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A NEW DYNAMIC INTEGRATED SATELLITE /TERRESTRIAL MODELS FOR HANDOFF PRIORITIZATION IN HIGHWAYS WIRELESS MOBILE SYSTEMS

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In Highways wireless mobile networks, in order to ensure that ongoing calls are not dropped while the users roam among cells, handoff calls may be admitted with a higher priority as compared to new calls. One way to improve system performance of cellular networks is to use efficient handoff models when users move between cells. In this paper, Non-priority Model (NPM) and Guard Channel Model (GCM) are presented and evaluated to improve the utilization of wireless network resources. However, Simulation results show that the required Grade of Service (GoS) of handoff calls is guaranteed at low and medium traffic loads only regardless that improvement of handoff calls blocking probability is at the expense of blocking probability of new calls. So, we reveal how to overlay highway microcells by macrocells to improve many teletraffic parameters. The new proposed models are called integrated Satellite/Terrestrial (Sat/Terr) models. Teletraffic performance of the proposed models is investigated using simulation technique. Simulation results are accumulated to evaluate the system performance.

KEYWORDS: wireless mobile networks, handoff, simulation, guard channel model, non-priority model, integrated satellite/terrestrial models.

1. INTRODUCTION

Today, the number of cellular subscribers has grown to many hundreds of million and, in some countries, around 50% of the population use mobile communications [1]. This rapid growth, increases market penetration and rising subscriber expectations define the driving force to which the cellular network must respond [2].

In cellular systems, service area is divided into small cells. Cells are defined by a circular region that ranges from few hundred meters to a few kilometers in radius. An improvement property of the network is that a user would change its access point several times. This fact causes technical problems in which fair bandwidth sharing between handoff calls and new calls is required [3]. As mobile user moves from one cell to another, its ongoing call is handed-off from the old cell to a new cell. This requires that the new cell accommodate the call. Since dropping a handoff call is more annoying than blocking a new call from user's perspective, handoff calls should be given higher priority than new calls [4]. It has been shown that a method by which handoff is achieved has a significant impact on the network's performance [5].

The handoff prioritization in wireless cellular systems were studied in [6, 7, 8]. There are two popular strategies for prioritizing handoff calls: the Guard Channel strategy and the handoff Queuing strategy. The Guard Channel strategy decreases the handoff dropping probability by reserving a fixed number of channels exclusively for handoff calls. New calls will be blocked if the number of the idle channels is equal to or less than the number of guard channels, while handoff calls can be served until all the channels are occupied. Handoff Queuing strategy is a way of delaying handoff calls due to the temporary unavailability of channels [6].

To cope with the rapidly increasing demand for mobile and personal communications, hierarchical cellular systems, which have multiple-layers of cellular cells, are being deployed in dense urban areas.

The third-generation mobile system encompasses complementary satellite and terrestrial components. In the integrated Sat/Terr system, the advantages of satellites and cellular systems can be combined. Satellites can provide wide area coverage, completion of coverage, immediate service, and additional capacity (by handling overflow traffic). Future Public Land Mobile Telecommunication Systems (FPLMTS) will provide a personal telephone system that enables a person with a handheld terminal to reach anywhere in the world. The FPLMTS will include Low Earth Orbit (LEO) or Geostationary Earth Orbit (GEO) satellites as well as terrestrial cellular systems.

2. DESCRIPTION OF THE WORK

In this paper, Non-priority Model (NPM) and Guard Channel Model (GCM) are presented and evaluated to improve the utilization of wireless network resources. The grade of service for each call type is accumulated and compared with each other in two models, with and without priority, to investigate the system performance in order to analyze the negative effect imposed by handoff protection on the new user admission. As well as we present how to overlay highway microcells by macrocells to improve many teletraffic parameters. The new proposed models are called integrated Satellite/Terrestrial (Sat/Terr) models. These models are proposed to reallocate channels in a hierarchical two-layers cellular network whereas a microcellular cluster having contiguous microcells is overlaid by a macrocell. These proposed models based on the integration of satellite system with cellular network in order to reduce the dropping of handoff calls and to make the blocking of new calls as low as possible.

When macrocell handles the handoff requests only, grade of service for each call type is accumulated and compared with each other, using dual services with and without priority algorithms. When macrocell handles both new and handoff calls, three algorithms, (dual services with priority, with priority plus reassignment and without priority) are proposed. The channels reallocation in a hierarchical two-layers cellular network depends on users speeds. Fast mobile users should be connected to the overlaid macrocellular system to reduce their handoff rate while slow moving users should connect to microcells to arrange high capacity communications. Teletraffic performance of the proposed models is investigated using a simulation technique.

3. SIMULATION MODEL

The performance of the proposed models are investigated using simulation techniques. The simulation is executed using Visual Basic programming language, with simulation time which is taken to be 10 hours with updating simulation interval of 3 seconds. The flow chart given in Fig. 1 states the sequence of simulation routines which is followed to accumulate the required grade of service for each user and call type in the models.

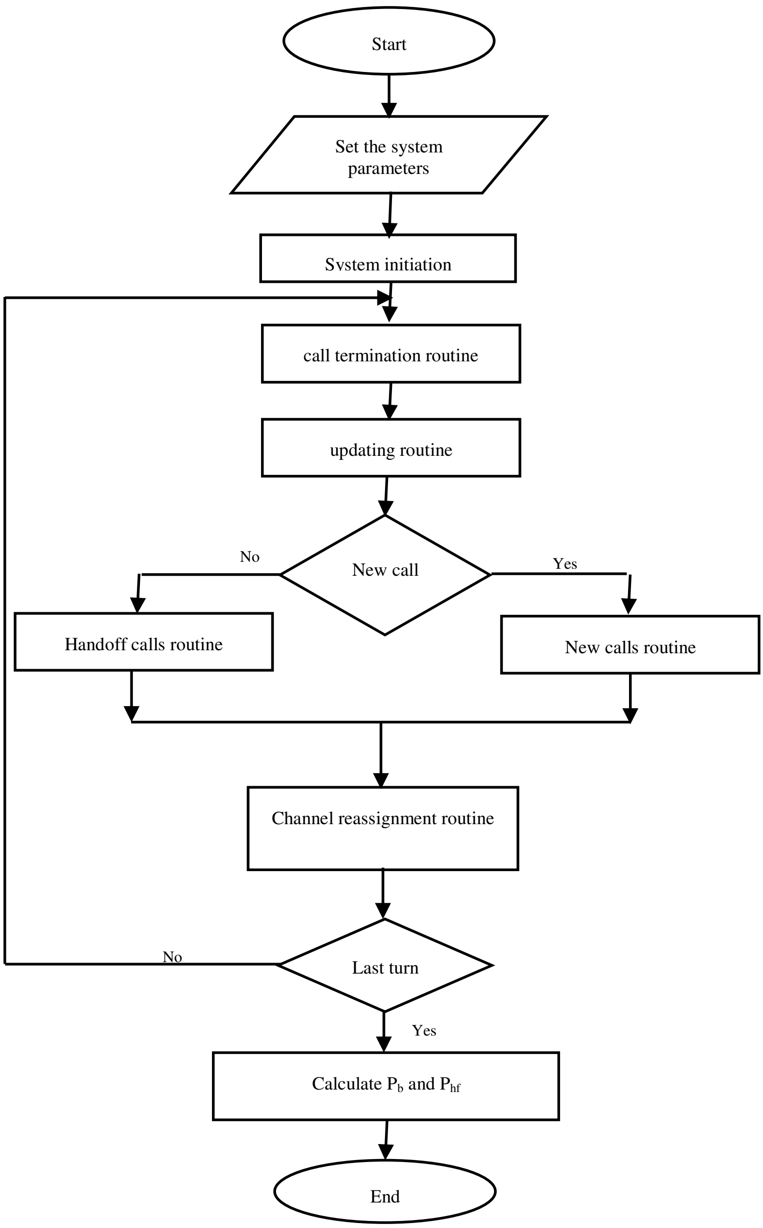

Fig. 1 Main routine sequence for achieving the simulation of the proposed models.

3.1 The system model

For simplicity, a one-dimensional array of cells is considered in these mentioned models. In order to avoid unwanted boundary effects like mobile leaving the system, it is assumed that microcells are folded. The microcellular structure is composed of concatenated segments of highway, each is a microcell. As a result, overlapping occur between adjacent cells. The Time-Division Multiple Access (TDMA) scheme consists of a number of carriers spaced 200 KHz a part. In every microcell the transmission on the uplink from Mobile Station(MS) to Base Station(BS) and the downlink (from BS to MS) occur on two different bands. Each one of these bands comprising several carriers such that an uplink carrier is uniquely associated with a downlink carrier. For simplicity, TDMA frame comprising eight slots per each microcell is assumed with possibility that these frames are organized in a more complex structure called hyperframe in which call is assigned to a defined time slot. The total number of users per cell M, is calculated as follows

$$M = 2nL/V \quad \text{Users} \ldots\ldots\ldots\ldots (1)$$

where, n is the number of lanes per direction of the highway, it is assumed n = 2, L is the microcell length and V is the effective length of the vehicle, i.e. the vehicle's space is 72 m that corresponds to the average speed on highway which is assumed to be uniformly distributed with an average 90 km/h. So, the total number of active users per cell is expected to be 100 users [7].

The teletraffic performance of the integrated Sat/Terr models are analyzed. Priority is given to handoff calls in microcells level over new calls by reserving 2 channels. The macrocell is assumed to overlay 10 microcells i.e., 20 km length of the highway. The TDMA frame is assumed to be 8 time slots. When macrocell handles the handoff requests only, the eight channels are dedicated for handoff calls. When macrocell handles both new and handoff calls, two of the eight channels are dedicated for handoff calls from the terrestrial layer while 6 are kept to serve satellite only users. To control the overflowed traffic to the macrocell a reassignment strategy is performed i.e., rerouting calls to microcells when a free channels is available.

3.2 The traffic model

In simulation models, homogeneous calls are considered, and it is assumed that each mobile station needs only one channel per call.

The new call arrival process is modeled as an independent Poisson process with an average arrival rate λ calls/sec. For each microcell, a quasi-random number for representing the next call arrival period is calculated by, [8]

$$T_{arr} = -(1/\lambda) \times \log(rnd) \quad \text{sec} \ldots\ldots\ldots\ldots (2)$$

where, rnd is a uniformly distributed random number between 0 and 1.

The new call holding time follows an independent exponential random variable with mean 1/μ = 120 sec [15]

$$T_c = -(\text{mean call duration}) \times \log(rnd) \quad \text{sec} \ldots\ldots\ldots\ldots (3)$$

3.3 The mobility model

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 the handoff increases. This is usual in the microcellular systems. For cases of high speeds, the handover handling is more probable to occur and vice versa.

The drivers make calls while they are in motion using transceivers having a handover mode of operation. A vehicular MS traveling along the highway with a call in progress requests a channel at the BS in the next microcell in order to continue its communication. Should a free channel be available, it is assigned to the handover call. Free flowing traffic of a user speed with a truncated Gaussian speed distribution is assumed with mean value of 90 km/h and standard deviation of 30 km/h as:

$$\text{User Speed} = \text{Gauss} \times (300/36) + (900/36) \quad \text{m/sec} \qquad (4)$$

where, Gauss is Gaussian distributed random number between -1 and 1.
A random location is given by [7]

$$\text{User Position} = \text{rnd} \times \text{L} \quad \text{m} \qquad (5)$$

where, L is microcell length.
The blocking probability of New calls (P_b) can be calculated as following,

$$P_b = \frac{[\text{Total blocked calls}]}{[\text{Total requested calls}]} \qquad (6)$$

while the probability of handoffs failure (P_{hf}) is calculated as,

$$P_{hf} = \frac{[\text{Total calls forced to terminate}]}{[\text{Total handoff requests}]} \qquad (7)$$

4. GCM AND NPM MODELS

All traffic loads are continuously varying especially in the wireless mobile networks. Since the wireless bandwidth is scarce and therefore precious due to the inherent bandwidth limitation in wireless cellular networks, channel allocation schemes are essential. The main objective of GCM is to preserve handoff calls blocking probability at the predetermined value and at the same time hold new calls blocking probability as near as possible to an accepted value. Priority is given to handoff calls over new calls by reserving 2 channels for handoff calls. It is assumed that a cell i consists of ordinary channels which carry both types of calls and guard channels which carry only the handoff calls. Any new call attempts are blocked if the ordinary channels are occupied, while handoff call attempts are assigned to the guard channels. Handoff calls attempts are dropped only when all channels are occupied.

5. INTEGRATED SAT/TERR MODELS

In the integrated Sat/Terr system, the advantages of satellites and cellular systems can be combined. Satellites can provide a wide area coverage and additional capacity by handling overflow traffic. A cellular system can provide a high-capacity economical system. When MS is inside the coverage area of the terrestrial cellular system, the BS will act as a relay station and provide a link between the MS and the satellite. When MS is outside the terrestrial system coverage area, it will have a direct communication link with the satellite. The two proposed scenarios in the integrated system are described below.

In the first scenario, the macrocell severs the handoff requests only. In this case, there are two algorithms: in the first one no priority is given to handoffs in the microcells, while in the second one some microcells channels are reserved to admit handoffs only as indicated in Fig. 2. The strategy of this contribution tends to prioritize handoffs.

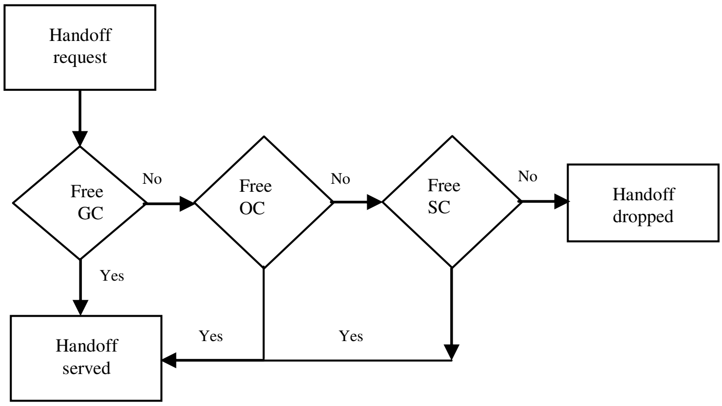

Fig. 2 Handoff routine sequence of the proposed integrated Sat/Terr model (Macrocell handles the handoffs only).

In the second scenario, the macrocell handles both new and handoff calls. There are three proposed algorithms in this case, dual services with priority, with priority plus reassignment and without priority reassignment as shown in Fig. 3.

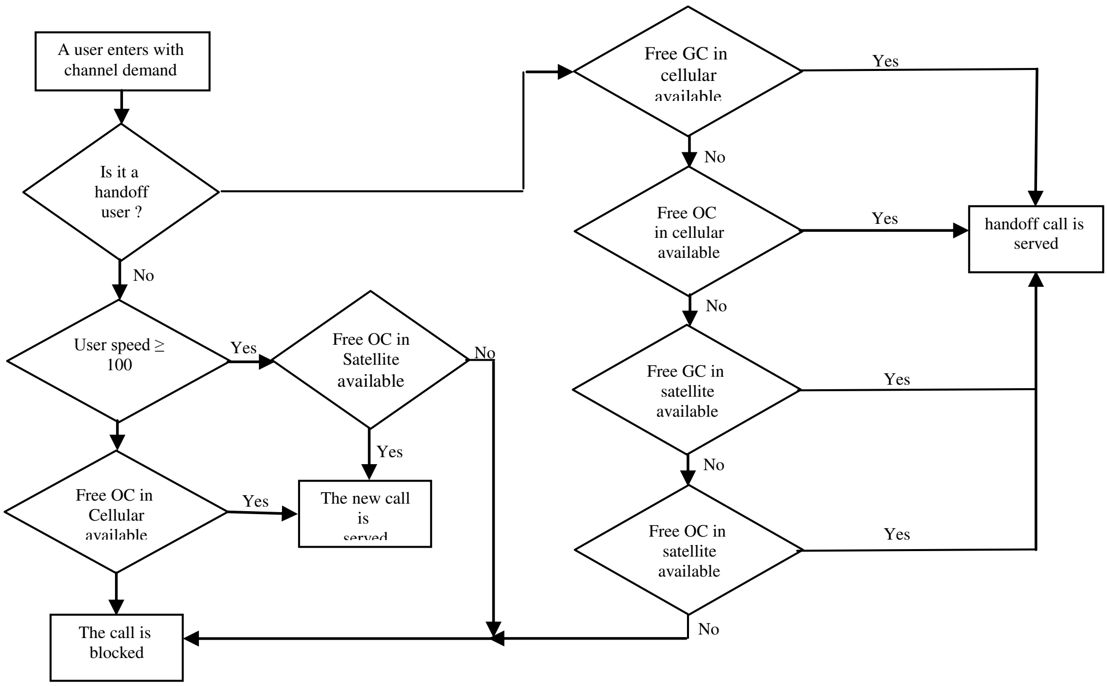

Fig. 3 Handoff routine sequence of the proposed integrated sat/terr model (Macrocell handles both new and handoff calls).

As shown two levels are considered, the lower level corresponding to the terrestrial segment and the upper level corresponding to the space segment of the integrated system. For simplicity, a single terrestrial microcell, and spot beam cell is illustrated in Fig. 4.

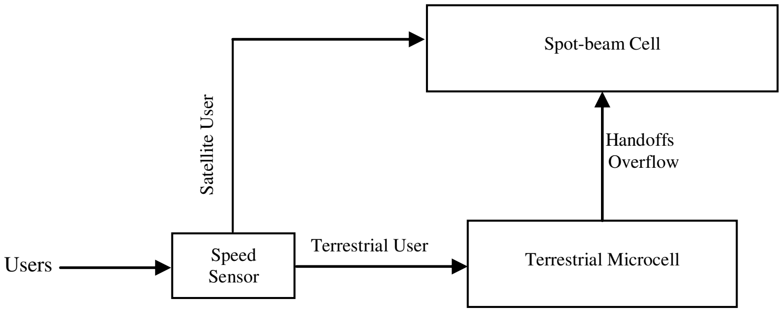

Fig. 4 Block diagram of proposed integrated model.

Users of the proposed integrated network are classified into three different categories:

- Terrestrial-only users.
- Satellite-only users.
- Dual-mode users.

Terrestrial-only users are those users that initiate and terminate their calls with the terrestrial microcell level, while satellite-only users are those who initiate and terminate their calls within the spot-beam cell layer. We differentiate between the two users types by using the speed sensitive technique such that users with high speed are directed towards the spot-beam cell level with its large size, while those with lower speed are directed to terrestrial microcellular level to minimize the required number of handoff process per cell and reduce the probability of handoff failure or forced termination in consequence.

For Dual-mode subscribers, call attempts are first directed to the lower level of a system hierarchy that can provide radio link with satisfactory quality if any is available, otherwise they are overflowed to the higher spot-beam cell layer for the same purpose. Furthermore, any call being served by a satellite will not be allowed to move down the hierarchy. So, satellite spot-beam cells are considered as umbrella cells used for absorbing the traffic peaks caused by rapid and unpredictable traffic variations in the cellular network cells.

6 PERFORMANCE EVALUATION FOR GCM AND NPM MODELS

In order to evaluate the proposed GCM and NPM, various values of new call blocking and handoff call dropping probabilities are estimated under the same assumptions and compared with each other.

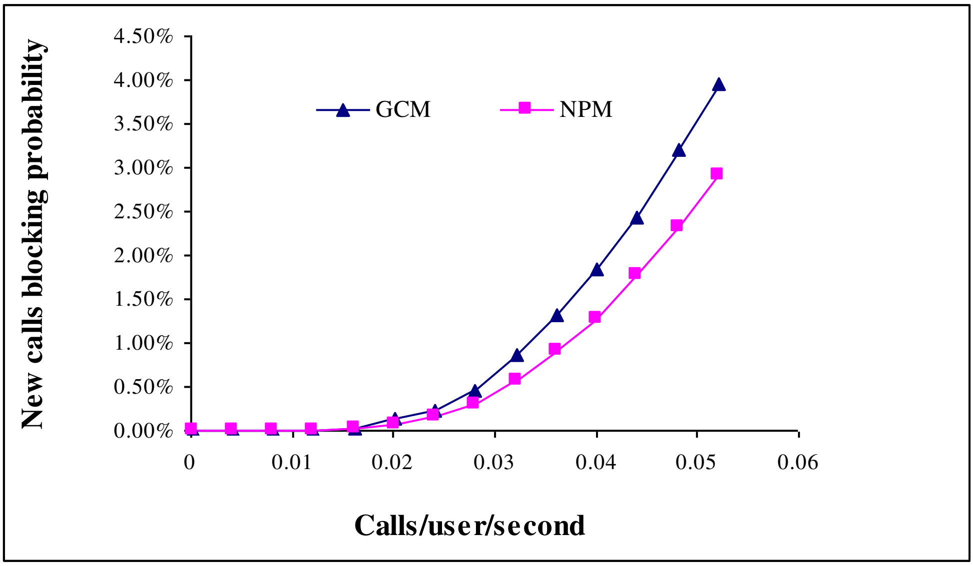

Fig. 5 Effect of service type on the blocking probability of a new call in NPM and GCM.

Figure 5 indicates the effect of the service type on the blocking probability of a new call. The effect of the type of service provided is clearly seen where the performance is better at NPM. The blocking probability of new calls increases at GCM more than that at NPM for the same value of λ. Hence, excluding 2 channels from 8 channels causes a bad effect on the new calls service all the six ordinary channels are busy so the call is blocked although 2 channels excluded for handling the handoff calls may still free.

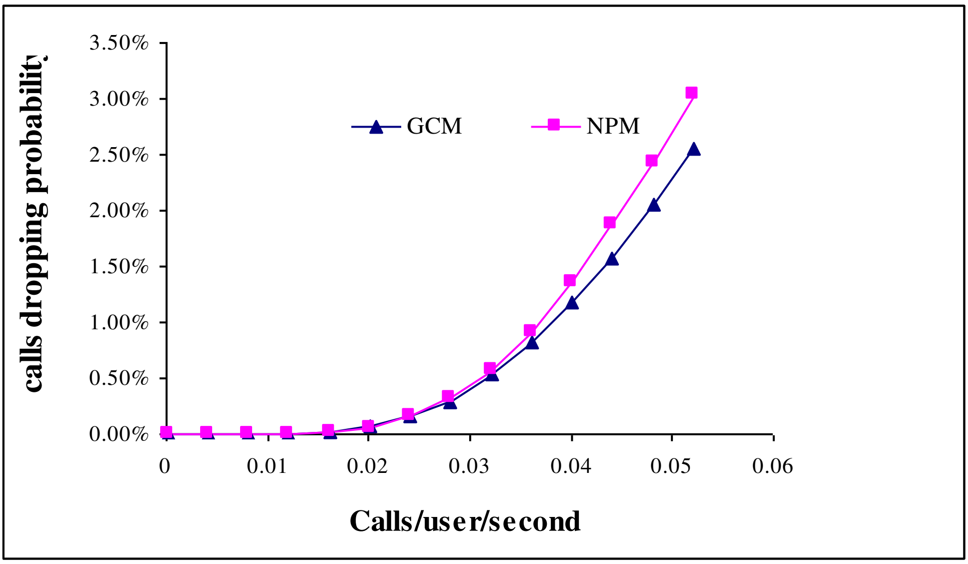

Fig. 6 Effect of service type on the probability of forcing calls to terminate in NPM and GCM.

Figure 6 shows the effect of service type on the probability of forcing calls to terminate in NPM and GCM . The performance is better at GCM. The probability of forced termination is decreased by reserving a number of channels exclusively for handoff attempts in each cell at GCM but it is increased at NPM at the same value of λ. Hence, excluding 2 channels from 8 channels has a good effect on the handoff calls.

To study the performance of the proposed GCM at certain values of λ. We take the handoffs failure probability (P_{hf}) for each cell and compare with the results obtained from NPM under the assumption. Three different cases are considered and illustrated in Figures 7, 8, and 9.

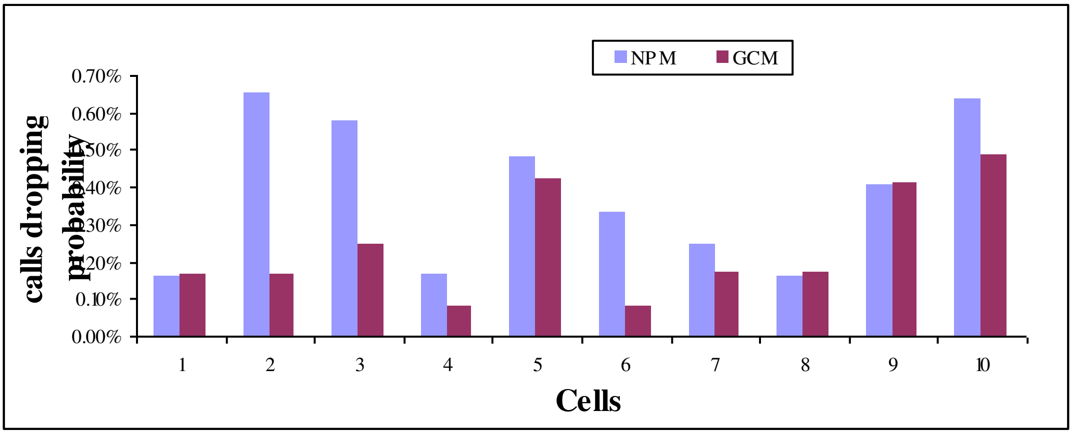

Fig. 7 The probability of forcing calls to terminate for each cell at λ = 0.0241.
Case (1): At λ = 0.0241 calls/user/sec & offered traffic = 2.892 Erlangs.

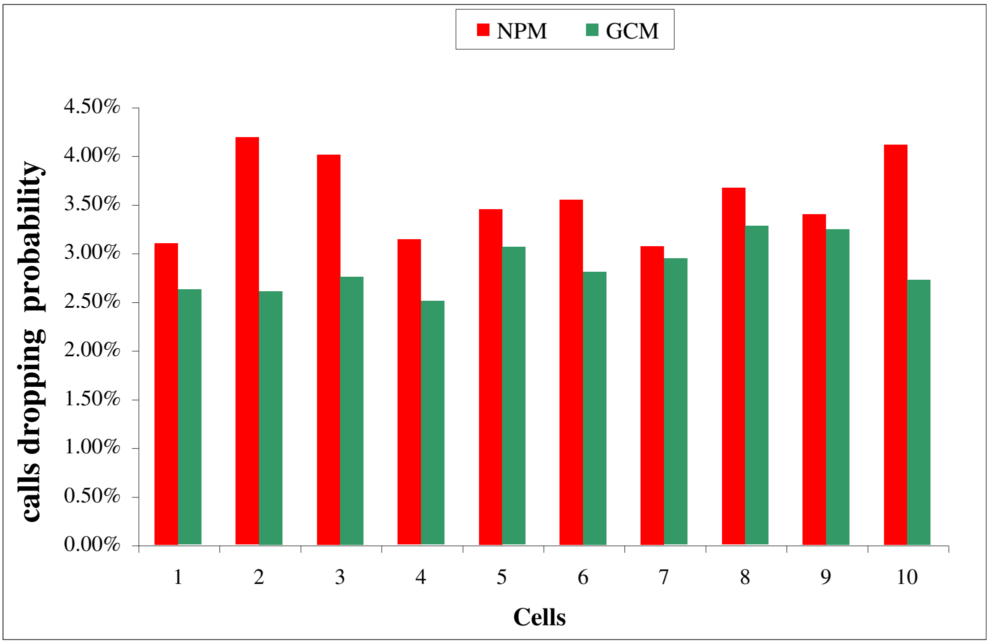

Fig. 8 The probability of forcing calls to terminate for each cell at λ = 0.0401.
Case (2): At λ = 0.0401 calls/user/sec & offered traffic = 4.812 Erlangs.

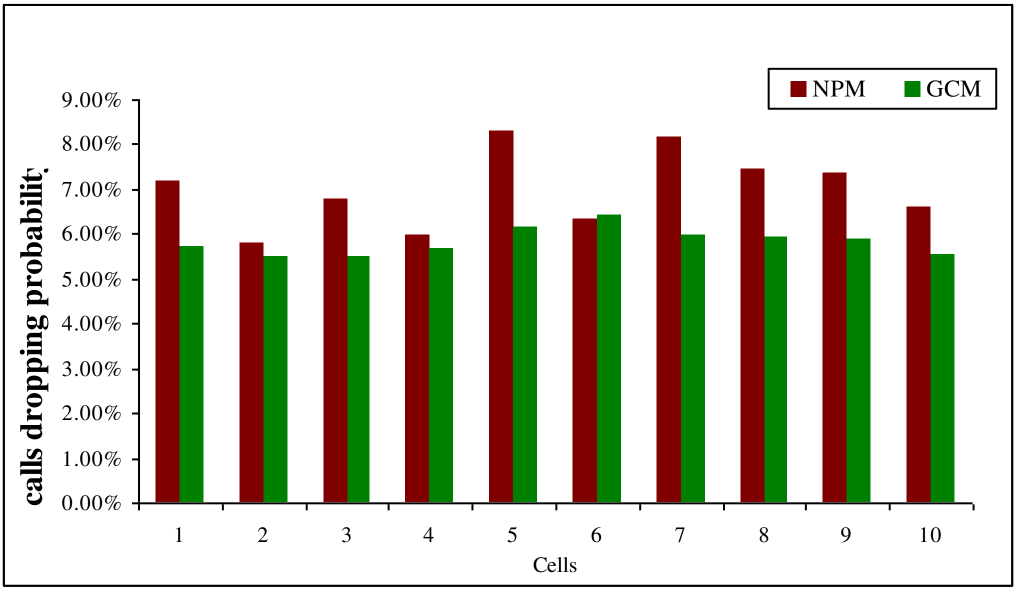

Fig. 9 The probability of forcing calls to terminate for each cell at λ = 0.0521.
Case (3): At λ = 0.0521 calls/user/sec & offered traffic = 6.252 Erlangs.

Figures 7 and 8 show that the performance is better at a terrestrial service with priority than that without priority at the low and medium traffic. The probability of forced termination is decreased at the terrestrial service with priority more than that at the terrestrial service without priority. Figure 9 indicates that the improvement is reduced to unacceptable limit due to the negative impact on the user admission capability. Therefore, it is concluded that GCM model can be effectively used in low and medium traffic cellular mobile systems but it is not efficient in high traffic cellular mobile systems.

7. CONCLUSIONS

In this paper, Non-Priority Model (NPM) is presented and evaluated. It is shown that the NPM is undesirable from the customer's satisfaction point of view. A guard Channel Model (GCM) is proposed for handoff prioritization. Extensive simulations are designed and implemented. The simulation results show that GCM model improves the handoffs dropping probability while maintaining an acceptable value of new calls blocking probability at low and medium traffic loads.

The integrated Sat/Terr model has been developed to study the impact of various bandwidth access control policies on the call level quality of service (QoS) guaranteed in a cellular network with mobile users. Precise simulation models to estimate call level QoS parameters such as, call blocking probability and call dropping probability are derived. The models have potential applications in network planning and bandwidth tuning of cellular networks. Some priority based bandwidth access control policies have also been proposed, and compared with conventional policies. Simulation results indicate that the priority based policies can achieve better throughput for higher priority services. As the cellular networks and services continue to evolve, and the traffic load fluctuates dynamically, reserving bandwidth exclusively and statically for each service may not be efficient from revenue generation perspectives. The priority based policies may, therefore, be attractive alternatives in these circumstances.

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موديل ديناميكي جديد لأولويات حجز المكالمات خلال شبكات اللاسلكي على الطرق السريعة

لضمان عدم فقدان المكالمات الصادرة (في شبكات اللاسلكي الخلوي على الطرق السريعة) تعطى المكالمات المنقولة أولوية بالمقارنة بالمكالمات الجديدة. من الطرق المتعارف عليها لتحسين أداء الشبكات الخلوية استعمال مخططات ذات كفاءة لنقل المكالمات أثناء تجول المستخدمين بين الخلايا. يقدم هذا البحث مخطط عدم إعطاء أولوية، كما نقترح مخططا ديناميكيا يسمى "نموذج حجز القنوات الدينامكي للقنوات في خلايا الشبكات الخلوية للطرق السريعة"، ويعمل هذا المخطط على تحسين الاستفادة من مصادر الشبكة اللاسلكية، ولكن توضح نتائج المحاكاة أن هذا المخطط يضمن المستوى المطلوب لخدمة المكالمات المنقولة عندما يكون مستوى الأحمال على الشبكة قليل أو متوسط فقط على الرغم من أن تحسين احتمالات فقد المكالمات المنقولة يكون على حساب احتمالات رفض المكالمات الجديدة. لذا يقدم هذا البحث أيضا "مخطط إدارة القنوات في نظام خلوي متكامل بين شبكة خلوية أرضية للطرق السريعة ونظم الأقمار الصناعية (Integrated Cellular/Satellite Systems)" وهو نظام متعدد الطبقات، وتوضح نتائج المحاكاة أن هذا المخطط المقترح يقلل احتمالات فقد المكالمات المنقولة و الجديدة.