals (i.e. high speed calls) and low speed moving terminals (i.e. low speed calls) increase moderately on increasing the traffic load inside the network whereas carried load decreases on increasing the arrival rate of incoming calls. The reduction in the blocking of the incoming calls also affects the directed retry scheme as it reduces the blocking probability of handoff calls to a certain extent depending upon the amount of the fraction of overlapping area with the neighboring cells. The new call bounding scheme is also beneficial to control the arrival of the new calls during the peak and busy hours in the network.

6. Conclusion

A two layer cellular network with directed retry and new call bounding scheme has been studied. Our study may be helpful to reduce the congestion and to improve the QoS in multi-layer cellular network which operates under techno-economic constraints due to limited resources. The concept of new call bounding scheme incorporated provides an insight to reduce the blocking of handoff attempts in case of heavy traffic situations. The suggested direct retry scheme has additional advantage to the subscribers to establish the communication link with more than one base station, so that they may get best quality.

In double layer cellular architecture, the macro cell provides the cost efficient service because fewer resources are dedicated to provide adequate services in rural area with overall low and scattered demand. The model developed can be further extended by incorporating the integrated voice/data traffic. It is hoped that the future design of cellular network of upcoming technology may be benefitted by our study as far as reduction in blocking calls is concerned.

Acknowledgements

We are thankful to Professor G. C. Sharma, Institute of Basic Science, Dr B.R.A. University, agra for his advice and to the Chief Editor and learned reviewers for their valuable suggestions and comments for the improvement of the paper.

References

[1] J. G. Markoulidakis, J. E. Dermitzakis, G. L. Lyberopoulos, and M. E. Theologou, "Optimal System Capacity in Handover Prioritized Schemes in Cellular Mobile Telecommunication," *Journal of Computer and Communication*, vol. 23, no. 3, pp. 462-475, 2000.

[2] F. Hu, and N. K. Sharma, "Multimedia Call Admission Control in Mobile Networks: A Dynamical Reservation-pool Approach," *Journal of Computer and Telecommunication*, vol. 43, no. 3, pp. 263-288, 2003.

[3] X. Yi, Q. L. Ding, and C. K. Chi, "Impact of Handoff Protection Strategies on Cellular Mobile System Capacity," *Journal of Wireless Communication*, vol. 3, no. 1, pp. 1076-1087, 2004.

[4] A. Kumar, A. Bhushan, and M. Kumar, "A Study on Minimization of 2G/3G Handover Failure," *Journal of Software Engineering*, vol. 2, no.4, pp. 4-7, 2012.

[5] J. Hou, and Y. Fang, "Mobility-based Call Admission Control Schemes for Wireless Mobile Networks," *Journal of Wireless Network Application Model*, vol. 1, no.2, pp. 269-282, 2001.

[6] P. Bellavista, A. Corradi, and L. Foschini, "Context-aware Handoff Middleware for Transparent Service Continuity in Wireless Networks," *Journal of Pervasive Mobile Computation*, vol. 3, no. 6, pp. 439-466, 2007.

[7] N. S. V. Shet, K. Chandrasekaran, and K. C. Shet, "Implementation of Handoff through Wireless Access Point Techniques," *Journal of Telecommunication*, vol. 2, no.3, pp. 143-146, 2010.

[8] J. Huang, W. K. Lai, C. C. Wang, Y. J. Jin, and H. W. Chen, "A Rationed of Channel Assignment Scheme for Initial and Handoff Attempts in Mobile Cellular Systems," *Journal of Computer and Communication*, vol. 24, no. 4, pp. 308-318, 2001.

[9] M. Jain, G. C. Sharma, and R. Mittal, "Transient Analysis of Channel Allocation in Cellular Radio Network with Balking and Reneging," *Computer Society of India*, vol. 38, no. 2, pp. 11-19, 2008.

[10] J. Khan, A. Abbas, and K. Khan, "Cellular Handover Approaches in 2.5G to 5G Technology," *Journal of Computer Application*, vol. 21, no. 2, pp. 28-37, 2011.

[11] M. Jain, G. C. Sharma, and R. Mittal, "Performance Analysis of a Prioritized Call Admission Control Schemes for Integrated Traffic in Wireless Network,' *Journal of Electronic Communication and Computer Engineering*, vol. 4, no. 2, pp. 283-291, 2013.

[12] T. P. Yum, and K. L. Yeung, "Blocking and Handoff Performance Analysis of Directed Retry in Cellular Mobile Systems," *IEEE Trans. Vehi. Technol.*, vol. 44, no. 4, pp. 645-650, 1995.

[13] T. P. Chu, and S. S. Rappaport, "Overlapping Coverage with Reuse Partitioning in Cellular Communication Systems," *IEEE Trans. Vehi. Technol.*, vol. 46, no. 6, pp. 41-54, 1997.

[14] M. Jain, "Finite Population Cellular Radio Systems with Directed Retry," *Journal of App. Math. Model.*, vol. 23, no. 3, pp. 77-86, 1999.

[15] R. Verdone, and A. Zanella, "Performance of a Cellular System with Directed Retry: A Comparison Between Analytical and Simulation Results," *Journal of Mobility Radio Communication*, vol. 1, no. 3, pp. 212-216, 2000.

[16] R. Verdone, and A. Zanella, "Analytical Evaluation of Blocking Probability in a Mobile System with Directed Retry," *Journal of Select Areas Communication*, vol. 19, no. 2, pp. 322-331, 2000.

[17] M. M. Islam, and M. Murshed, "Parametric Mobility Support Dynamic Resource Reservation and Call Admission Control Scheme for Cellular Multimedia Communications," *Journal of Computer and Communication*, vol. 30, no. 3, pp. 233-248, 2007.

[18] M. Jain, G. C. Sharma, and R. Mittal, "Queueing Analysis and Channel Assignment Scheme for Cellular Radio System with GPRS Services," *Journal of Math. Oper. Res.*, in press.

[19] M. Salamah, and H. Lababidi, "Dynamically Adaptive Channel Reservation Scheme for Cellular Networks," *Journal of Computer Network*, vol. 49, no. 4, pp. 787-796, 2005.

[20] M. Jain, and Rakhee, "A Subrating Channel Assignment Scheme for Cellular Radio Network with Directed Retry," *Journal of Comp. Oper. Res.*, vol. 32, no. 3, pp. 2407-2417, 2005.

[21] X. Wu, M. He, F. Wang, J. Zheng, E. Regentova, and G. Hao, "Performance Analysis of Sub-rating for Handoff Calls in HCN," *Journal of Communication Network System and Science*, vol. 2, no. 1, pp. 21-29, 2009.

[22] C. Y. Oh, M. Y. Chung, H. Choo, and T. J. Lee, "Resource Allocation with Partitioning Criterion for Macro-femto Overlay Cellular Networks with Fractional Frequency Reuse," *Journal of Wireless Communication*, vol. 68, no. 3, pp. 417-432, 2013.

[23] E. Ekici, and C. Ersoy, "Multi-tier Cellular Network Dimensioning," *Journal of Wireless Network*, vol. 7, no. 2, pp. 401-411, 2001.

[24] T. E. Klein, and S. J. Hann, "Assignment Strategies for Mobile Data Users in Hierarchical Overlay Networks: Performance of Optimal and Adaptive Strategies," *Journal of Select Areas Communication*, vol. 22, no. 2, pp. 849-861, 2004.

[25] V. Chandrasekhar, "Spectrum Allocation in Tiered Cellular Networks," *IEEE Trans. Commun.*, vol. 57, no. 5, pp. 3059-3068, 2009.

[26] N. D. Tripathi, N. J. H. Reed, and H. F. Vanlandingham, "Handoff in Cellular System," *IEEE Trans. Commun.*, vol. 4, no. 2, pp. 25-37, 1998.

[27] T. Salih, and K. Fidanboylu, "Modeling and Analysis of Queueing Handoff Calls in Single and Two-tier Cellular Networks," *Journal of Comp. and Commun.*, vol. 29, no. 1, pp. 3580-3590, 2006.

[28] K. J. Lin, Y. C. Tseng, and J. P. Sheu, "Channel-sharing Strategies in Two-tier Cellular PCS Systems," *Journal of Comp. and Commun.*, vol. 25, no. 2, pp. 1333-1342, 2002.

[29] V. Pandey, D. Ghosal, B. Mukherjee, and X. Wu, "Call Admission and Handoff Control in Multi-tier Cellular Networks: Algorithms and Analysis," *Journal of Wireless Communication*, vol. 43, no. 3, pp. 857-878, 2007.

[30] K. Purwani, and G. N. Purohit, "Performance Measures Hierarchical Cellular Networks on Queueing Handoff Calls," *Journal of Network Security*, vol. 3, no. 1, pp. 29-33, 2012.

[31] G. Sharma, K. Kumari, and G. N. Purohit, "Performance Comparison on Two-tire Cellular Networks: Queueing the Handoff Calls," *Journal of Math. Arch.*, vol. 3, no. 2, pp. 2135-2143, 2012.

[32] T. Q. S. Quek, G. D. L. Roche, I. Guvenc, and M. Kountouris, "Small Cell Networks: Deployment, PHY Techniques and Resource Allocation," Cambridge University, in Press.

[33] D. Gross and M. C. Harris, *Fundamentals of Queuing Theory*, Singapore: John Wiley and Sons, 2002.

Madhu Jain is Associate Professor in the Department of Mathematics, IIT Roorkee, India. She is a recipient of two gold medals of Agra University at M. Phil. Level. There are more than 350 research publications in refereed International/National journals and more than 20 books to her credit. She was the recipient of Young Scientist Award and SERC visiting fellow of Department of Science and Technology (DST), India and Career Award of University Grants Commission (UGC), India. She has successfully completed six sponsored major research project of MHRD, DST, UGC and CSIR. Her current research interest includes the performance modelling of computer communication networks, stochastic models, soft computing, bio-informatics, reliability engineering and queueing theory. Thirty-five candidates have received their Ph. D. under her supervision. She has visited more than 25 reputed universities/institutes in USA, Canada, UK, Australia, Germany, France, Holland, Belgium and Taiwan.

E-mail: drmadhujain.iitr@gmail.com

Ragini Mittal did her M. Sc. in Mathematics from Dr. B. R. Ambedkar University, Agra. At present, she is doing research for Ph. D. Degree from Dr. B. R. Ambedkar University, Agra. Her research area includes queueing theory, wireless communication and soft computing. She has participated and presented her research papers in 8 International/National Conferences. She has published four research papers jointly with Dr. Madhu Jain and Professor G. C. Sharma in refereed international/national journals.

E-mail: m234ragini@gmail.com

Paper Handling Data:

Submitted: 06.08.2013
Received in revised form: 09.10.2013
Accepted: 30.12.2013
Corresponding author: Dr. Ragini Mittal,
Department of Mathematics, St. John’s College, Agra, India.