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A HASP architecture solution in microcellular wireless networks

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Abstract: - This paper presents a two-layer cellular architecture which optimizes the handoff blocking probability performance of Priority Subscribers (PS) in a congested urban area. The lower layer of the proposed architecture is based on a microcellular solution for Normal Subscribers (NS) while the higher layer is based on a High Altitude Stratospheric Platform (HASP) overlay solution for absorbing the traffic load of the existed handoff calls of PS.

Key-Words: - Wireless Networks, Cellular Networks, HASP

1 Introduction

In modern wireless networks special care must be taken for priority subscribers (Police, National security, Special agents, government personnel or high speed moving terminals like trains) that might use the available resources (calls and handoff) and services (Quality of service, QoS) without any disturbance. The need for network resources without any disturbance can be assured, in everyday use, with a detailed and optimized cell-coverage design like Umbrella cells or specific tuning of network parameters for certain class of subscribers. In special time periods (sport events like Olympic Games, critical National crisis like War or terrorism attack or Natural distractions like Earthquake) the network resources are indeed over-demanded from several subscriber classes and there is no guarantee that priority subscriber classes can have always access and uninterrupted services. During these time periods the most serious problem that arises in this architecture is the handoff issue [1,2,4], because the parameters tuning can not assure the network operational stability and the prioritization of certain subscriber classes.

To overcome these problems and to keep the priority scheme and network service utilization uninterrupted, *High Altitude Stratosphere Platforms (HASP)* [3] overlay cell is proposed as a state of the art solution. HASP platforms will cover soon the non line of sight communication applications and are going to support satellite-like communications with the advantage of small energy demands on the used portable and mobile phones. The SkyStation, the SkyNet, the SkyTower and the EuroSkyWay Projects, declare the new promises to the applications on a large scale geographical coverage

2 Priority Handoff Procedure

The examined model adopts a traffic analysis for cellular mobile networks with prioritized handoff procedure [1,2,5]. A two-layer architecture is introduced in order to dedicate different layers to different subscriber classes. Figure 1 shows the proposed architecture where the HASP layer [3] services only handoff calls of PS and the remaining new calls of PS, handoff and new calls of NS subscribers are served from the lower microcell layer. It is needed also to preserve the handoff calls against the new calls in the microcell layer. Hence from the total number of channels (C) in every microcell, priority is given to handoff attempts by assigning guard channels (C_h) exclusively for handoff calls of NS. The remaining ($C-C_h$) channels are shared by both new calls of PS and NS and also handoff calls of NS. Let also C_u be the channels assigned exclusively to HASP cell and let n be the number of microcells; then the total offered load in the system is $T_{off}^{tot} = n \cdot T_{off}$ and the total number of channels in the system is $C_S = nC + C_u$.

New and handoff calls of NS are generated in the area of microcell according to a Poisson point process with mean rate of Λ_R^N, Λ_{Rh}^N respectively, while new calls and handoff calls of PS are generated with mean rates of Λ_R^P, Λ_{Rh}^P per cell. The mean rate of generation of handoff calls of PS is

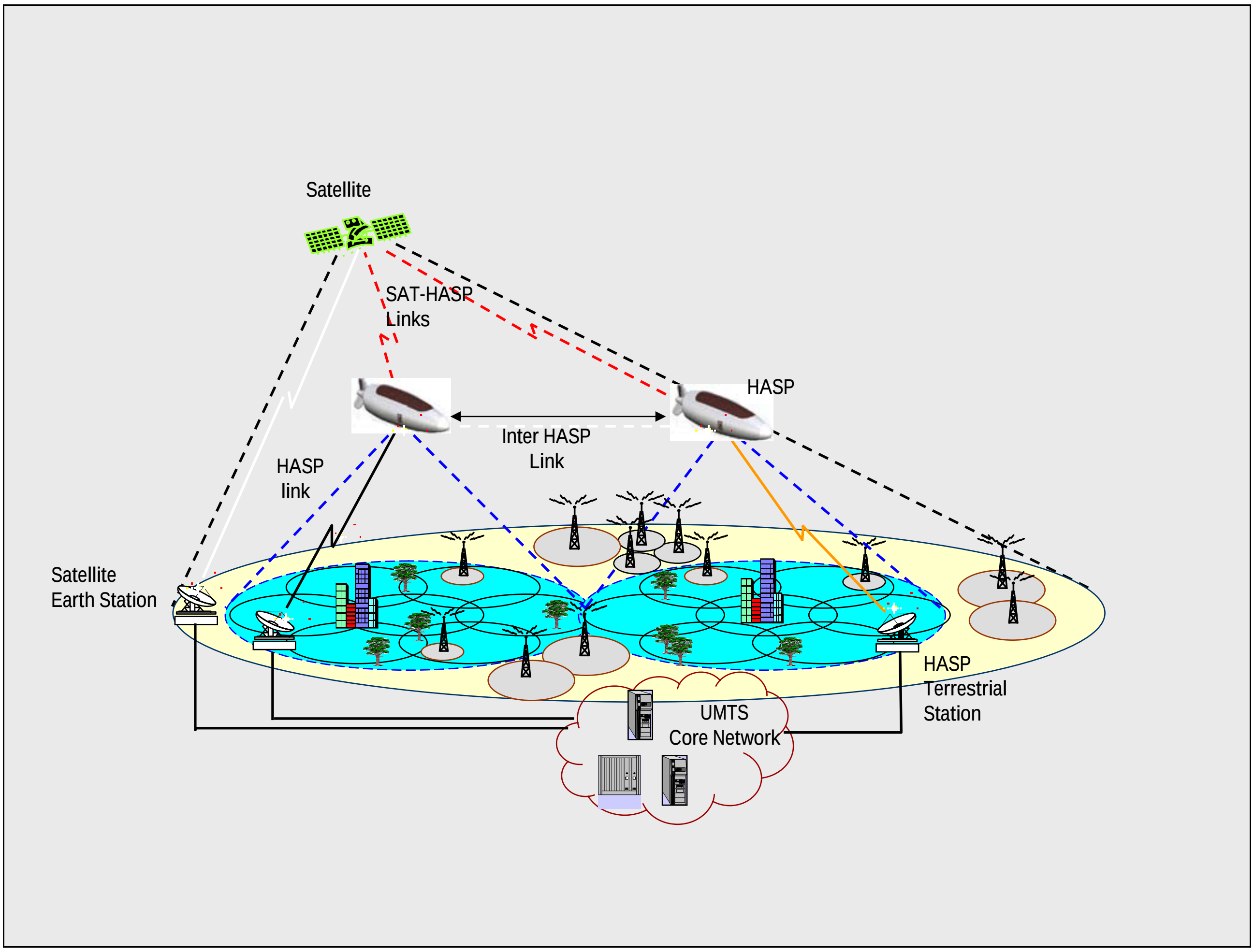

Figure 1: HASP overlay architecture in heterogeneous wireless networks

Λ^{P}_{Rh} per cell, so the mean rate generated in the HASP is $n \cdot \Lambda^{P}_{Rh}$.

Relative mobilities are defined for NS and PS respectively as

$$a_N = \frac{\Lambda^N_{Rh}}{\Lambda^N_{Rh} + \Lambda^N_R} \quad (1)$$

$$a_P = \frac{\Lambda^P_{Rh}}{\Lambda^P_{Rh} + \Lambda^P_R} \quad (2)$$

The total relative mobility for both PS and NS, is given by:

$$a_{PN} = \frac{\Lambda^P_{Rh} + \Lambda^N_{Rh}}{\Lambda^P_{Rh} + \Lambda^P_R + \Lambda^N_{Rh} + \Lambda^N_R} \quad (3)$$

The offered load per cell is

$$Toff = \frac{\Lambda^N_{Rh} + \Lambda^N_R + \Lambda^P_{Rh} + \Lambda^P_R}{\mu_H} \quad (4)$$

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

The proposed architecture, assigns a ratio C_u/C_S, according to α_P, α_N, α_{PN} and T^{tot}_{off}, contributing to the improvement of handoff call blocking probability of PS (blocking probability of the HASP layer), with the smallest possible effect on the mean call blocking probability of microcellular layer

The steady state probabilities that j channels are busy in a microcell [1,2] is

$$P^m_j = \begin{cases} \dfrac{\left(\Lambda^P_R + \Lambda^N_R + \Lambda^N_{Rh}\right)^j}{j!\,\mu_H{}^j} P^m_0 & for \quad j = 1,2,\ldots,C - C_h \\[2ex] \dfrac{\left(\Lambda^P_R + \Lambda^N_R + \Lambda^N_{Rh}\right)^{C-Ch} \Lambda^N_{Rh}{}^{j-(C-Ch)}}{j!\,\mu_H{}^j} P^m_0 & for \quad j = C - C_h + 1,\ldots,C \end{cases} \quad (5)$$

where:

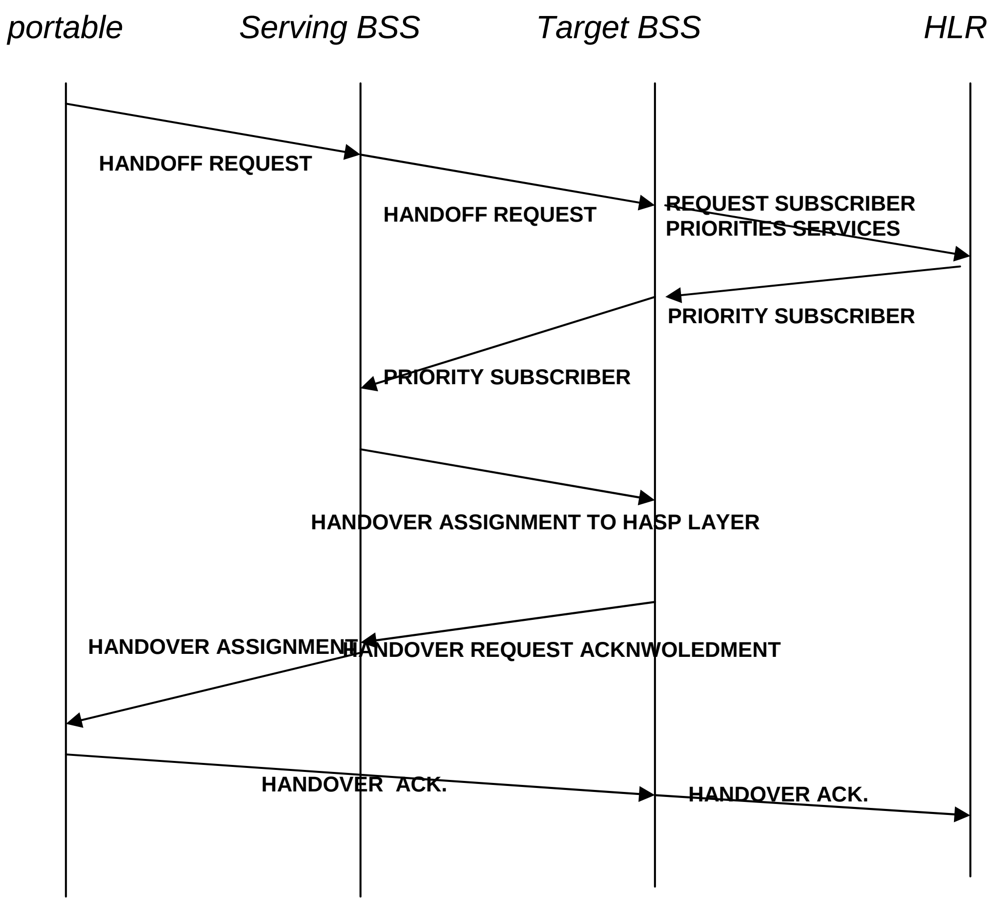

Figure 2: handover execution towards HASP layer

$$P_0 = \left[\sum_{k=0}^{C-C_h} \frac{\left(\Lambda_R^N + \Lambda_R^P + \Lambda_{Rh}^N\right)^k}{k!\,\mu_H{}^k} + \sum_{k=C-C_h+1}^{C} \frac{\left(\Lambda_R^N + \Lambda_R^P + \Lambda_{Rh}^N\right)^{C-C_h} \left(\Lambda_{Rh}^N\right)^{k-(C-C_h)}}{k!\,\mu_H{}^k} \right]^{-1} \quad (6)$$

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

$$P_B^m = \sum_{j=C-Ch}^{C} P_j^m \quad (7)$$

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

For the HASP layer, the steady state probabilities that j channels are busy [1,2] is

$$P_j^u = \frac{\left(n \cdot \Lambda_{Rh}^P\right)^j}{j!\,\mu_H{}^j} P_0^u \quad \text{for } j = 1,2,\dots,C_u \quad (8)$$

where

$$P_0^u = \left[\sum_{k=0}^{Cu} \frac{\left(n \cdot \Lambda_{Rh}^P\right)^k}{k!\,\mu_H{}^k} \right]^{-1} \quad (9)$$

The probability that a handoff call will be blocked in the HASP cell is P_{fh}^u and is the probability that state number of the cell is equal to C_u. Thus: $P_{fh}^u = P_{Cu}$. The mean call blocking probability (P_{nl}^m) for the microcellular layer (n microcells), considering new calls of NS and PS and handoff calls of NS is defined as:

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

(10)

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

Figure 2 shows the messages that are exchanged among the elements of the network during a priority handoff. The only difference to the normal handoff is the REQUEST FOR SUBSCRIBER PRIORITY message that the target BSS sends to HLR. This message is important in order to execute the correct handoff towards the HASP layer.

3 Results

In the performed simulation, the number of microcells is considered to be n=3, without affecting the generality of the model. Also C_h=0.1C, T_H=80s, α_N=0.2, α_P=0.3 and α_{PN}=0.22. Using these values and $0 \leq T_{off}^{tot} \leq 300$ erlangs, Λ_R^N, Λ_{Rh}^N , Λ_R^P, Λ_{Rh}^P are easily calculated. Figure 3 shows the handoff blocking probability of PS against T_{off}^{tot} . Figure 4 shows the mean call blocking probability of the microcellular layer (P_{nl}), respectively as a function of T_{off}^{tot} . In both figures, curve (i) represents the performance of a typical cellular system (TCS) for C_s=120 (according to a traffic model analysis with prioritized handoff procedure). In this case, there is no HASP layer and all the involved calls are served by microcells. Curve (ii), show the performance of a Cellular system with the proposed HASP architecture (CS–HASP) for C_s=120, C_u=48 and C=24where handoff calls of PS are served by the HASP layer and the new calls of PS and NS, and the handoff calls of NS by the microcellular layer.

4 Conclusions

A two-layer architecture based on a HASP layer has been proposed to preserve the handoff calls of certain priority subscribers by achieving low handoff call blocking probability. In this architecture, the HASP layer architecture has been introduced to serve handoff calls of PS. Curves of figures 3 and 4 presented an improvement in the handoff call blocking probability of PS as a result of using the proposed architecture, as well as adjusting the ratio C_u/C_S, according to the T_{off}^{tot} , α_N, α_P and α_{PN}. This improvement depends on the number of channels that are assigned to the HASP cell. From figures C_u/C_S = 48/120 optimizes the HASP layer with the minimum effect on the lower layer. This optimization refers to a decrease in blocking probability of the HASP layer with the minimum increase in blocking probability of microcellular layer. The optimal ratio C_u/C_S is not always the same with different C_s.

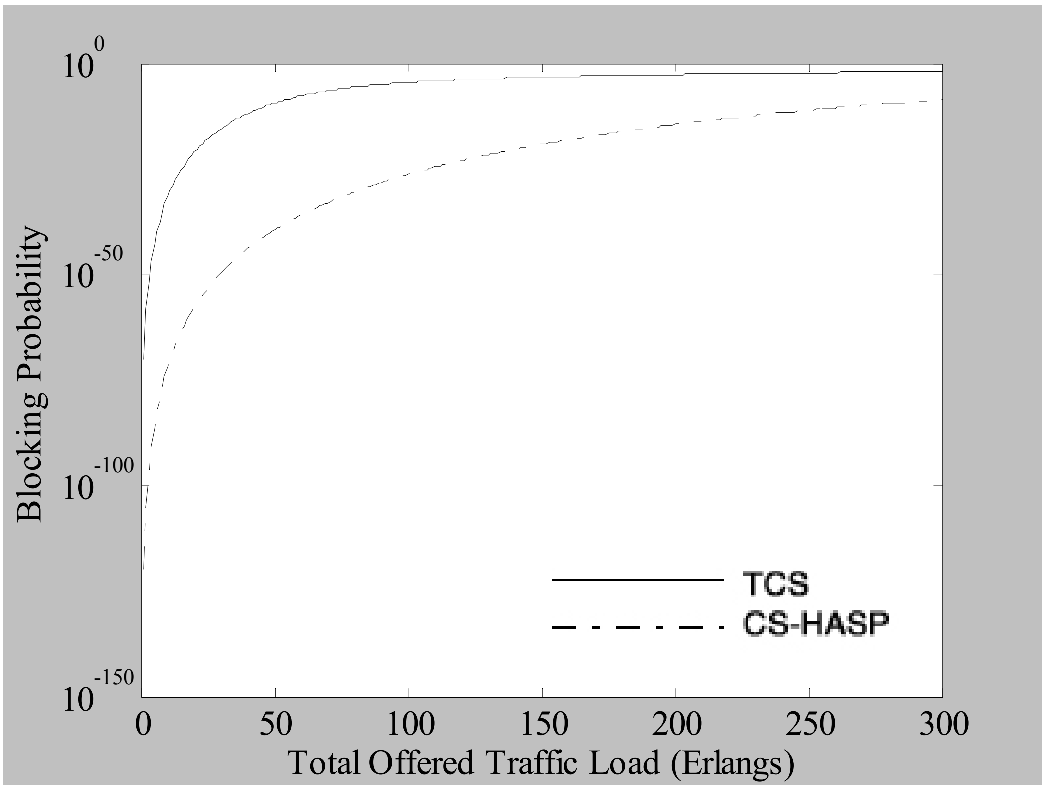

Figure 3: Handoff blocking probability of PS against total offered traffic load in the system.
(i) Architecture without HASP Layer and Cs=120, C=40.
(ii) Proposed Architecture with HASP Layer and Cs=120, Cu=48, C=24

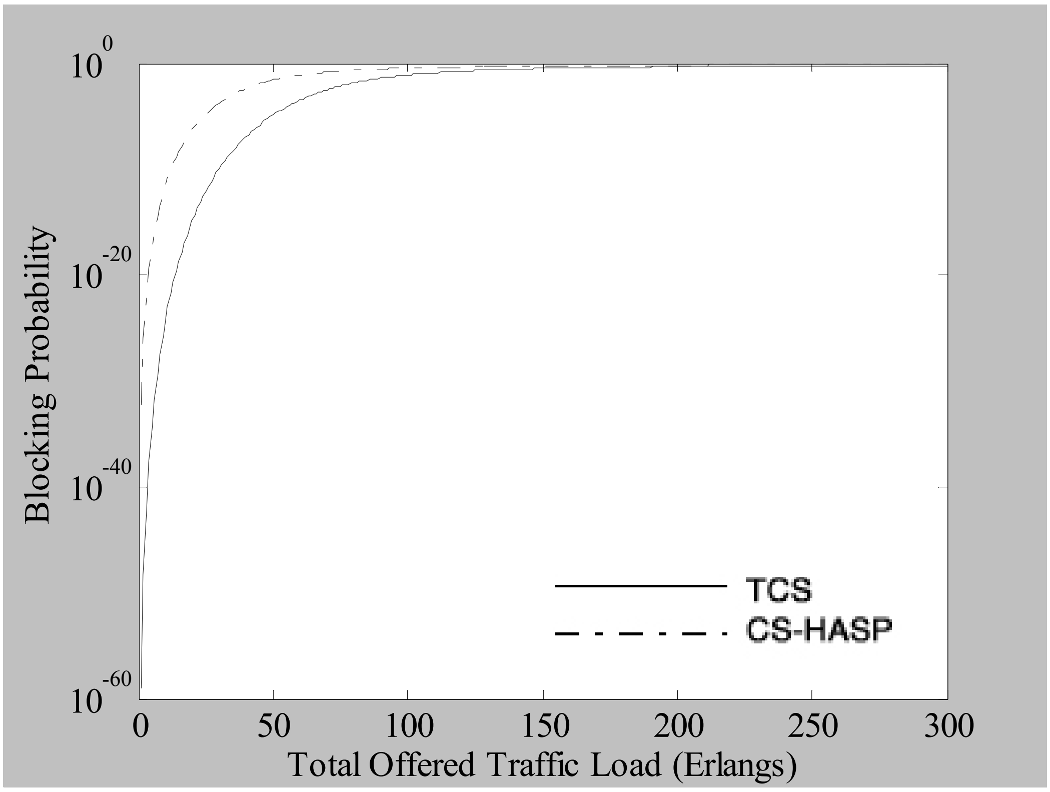

Figure 4: Mean call blocking probability of the microcellular layer (P_{nl}), against total offered traffic load in the system
(i) Architecture without HASP Layer and Cs=120, C=40.
(ii) Proposed Architecture with HASP Layer and Cs=120, Cu=48, C=24

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