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A Prioritized Dynamic Channel Assignment Scheme Based on Mobility in Micro-cellular Networks

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Abstract: In future wireless networks, bandwidth demands could fluctuate abruptly due to movement of high data rate users. Dynamic bandwidth allocation plays a key role in ensuring that mobile calls are not disrupted after they are admitted into the network. In this paper, a dynamic channel assignment technique is proposed to prioritize the handoff request to improve the quality of service as perceived by the users. In order to prioritize the handoff request a queuing priority scheme is also proposed. This technique employs the queuing priority scheme to enhance the performance of the system in terms of reduced blocking probability of handoff calls and forced termination. Simulation results show that the proposed technique outperforms the fixed channel assignment technique. The results have been plotted between traffic intensity per cell in erlang and blocking probability in terms of originating calls and handoff calls.

Key words: Handoff calls, mobility model, FCA, DCA, queuing

INTRODUCTION

Future wireless networks are expected to support multimedia applications over a wide range of heterogeneous equipment with diverse bandwidth requirements. It is desirable that these networks could provide Quality of Service (QoS) guarantees similar to those provided by wired networks. However, QoS provisioning in wireless networks is even more challenging than in wired networks. In addition to problems introduced by wireless channel fading, mobility and handoff place stringent requirement on network resources[1-2]. Whenever a Mobile Terminal (MT) in an active call moves from one cell to another, network resources need to be rerouted to the new Base Station (BS). QoS degradation or even forced termination may occur when there is insufficient radio or backbone bandwidth to accommodate the rerouting.

In cellular networks, the blocking of a handoff request is less desirable than the blocking of a new call. Therefore, it is necessary to employ some specific schemes to prioritize the handoff request. If the handoff request is not prioritized, a handoff call is handled as same as an originating call i.e., the handoff call is blocked immediately if no channel is available which in turn leads to forced termination of the handoff call. In user, satisfaction point of view blocking of an ongoing call is undesirable.

A successful handoff provides continuation of call, which is vital for perceived QoS. Therefore, a handoff call should be given priority over the originating call and served before the degradation interval expires, either by assuming an available normal channel or by queuing the handoff calls in a waiting queue and served based on queuing policy.

In this study, a Dynamic Channel Allocation ((DCA) technique has been proposed to prioritize the handoff request to improve the quality of service as perceived by the users. In order to prioritize the handoff request over call initiation requests when allocating the voice channel, queuing priority scheme, is proposed. The proposed dynamic channel allocation technique employs the queuing priority scheme to enhance the performance of the system in terms of reduced blocking probability of handoff calls, forced termination and compared with the Fixed Channel Assignment scheme (FCA). A suitable mobility model has been derived to determine the effect of handoffs on network performance following the assumptions underlying micro cellular concept. The superior performance of the proposed DCA technique is enhanced where the user mobility increases as in micro-cell and pico-cell networks.

Handoff strategies and user mobility: Handoff in cellular networks is the mechanism that transfers an on going call from the current cell to the next cell as the

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Mobile Unit (MU) moves through the coverage area of the cellular system. The user mobility plays an important role in determining the effect of handoff on the system performance because when the mobility increases the probability of handoff increases. This is usual in the micro cellular systems.

In terrestrial micro cellular networks, handoff management exerts considerable impact on the system performance. Handoff can occur in the time interval during which the ratio of the power levels received form the current cell site and the mobile user destination cell site is within two appropriate thresholds[3,4]. A handoff procedure results in a call termination in the current cell jointly with a call arrival in the destination cell.

Processing handoffs is an important task in any cellular radio system. Many handoff strategies prioritize handoff requests over call initiation requests when allocating channels on demand. Handoff must be performed successfully and as frequently as possible and be imperceptible to the users. In order to meet these requirements, system designers must specify an optimum signal level at which to initiate a handoff. Once a particular signal level is specified as the minimum usable signal for acceptable voice a slightly stronger signal receiver (normally taken as between -90 and -100 dBm), a slightly stronger signal level is used as a threshold at which a handoff is made. This margin, given by $\Delta = Pr_{handoff} - Pr_{minimum\ usable}$, cannot be too large or too small[5-8].

The probability that a call in progress may under take a handoff to a neighboring cell is not related to the number of handoff that the call has already undergone. Under this assumption, the average numbers of handoffs per call attempts, n_h results to be

$$n_h = \frac{(1-P_{ba})P_h}{1-(1-P_{bh})P_h} \tag{1}$$

Where, P_{ba} is the blocking probability for new call attempts and P_{bh} is the blocking probability for handoff attempts (i.e., the handoff failure probability).

Mobility model: In determining the effect of handoffs on the system performance, the user mobility must be accurately accounted. To this regard, a suitable user mobility model has to be defined under the following assumptions:

i. Users transiting a cell travel distance L, uniformly distributed between 0 and 2r, where, r is radius of a cell size.
ii. Users transit cells at a constant velocity V, uniformly distributed between 0 and V_{max}.
iii. All the neighboring cells have equal probabilities of being the user destination cell.

In order to characterize the user mobility, the parameter α can be defined as

$$\alpha = \frac{2r}{V_{max} T_m} \tag{2}$$

with T_m, the mean call duration time. Note that α decrease as the user mobility increases. The interval t_{mc} between the time a uses starts a call in a cell and the time that user reaches a cell boundary, is expressed as

$$t_{mc} = \frac{L}{V} \tag{3}$$

where, L and V are two random variables outlined above in the mobility assumptions. Therefore the probability density function (pdf) for t_{mc} can be derived as

$$ft_{mc}(t) = \frac{u(t)-u(t-\alpha T_m)}{2\alpha\alpha_m} + \frac{\alpha T_m}{2t^2} u(t-\alpha T_m) \tag{4}$$

where, u (t) is
u (t) = 1, t ≥ 0,
u (t) = 0, otherwise (5)

It is straight forward to note that, in our model a handoff occurs whenever $T_{mc} < t_d$ with t_d the call duration time.

Letting P_h be the probability that a call in the current cell produces a handoff towards a neighboring cell (destination cell) then,

$$P_h = \int_0^\infty prob\{t_d > t / t_{mc} = t\} ft_{mc}(t)dt \tag{6}$$

From equations 4, 5 and 6, it is obtained that:

$$P_h = \frac{1-e^{-\alpha}(1-\alpha)}{2\alpha} - \frac{\alpha}{2}\int_\alpha^\infty \frac{e^{-x}}{x} dx \tag{7}$$

According to the mobility model, the channel holding time in a cell t_H can be defined as:

$$t_H = \min[t_{mc}, t_d] \tag{8}$$

Recalling that t_d is exponentially distributed, the pdf of t_H can be derived from equations 4 and 5. The expected value of t_H is thus:

$$E[t_H] = T_m (1-P_h) \tag{9}$$

Equation 9 shows that the effect of handoff on channel holding time is to make its expected value less than T_m.

In order to obtain the effect of handoff on the system performance in a mobile cellular network, the user mobility must be accurately accounted for. To this regard, a user mobility model has been defined. When á is in the range of 0.3-0.6, a high handoff probability greater than 50% has been observed, which is likely to happen in micro cellular systems.

Handoff prioritization: When no priority is given to handoff call attempts over new call attempts, no difference exists between these call attempts; the probability of blocking and handoff attempts failure are the same. However, forced call terminations due to handoff call blocking are generally more objectionable than new call blocking[7]. The probability of forced termination can be decreased by giving priority (for channel) to the handoff attempts are described; the Non-Priority Scheme (NPS) and the Queuing Priority Scheme (QPS) and expressions for the blocking probability handoff calls and originating calls are derived.

In the first scheme (NPS), a handoff call is blocked if no channel is immediately available in the target cell. In the second scheme (QPS), the handoff call attempt is held in a queue until either a channel becomes available for it, or the received power level becomes lower than the receiver threshold level.

Non-priority scheme: In the non-priority scheme, the co-coordinating system handles a handoff call as same as an originating call (i.e., the handoff call is blocked immediately if no channel is available). This is the scheme employed by typical radio technologies[4].

In this scheme a channel is allocated only when it is available either the call is originating call or a handoff call, otherwise the call is blocked. But it is undesirable form the customer's satisfaction point of view. So, the handoff request should be given priority over the originating call request by adopting certain policy to serve the handoff calls.

Queuing priority scheme: Queuing of handoffs is more effective than two-threshold-level handoffs. The MTSO will queue the request of handoff call instead of rejecting them if the new cell sites are busy. A queuing priority scheme becomes effective only when the request for handoffs arrive at the MTSO in batches or bundles. If handoff requests arrive at the MTSO uniformly, then the queuing scheme is not needed. Before showing the equations, let us define the parameters as follows:

- $1/\mu$ is average calling time in seconds, including new calls and handoff calls
- $\lambda_{1\ is}$ arrival rate (λ_1 calls per second) for originating calls
- λ_2 is arrival rate (λ_2 handoff calls per second) for handoff calls
- M_1 is size of queue for originating calls
- M_2 is size of queue for handoff calls
- N-number of voice channels
- $a-(\lambda_1-\lambda_2)/2$
- $b_1-\lambda_1/\mu$
- $b_2-\lambda_2/\mu$

In this queuing priority scheme, for mobile unit controlled handoff, when a mobile unit with an ongoing call enters a handoff area, it checks if there is a channel available with the new cell. If not, this scheme requires that there be a way for the mobile unit to signal to the new cell site its desire for a handoff and for the new cell site to buffer the request in a waiting queue. The mobile unit continues to use the old cell site until a new channel becomes available.

The following analysis can be used to see the improvement

i. **No queuing on either the originating calls or handoff calls:** The blocking for either a originating call or a handoff call is

$$B_0 = \frac{a^N}{N!}P(0) \text{ where } P(0) = \left(\sum_{n=0}^{N}\frac{a^N}{n!}\right)^{-1} \tag{10}$$

ii. **Queuing the originating calls:** The blocking probability for originating call is

$$B_{oq} = \left(\frac{b_1}{N}\right)^{M_1} P_q(0)$$

$$\text{where, } P_q(0) = \left[N!\sum_{n=0}^{N-1}\frac{a^{n-N}}{n!} + \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)}\right]^{-1} \tag{11}$$

The blocking probability for the handoff call is

$$B_{oh} = \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)}P_q(0) \tag{12}$$

Now, from the Fig. 1 and 2 it is clear that with queuing of originating calls only, the probability of blocking of originating call is reduced. However, queuing of originating calls, results in increased blocking probability on handoff calls. However queuing of handoff is more important than queuing for those originating calls on assigned voice channels because call drops upset the customer more than the call blocking.

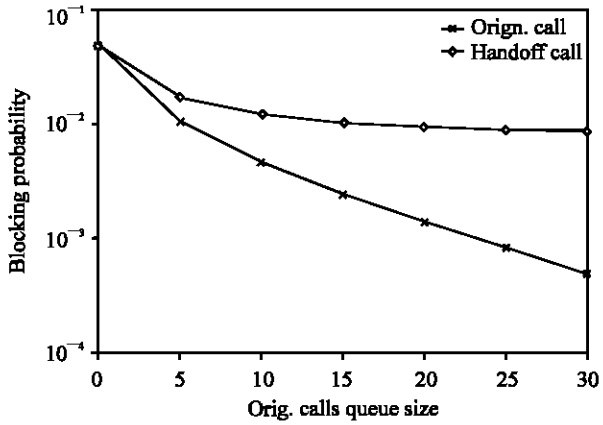

Fig. 1: Blocking probability of originating calls with originating calls queued

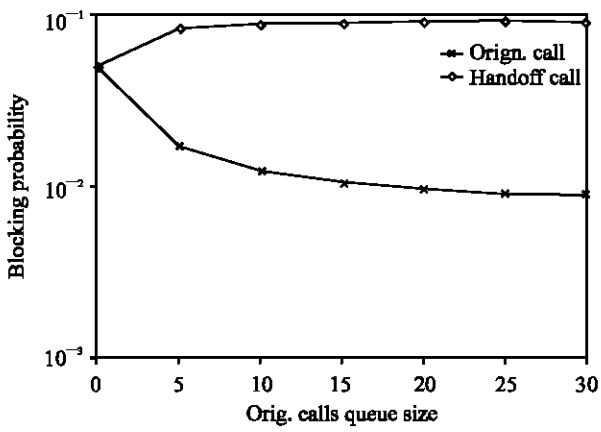

Fig. 2: Blocking probability of handoff calls with originating calls queued

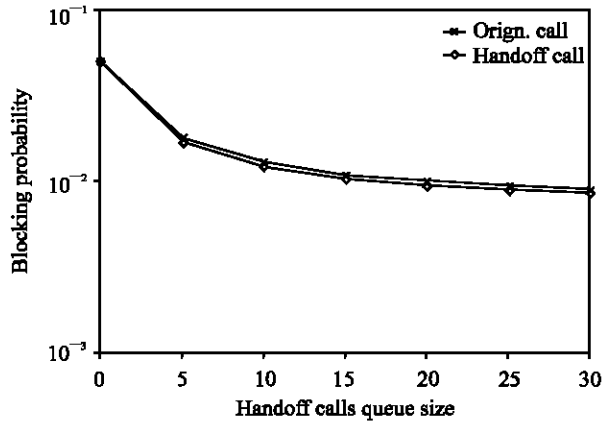

Fig. 3: Blocking probability of originating calls with handoff calls queued

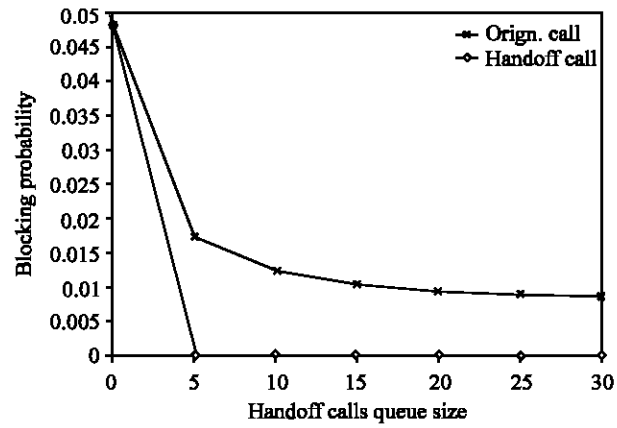

Fig. 4: Blocking probability of handoff calls with handoff calls queued

Queuing of handoffs is possible due to the fact that there is a finite time interval between the times the received signal level drops below the handoff threshold and the time the call is terminated due to insufficient signal level. The delay time and the size of the queue is determined from the traffic pattern of the particular service area. It should be noted that queuing does not guarantee a zero probability of forced termination, since large delays will cause the received signal level to drop below the minimum required level to maintain communication and hence lead to forced termination.

iii. Queuing the handoff calls: The blocking probability for handoff calls is

$$B_{hq} = \left(\frac{b_2}{N}\right)^{M_2} P_q(0)$$

where, $$P_q(0) = \left[N!\sum_{n=0}^{N-1}\frac{a^{n-N}}{n!} + \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)}\right]^{-1} \quad (13)$$

The blocking probability for originating call is

$$B_{ho} = \frac{1-(b_2/N)^{M_1+1}}{1-(b_2/N)} P_q(0) \quad (14)$$

But with queuing of handoff calls only, blocking probability decreases from 5.9 to 0.1% by using one queue space Fig. 3. Also adding queues in handoff calls does not affect the blocking probability of originating calls, which is shown in the Fig. 4.

Therefore, this scheme is based on the fact that, adjacent coverage areas in a mobile cellular network overlay. Thus, there is a considerable area where either base station, called the handoff area, can handle a call. The time that a MU moves across the handoff area is referred to as the degradation interval.

If a channel on the new cell becomes available, then the handoff actually occurs. In our study, if there is no idle channel after the MU moves out of the handoff area

(i.e., the degradation interval expires), then the call is forced terminated. In this scheme, when a channel is released, the MU first checks if the waiting queue is empty. If not, the released channel is assigned to a handoff call in the queue; otherwise the channel is assigned to the originating call. The "next" handoff call to be served is selected based on the queuing policy.

Note that the performance of the queuing schemes depends on the time that a mobile unit stays in the handoff area and the time that a mobile unit and the network will maintain the call connection while the radio link down or unavailable. The queuing priority scheme provides reduced blocking probability of handoff calls by prioritizing the handoff request. This scheme adds extra computational and implementation complexity (compared with NPS) to manage the waiting queues. Modifications to the cell site and mobile unit hardware/ software are required. However, it provides reduced blocking probability of handoff calls and improved spectrum utilization when integrated with the proposed dynamic channel assignment technique.

Proposed channel assignment scheme: In the proposed dynamic channel assignment scheme, channel assignment is based on the prevailing traffic condition and demand of the resources in the cell. Therefore, this assignment scheme has the potential to achieve significantly improved bandwidth utilization when there are temporal or spatial traffic variations.

The goal of the proposed DCA technique is that to provide the advantage of increased channel utilization and decreased probability of a blocked call by prioritizing the handoff request. In this technique, a channel cannot be simultaneously used in all the cells whose centers are closer than the frequency reuse distance D. These cells constitute the belt of interfering cells. Therefore the constraint on the frequency reuse distance should be respected.

When a new call attempt occurs in a cell, the local network controller carries the DCA. This controller may be a mobile telephone switching system or a Base station, depending on a centralized or decentralized implementation of resources assignment algorithm. In this work, centralized resource assignment algorithm is adopted.

The performance of the proposed DCA technique has been derived through simulations under the following assumptions.

i. The maximum number of available full duplex channels is M
ii. The call duration t_d is random and exponentially distributed with an expected value of T_m
iii. The call arrival process is Poisson with the same mean arrival rate in all the cells
iv. Large population of mobile users in each cell and mean arrival rate independent of the number of calls in progress
v. Blocked calls are cleared
vi. The cellular layout is regular hexagon with cell side equal to I
vii. Cells whose centers lie at distance D can reuse the same resource

Every time a Mobile Subscriber (MS) with a call in progress crosses the cell border, an available channel must be assigned to it in the destination cell to avoid a forced call termination.

Performance analysis: The performance of proposed dynamic channel assignment technique is evaluated in terms of the parameters of interest, new call blocking probability (P_{ba}), handoff call blocking probability (P_{bh}) and call dropping probability (P_{ns}) and compared with the results obtained by an fixed channel assignment technique under the assumption of an equal traffic load in each cell of the network. Specific channel propagation conditions have not been considered. It is only assumed that, according to the mobile environment envisaged, it is allowed to reuse a same distance $D = \sqrt{21R}$. Therefore, if channel is allocated to cell x, it cannot be used in adjacent cells with x because of unacceptable co-channel interference levels.

The performance of FCA technique has been derived by application of standard results of queuing theory under the following assumptions for the purpose of comparison with the proposed DCA technique.

i. Network cells are modeled as a loss queuing system with a number of servers S, equal to M/7 for a reuse distance $D = \sqrt{21R}$
ii. New call arrivals are Poisson-distributed with a mean arrival rate λ
iii. Handoff arrivals are Poisson-distributed and independent of new call arrivals with a mean arrival rate λ_h
iv. For arrivals due to handoff and new arrivals in a cell, assuming equal distribution

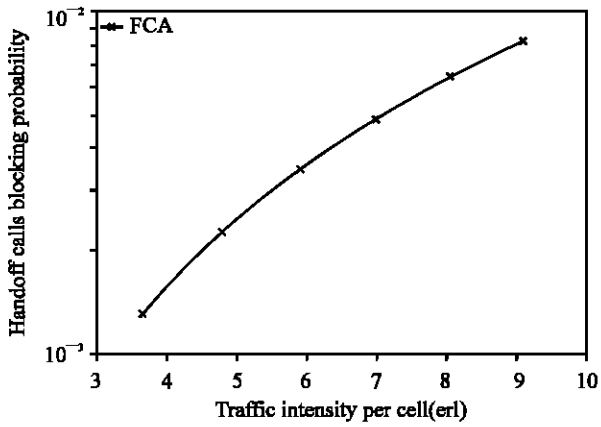

Fig. 5: Handoff blocking probability obtained with FCA

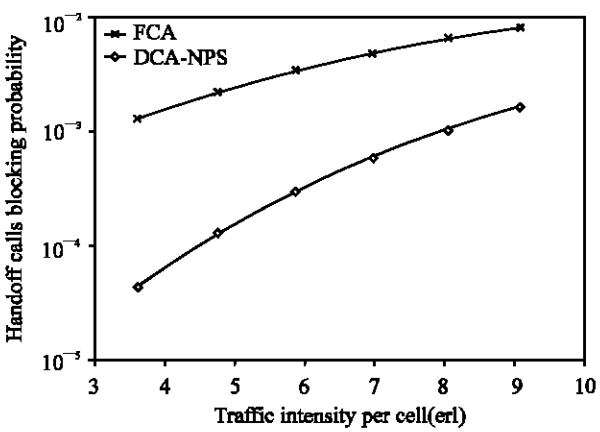

Fig. 6: Comparison between DCA and FCA, with case ($\alpha \to \infty$)

v. An exponential approximation with equal expected value, for the channel holding time t_H was assumed.

From above, total traffic intensity ρ_{tot}, in each cell is

$$\rho_{tot} = (\lambda + \lambda_h)\, E[t_H] \tag{15}$$

Therefore, the blocking probability value P_b, for both new and handoff arrivals can be derived using the ERLANG-B formula;

$$Pb = \frac{\rho_{tot}^{s}}{S!\sum_{n=0}^{s}\frac{\rho_{tot}^{c}}{n!}} \tag{16}$$

The parameter P_b must be obtained iteratively, since ρ_{tot}, (through λ_h) is related to P_b. The blocking probability of handoff call using fixed channel assignment scheme is shown in Fig. 5. In macro cellular system, the cells have

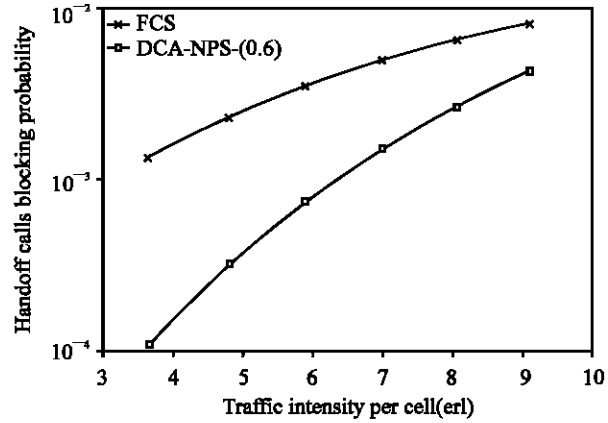

Fig. 7: Blocking probability on non-prioritized handoff calls (α=0.6)

wider sizes and handoff procedure occurrence during the call lifetime is very low. Therefore, in this case it is considered only "fixed users" ($\alpha \to \infty$); then $\lambda_h = 0$. The parameter P_b can be derived from the above equations by setting $\lambda_h = 0$.

Simulation of the DCA technique: The proposed technique is simulated using the following procedures:

i. Collect the real-time data on channel occupancy, traffic distribution and radio signal strength indication of all the channels on a continuous basis.
ii. Monitor the arrival of call request at the cell x
iii. Check the frequency is not presently in use in the cell or any other cell, which falls within the minimum restricted distance of frequency reuse to avoid co-channel interference.
iv. Evaluate the cost function defined for each available channel to find the optimum channel
v. Allocate the channel, if a channel is available
vi. Otherwise, check whether the call is originating one or a handoff call
vii. If the call is originating block the call. If it is a handoff call insert the call into a waiting queue
viii. Allocate the channel, if a channel is available before the call expires using the proposed queuing policy. Otherwise the call is forced terminated
ix. De-allocate the channel after the channel is released
x. Repeat the above procedure

Figure 6 shows the parameter P_b, the handoff blocking probability for the proposed DCA as a function of the traffic intensity per cell (=λ T_m), in the case of "fixed users". The parameter P_b derived from equation (16), in the case of a classical FCA technique, assuming 10 channels per cells, is also shown for comparison purposes.

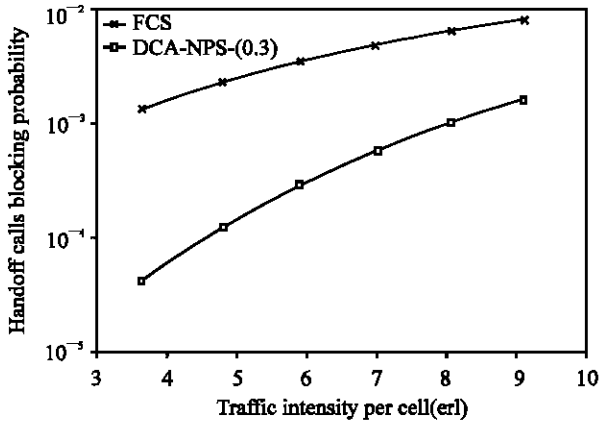

Fig. 8: Blocking probability on non-prioritized handoff calls (α=0.3)

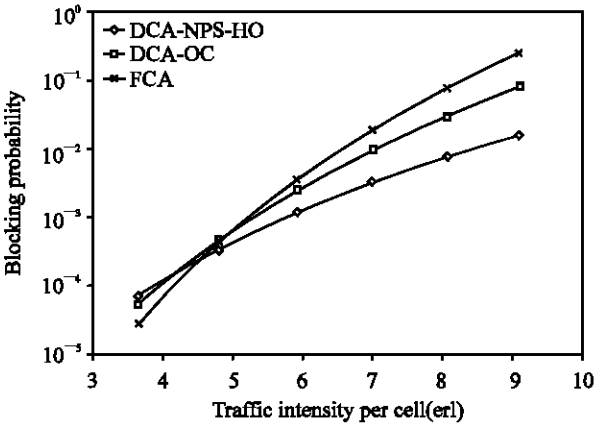

Fig. 9: Blocking probability for originating calls and non-prioritized calls

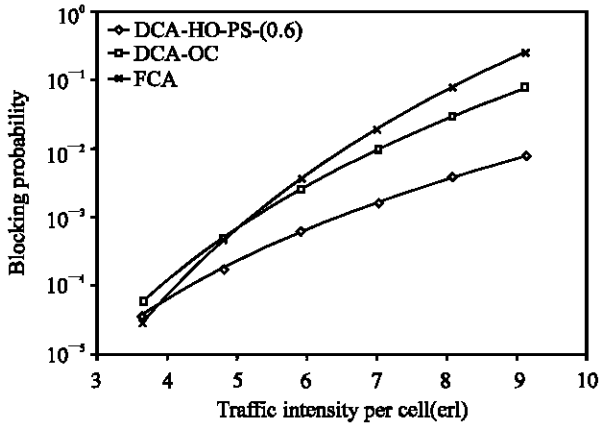

Fig. 10: Blocking probability for originating calls and prioritized calls (α=0.6)

The following parameters were used in the simulations:

i. Number of cell per side: N=7
ii. A set of interfering cells x, composed of two tiers of neighboring cells.
iii. Number of channels: M=70

The superior performance of the proposed DCA technique is evident from the Fig. 7 and 8, shows the handoff blocking probabilities (P_{bh}) when the handoffs are not prioritized as a function of the traffic per cell due to new arrivals both for the DCA and FAC technique for α=0.6 and α=0.3, respectively (typical value of α for micro cellular systems).

The proposed DCA technique out performs the FCA technique with practical blocking probabilities (< 60%) is evident from the Fig. 7. If the user mobility increases (decreasing α), P_{bh} decrease under the same traffic load conditions for DCA technique, these results are obtained for non-priority scheme. In this case, the handoff calls are treated as same as the originating calls and the handoff calls are blocked immediately if no free channel is available, but the probability of blocking is decreased appreciably by prioritizing the handoff requests. The proposed DCA technique permits to achieve handoff-blocking probability $P_{bh,}$ lower than the blocking probability of originating call P_{ba} by means of handoff prioritization and channel re-arrangement technique. FCA cannot obtain this advantage because call management in a cell is independent of what happens in the neighboring cells. The proposed DCA technique attains good performance levels with low to medium loads and constitutes an easier-to-manage allocation algorithm, even in the decentralized version[2].

Figure 9 shows the blocking probability for originating calls non-prioritized handoff calls as a function of the cell intensity for the proposed DCA technique and the FCA technique. Previous results point out that the density of potential users handled by a channel allocation technique significantly increases when cell side decreases. This advantage is highlighted well in the case of proposed DCA technique than in the classical FCA technique.

The blocking probability of handoff calls are decreased by prioritizing the handoff request over originating calls in the proposed technique. This is evident from Fig. 10 and 11 and the effect of mobility also plays an important role in improving the performance of the proposed DCA technique. As mobility increases, handoff-blocking probability, P_{bh} decreases, P_{ns}, the call completely served increases, which is evident from the Fig. 12. The proposed DCA technique allows obtaining P_{ns} value less than FCA technique. This is because the advantages obtained by using the rearrangement

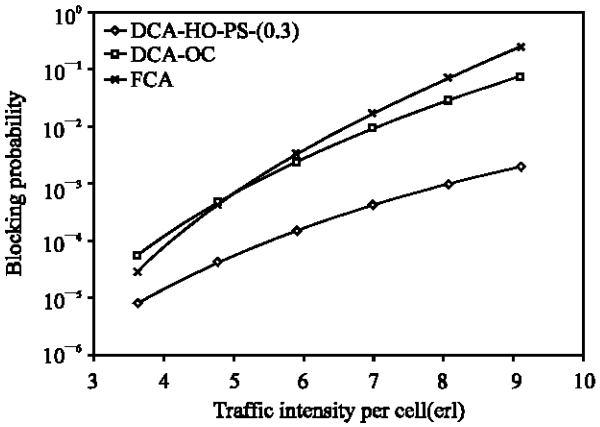

Fig. 11: Blocking probability for originating calls and prioritized calls (α=0.3)

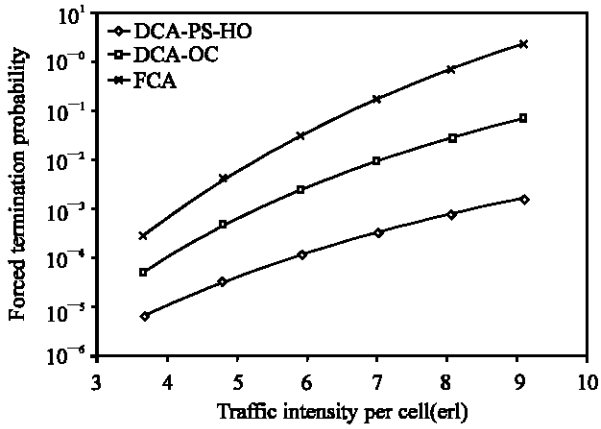

Fig. 12: Probability of forced termination for originating calls and prioritized handoff calls

technique and handoff prioritization in the DCA case are enhanced when mobility is high, as in micro cellular systems.

CONCLUSION

The performance of the proposed dynamic channel assignment technique for handoff prioritization has been evaluated and compared with the fixed channel assignment scheme. From the result, it is clear that the proposed dynamic channel assignment technique outperforms the fixed channel assignment technique and decreases the handoff blocking probability by giving priority to the handoff request by employing the queuing priority scheme. The results have been plotted between traffic intensity per cell in erlang and blocking probability in terms of originating calls and handoff calls. The influence of the mobility on blocking probability of originating calls and the handoff calls are evident from the result that as mobility increases P_{bh} decrease. The better performance of the proposed DCA technique increases the spectrum efficiency by allocating the channel on demand and prioritizing the handoff request.

REFERENCES

1. Zhang, M. and P. Tak-shing Yum, 1989. Comparisons of channel assignment in high capacity mobile telephone systems. IEEE Trans. Vehicular Technol., 39: 211-215.
2. Sivaradje, G. and P. Dananjayan, 2003. A novel dynamic guard channel scheme for channel allocation in cellular mobile network. Intl. J. Computers and Applications, 25, No. 4, 2003, IASTED, Canada.
3. Beck, R. and H. Panzer, 1989. Strategies for handover and dynamic control allocation in micro cellular mobile radio system. Proceedings of IEEE Vech. Tech. Conf., pp: 175-178.
4. Choi, S. and G. Shin, 1998. Predictive and adaptive bandwidth reservation for handoffs in QoS-sensitive cellular networks. Proceedings of ACM SIGCOMM'98, pp: 155-166.
5. Hong, D. and S.S. Rappaport, 1986. Traffic model and performance analysis for cellular mobile radio telephone systems with prioritized and non-prioritized handoff procedures. IEEE Trans., Vech. Tech., VT-35: 77-92.
6. Oh, S.H. and D.W. Teha, 1992. Prioritized channel assignment in a cellular radio network. IEEE Trans. Commn., 40: 1259-1269.
7. Zander, J., 1997. Radio resource management in future wireless networks: Requirements and limitations. IEEE Communication Mag., 35: 30-36.
8. Myuran, R. and F. Takawira, 2000. Non Classical traffic modelling and performance analysis of cellular mobile networks with and without channel reservation. IEEE Vech. Tech., 49: 817-834.