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Experimental Analysis of Xie and Kuek's Traffic Model with Handoff Scheme in Wireless Networks

BISWAJIT BHOWMIK [1] , POOJA [2] , NUPUR THAKUR [2] , PIYALI SARKAR [2]

[1] *Member of IEEE, IACSIT, IAENG, PASS, IAOE, IAS, and UACEE,*
Department of Computer Science & Engineering, Indian Institute of Technology Guwahati, 781039, India.
Email: b.bhowmik@iitg.ernet.in, biswajitbhowmik@gmail.com

[2] *Department of Computer Science & Engineering, Bengal College of Engineering and Technology,*
Durgapur, 713212, India
E-mail: pooja.cse2308@gmail.com, nupurcse07@gmail.com, piyali.doanju@gmail.com

Abstract—**Mobility becomes a distinct feature for a wireless mobile cellular system. For the traffic which is non stationary and is away from the base station, the chances of a call to be handed off are increased. In urban mobile cellular systems, especially when the cell size becomes relatively small, the** *Handoff* **procedure has a significant impact on system performance. Blocking probability of originating calls and the forced termination probability of ongoing calls are the primary criteria for indicating this performance. In this paper, we report our recent work on closed form solutions to the blocking probability followed by dropping probability in wireless cellular networks with** *Handoff* **. First, we develop a performance model** *EATM* **of a cell in a wireless network where the effect of** *Handoff Arrivals* **arrivals and the use of guard channels are included. Then we simulate the** *Xie and Kuek's* **Traffic Model with exploiting our model.**

Index Terms — **Mobile Station, Arrival Rate, Outgoing Rate, Blocking Probability, CBR.**

1. Introduction

The rapid growth in the demand for mobile communications has led to an intense research effort to achieve an efficient use of the scarce spectrum or channel allocated for cellular communications. Traffics (request and demand for service) in the wireless networks are ever increasing and are expected to be extremely non stationary [1][2]. The channel associated with the current connection serviced by a *Base Stations* (BS) is changed while a call is in progress. The Non Stationary Calls simply called *Mobile Stations* (MSs) are when away from the current *BS* (also called *Mobile Terminal*, (MT)) the chances of *Handoff* [3] are increased. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel. The existing call is then changed to a new nearest *BS* . Continuous service is achieved by supporting *Handoff* mechanism from one cell to the next adjacent cell as the *MSs* move through the coverage area is shown in Figure 1 below. We assume that every cell in the system is of the same size and has the same fixed number of channels. There are no guarded channels for *Handoff* calls in any cell, i.e., both new and *Handoff* calls have access to all the channels. Each *MS* is associated with a call at any given time. If a new call that is generated in a cell cannot find an idle channel in that cell, the call is discarded (blocked) immediately. An *Handoff* algorithm determines the dynamics of the *MS* which moves through the network. Therefore, Handoffs in a mobile cellular communications environment have become an increasingly important issue accommodating an increasingly large demand for services with simultaneous reduced cell sizes [3][4][5][6][7][8][9][10].

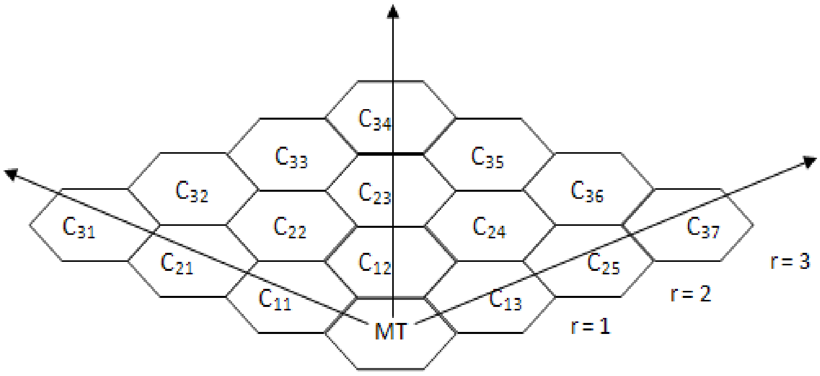
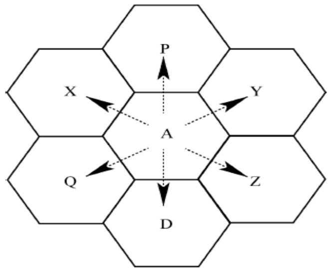


Figure 1. Same Column and Non-column Cellular Configuration for r = 3

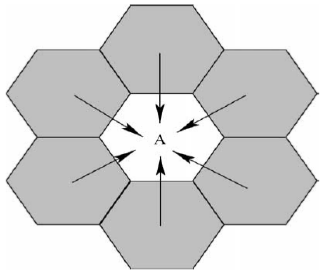
In urban mobile cellular radio systems, especially when the cell size becomes relatively small, the *Handoff* mechanism has a significant impact on primary system performance criteria: Blocking probability of originating calls (B_O), Blocking probability of *Handoff* calls (B_H), and the forced termination probability of ongoing calls [3][8]. Before analyzing these performance criteria, it is important to establish a traffic model. In this paper we propose to modelling, implement and simulate the *Xie and Kuek's* Traffic Model [3] with *Handoff* behavior for mobile network. A simulation model *EATM* (Experimental Analysis of Traffic Model) with priority *Handoff* scheme is developed to investigate the *Handoff* performances. Simulation results show that measurement of blocking probabilities for both originating and *Handoff* calls is an impressive achievement of the model. In addition to this, the proposed model can increase Call Blocking Rate (CBR) as derived in [1][8][11][12] and shown in Equation (11) of *Handoff* calls.

2. Proposed Work

Every cell in cellular network architecture (shown in Figure 1) is served by an underlying *BS* that is *MT*. *BSs* are connected together by using a wireless network. Figure 2(a) shows the fact that each hexagonal cell A, D, Q, P, X, Y, and Z are nothing but each *MT*. *MSs* generally move in the coverage area (each hexagon) similar to Figure 2 [13][14][15] and Table I [8] and when moving from a cell to another cell, *Handoff* occurs [3]. Movements may be made away from and/or towards the *MT*. However, movements away from the current *MT* is primarily responsible for *Handoff* to be taken place. For the time being suppose cell A in Figure 2(a) is our current *BS*. However, one-third of the coverage area of this *BS* is considered in this paper and equivalent to Figure 1.



(a)



(b)

Figure 2. Mobility of Mobile Stations (*MSs*)

When *MSs* move irrespective of the direction of movements in the cell of the current servicing *BS* then the following two cases and their corresponding sub cases [15] may arise: First, Call Acceptance - (a) A successful *Handoff* completion to the target cell, (b) New call arrival in the target cell, and (c) Active mobile terminal increases its resource demands. Second, Call Rejection - (a) A successful *Handoff* completion from the target cell. (b) Call termination in the target cell and (c) Active mobile terminal decreases its resource demands.

The current researches on *Handoff* mainly involve following two issues: (1) How does the *Handoff* process affect performance of wireless cellular system; (2) How do we design *Handoff* scheme so that channel resources are used efficiently and quality of service (QoS) is still guaranteed.

Recently, many analytical and simulation models have characterized the *Handoff* problems. Our approach provides high precise location and tracking of *MTs* by exploiting advanced traffic models. Some of these we have studied it in [1][7][8].

Table I: Generated *Handoff* Approaches

Approach	Movement of *MSs* w.r.t MT		Adjacent Level		Position of Cells Column	
	Towards	Away from	Upper	Lower	Same Column	Not Same Column
I	N	Y	Y	N	Y	N
	Y	N	N	Y	Y	N
II	N	Y	Y	N	Y	N
	Y	N	N	Y	N	Y
III	N	Y	Y	N	N	Y
	Y	N	N	Y	Y	N
IV	N	Y	Y	N	N	Y
	Y	N	N	Y	N	Y

Here we have extended our work [16] with *Xie and Kuek's* Traffic Model [3]. Our approach *EATM Model* takes more advantages over previous models described in [1][7][8]. Major functionalities of the proposed model in this paper are organized in as follows:

First, we present an expression to Determine Arrival Rate (λo) of the calls followed by the expression of their Departure Rate (μ) Determination. Next, we choose a model through Traffic Model Selection. Next, we are going to implement a Priority *Handoff* Scheme. And last we have determined Call Blocking Rate of both originating calls and *Handoff* calls.

2.1 Determination of Arrival Rate

Number of *MSs* (also called *Traffic Density* [17]) varies location to location. And this location on the contrary affects arrival rate λo of originating calls from *MSs* to nearest *BS* (*MT*) . Likewise number of *BSs* varies. Assuming distance D [18][19] between two base stations is 1 km, λo [3] has been determined in *S2BPQ* model [16] as:

$$\lambda o = \frac{\text{Total Number of Subscriber(S) in that Region}}{\text{Total Number of MTs(X)}} \qquad (1)$$

2.2 Determination of Departure Rate

The departure rate μ (say, number of mobile stations get serviced in unit time) should be at least equal to arrival rate λo such that waiting for getting service becomes zero. Although in reality μ is much larger than λo . Exploiting Poison Distribution [17], with the traffic intensity factor ρ (defined as $\lambda o / \mu$) lies between 0 and 1, departure rate μ has been established in *S2BPQ Model* [16] as:

$$0 \le \lambda o \le \mu \qquad (2)$$

2.3 Selection of Traffic Model

Every cell in cellular network architecture (shown in Figure 1) is served by an underlying *BS* . Establishment of a traffic model, in cellular system, is more imperative before analyzing the performance of the system [8][16]. Several traffic models [3][20] as well as different schemes [21][22][15][10] have been established on basis of making different assumptions about user mobility. One of them is the Expected Rate of *Handoff* (λ_H) . For our purpose *Xie and Kuek's* Traffic Model [3] shown in Equation (3) has been chosen as underlying implementation model with the assumption that the Arrival Rate of *Handoff* calls (λ_H) is determined by:

$$\lambda_H = \prod (E[c], \mu c - dwell) \qquad (3)$$

Where,

$E[c]$ = the average number of calls in a cell

$\mu c - dwell$ = the outgoing rate of mobile users

2.3.1 Determination of E[c]

For a maximum radial distance $R_{\max}$ (maximum distance from the current *BS* that provides services its *MSs* and after the distance an *MS* forcefully changes from current *BS* to another *BS*) from the underlying network, total cells N under a *BS* is given by:

$$N = \sum_{r=1}^{R\max} (2 \times r + 1) \qquad (4)$$

Average number of *MSs* we called here as *Subscribers*(*Subs*) , in any cell j at radial distance r (represented as *Crj* in Figure 1) is obtained by Equation (5):

$$Subs = \frac{\text{Total Number of MSs (S)}}{\text{Total Number of Cells (N)}} \quad (5)$$

Let us consider average number of calls originated by a $Sub\ (MS)$ is $Calls\ Per\ Day\ Per\ Subscriber\ \ (CPD)$. Thus,

$$E[c] = \prod (Subs, CPD) \quad (6)$$

2.3.2 Determination of μc—dwell

Assuming that MSs move any one of the three directions - outwards, inwards and along the same radial level (shown in both Figure 1 and Figure 2) , the probability of MSs for simplicity moving outwards is $one-third$. Since, in every radial distance $r \le R_{\max}$, there are $2 \times r + 1$ cells, thus, average number of calls going outwards (away from the current BS) for N cells are given by:

$$Calls(\uparrow) = \frac{1}{3}\sum_{r=1}^{R\max} Subs \times CPD \times (2 \times r + 1) \quad (7)$$

Out of the total number of callers (MSs) going out from one radial level to the other, let us assume for the time being again $one-third$ of them come back to the previous radial level. Therefore, total number of calls coming inwards (towards the underlying BS) is:

$$Calls(\downarrow) = \prod (1/3, \quad Calls(\uparrow)) \quad (8)$$

Effective outgoing calls for the base station are therefore obtained by the Equation (9) as:

$$Effective \quad Calls(\uparrow) = Calls(\uparrow) - Calls(\downarrow) \quad (9)$$

Now, for Equation (3) we can compute the outgoing rate of mobile users' $\mu c - dwell$ and it is given by:

$$\mu c - dwell = \frac{\text{Effective} \quad \text{Calls}(\uparrow)}{\text{Total Number of Cells (N)}} \quad (10)$$

2.4. Priority Handoff Scheme

An MS approaches cells from a cell with significant signal strength as priority set to $Handoff$ requests by assigning channels S_R exclusively for $Handoff$ calls out of S channels. Both originating calls and $Handoff$ requests share the remaining $S_C = S - S_R$ channels. The blocking probabilities, B_O for an originating call, and B_H of a $Handoff$ request have been determined by Equations 1.22, and 1.23 in [3] with the steady-state probabilities $P(0)$ and $P(i)$ at states "0" and "i" as expressed in Equations. 1.20 , and 1.21 in [3] respectively.

2.5 Determination of Call Blocking Rate

An MS when initiates a call generally expects to be serviced and enqueued in priority queue. Afterward a call gets serviced by its current MT taking advantage of $Splay$ operations [16][23] on the $Splay\ \ Tree$ [23] implementation of the priority queue followed by selection of the call from the tree using $SIRO$ [16][17] queuing principle for providing service. At particular level r, $1 \le r \le R_{\max}$ number of calls blocked i.e. Call Blocking Rate (CBR_r) can be decided by the Equation (11). This blocking does not mean discard of calls rather number calls gets serviced.

$$CBR_r = \frac{1}{3}\prod (R_{C_{jr}}\ , \quad B_O\ , (2 \times r + 1)) \quad (11)$$

It is generally expected to be 90-100% so that the Call Dropping Rate (CDR_r) at a $r \le R_{\max}$ [1][8] is minimum as much as possible.

3. Numerical Results

The parameters used for simulation are commonly used to analyze $Handoff$ performance. Simulation of the suggested model has been performed in MATLAB Version 7.6.0.324 (R2008A). Numerical values of the fundamental parameters for $Handoff$ initiation, arrival rate λ_O , and the departure rate μ are based on COAI Report [24][25] for our beloved Megacity Kolkata. And they are set as $\lambda_O = 1991$, and $\mu = 2212$ [13]. Exploiting these numerical values and inheriting necessary data from [16], all the Equations (3) through (10) and section 2.4 in this paper we have shown two observations.

3.1 Observation I

Let us suppose that a mobile station makes at least 5 requests per day. Other values are shown in Table II. Graphical views of the Table II and followed by it, have been shown for the parameters λ_H , B_O , and B_H with varying radius (radial) distance in Figures 3 to 5 respectively.

Table II: Performance Metrics for Different Parameters at Radial Levels

<table>
<tr><th>Parameters</th><th>Outgoing Calls</th><th>Incoming Calls</th><th>Effective Calls</th><th>μ_c</th><th>λ_o</th><th>μ</th><th>P(0)</th><th>Average B_o</th></tr>
<tr><td></td><td>221.249</td><td>73.749</td><td>147.499</td><td>0.6584</td><td>22.885</td><td>25.427</td><td>0.2363</td><td>0.7636</td></tr>
<tr><td>λ_h</td><td colspan="8">29.26776 48.77959 68.29143 87.80327 107.3151 126.8269 146.3388 165.8506
185.3625 204.8743 224.3861 243.898 263.4098 282.9216</td></tr>
<tr><td>Bo</td><td colspan="8">0.25456 0.40729 0.51639 0.60124 0.67066 0.72941 0.78032
0.82524 0.86543 0.9018 0.935 0.96555 0.99383 1.0202</td></tr>
<tr><td>B_h</td><td colspan="8">0.092985 0.12777 0.16256 0.19735 0.23214 0.26693 0.30172
0.3365 0.37129 0.40608 0.44087 0.47566 0.51045 0.54524</td></tr>
</table>

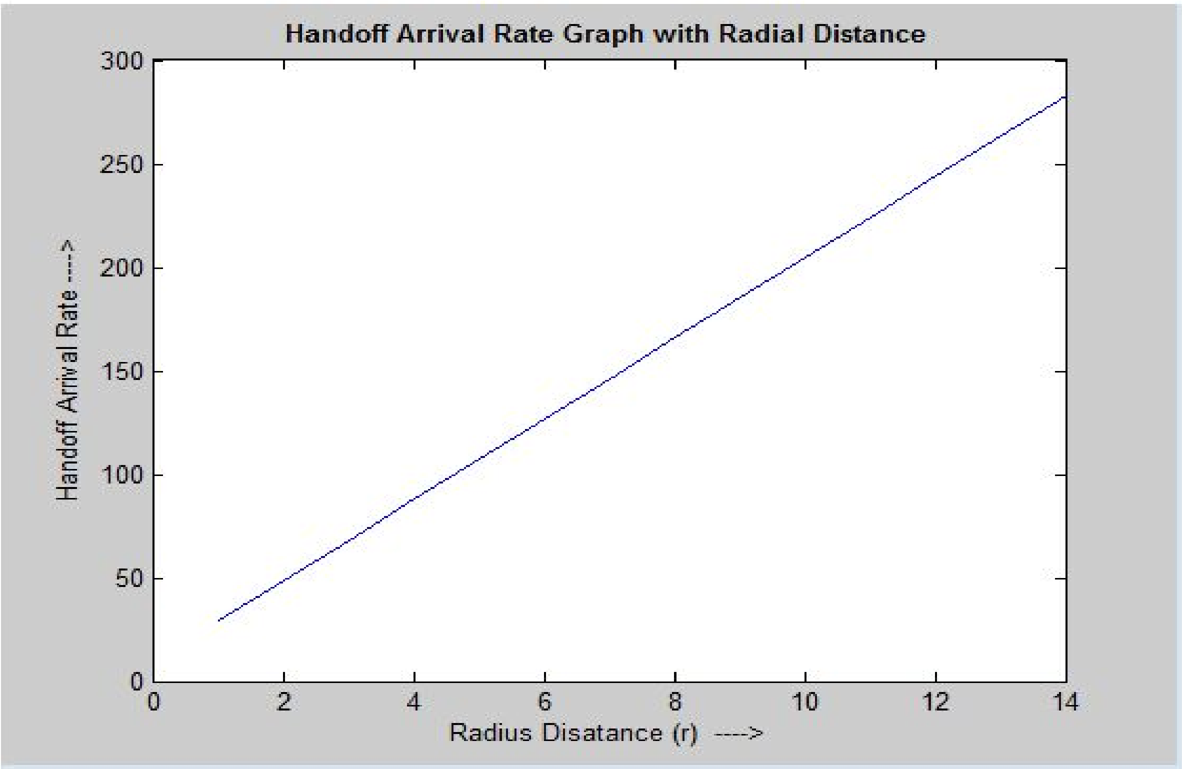


Figure 3. Handoff Arrival Rate vs. Radial Distance

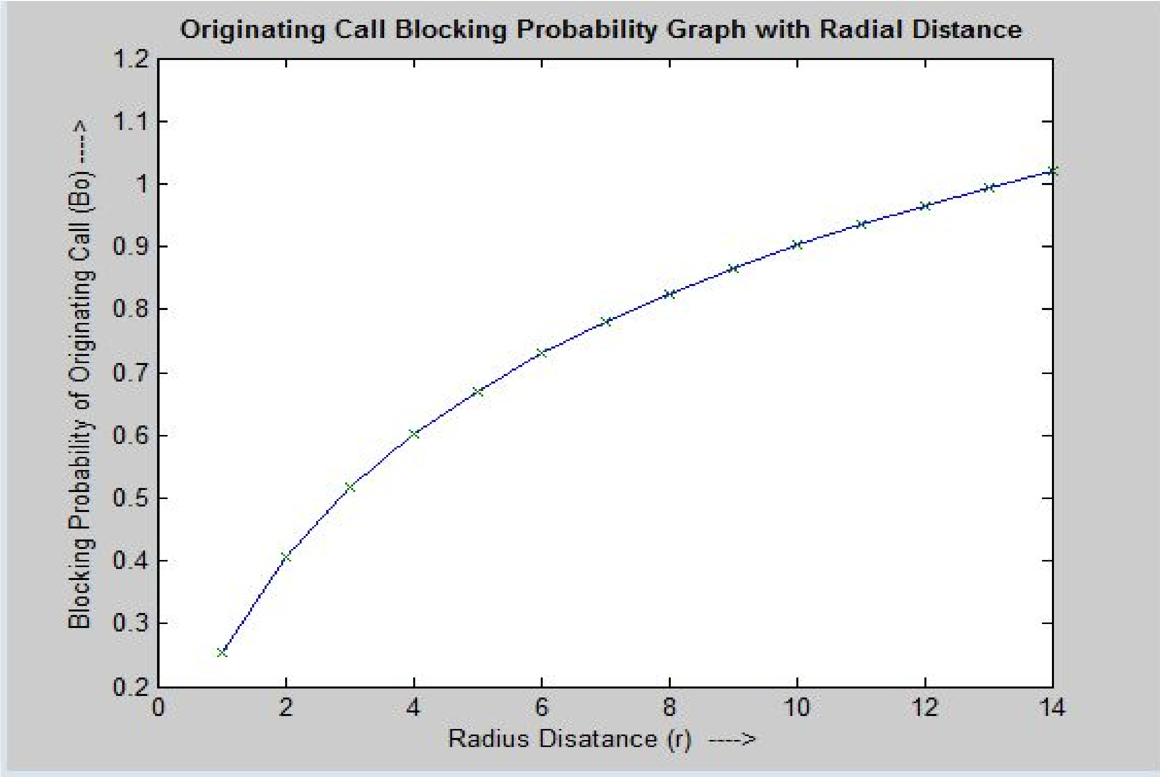


Figure 4. Blocking Probability of Originating Call vs. Radial Distance

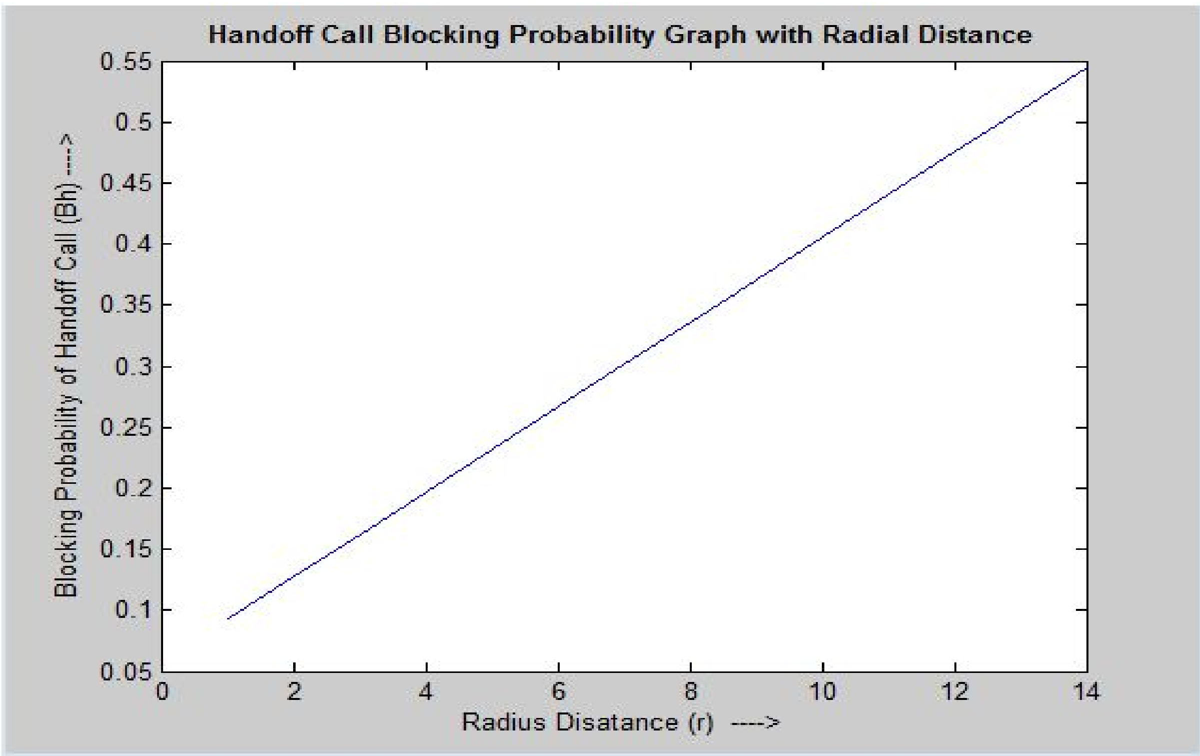


Figure 5. Blocking Probability of Handoff Call vs. Radial Distance

3.2 Observation II

Let us suppose that a mobile station makes at least 6 requests per day. Other values are shown in Table III. Similarly graphical views of the Table III and followed by it, have been shown for the parameters λ_H , B_O , and B_H with varying radius (radial) distance in Figures 6 to 8 respectively.

Table III: Performance Metrics for Different Parameters at Radial Levels

Parameters	Outgoing Calls	Incoming Calls	Effective Calls	μ_c	λ_o	μ	P(0)	Average B_o
	221.2494	73.7498	147.4996	0.8779	26.546	29.496	0.1662	0.833
λ_h	52.03157 86.71928 121.407 156.0947 190.7824 225.4701 260.1578 294.8455 329.5332 364.221 398.9087 433.5964							
Bo	0.2779 0.44465 0.56375 0.65638 0.73217 0.79631 0.85189 0.90093 0.94481 0.98451 1.0208 1.0541							
B_h	0.18773 0.24523 0.30272 0.36021 0.41771 0.4752 0.53269 0.59019 0.64768 0.70517 0.76267							

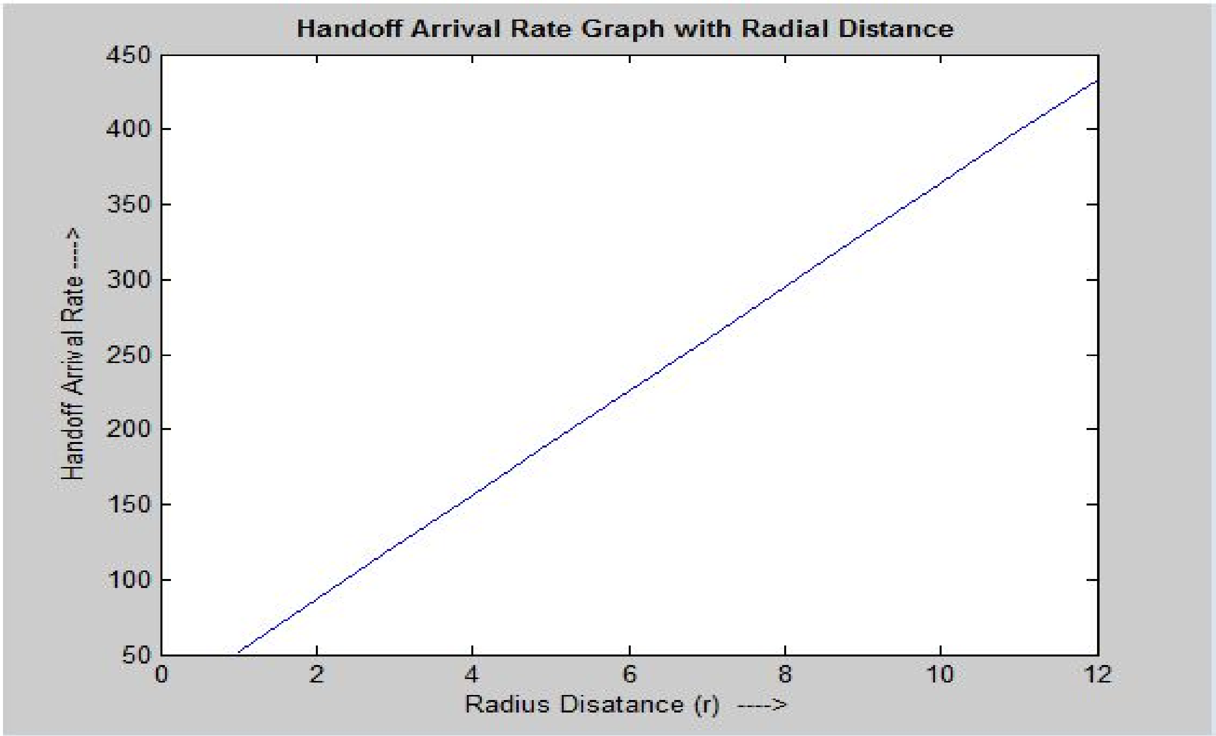


Figure 6. Handoff Arrival Rate vs. Radial Distance

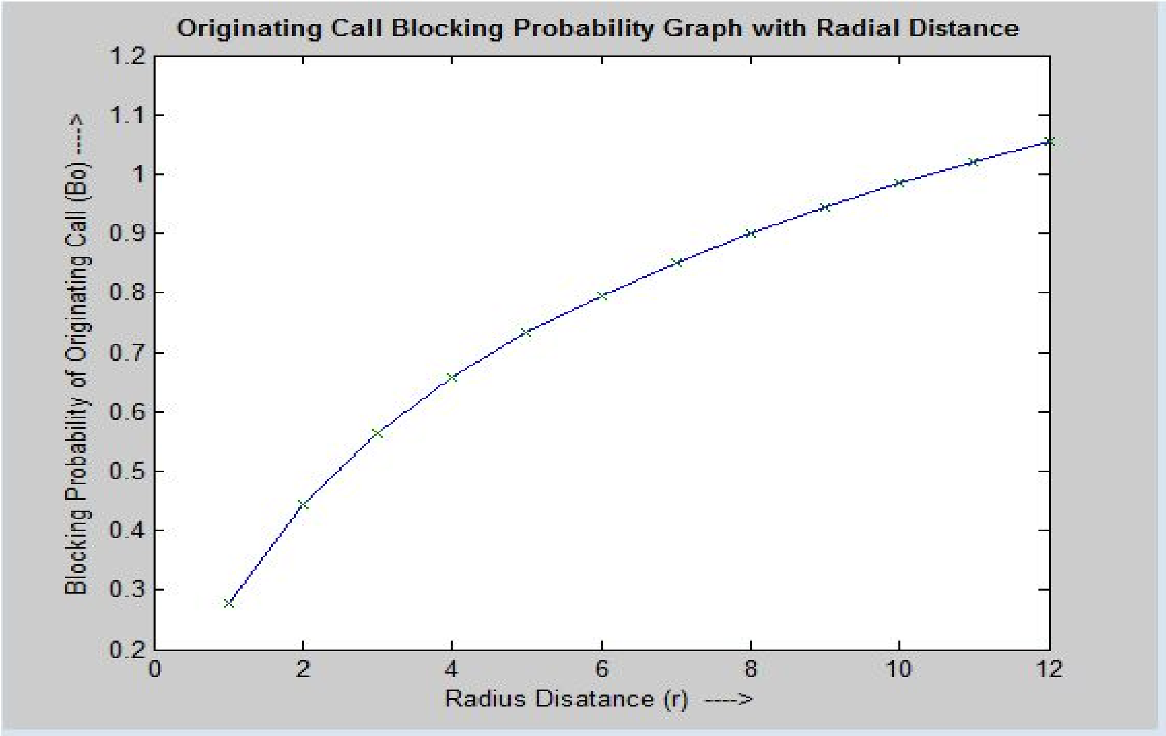


Figure 7. Blocking Probability of Originating Call vs. Radial Distance

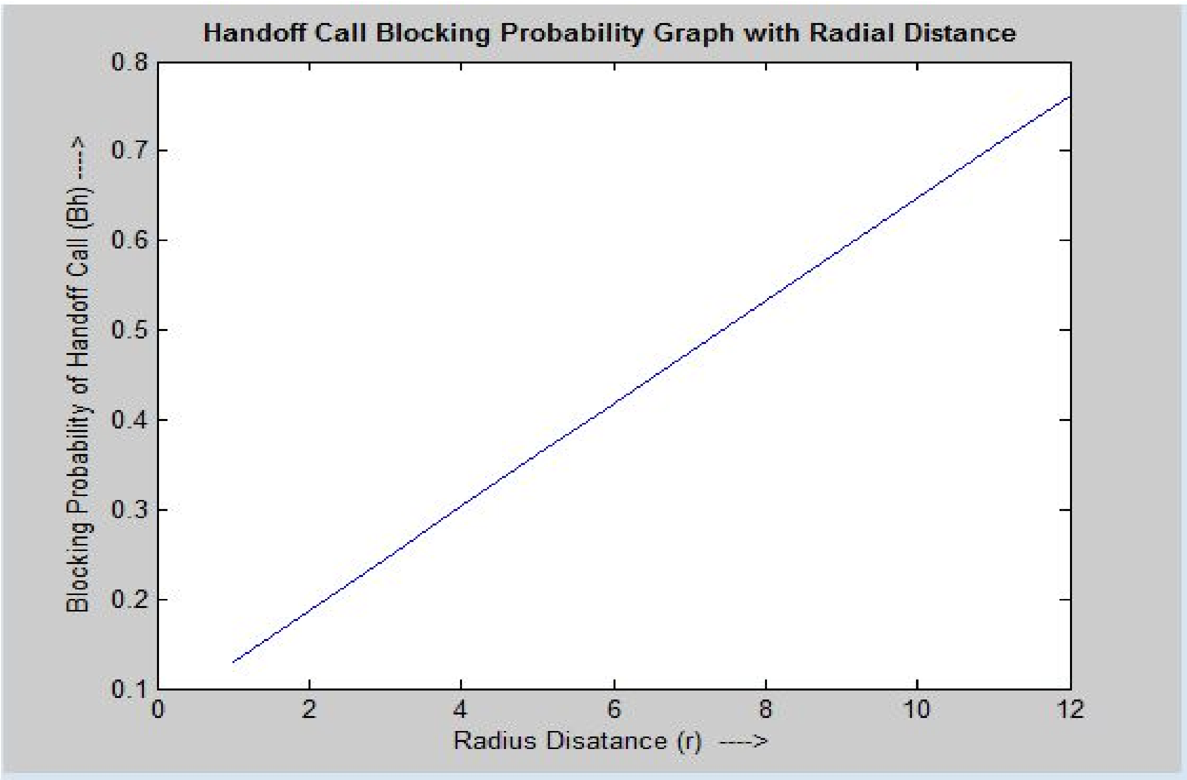


Figure 8. Blocking Probability of Handoff Call vs. Radial Distance

4. Concluding Remarks

In this paper we claim that simulated results guarantee that our approach or the model described performs better like some existing algorithms for *Handoff* scheme. It is observed that increasing average number of calls per mobile station per day helps in improvement of the blocking probabilities for both originating calls and *Handoff* request calls. And these values are nearer to their actual values. Another achievement of the proposed model is working out of rate of blocked calls CBR, in addition. Although its behavior is not shown in this paper but similar job has been done in [1][8]. Simulation shows that CBR is increasing in nature with the increase in certain radial distance. After that increases slowly and saturates at $r = R_{\max}$. Surprisingly at $r > R_{\max}$ it is decreasing in nature. It shows that a *Handoff* just occurred.

However, exact analytical models are difficult to define for the schemes, and if data traffic also needs to be incorporated, it becomes very difficult to have even an approximate model. This is an interesting topic that calls for further research.

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[1] **Biswajit Bhowmik** is currently doing PhD in the Department of Computer Science & Engineering of Indian Institute of Technology Guwahati. He was a very renowned faculty member with Bengal College of Engineering and Technology, Durgapur, India as Assistant Professor in the Department of Computer Science & Engineering for almost 7 years. He is a member of different professional bodies such as IEEE, IACSIT, IAENG, PASS, IAOE, UACEE, etc. He is also member of IEEE Computer Society, IAENG Society of Computer Science, IAENG Society of Wireless Networks, IAENG Society of Software Engineering, and IAENG Society of Artificial Intelligence. He is reviewer of several international journals such as IJCSIC, IJCSIS, JACSM, IJoAT, JWMC, etc in the area of computer science. He has authored a book titled Design and Analysis of Algorithms. He has many publications in international journals including international conference proceedings on the subjects ranging from Algorithms Analysis, Graph Theory, Mobile Computing, Data Structures & Algorithms, Computational Geometry, and Green Computing. He has guided several projects at under graduate level. This paper is based on Mobile Computing as Final Year Thesis Work done by the co-authors for UG Curriculum under West Bengal University of Technology, Kolkata, India.

[2] **Pooja, Nupur Thakur, and Piyali Sarkar** are Final Year UG (B.Tech) students in the Department of Computer Science & Engineering of Bengal College of Engineering and Technology, Durgapur, India.