

## Investigation of Macrocell / Microcell Channels Selection In Multitier Cellular Networks

SAMI A. MAWJOURD  
Elect. Eng. Dept.  
University of Mosul

FARHAD E. MAHMOOD  
Elect. Eng. Dept.  
University of Mosul

SANA S. M. TAHIR  
Computer Center  
University of Mosul

### Abstract:

A proposed method of Macrocell / Microcell channel selection in multitier cellular system using sojourn time of microcell overlapped region. To keep the handoff rate to acceptable level, low mobility users (with speed  $V < V_{th}$ ) should undergo handoffs at microcell boundaries and high mobility users (with speed  $V > V_{th}$ ) should undergo handoffs at macrocell boundaries. Investigation of variation of the number of channels in the microcells and the macrocell with the blocking probability. Also the variation of microcell radius on the blocking probability for different mobile stations speed.

**Keywords:** Macrocell, Microcell, Channel Selection.

تفصي اختيار القنوات لخلية كبيرة (ماكرو) متكونة من عدة خلايا صغيرة (مايكرو) في شبكة  
النظام الخلوي

فرهاد عز الدين محمود  
قسم الهندسة الكهربائية  
جامعة الموصل

سامي عبد الموجود  
قسم الهندسة الكهربائية  
جامعة الموصل

سنا سامي محمد طاهر  
مركز الحاسبة الالكترونية  
جامعة الموصل

### المستخلص :

تم اقتراح طريقة لانتقاء قنوات الماكرو/مايكرو في النظام الخلوي باستخدام زمن البقاء في منطقة التراكب (Overlap) للخلية المايكرو. لإبقاء معدل المناقلة إلى مستوى مقبول ، فإن المستخدمين ذوي السرعة القليلة (بسرعة  $V < V_{th}$ ) يجب أن تتم المناقلة عند حدود الخلية الصغيرة الـ (المايكرو) ، والمستخدمين ذوي السرعة العالية (بسرعة  $V > V_{th}$ ) تتم المناقلة عند حدود الخلية الكبيرة (الماكرو). تم دراسة تأثير تغيير عدد القنوات في الخلايا المايكرو في الخلية الماكرو مع احتمالية الصد ولسرع مختلفة للمحطة المتنقلة كذلك تغير نصف قطر الخلية المايكرو مع احتمالية الصد ولسرع مختلفة للمحطة المتنقلة.

## 1. Introduction:

In multimedia services in order to cope with increasing traffic (increase capacity) is to use microcell of radius few hundred meters. On the other had the number of handoffs increase extensively. In this multitier cell structure consisting of microcell overlay with macrocell is efficient solution. In this scenario, high speed mobile stations (MSs) are serviced in the macrocell and low speed MSs are served in the microcell to reduce the number of handoffs. The speed of the MS has to be estimated precisely in the overlap region[1][2].

## 2. Theoretical Analysis:

The proposed scheme consists of four microcells based on sojourn time of the microcells overlapped region such as handoff region. The sojourn time measuring region is the same as in conventional handoff method. When a call originates it is first assigned to microcell after a call origination, the MS starts measuring the overlap region sojourn time.

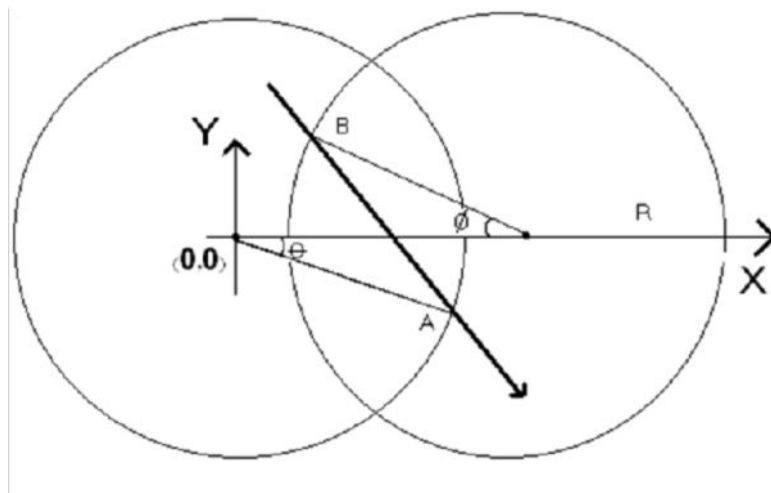
When cell originates in the overlap area, the MS measures the sojourn time until reaching the boundary of the overlap area.

The MS receives four paging signals from four adjacent microcells Base Stations (BSs) the first strongest paging signal received by the MS is the source microcell, the microcell sending the second strongest paging signal is the target microcell [1].

The cell selection is determined when the MS reaches the boundary of the microcell source. After cell selection, the MS handoffs to the target microcell or its locating macrocell [2][3]. If the overlapped region sojourn time is longer than the threshold time, the MS is estimated to be a low-speed MS and handoff to microcell. If the MS is estimated to be high speed MS and handoff to macrocell. The advantages of this scheme are:

- Good performance can be obtained in case of MS moving without changing direction, as in case of MS varying direction.
- In case of fast moving MS changes its direction the sojourn time of the MS will be long and the MS speed is regarded as low speed. In the measuring (overlap) region, the smaller the sojourn time, the lower the probability of changing direction in that region.

- In this scheme, the users (traffic) allocation to macrocell/microcell is efficient.
- Since the capacity of macrocell is much smaller than the embedded microcells of the macrocell in the multitier structure.
- The MS cells selection for handoff is that only fast moving MS's are allocated to macrocell which requires handoff and this can minimize blocking probability of macrocell.
- The limitation is that when the MS speed varies enormously, the sojourn time measuring region is small.



**Figure 1 Overlapped region model**

Figure 1 shows the overlapped region model .

Let  $\theta$  and  $\phi$  be random variables and uniformly distributed between  $\left[-\frac{\pi}{6}, \frac{\pi}{6}\right]$ .

Let the base station of the source cell be located in (0,0) and the distance between A and B be Z.

The coordinate of A and B as well as the value of Z are given by:

$$A = R(\cos \theta, \sin \theta) \quad \left(-\frac{\pi}{6} \leq \theta \leq \frac{\pi}{6}\right)$$

$$B = R(\sqrt{3} - \cos \phi, \sin \phi) \quad \left(-\frac{\pi}{6} \leq \phi \leq \frac{\pi}{6}\right)$$

Where R is the Microcell radius.

$$\text{Then } Z = R \sqrt{(\cos \theta + \cos \phi - \sqrt{3})^2 + (\sin \theta - \sin \phi)^2} \quad 0 \leq Z \leq R \quad \dots (1)$$

The mean of Z can be found as:

$$E(Z) = \int_{\phi} \int_{\theta} Z \, d\theta \, d\phi \quad \dots (2)$$

Using MATLAB 7.4 the value of E(Z) can be found as E(Z) = mean (Z).

If V is the Mobile Velocity Then:

$$T_h = \frac{Z}{V} \quad \dots (3)$$

Where  $T_h$  is the overlapped region sojourn time (ORST).

$$E[T_h] = E(Z) E\left[\frac{1}{V}\right] \text{ the mean value of ORST}$$

Assume the ORST has a Gaussian distribution, then the pdf of  $T_h$  is given by [1][5]:

$$f_{T_h}(t) = \frac{1}{\sqrt{2\pi} \sigma_{T_h}} e^{-\frac{(t - E(T_h))^2}{2\sigma_{T_h}^2}} \quad \dots (4)$$

Where  $E[T_h]$  is the mean value of ORST.

$\sigma_{T_h}$  is standard deviation of ORST.

Let  $P_{em}$  and  $P_{e\mu}$  be the probability of erroneous assignment of a call to macro cell and to micro cell then  $P_{em}$ ,  $P_{e\mu}$  and threshold time  $\tau_o$  can be obtained as:

$$\left. \begin{aligned} P_{em} &= F_{T_h}(\tau_o) \\ P_{e\mu} &= 1 - T_h(\tau_o) \\ \tau_o &= \frac{E(Z)}{V_{th}} \end{aligned} \right\} \quad \dots (5)$$

Where  $F_{T_h}$  is the cumulative distribution function and  $V_{th}$  is the threshold speed such that the calls initiated by mobile with speed  $V < V_{th}$  are to be assigned to microcall, since mean microcell speeds are relatively difficult to obtain with time, threshold parameter decision can be used. On the other hand if the mobile speed V is such that  $V > V_{th}$  the assignment is to macrocell.

### 3. Simulation of the Model:

This simulation is performed using MATLAB 7.4 .

Assumptions:

- The macrocell contains 10 microcells.
- The microcell radius (R) is 300 m.
- $V_{\text{threshold}}$  ( $V_{\text{th}}$ ) is 12 m/s.
- Numbers of channels is 10 in the microcell and 10 in the macrocell.
- Sojourn time ( $S_t$ ) is 120 Sec.
- Call arrival rate ( $\lambda$ ) is 500 call/hour to 3000 call/hour.

The blocking probabilities calculated using Erlang B formula [4] as shown below:

$$B(S, \alpha) = \frac{\frac{\alpha^S}{S!}}{\sum_{k=a}^S \frac{\alpha^k}{k!}} \quad \dots (6)$$

Where: S is the number of channels in the cell.

$\alpha$  is the offered traffic land in Erlang and is given as:

$$\alpha = \lambda S_t \quad \dots (7)$$

To see the effect of speeds of the MS which are below and above threshold speed, four values are considered 2m/s, 6 m/s, 10 m/s and 14 m/s.

Comparison of our result with the result obtained in reference [1] are shown in table1.

**Table 1: The probability of erroneous assignment in the case of no direction change.**

| Velocity m/s. | $P_{em}$ |        |        | $P_{e\mu}$ |
|---------------|----------|--------|--------|------------|
|               | 2        | 6      | 10     | 14         |
| Ref [1]       | 0.044    | 0.153  | 0.366  | 0.367      |
| Present       | 0.0323   | 0.1337 | 0.3558 | 0.3558     |

Assuming the call arrival rate to a macrocell and its embedded microcells be 1000 call/hour and the call holding time be exponentially distributed with a mean value of 120s. Let  $B_n$  and  $B_\mu$  be the call blocking probabilities in macrocell and microcell respectively.

Given microcell/macrocell selection, the loads should be 100 calls/h to the macrocell and 90 calls/h to each microcell with erroneous assignments, the actual call arrival rates to the macrocell and each microcell are [1][5].

$$\lambda_m = 100(1 - P_{e\mu}) + 900 P_{em}$$

And

$$\lambda_\mu = 10 P_{e\mu} - 90(1 - P_{em})$$

Where

$\lambda_m, \lambda_\mu$  are call arrival rate to each microcell and macrocell respectively.

#### 4. Results:

The number of channels is varied in the macrocell and in the microcell versus blocking probability for different MS speeds (6 m/s, 10 m/s and 14 m/s) as shown in figure 2, 3 and 4 for five channels in macrocell and variable channels in microcell. It can be seen that the blocking probability decreases as the number of channels in microcell increases, increasing mobile speed increase the blocking probability.

The number of channels in the microcell is fixed to S channel and the number of channels in the macrocell is varied for different MS speeds (6 m/s, 10 m/s and 14 m/s) as shown in figure 5, 6 and 7.

Figure 8, 9 and 10 are for varying microcell radius versus blocking probability for MS speeds of 6 m/s, 10 m/s, 14 m/s. It can be seen that increasing the microcell radius, the blocking probability decreases while it increases slightly for speed (V) greater than the threshold speed as in figure 8.

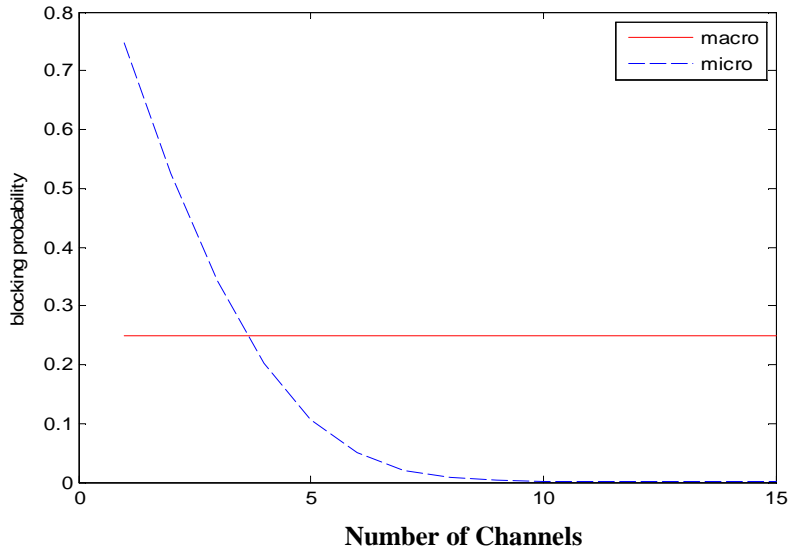


Figure 2 Variations of blocking probability versus microcell channels for fixed macrocell channels at mobile speed of 6 m/s.

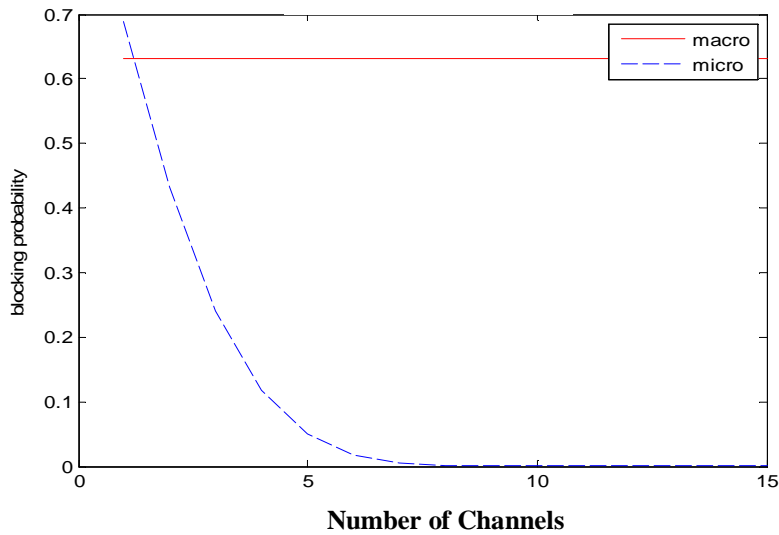


Figure 3 Variations of blocking probability versus microcell channels for fixed macrocell channels at mobile speed of 10 m/s.

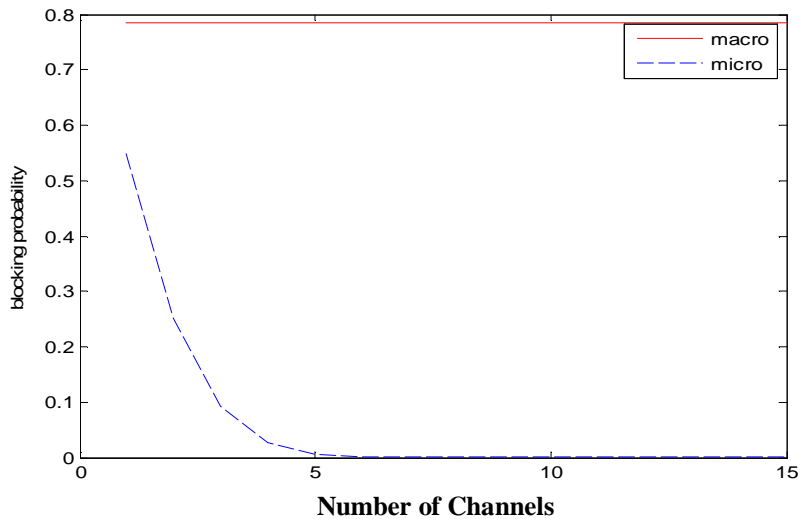
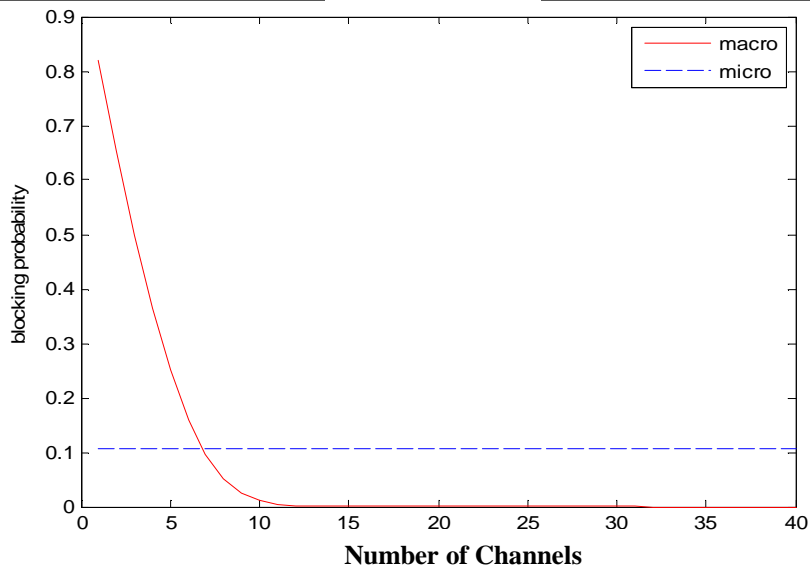
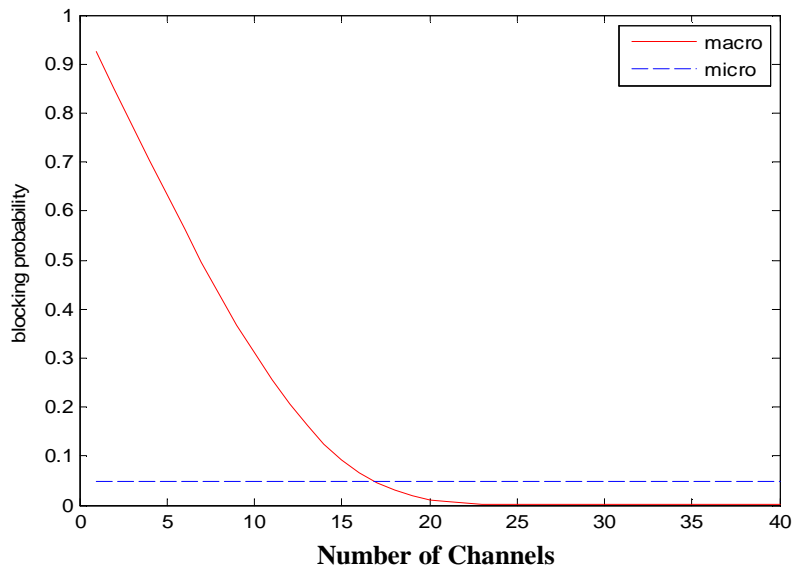


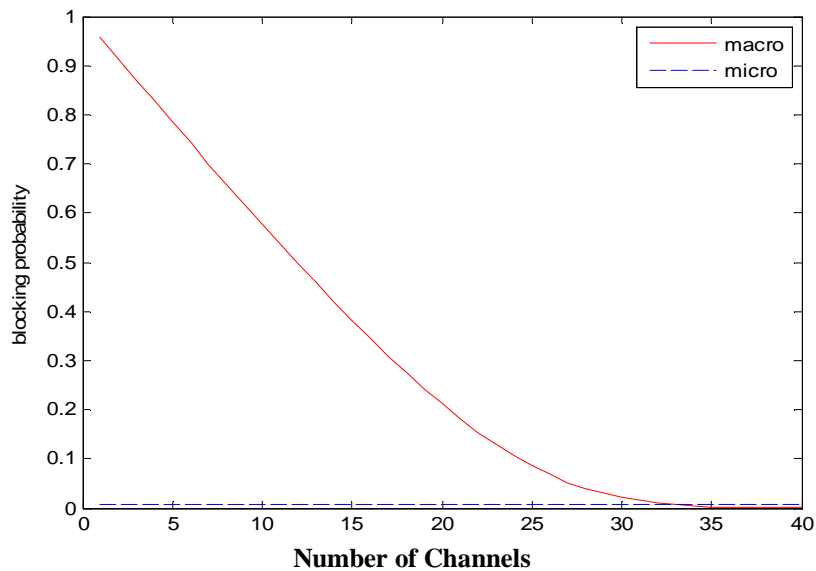
Figure 4 Variations of blocking probability versus microcell channels for fixed macrocell channels at mobile speed of 14 m/s.



**Figure 5** Variations of blocking probability versus macrocell channels for fixed microcell channels at mobile speed of 6 m/s.

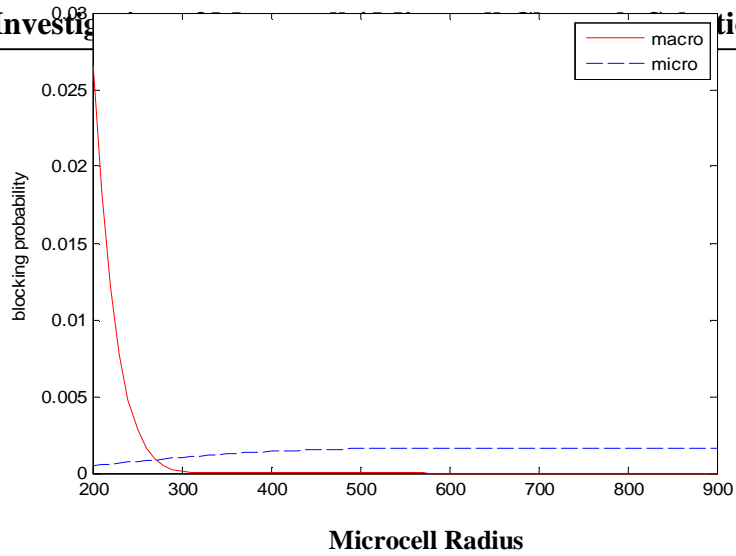


**Figure 6** Variations of blocking probability versus macrocell channels for fixed microcell channels at mobile speed of 10 m/s.

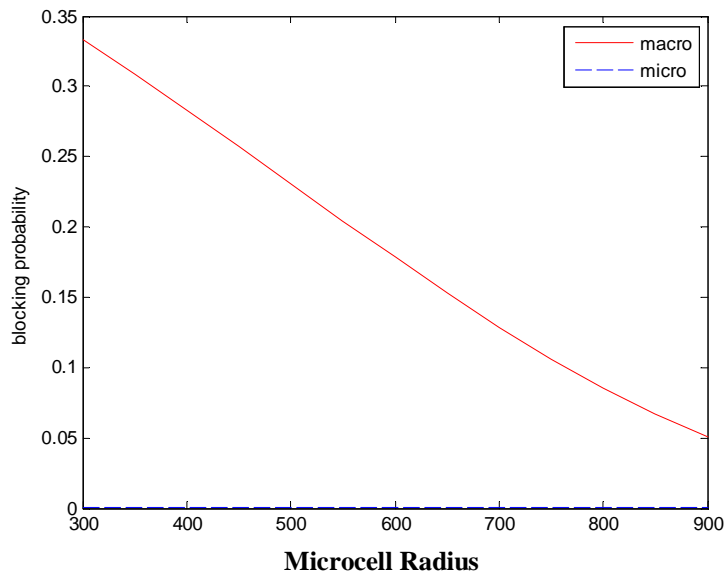


**Figure 7** Variations of blocking probability versus macrocell channels for fixed microcell channels at mobile speed of 14 m/s.

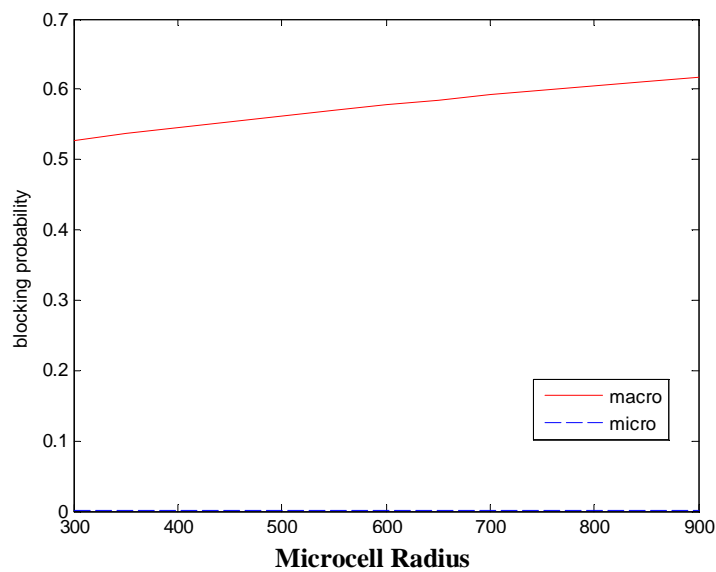




**Figure 8** Variations of blocking probability versus microcell radius for mobile speed of 6 m/s.



**Figure 9** Variations of blocking probability versus microcell radius for mobile speed of 10 m/s.



**Figure 10** Variations of blocking probability versus microcell radius for mobile speed of 14 m/s.

**Conclusions:**

It can be noticed from the results obtained that equations 2 and 4 are easier evaluated using MATLAB 7.4 and are checked with the calculated values [1] and [5].

The results obtained for different MSs speed and different channels allocation for macrocell and microcells. This indicates that when number of MS increases the load on the microcells increase. While the load decreases on the macrocell. When increasing the number of channels in the microcell the blocking probability decreases exponentially.

With increasing speed, the number of channels in the microcell decreases for the same value of blocking probability.

Increasing the speed of the MS in the macrocell the number of channels increases for the same value of blocking probability. Increasing the microcells radius for constant macrocell radius, the blocking probability (load) on the macrocell decreases while it increases for microcell, the load increases with increasing MS speed.

**5. References:**

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