Military Technical College
Kobry El-Kobbah
Cairo, Egypt

10th International Conference
On Aerospace Sciences&
Aviation Technology

TELETRAFFIC PERFORMANCE ANALYSIS OF MOBILE RADIO NETWORKS WITH OVERLAPPING MICROCELLS

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ABSTRACT

Overlapping coverage of nearby base stations is exploited in order to improve the performance of microcellular mobile radio networks. A teletraffic model is developed and the performance is analyzed for the network scenarios when overlapping coverage is and is not utilized. Furthermore, handover priority policies are considered in the analysis. The grade of service of the network is gauged in terms of the estimation of call blocking rate as well as handover failure probability. Numerical results are obtained through analytical as well as simulation modeling as possible and good agreement is achieved. The results dictate the exploitation of the overlapping coverage as alternative routes in order to improve the network performance and increase its capacity.

KEY WORDS

Teletraffic, microcells, channel assignment.

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1. INTRODUCTION

To meet the tremendous growth in the demand for mobile communications, an efficient utilization of the allocated frequency spectrum is inevitable. Working with microcells is an optimum approach for achieving this goal. Microcells can be used to increase the capacity of mobile networks through reusing the resources more intensively in high traffic demand areas [1,2]. However, reducing the cell size leads to the undesirable consequence of an increase in the handover rate and the probability that a call is forced to terminate prematurely. The quality of service (QoS) of the network is affected by the handover process. If unnecessary handover occurs frequently, the signaling load can become too high. On the other hand, if the decision for handover is delayed too long, the call may be dropped before successful handover. Such degradation of QoS can influence negatively the system capacity. In order to provide high–quality services as well as to maximize the system capacity, we need to handle the handover process very carefully and optimally [3,4]. The handover attempt should attain a channel when the associated mobile station (MS) moves out of the current cell to enter the destination cell. Different handover strategies have been proposed in the literature[1]-[7]. Among these, handover prioritization schemes allocate channels prior to handover requests have proved to be very efficient.

Channel allocation techniques can also play an important role in improving the spectrum efficiency [8-10]. In fixed channel assignment (FCA), specific groups of channels are assigned to base stations (BSs) in such a way that base stations can assign channels to users independently. In dynamic channel assignment (DCA), any channel can be used in any base station as long as no interference constraints are violated. In hybrid channel assignment (HCA), some channels are assigned to base stations by fixed assignment, and others are assigned dynamically. Although FCA has the maximum spatial efficiency in channel reuse, it cannot cope with the sudden variation of the traffic pattern. On the other hand, DCA and HCA can tolerate hot spot traffic but require a substantial amount of signaling data interchange. Basically, these channel assignment schemes assume fixed cell boundaries. Practically, the cell boundaries are uncertain and shifting because radio propagation is variable both in space and time. This results in overlapping coverage of nearby base stations [11,13]. If a mobile is near a microcell boundary, it may have adequate communication with more than one BS. This overlap can be used to advantage as an alternative route in several ways. If the channel of a base station is fully occupied, a call that is originated in a region of overlapping coverage may still receive service from other base stations. If there is a hot spot, the neighboring base stations can share the loading. Even under uniform and normal operating conditions, with appropriate system control strategies the overlapping coverage can be used to improve teletraffic performance characteristics such as blocking probability and carried traffic.

The current paper proposes an efficient approach for exploiting the overlapping coverage between highway microcells as an alternative route for calls in crisis. The goal is to improve the network performance and increase its capacity. The highway microcellular network is considered as a case study due to its commercial interest. However, the analysis is fairly general for other scenarios.

2. HIGHWAY MICROCELLULAR STRUCTURE

The microcellular scenario of a highway is composed of segments, each represents a microcell of length L. Each microcell is illuminated by a BS that is mounted at lamp post elevation along the highway as shown in Fig. 1. The field of the BS covers the highway with approximately equal radiation on the top and down lanes.

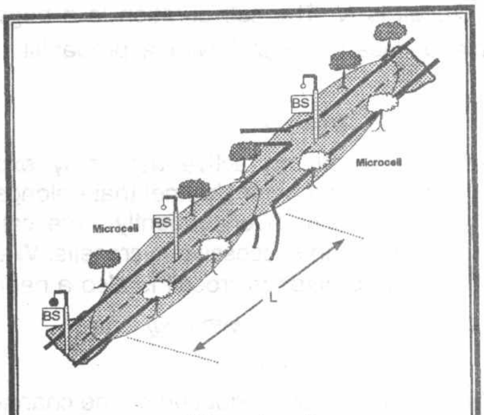

Fig. 1: Highway microcells.

The microcells are grouped into clusters. The total allocated frequency spectrum is shared between the microcells in the cluster. The cochannel microcells are spaced by a minimum separation distance called the reuse distance D_c. To determine the relationship between the available number of channels per microcell and the attainable carrier to interference ratio "CIR", consider a cluster of M microcells. The reuse distance between cochannel microcells is given by

$$D_c = ML \tag{1}$$

Consider a mobile station at a microcell boundary. It is at a distance L away from its serving BS and at a distance ($ML + L$) from the cochannel BS in the pervious cluster. Therefore, carrier to interference ratio, is given by

$$CIR = [M + 1]^{\gamma} \tag{2}$$

where γ is the propagation path loss. This results in a cluster size M to be given by

$$M = CIR^{1/\gamma} - 1 \tag{3}$$

Let $2B_T$ and $2B_c$ Hz denote the total frequency spectrum allocated to the network and the channel bandwidth for duplex transmission, respectively. The number of channels, N, available per microcell is given by

$$N = \frac{B_T}{B_c[CIR^{1/\gamma} - 1]} \tag{4}$$

3. NON-OVERLAPPING SCENARIO

The non-overlapping scenario with both non-prioritized and prioritized handover schemes are analyzed first. In order to establish a teletraffic model for the highway microcells, some basic assumptions are considered. The new calls in a microcell are generated according to Poisson process with a mean rate of λ_o. The number of channels assigned per microcell is *N*. The call duration is a negative exponential distributed random variable of mean $\overline{T_c} = \mu_c^{-1}$ with a probability density function (pdf) as

$$f_{T_c}(t) = \mu_c e^{-\mu_c t} \qquad (5)$$

Due to the small size of a microcell, an active user may experience several handovers during his call. The user will hold a channel that belongs to the microcell BS in which he resides at a given time. Consequently, the call duration is the accumulation of channel holding times in successive microcells. We assume that the channel holding time T_H of a call in a given microcell is also a negative exponential distributed random variable of mean $\overline{T_H} = \mu_H^{-1}$ with (pdf) as

$$f_{T_H}(t) = \mu_H e^{-\mu_H t} \qquad (6)$$

The assumption of a negative exponential distribution of the channel holding time is literaturally accepted and verified due to its mathematical tractability [14]. However, the network performance of a one-dimensional queuing system (which resembles our case) is influenced by the mean value only, not the exact distribution [1].
The expression of T_H is to be defined for each scenario.

a. Non-Priority Scheme

This scheme can be modeled as a Marckov process with $N+1$ states. In this case, the new and handover attempts have the right to occupy any of the N channels as long as the channel is free. Let P_j denote the statistical equilibrium probability of j busy channels in a given microcell. The total call rate placed by users in a microcell is $(\lambda_o + \lambda_h)$, where λ_h is the handover call rate commences from the neighboring microcells. The state transition diagram is displayed in Fig. 2. The probability P_j is given by

$$P_j = \frac{(\lambda_o + \lambda_h)^j}{\mu_H^{\,j}\, j!} P_0 \qquad 0 \le j \le N \qquad (7)$$

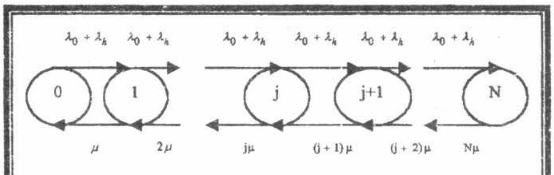

Fig. 2 State transition diagram for a non-priority scheme.

where P_0 is obtained from the identity

$$\sum_{j=0}^{N} P_j = 1 \tag{8}$$

The blocking probability P_B of a new call is equal to the probability of finding all channels being busy. It is also equal, by definition, to the handover failure probability P_{fh}, i.e.,

$$P_B = P_{fh} = P_N = \frac{(\lambda_o + \lambda_h)^N}{\mu_H{}^N N!} P_0 \tag{9}$$

where P_0 is given by

$$P_0^{-1} = \sum_{k=0}^{N} \frac{(\lambda_o + \lambda_h)^k}{\mu_H{}^k k!} \tag{10}$$

In order to solve this equation, it is required to determine the handover rate λ_h and the mean channel holding time $\overline{T}_H = \mu_H{}^{-1}$. Let P_i and P_h denote the probability that a successful initiated call and a handover call will need handover to the adjacent microcell, respectively. The handover rate can be obtained as [1,2]

$$\lambda_h = \lambda_0(1-P_B)P_i + \lambda_0(1-P_B)P_i(1-P_{fh})P_h + \lambda_0(1-P_B)P_i(1-P_{fh})P_h(1-P_{fh})P_h \cdots$$

$$\lambda_h = \frac{\lambda_0(1-P_B)P_i}{1-(1-P_{fh})P_h} \tag{11}$$

The probability P_i is equal to the probability that the call duration is greater than the residing time T_i spent by a MS in the origination microcell, i.e.,

$$P_i = P(T_c > T_i) = \frac{\mu_i}{\mu_i + \mu_c} \tag{12}$$

where $\mu_i = \overline{T}_i^{-1} = 2v/L$ with v refers to the average mobile speed. The average channel holding time of a new call in a microcell is given by [3]

$$\overline{T}_{Hi} = \frac{1}{\mu_i + \mu_c} \tag{13}$$

In a similar approach, if $\overline{T}_0 = \mu_0^{-1} = L/v$ represents the residing time spent by a MS in the handover microcell, the probability P_h is given by

$$P_h = P(T_c > T_0) = \frac{\mu_0}{\mu_0 + \mu_c} \tag{14}$$

The average channel holding time of a handover call in a microcell is given by

$$\overline{T}_{Hh} = \frac{1}{\mu_0 + \mu_c} \tag{15}$$

Let us define

$$\xi = \frac{\lambda_0[1-P_B]}{\lambda_0[1-P_B] + \lambda_h[1-P_{fh}]} \tag{16}$$

The termination rate μ_H can be obtained as

$$\overline{T}_H = \mu_H^{-1} = \xi\overline{T}_{Hi} + [1-\xi]\overline{T}_{Hh} \quad (17)$$

An interesting performance parameter to be investigated is the forced termination probability P_F. It is defined as the probability that a call that is originally accepted by the system, and may experience multiple successful handovers, is ultimately interrupted during its progress due to handover failure. The value of P_F can be obtained as [2]

$$P_F = \frac{P_{fh}P_i}{1-P_h(1-P_{fh})} \quad (18)$$

On the other hand, the probability P_{nc} that a call is not completed either by blocking (as a new call attempt) or forced termination (as a handover call) is given by

$$P_{nc} = P_B + (1-P_B)P_F = P_B + \frac{P_{fh}P_i(1-P_B)}{1-P_h(1-P_{fh})} \quad (19)$$

b. Guard channels Scheme

A specific number of channels N_h out of the available N channels is reserved exclusively for handover requests in this algorithm. If a new call is originated while there are $N_c = N - N_h$ channels being busy, the access of the attempted call is denied. On the other hand, handover requests will be served as long as there is at least one free channel. The state transition diagram that describes the system performance is shown in Fig. 3. Handover arrivals will only be blocked if the number of busy channels in the target microcell is equal to N. The steady-state probability P_j is given by

$$P_j = \begin{cases} \dfrac{(\lambda_o+\lambda_h)^j}{\mu_H{}^j j!}P_0 & 0 \le j \le N_c \\ \dfrac{(\lambda_o+\lambda_h)^{N_c}\lambda_h{}^{j-N_c}}{\mu_H{}^j j!}P_0 & N_c < j \le N \end{cases} \quad (20)$$

where P_0 is given by

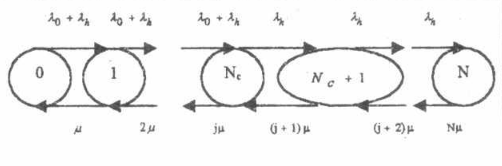

Fig. 3 State transition diagram for a handover priority scheme.

$$P_0^{-1} = \sum_{i=0}^{N_c} \frac{(\lambda_o + \lambda_h)^i}{\mu_H{}^i i!} + \sum_{i=N_c+1}^{N} \frac{(\lambda_o + \lambda_h)^{N_c} \lambda_h{}^{i-N_c}}{\mu_H{}^i i!} \quad (21)$$

The blocking probability P_B of an attempted call is given by

$$P_B = \sum_{j=N_c}^{N} P_j \quad (22)$$

and the handover failure probability P_{fh} is given by

$$P_{fh} = P_N \quad (23)$$

The probabilities P_F and P_{nc} are still given by Equations. 18 and 19, respectively when substituting the new expressions for P_B and P_{fh}.

4. OVERLAPPING SCENARIO

The structure of highway microcellular system with overlapping coverage between adjacent cells is shown in Fig. 4. The *BSs* are placed close to each other and extend their coverage beyond its predefined areas in order to produce reasonable overlapping regions. It is through these areas, that teletraffic demand can be directed away from heavily loaded *BSs* [4]. The distance from the center of a microcell to its border is L/2, and the length of the overlapping zone is *w*.

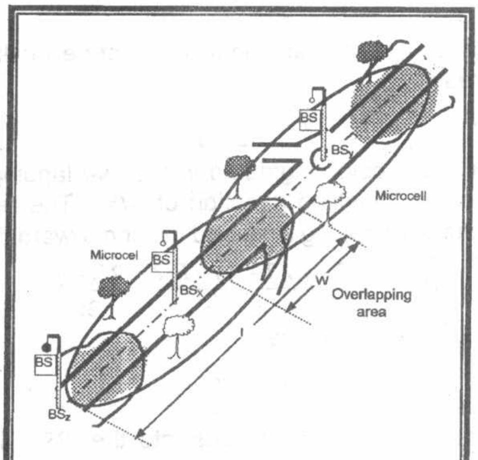

Fig. 4: Highway microcells with overlapping areas between adjacent microcells.

The coverage area of a microcell, as shown in Fig. 4, entails one non-overlapping area and two overlapping areas with other neighboring microcells. Let ζ represent the ratio of the non-overlapping area to the overlapping area. The new call rate originated in the non-overlapping area is

$$\lambda_{non} = \left(\frac{\zeta}{1+\zeta}\right)\lambda_o P_{BS_x} \quad (24)$$

where P_{BS_x} is the probability that a MS in the non-overlapping area has an adequate signal strength to the current microcell of base station x, i.e., BS_x. The new call rate, λ_1, originated in one of the two overlapping areas and directed to BS_x is given by

$$\lambda_1 = \lambda_o\left(\frac{1}{1+\zeta}\right)\frac{1}{2}[P_{BS_{xx}} + P_{BS_{xy}}P_{BS_{x>y}} + P_{BS_{xy}}P_{BS_{y>x}}P_{B2}] \quad (25)$$

where P_{B_2} is the probability that a new call in the overlapping area that is directed to BS_y is blocked, $P_{BS_{xx}}$ is the probability that a MS in the overlapping area has an adequate signal strength to BS_x only, $P_{BS_{x>y}}$ is the probability that a MS in the overlapping area receives a signal from BS_x that is greater than that received from BS_y, and $P_{BS_{y>x}}$ is the probability that a MS in the overlapping area receives a signal from BS_y that is greater than that received from BS_x. The total new call rate λ_{tot}, at P_{BS_x} is due to those calls initiated in the non-overlapping area in addition to those calls directed to the BS_x from the two overlapping areas, i.e.,

$$\lambda_{tot} = \lambda_{non} + \lambda_{over} = \lambda_{non} + 2\lambda_1 \quad (26)$$

Calls will depart from the microcell at the end of its coverage area i.e., at a distance L/2 from BS_x. Therefore, the average residing time of new calls originated in the non-overlapping area by an MS travelling with an average speed *v* is given by

$$\overline{T}_1 = \frac{1}{\mu_1} = \frac{L-2w}{2v} \quad (27)$$

Consequently, the average channel holding time $\overline{T}_{Hn1}$ of new calls being originated in the non-overlapping area is

$$\overline{T}_{Hn1} = \frac{1}{\mu_1 + \mu_c} \quad (28)$$

On the other hand, for those calls originated in the overlapping area, we have two conditions according to the travelling direction of MSs. The residing time for MSs who initiated a call in one overlapping area and moving toward the BS_x is

$$\overline{T}_{2r} = \frac{w/2 + (L/2 - w) + L/2}{v} = \frac{2L - w}{2v} \quad (29)$$

while for a MS moving away from BS_x is

$$\overline{T}_{2l} = \frac{w}{2v} \quad (30)$$

Let β denote the fraction of MSs that moves into the BS_x, the average value of residing time of those calls originated in the overlapping area is

$$\overline{T}_2 = \beta\overline{T}_{2r} + (1-\beta)\overline{T}_{2l} \quad (31)$$

and their average channel holding time is

$$\overline{T}_{Hn2} = \frac{1}{\mu_2 + \mu_c} \tag{32}$$

The probabilities that a new call originated in the non-overlapping and overlapping areas may need handover to the next microcell are, respectively; given by

$$P_{i1} = \frac{\mu_1}{\mu_1 + \mu_c}$$
$$P_{i2} = \frac{\mu_2}{\mu_2 + \mu_c} \tag{33}$$

The residing time of a handover call is given by

$$\overline{T}_h = \frac{1}{\mu_h} = \frac{L - w}{v} \tag{34}$$

The average channel holding time of handover calls at BS_x is

$$\overline{T}_{Hh} = \frac{1}{\mu_h + \mu_c} \tag{35}$$

The probability that a handed over call will need more handover is given by

$$P_h = \frac{\mu_h}{\mu_h + \mu_c} \tag{36}$$

Let P_{B1} denote the blocking probability of new calls in the non-overlapping area, while P_{B2} as previously defined, represents the blocking rate of new calls in the overlapping area. The handover call rate requested from BS_x is given by

$$\lambda_h = \frac{\lambda_{non}(1 - P_{B1})P_{i1} + \lambda_{over}(1 - P_{B2})P_{i2}}{1 - (1 - P_{fh})P_h} \tag{37}$$

The average channel holding time $\overline{T}_H$ of all calls being handled by BS_x is the weighted average of channel holding times of all calls. The value of $\overline{T}_H$ can be obtained as

$$\overline{T}_H = \frac{1}{\mu_H} = \left[\frac{1}{\lambda_{non}(1-P_{B1})+\lambda_{over}(1-P_{B2})+\lambda_h(1-P_{fh})}\right] \cdot \left[\frac{\lambda_{non}(1-P_{B1})}{\mu_1+\mu_c}+\frac{\lambda_{over}(1-P_{B2})}{\mu_2+\mu_c}+\frac{\lambda_h(1-P_{fh})}{\mu_h+\mu_c}\right] \tag{38}$$

The state transition equations that describes BS_x at statistical equilibrium can be given by

$$P_j = \begin{cases} \frac{1}{j!}\left[\frac{\lambda_{non}+\lambda_{over}+\lambda_h}{\mu_H}\right]^j P_0 & 0 \le j \le N_c \\ \frac{1}{j!}\left[\frac{\lambda_{non}+\lambda_{over}+\lambda_h}{\mu_H}\right]^{N_c}\left(\frac{\lambda_h}{\mu_H}\right)^{j-N_c} P_0 & N_c < j \le N \end{cases} \tag{39}$$

and the idle state P_0 is obtained by setting $\sum_{j=0}^{N} P_j = 1$.

Performance parameters

a. Blocking probability of new calls

New calls originated in the non-overlapping area are blocked due to either no signal strength above threshold is received, i.e., $(1-P_{BS_x})$, or the signal strength is adequate but no channel is available, i.e., $(P_{BS_x}P_{j\geq N_c})$, where $P_{j\geq N_c}$ is the probability that the number of busy channels at BS_x $j\geq N_c$. We have

$$P_{j\geq N_c} = \sum_{j=N_c}^{N} \frac{(\lambda_{non}+\lambda_{over}+\lambda_h)^{N_c}(\lambda_h)^{j-N_c}}{\mu_H{}^j j!}P_0 \tag{40}$$

Then the blocking probability of such calls is given by

$$P_{B1} = (1-P_{BSx}) + P_{BSx}P_{j\geq N_c} \tag{41}$$

On the other hand, new calls initiated in the overlapping area are blocked in either of the following conditions:

There is no adequate signal strength to any BS, i.e., $\{1-P_{BS\,xy}\}^2$.

There is adequate signal strength to both BSs, but the number of busy channels $j\geq N_c$ at each BS, i.e., $[P_{BS_{xy}} \times P_{j\geq N_c}]^2$.

The call has an adequate signal strength to one BS only but at that BS we have $j\geq N_c$, i.e., $P_{BS_{xx}}P_{j\geq N_c}$.

Therefore, the blocking probability of calls in the overlapping area is

$$P_{B2} = \{1-P_{BS_{xy}}\}^2 + [P_{BS\,xy} \times P_{j\geq N_c}]^2 + 2P_{BSxx}P_{j\geq N_c} \tag{42}$$

b. Handover failure probability

Unlike new calls, handover requests are privileged with channel reservation so that a handover attempt fails only in the following situations:

There is no adequate signal strength at the border of the microcell when and where handover is needed, i.e., $(1-P_{Border})$.

The call has adequate signal strength at the border but there are no free channels at the BS, i.e., $P_{Border}P_N$.

Consequently, the handover failure probability is given by

$$P_{fh} = (1-P_{Border}) + P_{Border}P_N\,.$$

c. Forced termination probability

The forced termination probability P_F and the non-completion probability P_{nc} for calls in overlapping area can be calculated using the following expression

$$\begin{aligned} P_F^{over} &\equiv \sum_{k=0}^{\infty} P_{fh}P_h{}^k(1-P_{fh})^k \\ &= \frac{P_{fh}P_{i2}}{1-P_h(1-P_{fh})} \end{aligned} \tag{43}$$

$$P_{nc}^{over} \equiv P_{B2} + (1-P_{B2})P_F^{over} = P_{B2} + \frac{P_{fh}P_{i2}(1-P_{B2})}{1-P_h(1-P_{fh})} \qquad (44)$$

d. The carried traffic and channel utilization

The carried traffic by a microcell is defined as the average number of busy channels. Mathematically, the carried traffic is given by

$$A_c = \sum_{j=0}^{N} jP_j = [\lambda_{non}(1-P_{B1}) + \lambda_{over}(1-P_{B2}) + \lambda_h(1-P_{fh})] \times \overline{T}_H \qquad (45)$$

The channel utilization gives an indication of the proportion of time during which the channel being busy. It is defined as the average traffic carried by a channel, i.e.,

$$\rho = \frac{A_c}{N} \quad \text{Erlang/channel.} \qquad (46)$$

e. Network capacity

The network capacity, measured in terms of the number of served users during the busy hour (BH) by the microcell, is given by

$$Capacity = \frac{A_c}{T_H} \times BH \quad \text{users/microcell/BH} \qquad (47)$$

f. Spectral efficiency

The spectral efficiency is one of the most important parameters for gauging the teletraffic performance of the network because of the strictly limited allocated spectrum. Let S define the microcell area and B_c kHz represent the average channel bandwidth. The spectral efficiency, η_s , can be defined as

$$\eta_s = \frac{\rho}{B_c \times S \times M} \quad \text{Erlang/kHz/}km^2 \qquad (48)$$

5. SIMULATION MODEL

A one dimensional teletraffic simulation model for the highway microcellular mobile radio system is developed. The microcellular cluster is composed of highway segments where each segment is a microcell. We consider two scenarios; namely, the non-overlapping and overlapping configurations of the highway microcells. The handover priority and non-priority conditions are considered. The microcell length, L, was set to 2000 m, the number of channels, N , at each BS was 8 while zero or two out of these channels were reserved for handovers. Sufficient time was allowed for the system to attain a steady state. Various performance measures were computed for the system as a whole.

The average call duration is set to be 120 sec. For a microcell of 2000m length and 4 lanes, the number of mobile stations roaming in a microcell is 100 if the average headway distance is 40m. For a 18 $dB\ CIR$ to be satisfied, a cluster size of 2 micrcells can be realized.

6. RESULTS AND DISCUSSION

Numerical results will be presented for the non-overlapping scenario first. Figs. 5-9 describes the network performance for that scheme. Fig. 5 displays the fraction of new call attempts that were blocked, P_B, as a function of the average new call rate attempted per microcell, with N_h=0 and 2. In the handover priority scheme where N_h=2, the fraction of new call being blocked was slightly increased as less channels were available for new calls. By contrast, the fraction of handover requests being blocked, i.e. the probability of handover failure, P_{fh}, significantly decreased when handover priority with N_h=2 was introduced specially at higher traffic load. This is evident in Fig.6. Fig. 7 displays the fraction of successful new call that were prematurely terminated in the handover process namely, P_F, as a function of the average new call rate per microcell. Fig. 8 displays the fraction of non completed new calls and handover calls namely, P_{nc}, as a function of the average new call rate per microcell. Fig. 9 shows how the channel utilization varies as a function of the average new call rate per microcell. Notice that the channel utilization was higher for N_h=0 because no channels were reserved for handover.

Figs. 10-16 show The blocking probabilities of new calls and handover calls as well as premature termination probability and non-completion probability for the overlapping scheme in comparison with that of the non-overlapping one. Fig. 17 shows the channel utilization,. Our numerical results showed that exploiting the overlapping scheme resulted in a reduction in P_B, P_{fh}, P_F, and P_{nc}. Also, it improves the network parameters as the channel utilization.

7. CONCLUSION

The overlapping coverage between adjacent microcells was exploited in order to improve the teletraffic performance of mobile radio networks. A teletraffic model is established for two scenarios when overlapping is and is not considered. A computer simulation is carried out in order to evaluate the accuracy of the analytical model. Fortunately, good agreement is achieved. The results presented in this paper may assist network planners to efficiently design their systems based on sound concepts.

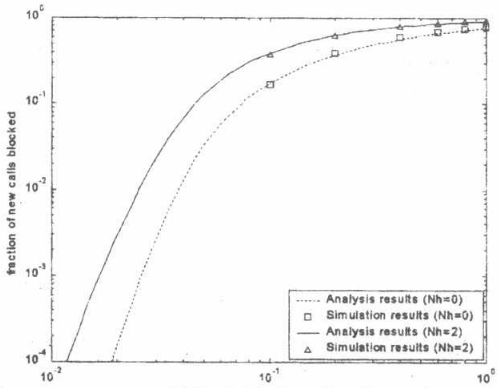

Fig. 5: Variation of the fraction of new calls that being blocked as a function of the average new call rate per microcell for the non-overlapping scheme.

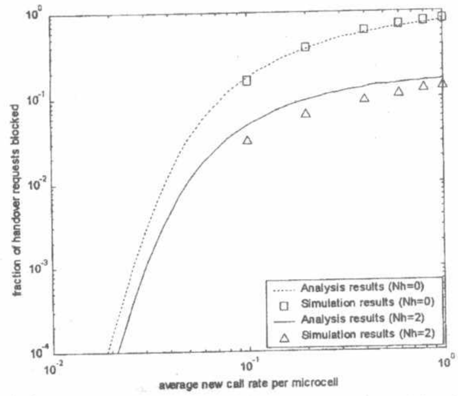

Fig. 6: Variation of the fraction of handover calls that being blocked as a function of the average new call rate per microcell for the non-overlapping scheme.

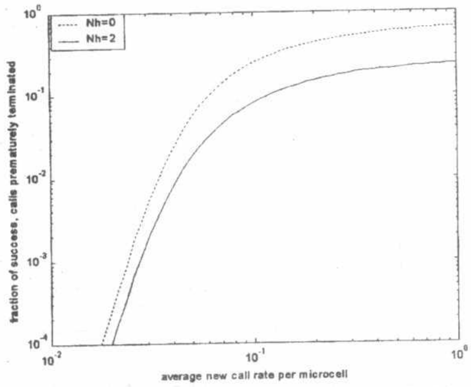

Fig. 7: Variation of the fraction of successful new calls forced terminated during handover as a function of the average new call rate per microcell for non-overlapping scheme.

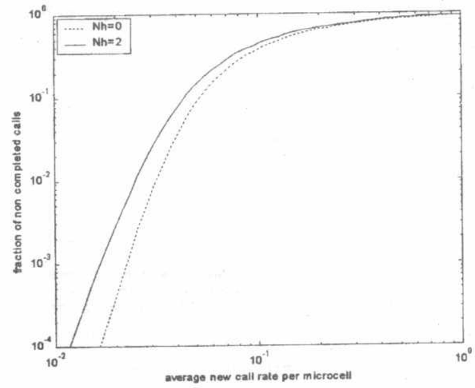

Fig. 8: Variation of the fraction of calls that is not completed as a function of the average new call rate per microcell for the non-overlapping scheme.

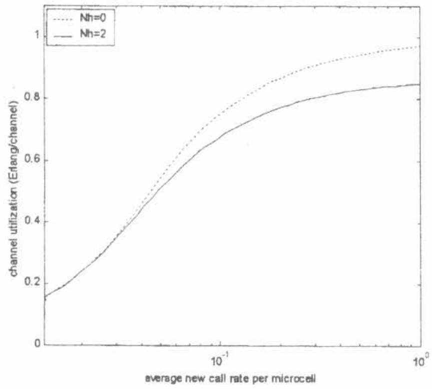

Fig. 9: Variation of the channel utilization as a function of the average new call rate per microcell for the non-overlapping scheme.

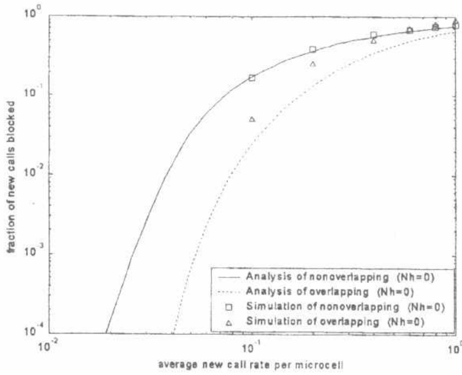

Fig. 10: Variation of the fraction of new calls that being blocked as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

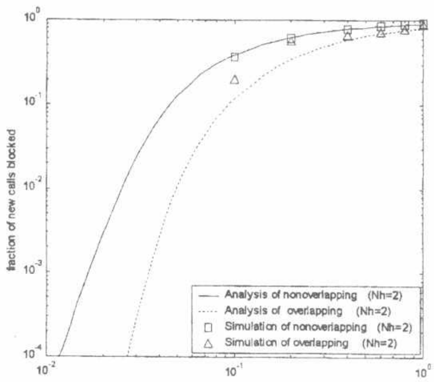

Fig. 11: Variation of the fraction of new calls that being blocked as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

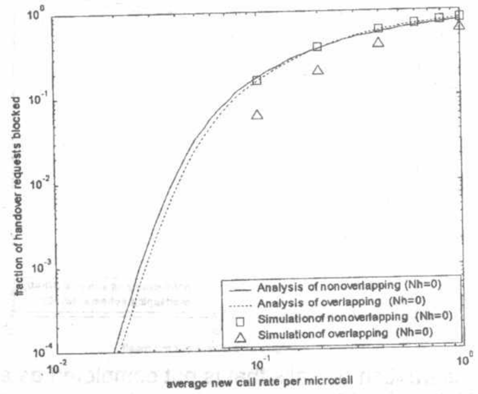

Fig. 12: Variation of the fraction of handover calls that being blocked as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

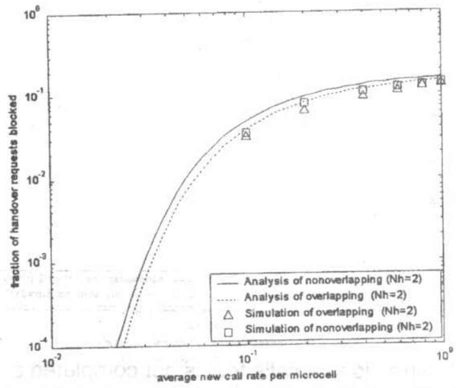

Fig. 13: Variation of the fraction of handover calls that being blocked as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

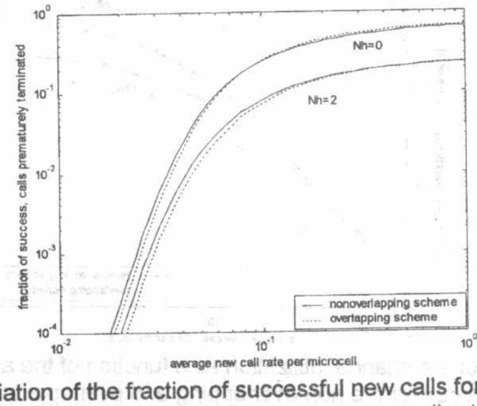

Fig. 14: Variation of the fraction of successful new calls forced terminated during handover as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

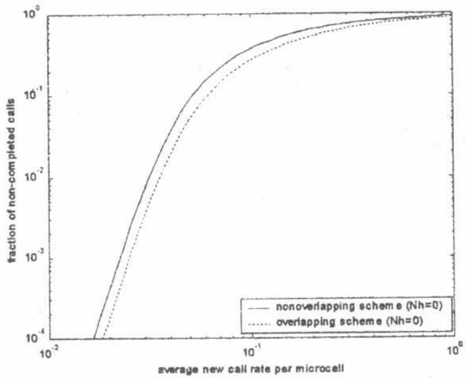

Fig. 15: Variation of the fraction of calls that is not completed as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

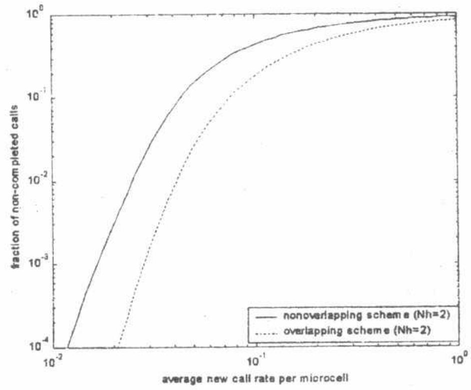

Fig. 16: Variation of the fraction of calls that is not completed as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

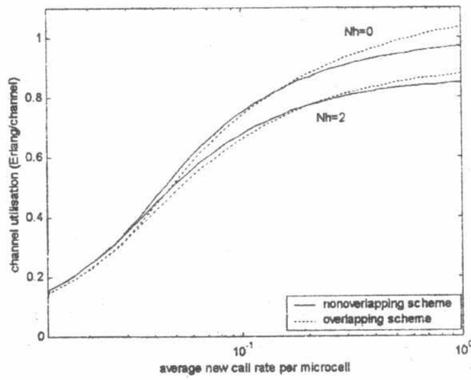

Fig. 17: Variation of the channel utilization as a function of the average new call rate per microcell for the non-overlapping and overlapping schemes.

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