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New Technique giving Priority to Emergency Calls in Wireless Cellular Security Networks

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*Abstract: - In t*his paper is presented a new technique that gives priority to Emergency Calls in Wireless Cellular Security Networks. The new technique uses a channel management scheme and it is based on a two-layer cellular architecture The lower layer of the proposed architecture is based on a microcellular solution, for absorbing the traffic loads of both the handoff and new calls of Emergency Calls (EC). The higher layer is based on a macro-cell umbrella solution, for absorbing the traffic load of the handoff and new calls of the Non Emergency Calls (NEC). The results show that using the optimum number of channels in each layer, the QoS of EC in a congested area where an extreme event was happened is optimized, having the minimum negative effect on the QoS of the NEC.

Key-Words: - Wireless communication, Security Networks, Channel Assignment Scheme

1 Introduction

Public Safety and Security organisations require the highest levels of reliability and availability in their communications. Wireless Cellular Security Networks networks provide communications in extreme situations that may cause other communications networks to fail. For example, thunderstorms or earthquakes often cause wide area or even nationwide blackouts in electricity production and distribution and restoring power may take days or even weeks. In such conditions, public services are typically blocked by heavy traffic or are totally out of operation. Wireless Cellular Security Networks systems are designed to ensure operations in these situations. All critical network elements are duplicated to ensure continuous operation. User and call priorities are designed to give priority to critical communication. Reliability is a key criterion in the design of Wireless Cellular Security Networks radios. These can be used in harsh environmental conditions and are much more rugged than cellular handsets.

The most serious problem that arises in these systems under extreme situations is that services are blocked. This happens because in the area the event happens many users are concentrating there.

A great effort has been spent in order to study the channel management schemes in order to minimize the involved blocking probability [2]. The handoff blocking probability is considered to be more important than the blocking probability of new calls because the call is already active and the QoS is more sensitive for the handoff calls.

The proposed technique will be compared with two models. The first adopts a traffic analysis for wireless cellular security network with non-prioritized handoff procedure. All channels are available to all calls (Erlang-B model) The second adopts a traffic analysis for cellular mobile networks with prioritized handoff procedure. By taking into account that C are the available channels in every microcell and the priority technique for handoff calls is realized by assigning guard channels (C_h) exclusively for handoff calls, the remaining ($C-C_h$) channels are shared both by new and handoff calls. The following assumptions, without affecting the results, are considered: a) the terminals are characterized as NEC or EC according to the emergency. b) Homogenous traffic, same capacity and same mean holding time T_h are considered in all microcells.

New and handoff calls of NEC are generated in the area of microcell according to a Poisson point process, with mean rates of Λ_R^{NEC}, Λ_{Rh}^{NEC} respectively, while new calls and handoff calls of EC are generated with mean rates of Λ_R^{EC}, Λ_{Rh}^{EC} per cell. The relative mobilities are defined as:

for NEC:

$$a_{NEC} = \frac{\Lambda_{Rh}^{NEC}}{\Lambda_{Rh}^{NEC} + \Lambda_R^{NEC}} \tag{1}$$

for EC:

$$a_{EC} = \frac{\Lambda_{Rh}^{EC}}{\Lambda_{Rh}^{EC} + \Lambda_R^{EC}} \tag{2}$$

also it is defined a coefficient for NEC:

$$k_{NEC} = \frac{\Lambda_{Rh}^{NEC} + \Lambda_R^{NEC}}{\Lambda_{Rh}^{NEC} + \Lambda_R^{NEC} + \Lambda_{Rh}^{EC} + \Lambda_R^{EC}} \tag{3}$$

and for EC

$$k_{EC} = \frac{\Lambda_{Rh}^{EC} + \Lambda_R^{EC}}{\Lambda_{Rh}^{NEC} + \Lambda_R^{NEC} + \Lambda_{Rh}^{EC} + \Lambda_R^{EC}} \tag{4}$$

The offered load per cell is

$$Toff = \frac{\Lambda_{Rh}^{NEC} + \Lambda_R^{NEC} + \Lambda_{Rh}^{EC} + \Lambda_R^{EC}}{\mu_H} \tag{5}$$

where $\mu_H=1/T_H$ and T_H is the channel holding time.

2 New Proposed Technique

Let n be the number of microcells in the microcellular area. The total offered load in the system is:

$$T_{off}^{tot} = n \cdot T_{off} \tag{6}$$

and the total number of channels in the system is

$$C_s = n \cdot C \tag{7}$$

The steady state probabilities that j channels are busy in every microcell, can be derived from [3]

$$P_j = \begin{cases} \dfrac{\left(\Lambda_R^{NEC} + \Lambda_R^{EC} + \Lambda_{Rh}^{NEC} + \Lambda_{Rh}^{EC}\right)^j}{j!\,\mu_H{}^j} P_0 \\[2ex] \dfrac{\left(\Lambda_R^{NEC} + \Lambda_R^{EC} + \Lambda_{Rh}^{NEC} + \Lambda_{Rh}^{EC}\right)^{C-C_h} \left(\Lambda_{Rh}^{NEC} + \Lambda_{Rh}^{EC}\right)^{j-(C-C_h)}}{j!\,\mu_H{}^j} P_0 \end{cases}$$

$$\begin{aligned} &for\ \ j = 1,2,\ldots,C-C_h \\ &for\ \ j = C-C_h+1,\ldots,C \end{aligned} \tag{8}$$

where:

$$P_0 = \left[\sum_{k=0}^{C-C_h} \frac{\left(\Lambda_R^{NEC} + \Lambda_R^{EC} + \Lambda_{Rh}^{NEC} + \Lambda_{Rh}^{EC}\right)^k}{k!\,\mu_H{}^k} \right. \tag{9}$$

$$\left. + \sum_{k=C-C_h+1}^{C} \frac{\left(\Lambda_R^{NEC} + \Lambda_R^{EC} + \Lambda_{Rh}^{NEC} + \Lambda_{Rh}^{EC}\right)^{C-C_h} \left(\Lambda_{Rh}^{NEC} + \Lambda_{Rh}^{EC}\right)^{k-(C-C_h)}}{k!\,\mu_H{}^k}\right]^{-1}$$

The blocking probability (P_B) for a new call (either EC or NEC) per microcell is the sum of probabilities that the state number (j) of the microcell is ≥($C-C_h$). Hence:

$$P_B = \sum_{j=C-Ch}^{C} P_j \tag{10}$$

The probability of handoff attempt failure P_{fh} is the probability that the state number of the microcell is equal to C. Thus:

$$P_{fh} = P_C \tag{11}$$

The P_{fh} of EC is:

$$P_{fh}^{EC} = \frac{\Lambda_{Rh}^{EC}}{\Lambda_{Rh}^{NEC} + \Lambda_{Rh}^{EC}} P_{fh} \tag{12}$$

The mean call blocking probability (P_{nl}) for the microcellular layer (n microcells), considering new and handoff calls of NEC and EC, is defined as:

$$P_{nl} = \frac{\sum_{i=1}^{n}\left(\left(\Lambda_R^H(i) + \Lambda_R^L(i)\right)\cdot P_B^m(i) + \left(\Lambda_{Rh}^H(i) + \Lambda_{Rh}^L(i)\right)\cdot P_{fh}(i)\right)}{\sum_{i=1}^{n}\left(\Lambda_R^L(i) + \Lambda_R^H(i) + \Lambda_{Rh}^H(i) + \Lambda_{Rh}^L(i)\right)}$$

(13)

The new proposed technique uses a channel management scheme. It is based on a two-layer architecture and it is introduced in order to dedicate different layers to different types of subscribers, according to the emergency of call (Emergency Calls and Non Emergency Calls). The implementation of the different layers doesn't require any special hardware setting but only new radio parameters in the existing software. This approximation introduces a two-layer architecture, the lower microcellular layer and the higher, the "Umbrella layer", which is implemented by a "macrocell" [4],[5]. Figure 1 shows the proposed architecture. In addition, the microcell cell layer services handoff calls of EC and new calls of EC, the umbrella layer services new and handoff calls of NEC, homogeneous traffic is considered in all microcells and umbrella cell, and the T_h is the same for the microcells and the umbrella cell.

Let n be the number of microcells that consist the microcellular layer and C_{mi} the number of channels that assigned to every microcell. Let C_S be the total number of channels in the system and C_{ma} the channels assigned to macrocell to serve both handoff calls of EC and new calls of EC. Hence:

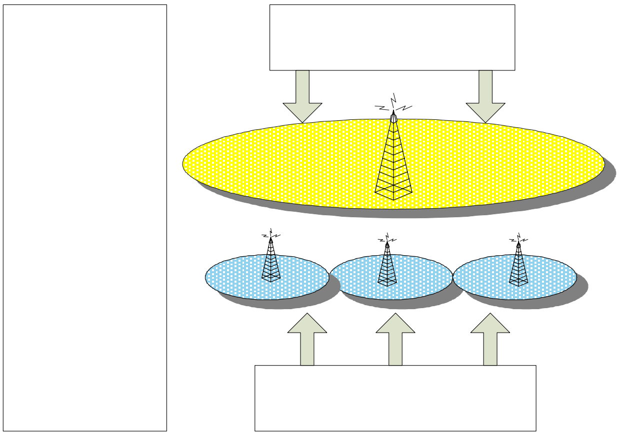

Figure 1: Proposed two-layer architecture

$$C_S = nC_{mi} + C_{ma} \qquad (14)$$

The handoff blocking probability is considered to be more important than the blocking probability of new calls because the call is already active and the QoS is more sensitive for the handoff calls. So in the microcellular layer, priority is given to handoff attempts by assigning guard channels (C_{hmi}) exclusively for handoff calls of NEC among the C_{mi} channels in a cell. The remaining (C_{mi}-C_{hmi}) channels are shared by both new calls of NEC and handoff calls of NEC [3]. Similarly, in the higher layer (macrocell), priority is given to handoff attempts of EC by assigning C_{hma} guard channels exclusively for handoff calls of EC among the C_{ma} channels in umbrella. The remaining (C_{ma}-C_{hma} channels are shared by both new calls of EC and handoff calls of EC. The mean rate of generation of handoff calls of EC is Λ_{Rh}^{EC} per cell and the mean rate of generation of new calls of EC is Λ_{R}^{EC}. So the mean rate generated in the umbrella is n·($\Lambda_{Rh}^{EC} + \Lambda_{R}^{EC}$).

In the new proposed technique, a ratio C_{ma}/C_S is assigned according to α_{NEC}, α_{EC}, k_{NEC}, k_{EC} and T_{off}^{tot}, contributing to the improvement of QoS of EC with the smallest negative effect on the QoS of NEC. Each time a channel must be allocated in the micro-cell, the existing conditions of offered load in the system are checked. The suitable number of channels that can be assigned in the micro-cell is determined depending on the presented traffic. The algorithm continues the process for different values of C_{ma}/C_S. The results are compared with those of a simple model in which the higher level of umbrella-cell does not exist.

The steady state probabilities that j channels are busy in a microcell can be derived from figure 2 [2],[3]

$$P_j^{mi} = \begin{cases} \dfrac{\left(\Lambda_R^{NEC} + \Lambda_{Rh}^{NEC}\right)^j}{j!\,\mu_H{}^j} P_0^{mi} \\ \dfrac{\left(\Lambda_R^{NEC} + \Lambda_{Rh}^{NEC}\right)^{Cm-Chm} \Lambda_{Rh}^{NEC\;j-(Cm-Chm)}}{j!\,\mu_H{}^j} P_0^{mi} \end{cases} \qquad (15)$$

$$j = 1, 2, \ldots, C_{mi} - C_{hmi}$$

$$j = C_{mi} - C_{hmi} + 1, \ldots, C_{mi}$$

where

$$P_0^m = \left[\sum_{k=0}^{Cmi-Chmi} \frac{\left(\Lambda_R^{NEC} + \Lambda_{Rh}^{NEC}\right)^k}{k!\,\mu_H{}^k} + \right.$$

$$\left. \sum_{k=Cmi-Chmi+1}^{Cmi} \frac{\left(\Lambda_R^{NEC} + \Lambda_{Rh}^{NEC}\right)^{Cmi-Chmi} \Lambda_{Rh}^{NECk-(Cmi-Chmi)}}{k!\,\mu_H{}^k} \right]^{-1} \qquad (16)$$

The blocking probability for a new call of NEC per microcell is the sum of probabilities that the state number of the microcell is ≥ C_{mi}-C_{hmi}. Hence:

$$P_B^{mi} = \sum_{j=C_{mi}-Ch}^{C_{mi}} P_j^{mi} \qquad (17)$$

The probability of handoff attempt failure P_{fh}^{mi} is the probability that the state number of the microcell is equal to C_{mi}. Thus:

$$P_{fh}^{mi} = P_C^{mi} \qquad (18)$$

For the umbrella cell, the steady state probabilities that j channels are busy can be derived from figure 2 [2],[3]:

$$P_j^{ma} = \begin{cases} \dfrac{\left(\Lambda_R^{EC} + \Lambda_{Rh}^{EC}\right)^j}{j!\,\mu_H{}^j} P_0^{ma} \\ \dfrac{\left(\Lambda_R^{EC} + \Lambda_{Rh}^{EC}\right)^{Cma-Chma} \Lambda_{Rh}^{EC\;j-(Cma-Chma)}}{j!\,\mu_H{}^j} P_0^{ma} \end{cases}$$

$$j = 1, 2, \ldots, C_{ma} - C_{hma} \qquad (19)$$

$$j = C_{ma} - C_{hma} + 1, \ldots, C_{ma}$$

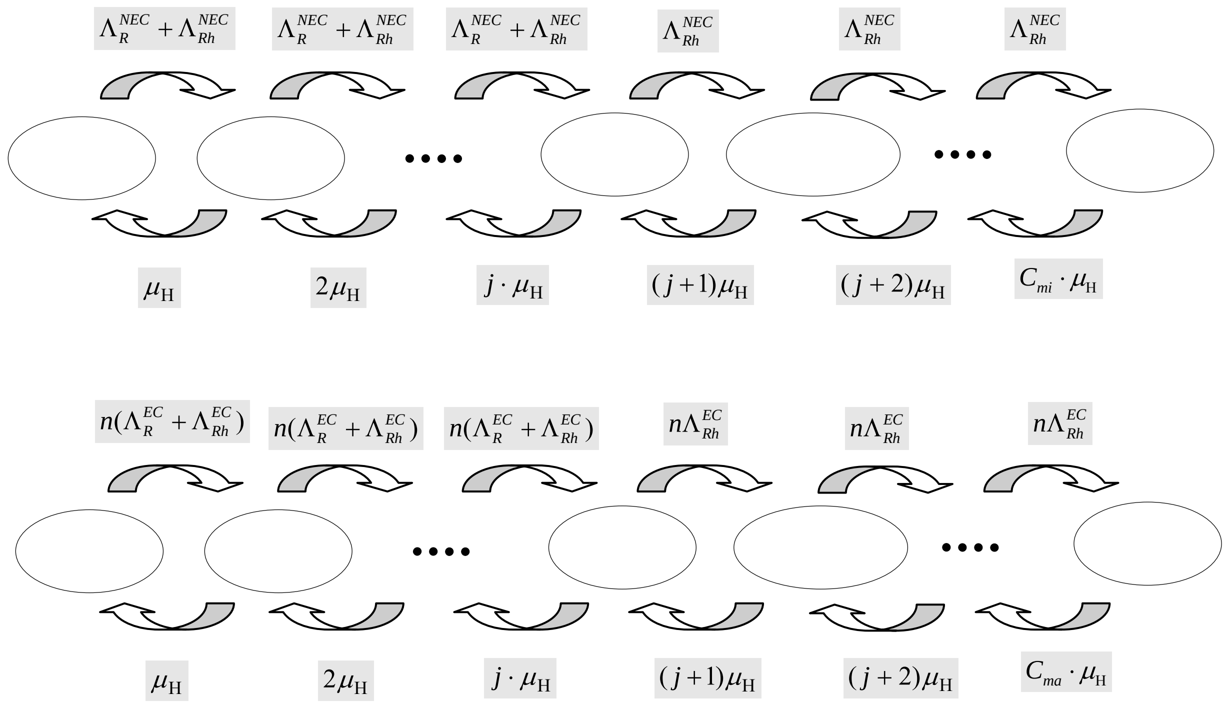

Figure 2: State Transition diagram for: (a) every microcell and (b) umbrella cell of proposed architecture

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where

$$P_0^{ma} = \left[\sum_{k=0}^{Cma-C_{hma}} \frac{\left(\Lambda_R^{EC}+\Lambda_{Rh}^{EC}\right)^k}{k!\,\mu_H{}^k} + \sum_{k=C_{ma}-C_{hma}+1}^{C_{ma}} \frac{\left(\Lambda_R^{EC}+\Lambda_{Rh}^{EC}\right)^{C_{ma}-C_{hma}} \Lambda_{Rh}^{EC\,k-(C_{ma}-C_{hma})}}{k!\,\mu_H{}^k} \right]^{-1} \quad (20)$$

The blocking probability for a new call of EC per cell is the sum of probabilities that the state number of the umbrella cell is ≥ C_{ma}-C_{hma} .Hence:

$$P_B^{ma} = \sum_{j=C_{ma}-Ch_{ma}}^{C_{ma}} P_j^u \quad (21)$$

The probability that a handoff call will be blocked in the umbrella cell is P_{fh}^{ma} and is the probability that state number of the cell is equal to C_{ma}. Thus:

The probability that a handoff call will be blocked in the umbrella cell is P_{fh}^{ma} and is the probability that state number of the cell is equal to C_{ma}. Thus:

$$P_{fh}^{ma} = P_{Cma} \quad (22)$$

The QoS the microcellular layer (n microcells), is defined as:

$$QoS_{NEC} = \frac{\sum_{i=1}^{n}\left(\left(\Lambda_R^L(i)\right)\cdot P_B^{mi}(i) + \Lambda_{Rh}^L(i)\cdot P_{fh}^{mi}(i)\right)}{\sum_{i=1}^{n}\left(\Lambda_{Rh}^L(i)+\Lambda_R^L(i)\right)} \quad (23)$$

For the umbrella layer the QoS of EC is defined as:

$$QoS_{EC} = \frac{\sum_{i=1}^{n}\left(\left(\Lambda_R^H(i)\right)\cdot P_B^{ma}(i) + \Lambda_{Rh}^H(i)\cdot P_{fh}^{ma}(i)\right)}{\sum_{i=1}^{n}\left(\Lambda_{Rh}^H(i)+\Lambda_R^H(i)\right)} \quad (24)$$

Therefore, the QoS for handoff calls especially for EC must be guaranteed while allowing high utilization of channels. The objective of the proposed architecture is to guarantee the required handoff blocking probability for EC.

3 Results

The above technique was simulated. In the performed simulation, the number of microcells is considered to be n=3, without affecting the generality of the model. The following parameters are also considered: C_{hmi}=0.2C_{mi}, C_{hma}=0.1C_{ma} T_H=75s, α_{NEC}=0.2, α_{EC}=0.4, k_{NEC}=0.8 and k_{EC}=0.2 and C_S=120 and C=40.

Figure 3 and 4 present the performance of call

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blocking probability for new and handoff calls of NEC respectively. Figure 5 presents the QoS of EC.

In all figures, curve (i) represents the performance of a typical cellular security wireless network according to a traffic model analysis based on erlang b model (OLA-EB). Curve (ii) represents the performance of a typical cellular security wireless network according to a traffic model analysis with prioritized handoff procedure (OLA-GC). In these cases, there is no umbrella layer and all the involved calls are served by microcells. Curve (iii) shows the performance of a cellular security wireless network which uses the Proposed Technique that gives Priority to Emergency Calls (TgPEC) and it is based on the two layer architecture, where new and handoff calls of EC are served by the umbrella layer and the new and handoff calls of NEC by the microcellular layer. In curve (iii): C_{ma}/C_S=48/120, C_{mi}/C_S=24/120.

Curves show a great improvement in the QoS of EC and in Call Blocking Probability of Handoff Calls of NEC as a result of using the proposed technique with the a negative effect in Call Blocking Probability of New Calls of NEC.

4 Conclusion

A new proposed technique that gives priority to Emergency Calls in Wireless Cellular Security Networks in order to achieve better QoS for EC in areas that a extreme event was happened. In this architecture, the umbrella cell philosophy has been introduced to serve new and handoff calls of EC. Moreover, according to the obtained results, the Call Blocking Probability of Handoff Calls of NEC has been optimized having negative effect on the Call Blocking Probability of New Calls of NEC.

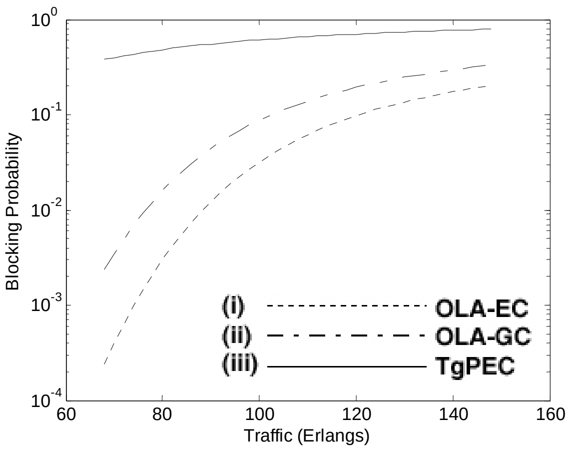

Figure 3: Call Blocking Probability of New Calls of NEC

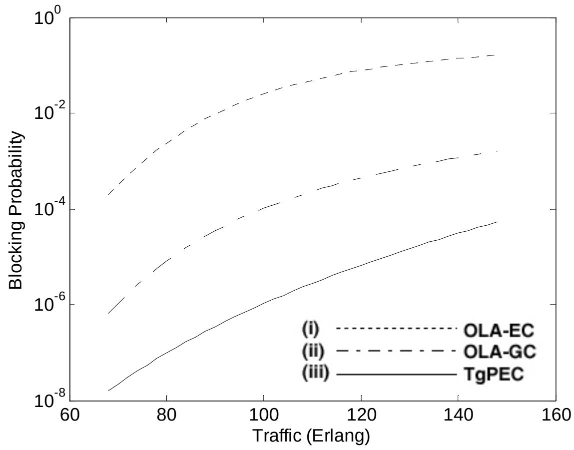

Figure 4: Call Blocking Probability of Handoff Calls of NEC

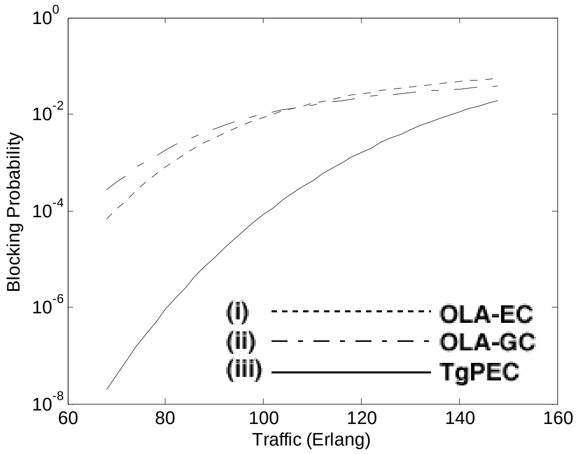

Figure 5: QoS of EC

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