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Received Signal Strength Based Effective Call Scheduling in Wireless Mobile Network

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Abstract

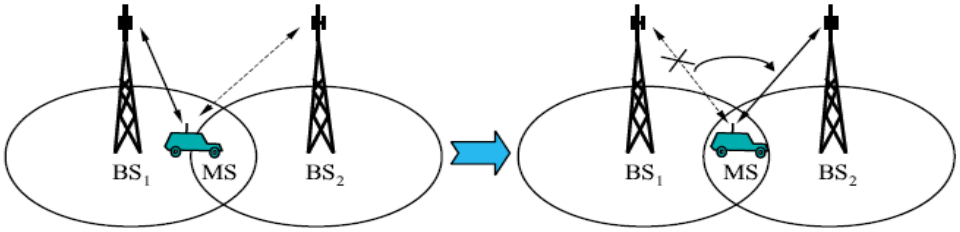
Mobility is the most imperative aspect in a wireless cellular communication system. The channel associated with the current connection (Base Station), while a call is in progress, is changed. The existing call may then change to a new Base Station (BS). Either crossing a cell boundary of current BS by the mobile caller also called mobile station (MS) or deterioration in quality of the signal in the current channel is primarily responsible for initiating this new connection. In this paper an improved Signal Strength Based Priority Queue Generation (S2BPQ) model is introduced for effective call scheduling. The model computes signal strength of a mobile caller (MC) to enqueue and introduces a tree with heap like structure for generated queue implementation in considerably reduced time. Determination of arrival rate of MCs and introduction of auto-generated data structure for selection of MCs in low starvation scheme reflect both originality and generality of the model.

Index Terms: *Mobile Station, Handover, Signal Strength, Treap, Arrival Rate, Departure Rate, Blocking Probability, SIRO, Splay Operations.*

1. Introduction

Mobile Networks have gained an impulsion in the past few years in rapacious dimensions [3]. And since then mobility becomes a distinct feature of wireless mobile cellular system [5]. While a call (mobile caller/user in service) is in progress the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection is changed through Channel Allocation Control (CAC) proposals [6]. The existing call may change its present Base Station (BS) also termed as Mobile Terminal (MT) to a new one. This phenomenon is whatever we call handover (handoff). It is shown in Fig 1.

Usually, this handover mechanism supports continuous services by transfer of an ongoing call from the current cell to the next adjacent cell as the mobile (MS) moves through the coverage area. Either crossing a cell boundary of current BS by mobile station (MS) or deterioration in quality of the signal in the current channel is the primary responsible factor for initiating a handover [6][5].



(a) Before Handoff (b) After Handoff

Fig. 1: Handoff between the MS and BSs.

As a rule, continuous service is achieved by supporting inter cell (from one cell to another) handoff. In this paper we consider that a handoff is assumed to occur only at the cell boundary. The paper is organized in the following sections.

(a) Related Work.
(b) Proposed Model.
(c) Queuing Analysis.
(d) Numerical Results.
(e) Conclusion.

2. Previous Work

The dynamic pricing scheme PQSHI model [3] depicts call scheduling using radial distance r from BS (MT) as a priority factor of the requested calls. Location of a MS is represented by hexagonal cellular structure as shown in Fig. 2. All new calls (MCs) are included in priority queue under a MT based on their respective r value. Here, r = 1, 2, 3, …….. In IPBCS [2] model this priority queue has come with Heap [4][9] tree implementation in reduced time minimizing overall cost of generating priority queue. In both the cases [3][2] each cell contains only one MC. And each cell (MC) is denoted by C_{ij} or simply ij, where i, j = 1, 2, 3, ……..

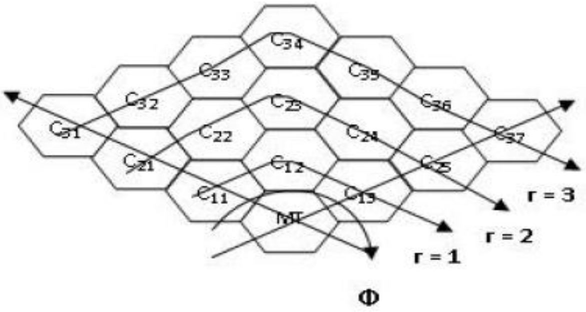


Fig. 2: Cellular structure under MT

3. Proposed Work

In this paper, we have extended and have tried to improve our earlier work [2][3] by introducing the concept of Tree with Heap like structure [9] to generate priority queue for call handling in subsequent less computation time with logarithmic time bound. This is a new as well as a variation of PQSHIM [2]. Major functionalities of this S2BPQ model are described in brief as follows:

(a) Signal Strength Measurement.
(b) Priority Queue Generation.
(c) Priority Queue Implementation.
(d) Arrival Rate (λo) Determination.
(e) Departure Rate (μ) Determination.
(f) Selection of Requested Call.
(g) Traffic Model selection.
(h) Priority Handoff Scheme.

3.1 *Signal Strength Metric*

Each mobile device monitors signal strength that helps in assisting handoff decisions. Deterioration in quality of the received signal strength of an MC can be referred to positioning it [7]. The received signal is measured w.r.t. radial distance r from MT under area of coverage. An MC initiating a call is able to move from the current location in any direction with equal probability [8]. We assume that at particular level r received signal strength will remain same for every cell (MCs). We record this signal value in priority queue. When a mobile device moves in the same area, the signal received from it is compared with the entry in the queue, and thus its location is determined [7]. Suppose, a mobile station (MS) is allowed to continue maintaining its current connection with MT A, until the signal strength from it exceeds that of MT B by some pre-specified threshold value say 50.1 [5][15]. Consider a two base station model shown in Fig. 3 and assume that a MS is moving at constant speed along the straight line path from MT A to MT B separated by D distance.

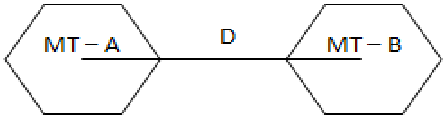


Fig. 3: Two Base Station Model

The signal due to path loss received from these two base stations to the mobile station can be written as [5]:

$$MT_A(r) = \text{Є} - \eta \log(r) + \xi(r) \quad \text{……..…….. (1)}$$
$$MT_B(r) = \text{Є} - \eta \log(D - r) + \chi(r) \quad \text{……..…….. (2)}$$

Where:
D is the distance between two BSs.
r is the position of the MS from MT A.
Є and η are parameters for path loss.
Є depends on transmitted power at the base station.
η is equivalent to path loss slope equals 3 for the attenuation
in this environment (η = ten times the path loss exponent).
ξ(r) , χ(r) represent shadow fading (slower fading effect) follow log-normal distribution.

We use the above equation (1) to determine signal values of MCs as priority factors for priority queue generation. Assume that signal received by an MT from an MC is 100% at $r = 0$ as path loss signal strength is assumed to be 0. Naturally, whenever an MC is away from an MT, its call request strength is gradually decreasing increasing path loss signals. These call requests are in essence deemed as both originating calls and handoff requests [6]. Thus, requested call strength for an MC under an MT say A at radial distance r from it, can be determined as below.

$$MC_A(r) = [\ 100 - MT_A(r)\ ]\% \qquad \text{……..…….. (3)}$$

Generally the signal strengths around base stations follow the pattern as shown in Fig. 4 [7]. Handoff will occur when $MS_A < MS_B$. The radial distance at this moment will be maximum allowable radial distance from the Base Station A.

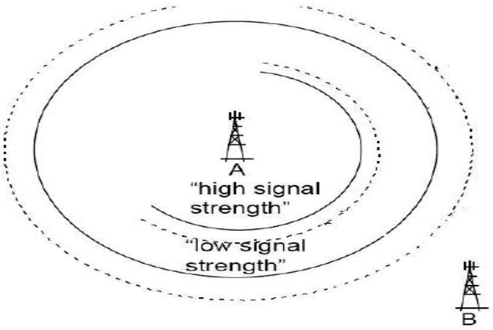


Fig. 4: The signal strength pattern.

3.2 *Priority Queue Construction*

Each MC having some signal value computed based on Equation (1) when initiating a request is included in the queue with the condition that the call having higher value should be frontier. Though cells (MSs at different cells ij) at r have the same strength, however we enque a call (cell ij) on the basis whether the MS (requested call) is located in same column path or not from MT. This situation is shown in Fig. 5. The cells (incoming calls from these cells) which are non column are inserted after enqueueing cells in same column at particular radial distance r from MT.

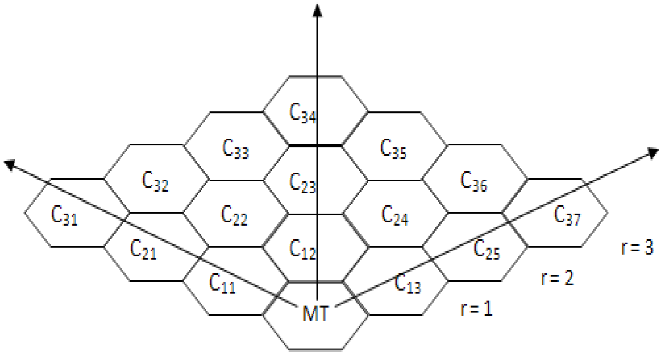


Fig. 5: Same Column and Non-column Configuration for r = 3.

Thus, corresponding priority queue L and its algorithm can be designed as below.

Algorithm: PriorityQ (L, r)

```
Input: C_ij = j^th cell at level i.
       r = radial distance from BS A when MS_A < MS_B.
       Output:  L= generated priority queue of cells.

(1) Repeat for i = 1 to r
(2)     Enque C_ii , C_i(i+1) ,C_i(2i+1) successively in the
(3)       given order.
(4)     Repeat for j = 1 to 2i+1
(5)         If j ≠1 and j ≠i+1 and j ≠2i+1
(6)             Enque C_ij to L.
(7)  Exit.
```

Complexity Analysis: Time complexity of the above algorithm mainly depends on both outer and inner loops in step 1. Outer loop executes at most r times whereas inner loop is varying with number of cells level wise. However, all cells at level r are to be considered. From Fig. 5 it is seen that specific level i contains (2*i +1) number of cells. Thus the running time T(n) of the procedure PriorityQ() is O(nr), where n is total cells under the base station under consideration for maximum allowable radial distance r.

Now, $n = \sum_{i=1}^{r}(2 * i + 1)$

$= 2\sum_{i=1}^{r} i + \sum_{i=1}^{r} 1)$

$= 2(1 + 2 + 3 + \ldots\ldots + r) + (1 + 1 + \ldots + r \text{ times})$

$= 2* \frac{r(r+1)}{2} + r$

$= r(r + 1) + r$

$= r^2 + 2r$

$\geq \Theta(r^2)$

Therefore, the above procedure runs in $\Theta(r^3)$ time to include all cells for r. The generated priority queue L under MT is shown in Fig. 6 below.

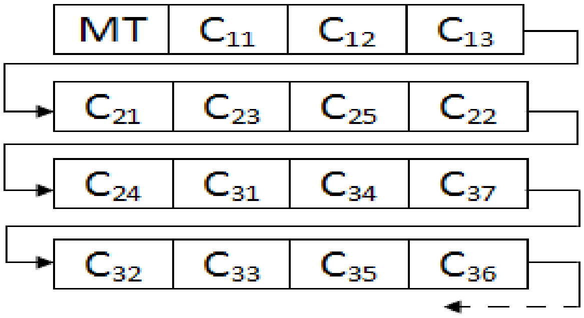


Fig. 6: Generated Priority Queue for Fig. 5

3.3 *Priority Queue Implementation*

In PQSHI model [3] and its improved models IPBCS [2] and PH2 [1], generated priority queue have been implemented using both linear list and heap like tree data structures respectively. The same essence like heap structure can be achieved with a binary tree with heap property named Treap[12] structures in O(nlogn) << $\Theta(r^3)$ time employing any standard algorithm of construction of heap tree [9] with cells C_{ij} as key elements (taken from L) to little modification for the tree structure. There are 15 cells under MT up to radial level r = 3. Thus the corresponding Treap in Fig. 7 of the priority queue L gives you an idea about.

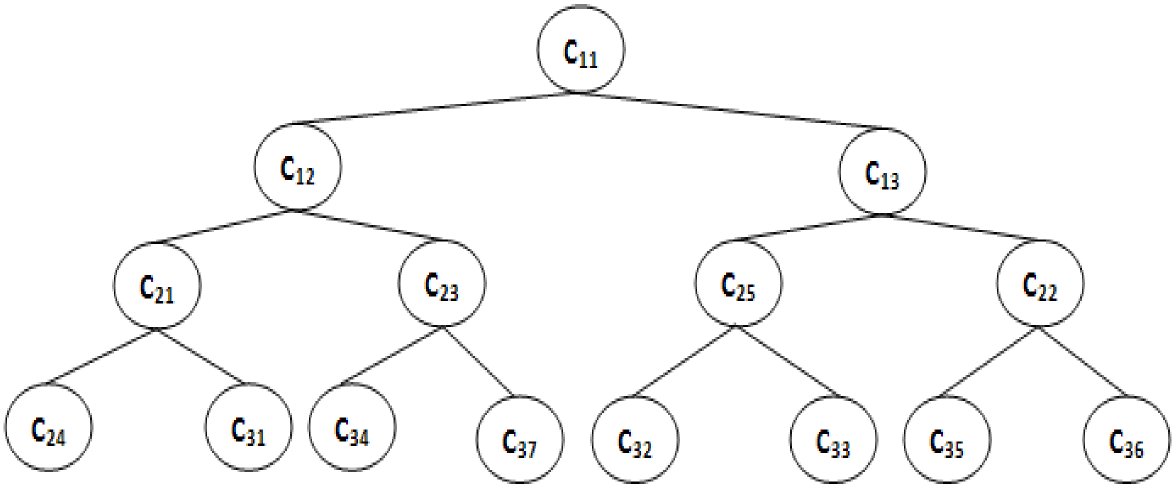


Fig. 7: Treap representation of L for r = 3.

3.4 Determination of Arrival Rate (λo)

In the model S2BPQ, MSs are spread evenly over the service area. However, number of MSs varies location to location. And this location on the contrary affects arrival rate (λo) of MSs to BS. In megacity value of λo is very high in contrast to λo value in rural village area. Likewise number of BSs (MTs) varies. For high λo value, distance D between two BSs should have least value because of better service. For simplicity here we consider D = 1 km. Thus in a particular region, number of subscribers S, and number of MTs X, λo can be determined as:

$$\lambda o = \frac{Total\ Number\ of\ Subscribers\ in\ that\ Region}{Total\ Number\ of\ MTs}$$

$$= \frac{S}{X} \qquad \text{……..…….. (4)}$$

3.5 Determination of Departure Rate (μ)

The model S2BPQ must be competent of providing services to all (may be infinite number) MSs with least waiting time after enqueueing in L. In practice the model would have departure rate, µ (number of MSs get serviced in unit time) at least equal to arrival rate λo such that waiting for getting service becomes zero. However, it depends basically on traffic intensity. From Poison distribution [10], the traffic intensity factor ρ (defined as λ/µ) lies between 0 and 1 i.e.

⇨ $0 \le \rho \le 1$ ……..…….. (5)

⇨ $0 \le \lambda o/\mu \le 1$ ……..…….. (6)

⇨ $0 \le \lambda o \le \mu$ ……..…….. (7)

3.6 Selection of Requested Calls

One of the major obstacles after a call in L initiating a request for handoff is the selection of a cell from this list. If a call is selected based on FCFS queuing principle [10], it results a problem of *not fully get rid of* termed starvation [galvin] for the calls having furthest radial distances. A great solution may be imposing randomness in selection irrespective of priorities of calls in L and it is not anything but SIRO [10] queuing working methodology. However providing services to these calls in L before others with higher priorities violates necessity of construction of L. Thus, internal up-gradation is mandatory of a call of low signal value (priority) once selected on the Treap in Fig. 7.

Splay Rotations (Zig, Zag, Zig-Zig, Zag-Zag, Zig-Zag, Zag-Zig) [11] in it is the alternative solution for internal up-gradation. Rotations are continued till the selected call (a node in Treap) becomes its root so that it would be directly accessible to MT. Simple Splay rotations selecting a call (a cell) say C_{24} with lower strength (priority) from above Treap in Fig. 7 are represented through Fig. 8 to Fig. 10.

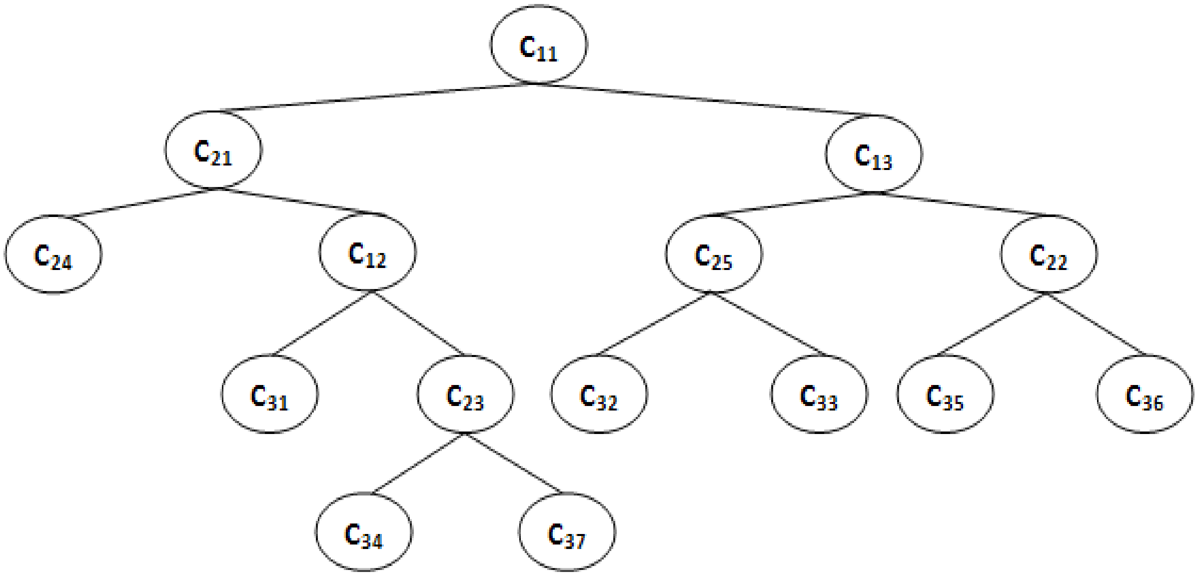


Fig. 8: Treap after Zig Operation on Treap in Fig. 7 w.r.t Cell 12

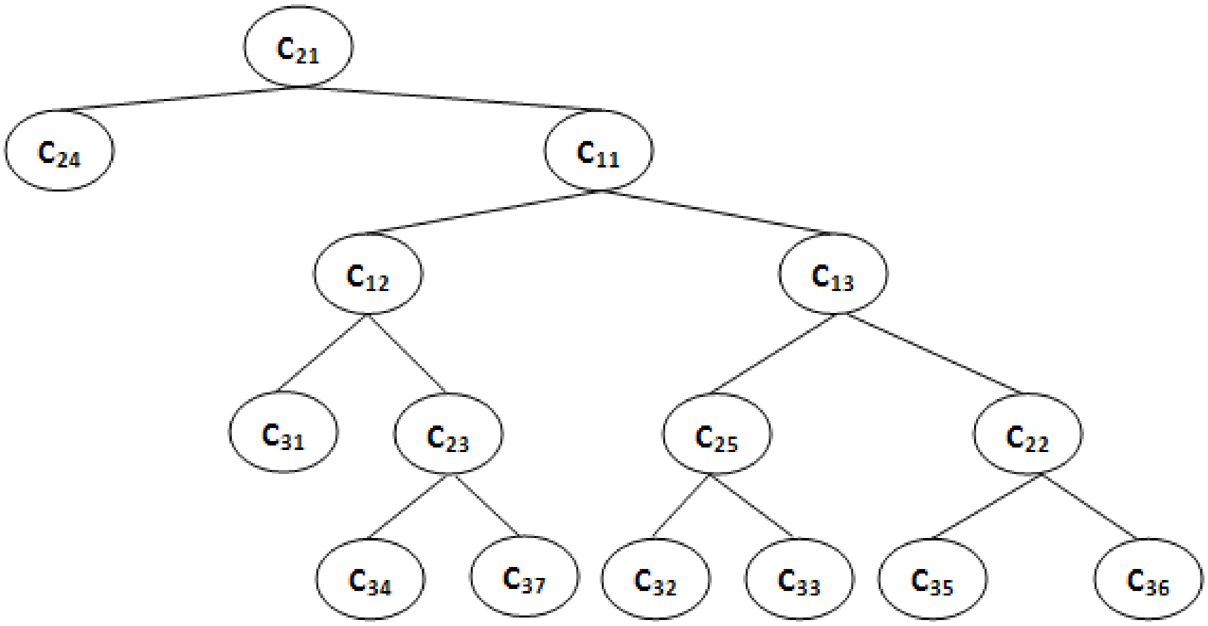


Fig. 9: Treap after Zig Operation on Treap in Fig. 8 w.r.t Cell 11

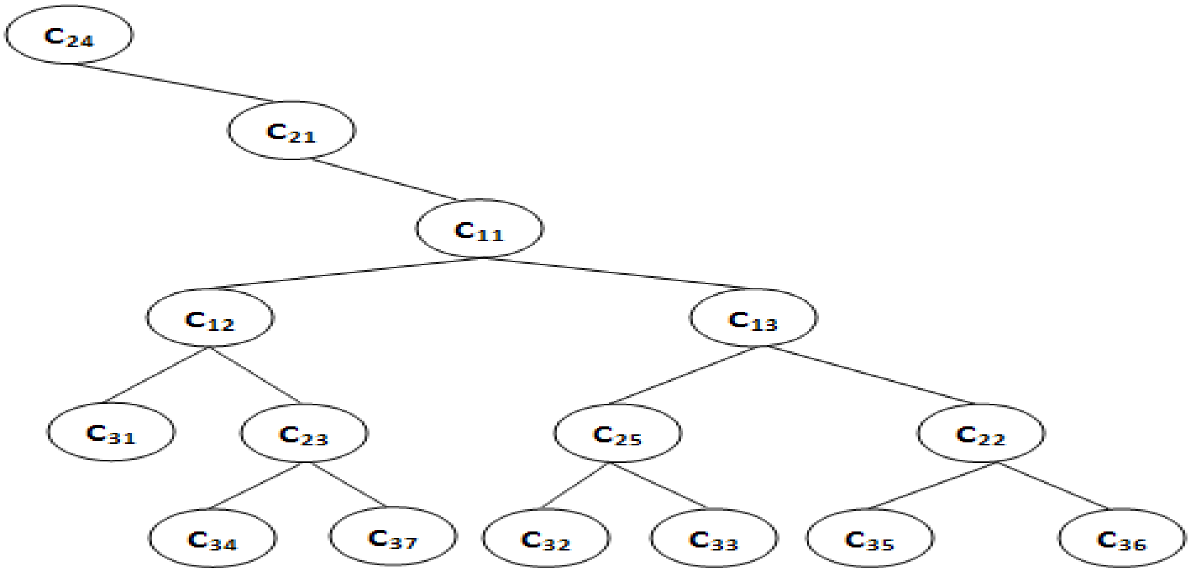


Fig. 10: Treap after Zig Operation on Treap in Fig. 9 w.r.t Cell 21

Thus through repeated ‘Zig’ operation the call just selected for a moment is accessible to MT and is ready to get serviced.

3.7 *Selection of Traffic Model*

Every cell in cellular network architecture is served by a BS. BSs are connected together by using a wireless network. Establishment of a traffic model, in cellular system, is more imperative before analyzing the performance of the system [1]. Several traffic models [6] have been established on basis of making different assumptions about user mobility. For our purpose ***El-Dolil et al.’s*** *Traffic Model* [6] shown in Equation (8) has been chosen as underlying implementation model with the assumption that the arrival rate of handoff calls λ_H is [1][6].

$$\lambda_H = (R_{cj} - R_{sh})P_{hi} + R_{sh}P_{hh} \qquad \text{……………….. (8)}$$

3.8 *Priority Handoff Scheme*

Newly generated calls in a cell are labeled as originating calls (new calls). A handoff request is generated in the cell when a MS approaches the cell from a neighboring cell with significant signal strength. Priority is set to calls for making handoff requests by assigning *SR* channels exclusively for handoff calls out of *S* channels in a cell. Both originating calls and handoff requests share the remaining *SC* (= *S* – *SR*) channels. Obviously, an originating call is blocked when in a cell available channels number is ≤ *SR*. A handoff request is failed if no channel is available in the target cell [1][6]. The system model is shown in Fig. 11 below.

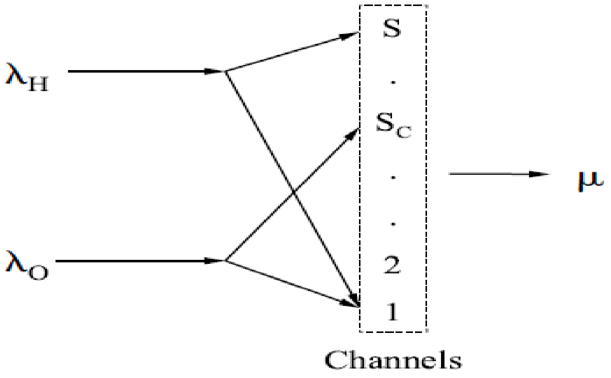


Fig. 11: System Model with Priority for Handoff Call.

We define the state *i* (*i* = 0, 1, · · · , *S*) of a cell as the number of calls in progress for the BS of that cell shown in Fig. 12. Let *P*(*i*) represent the steady-state probability that the BS is in state *i*. The probabilities *P*(*i*) can be determined as in Equation (9) in the usual way for birth–death processes. The pertinent state transition diagram is shown [6][1][10].

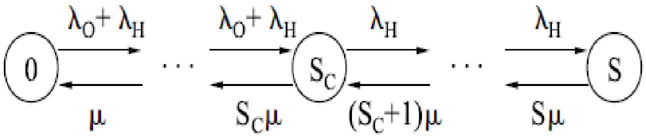


Fig. 12: State Transition Diagram for Fig. 11

$$P(i)=\begin{cases}\dfrac{(\lambda_O+\lambda_H)^i}{i!\,\mu^i}P(0) & 0\le i\le S_C\\[2ex]\dfrac{(\lambda_O+\lambda_H)^{S_C}\lambda_H^{\,i-S_C}}{i!\,\mu^i}P(0) & S_C\le i\le S\end{cases} \qquad \text{……………..(9)}$$

Thus, steady state probability P(o) that the system is in state "0" could be observed as in Eqn. (10) [1][6]:

$$P(0)=\left[\sum_{i=0}^{S_C}\frac{(\lambda_O+\lambda_H)^i}{i!\,\mu^i}+\sum_{i=S_C+1}^{S}\frac{(\lambda_O+\lambda_H)^{S_C}\lambda_H^{\,i-S_C}}{i!\,\mu^i}\right]^{-1} \qquad \text{……………....(10)}$$

The blocking probabilities, B_O for an originating call, and B_H of a handoff request [6][1] can be determined by equations (11), and (12) respectively.

$$B_O = \sum_{i=S_C}^{S} P(i) \qquad \text{.......................... (11)}$$

And

$$B_H = P(S) = \frac{(\lambda_O + \lambda_H)^{S_C} \lambda_H^{S-S_C}}{S!\,\mu^S} P(0) \qquad \text{……………..... (12)}$$

A blocked handoff request call can still maintain the communication via either the current BS until or the conversation is completed before the received signal strength goes below the receiver threshold [1][6].

4. Simulation

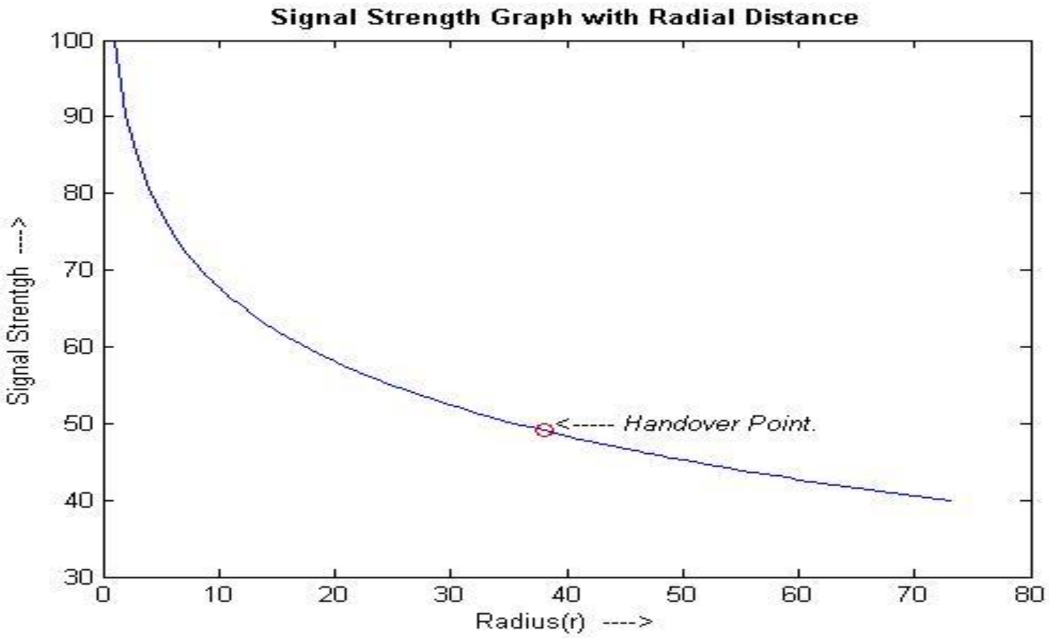
Taking advantage of the Eqn. (4), the arrival rate λo in this model is computed based on the collected data according to COAI REPORT for our beloved Megacity Kolkata [13][14]. We assume that distance between any two MTs is 1 km. Consequently its coverage area is around 1 km^2.

Total no. of subscribers in Kolkata, S ≈ 29,47,042
Area of Kolkata, A ≈ 1480 km^2.
Hence, Number of MTs in Kolkata, X ≈ Total Area = 1480
Thus, $\lambda o = \frac{S}{X}$
$= \frac{2947042}{1480}$
≈ 1991
By means of Eqn. (6), the departure rate μ can just be determined as:
$0 \le \lambda o/\mu \le 1$
⇨ $0 \le 1991/\mu \le 1$ [putting λo value]
⇨ $\infty \ge \mu/1991 \ge 1$
⇨ $1991 \le \mu \le \infty$
But, $\rho = \lambda o/\mu$
Let, traffic intensity (ρ) = 0.9
Therefore, $\lambda o/\mu = 0.9$
⇨ $\mu = 1991/0.9 \approx 2212$.

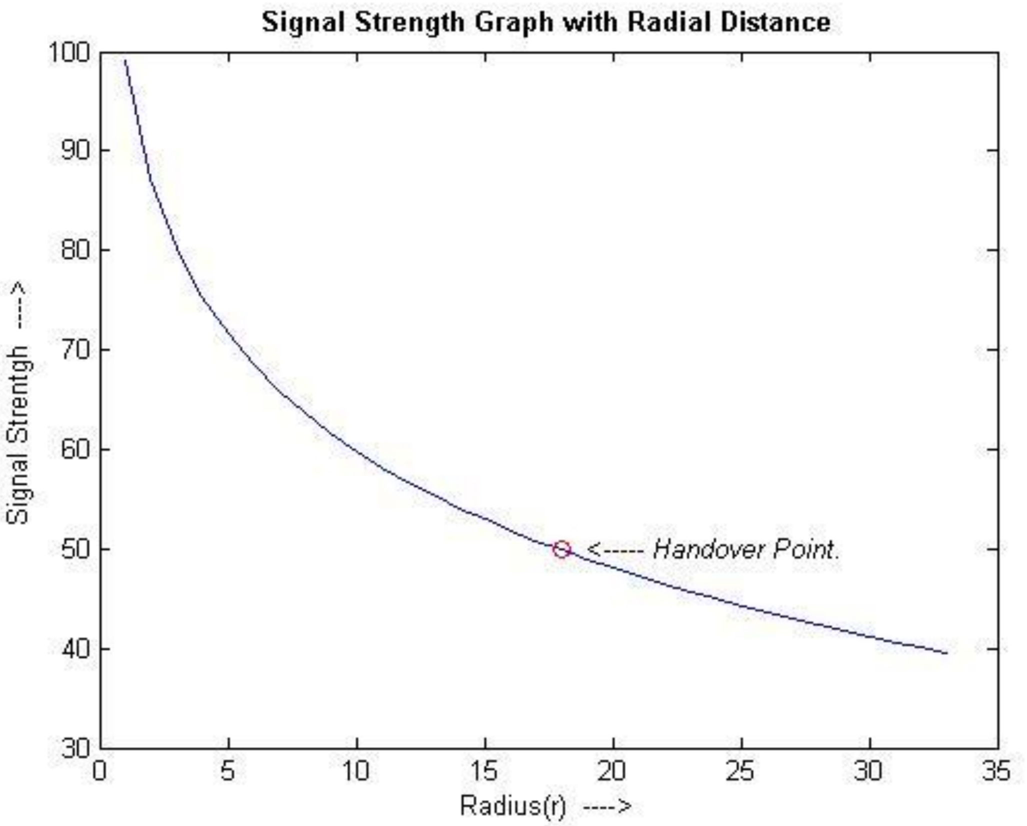
The general relationship between the handoff received signal strength and distance is computed using the above Eqn. (3) to determine values for different areas around the base station MT_A [7]. The model is simulated in MATLAB Version 7.6.0.324 (R2008A). The values of the parameters are assumed during simulation are shown in Table 1 with shadow fading effect $\zeta(r) = \log(r)$. Corresponding signal strength behavior has been shown graphically in Fig. 13. The bold values in Table 1 and marked 'O' in Fig 13 represent handoff points when a MS moves away from MT.

Table 1: Signal Strengths vs. Radial Distance

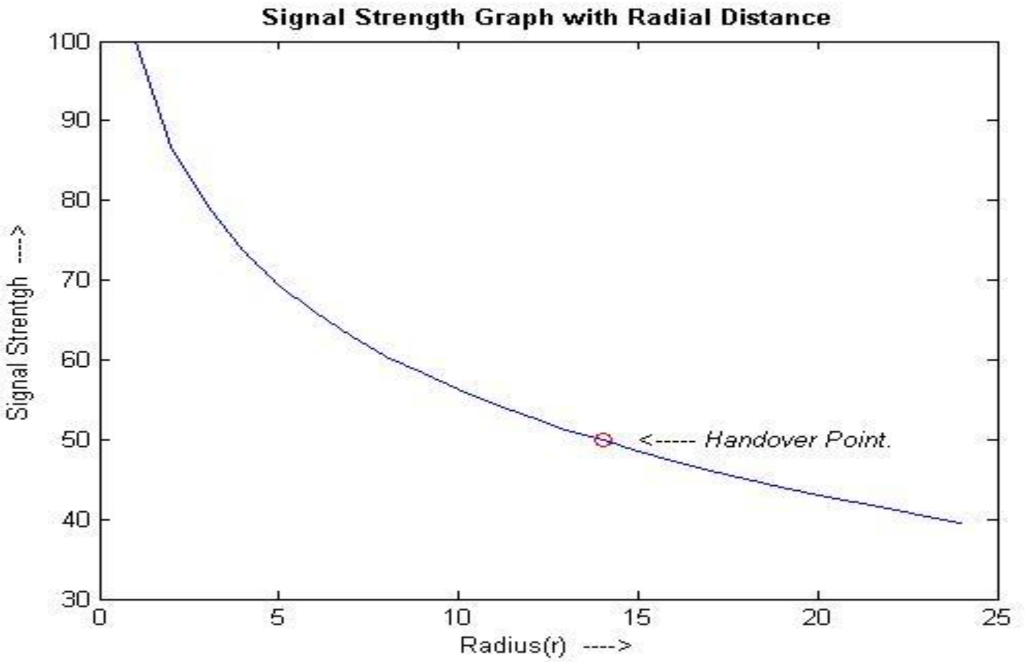
Parameters	**Received Signal Values**
Є = 0 η = 15	100.000 90.2959 84.6194 80.5919 77.4679 74.9154 72.7573 70.8878 69.2389 67.7638 66.4295 65.2113 64.0907 63.0532 62.0873 61.1838 60.3350 59.5348 58.7779 58.0597 57.3767 56.7254 56.1031 55.5072 54.9357 54.3866 53.8583 53.3491 52.8579 52.3832 51.9242 51.4797 51.0489 50.631 50.2251 49.8307 49.4471 **49.0738** 48.7101 48.3557 48.01
Є = 1 η = 18	99.0000 87.2165 80.3236 75.433 71.6396 68.5401 65.9195 63.6495 61.6472 59.8561 58.2358 56.7566 55.3959 54.136 52.9631 51.866 50.8354 **49.8637** 48.9445 48.0726
Є = 0 η = 20	100 86.8302 79.1264 73.6604 69.4207 65.9566 63.0277 60.4906 58.2527 56.2509 54.44 52.7868 51.266 **49.8579** 48.547 47.3208



(a)



(b)



(c)

Fig. 13: Signal Strength Behaviors at Different Path Loss Parameters

5. Conclusion

Since all quantities in Eqn. (1) and Eqn. (2) are expressed as function of distance, the results thus obtained are independent of the speed of the MS. The performance evaluated of this model makes available finding handoff points; visualize signal strength behavior of MS in the serving MT, and minimizing indefinite blocking of a call through splay operations. It is also observed that with more path loss, two base stations get closer or vice-versa.

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References

[1] Biswajit Bhowmik, Smita Roy, Parag Kumar Guha Thakurta, Arnab Sarkar, “Priority Based Hard Handoff Management Scheme for Minimizing Congestion Control in Single Traffic Wireless Mobile Networks”, International Journal of Advancements in Technology, Vol. 2(1), 2011, Pp: 90-99.

[2] Biswajit Bhowmik, Arnab Sarkar, Parag Kumar Guha Thakurta, “Simulation of Handoff Management Scheme for Improved Priority Based Call Scheduling with a Single Traffic System in Mobile Network”, Int. J. of Advanced Research in Computer Science”, Vol. 1(3), 2010, Pp: 354-358.

[3] P. K. Guha Thakurta, Souvik Sonar, Biswajit Bhowmik, Swapan Bhattacharya, Subhansu Bandyopadhyay, “A New Approach on Priority Queue based Scheduling with Handoff Management for Mobile Networks”, 19th Int. Conf. on SEDE, ISCA, 2010, Pp: 69 – 74.

[4] Biswajit Bhowmik, “Design and Analysis of Algorithms”, S.K. Kataria & Sons, 1st Edition, 2011.

[5] S. A. Mawjoud, “Simulation of Handoff Techniques in Mobile Cellular Networks”, Al-Rafidain Engineering Vol.15 No.4, 2007.

[6] Qing-an Zeng and Dharma P. Agrawal, “Handbook of Wireless Networks and Mobile Computing”, John Wiley & Sons, Chapter 1, 2002.

[7] Syed Asad Hussain, Muhammad Emran, Muhammad Salman, Usman Shakeel, Muhammad Naeem, Sharjeel Ahmed, Muhammad Azeem, “Positioning a Mobile Subscriber in a Cellular Network System based on Signal Strength”, IAENG Int. J. of Computer Science, Vol. 34, No. 2, 2007.

[8] Hua Jiang and Stephen S. Rappaport, “Hand-Off Analysis For Cbwl Schemes Ln Cellular Communications”, CEAS Technical Report, Version 6, 1993.

[9] Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, “Introduction to Algorithms”, PHI, 2nd Edition, 2006.

[10] J K Sharma, “Operations Research - Theory and Application”, Macmillan Publishers, 3/e, 2006.

[11] D. Samanta, “Classic Data Structures”, PHI, 2nd Edition, 18th printing, 2010.

[12] http://en.wikipedia.org/wiki/Treap.

[13] http://www.coai.com/study_papers.php?val=2010.

[14] http://en.wikipedia.org/wiki/Kolkata#Geography.

[15] Raymond M. Bendett and Perambur S. Neelakanta, “Alternative Metrics for Hard Handoffs in Mobile Communication”, IEEE, ICPWC, 2008.