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A New Scheme for Efficiently Managing Call Adı

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A New Scheme for Efficiently Managing Call Admissions in 3G/WLAN Mixed Cells

Abstract

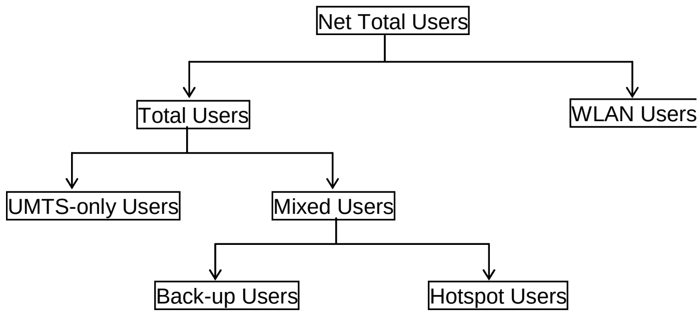
real traffic) may leave WLAN hotspot and wish to continue the data session in UMTS. Therefore upward vertical handoff from WLAN to UMTS must be supported. This upward handoff traffic adds to the UMTS traffic. Thus it is essential to consider the upward vertical handoff traffic to capture the net traffic in UMTS. When a user moves from WLAN to UMTS, the user equipment automatically switches to UMTS mode [10] and initiates a request. It is a fresh request in the UMTS system. It needs to be handled with the priority in UMTS because the ongoing WLAN session is now to be made through to UMTS. This WLAN session needs priority in UMTS because a user may move halfway during downloading a large file and termination of the session at that juncture will require a fresh downloading of the large file. So, a user will suffer loss of subscription. Thus an upward vertical handoff request (VHR) must be dealt at least with the priority of horizontal handoff request (HHR) to provide low dropping probability. The CAC scheme proposed in [6] and [7] support only take-back vertical handoff i.e., these schemes support upward handoff for an already vertically handed over session (VHS). Both the schemes do not support the upward vertical handoff for the sessions originated in WLAN. A user has to terminate the WLAN session and initiate a fresh request in UMTS to make the session. Th

II. Review of Related Works

The *simulation model* of [8] evaluates the traffic handling capacity of a hybrid cell with underlying WLANs. It is seen that the capacity increases by nearly three times with 25% increment of service area covered by WLAN hotspots in a UMTS cell. The light and medium loaded hotspots can absorb up to 50% of the load of a congested

- **Back-up User**: The mixed users who are residing in UMTS-only coverage are called backup users. Some of the back-up users (with or without data sessions) may move to WLAN hotspots and they become hotspot users.
- **Background User**: The *UMTS-only users* and *back-up* users are together called background users. Currently all background users are under UMTS system.
- **Total User:** The sum of background users and hotspots users is called total users i.e., the sum of *UMTS-only users* and *mixed users* is equal to total users.
- **Net Total User**: The sum of UMTS-only users, mixed users and WLAN users is called net total users i.e., the sum of total users and WLAN users is equal to net total users (Chart 1).

Chart 1: Users' classes in a mixed cell.



We define the following parameters in respect of a mixed cell.
A -Ratio of total WLAN coverage in mixed cell to the coverage of a pure UMTS cell.
p - Relative fraction, i.e., ratio of mixed users to total users.
d- Ratio of users' density in WLAN to that in UMTS-only coverage. It is called density ratio.
g - This the ratio of hotspot user to mixed users. It represents the probability that a mixed user is a hotspot user i.e., the probability that a mixed user will reside in WLAN hotspot. We assuime that a mixed user moves from UMTS-only coverage to a WLAN hotspot with the probability of g . It is termed as *coverage probability*.

$$g \approx \frac{1}{[Ad]^{-1} + 1} \tag{1}$$

For detailed derivation see APPENDIX. I. From equation (1), it is seen that g increases with increasing A and d .

B. *Mobility Pattern and Its Model*

Session-Mobility Scenarios: We specify following mobility scenarios of sessions in a mixed cell (Fig. 2).

- A new session (NS) (i.e., a session established by a new request), or a horizontally handed over session (HHS) of a *UMTS-only user* may be completed within the same cell or it may initiate HHR in a neighbor UMTS cell.
- An NS, or an HHS or a VHS (i.e., vertically handed over session) of a *back-up user* may be completed in the UMTS-only coverage of the same cell or it may initiate HHR in neighbor cell or it may initiate VHR in WLAN.
- An NS, or a VHS of *hotspot user* may be completed in WLAN itself or it may initiate VHR in the UMTS-only coverage.
- An NS of a *WLAN user* is always completed in the WLAN itself.

A Use's mobility in a cellular network is characterized by its CRT and its distribution pattern [17]. CRT also influences the cell performance [18], [19]. A user, in a packet data mobile network (i.e., GPRS, UMTS) will occupy a data channel similarly to a typical voice user [20]. Therefore, when a user gets a channel in a UMTS cell, she will use it for the duration of cell residence. Thus, the modeling of radio resource allocation in UMTS networks is similar to the radio channel allocation for personal communication system. Channel holding time (CHT) depends on the user's mobility which is characterized by CRT. The cell shapes specifically UMTS coverage in mixed cells are irregular, and the speed and direction of mobile users are hard to characterize. In recent time, hyper-Erlang distribution is adopted to model the CRT in mobile networks [21], [22], [23]. The hyper-Erlang distribution preserves the Markovian property of the resulting queuing networks models. This also has universal approximation properties. So, field data can be readily used to find the model parameters statistically. We use hiper-Erlang distribution for CRTs in UMTS-only coverage and in WLAN of a mixed cell.

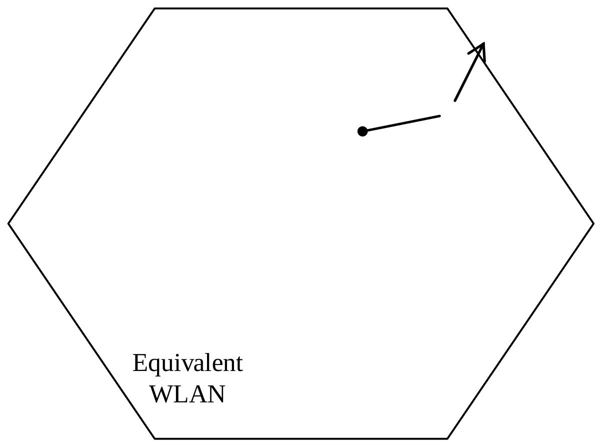


Figure 2. Mobility scenarios in a mixed cell.

Hyper-Erlang Distribution Model: Let t repreent the hyper-Erlang distribution of an arbitray random variable X**.** Then, the density function of Hyper-Erlang discribution is as follows [21].

$$f_X(t) = \sum_{i=1}^{N} \alpha_i \frac{(n_i\theta_i)^{n_i} t^{m_i-1}}{(m_i-1)!} e^{-m_i\theta_i t} \quad (t \geq 0), \tag{2}$$

$$f_X^*(s) = \sum_{i=1}^{N} \alpha_i \left(\frac{n_i\theta_i}{s+n_i\theta_i} \right)^{n_i}, \tag{3}$$

where $f^*_{R^U}(s)$ is Laplace transform of $f_{R^U}(t)$ and $\alpha_i \geq 0$, $\sum_{i=0}^{N} \alpha_i = 1$, and N, n_i and θ_i are positive numbers.

Hyper-Erlang distribution is easier to use than the other models. The k^{th} moment can be computed through Laplace transform approach as follows [22].

$$E[t^k] = (-1)^k f_X^{*(k)}(0) = \sum_{i=0}^{N} \alpha_i \frac{(n_i+k-1)!}{(n_i-1)!} (n_i\theta_i)^{-k} \tag{4}$$

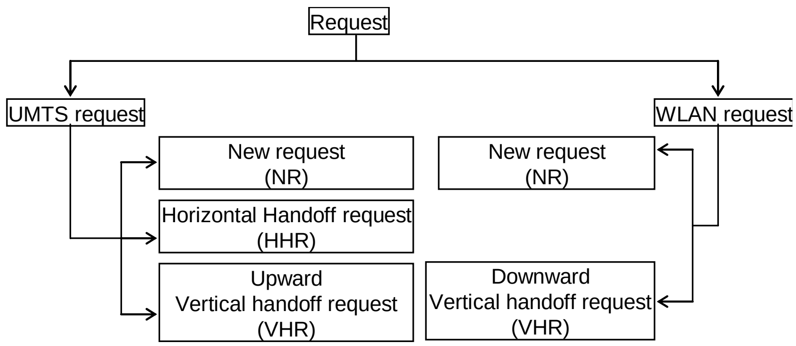
There are two options to use the equation (4): one, the parameters α_i, n_i and θ_i can be estimated by fitting a number of moments from field data; two, expected value (i.e., mean CRT) can be estimated from equation (4) by setting $k=1$ and setting suitable values of parameters α_i, n_i and θ_i. The mean CRT can be used to estimate the mean CHT. We use the second option for performance analysis of a mixed cell.
UMTS provides wider coverage with lower bit rates and WLAN provides small coverage with higher bit rates. During a single session, a user is visible to one system (either UMTS or WLAN) at a time. So, we assume separate

CRTs for UMTS and WLAN in a mixed cell. Let R^U and R^W denote CRTs in UMTS and WLAN, respectively, with means $\frac{1}{r^u}$ and $\frac{1}{r^w}$.

C. Traffic and its Model

There are broadly two classes of traffic in a mixed cell, real traffic such as voice traffic and non-real traffic such as elastic data session. We consider same mobility pattern for both the classes of traffic. Each class of traffic is generated by various types of requests as shown in Chart 2. There are two basic types of requests in a mixed cell, UMTS request and WLAN request, and they are generated for UMTS and WLAN systems, respectively. UMTS requests comprise NRs, HHRs and upward VHRs. WLAN requests comprise NRs and downward VHRs. We define the request-life as the duration of time elapsed between the instant a request is initiated and the instant the request is dropped or the session is terminated. During request-life, depending upon the channel availability of the systems and mobility the user a request may undergo certain distinct states. For our model and traffic estimation, we define the following seven states of the requests during a request-life: *arrival*, *blocked*, *dropped*, *successful*, *completion*, *VHR-arrival*, *HHR-arrival* (Figure 3). The scenarios of forced termination of a session due to bad channel condition or system failure are included in *completion* state.

Chart 2: Types of requests in a mixed cell



Arrival: A *request (NR or, HHR* or VHR) attains *arrival* state when it is initiated by a user (Fig. 3).
Blocked: When a request is denied by a system due to non-availability of channel, a request moves from *arrival* to *blocked* state. A blocked request in WLAN can initiate NR in UMTS. So a *blocked* state can transit to *VHR-arrival* state again.
Dropped: A blocked request is dropped in this state. A blocked request in UMTS is necessarily dropped. So, *blocked* state can transit to *dropped* state.
Successful: In *successful* state, data session is established. So an *arrival* state moves to *successful* state.
Completion: In this state, a user's data session is terminated by a user after the completion of the session. A *successful* state can move to *completion* state.
HHR arrival: When a request initiates an HHR in neighbor cell from its *successful state,* it reaches *HHR arrival* state and this becomes a new *arrival*.
VHR arrival: When a request initiates a VHR from its *successful state*, it reaches *VHR arrival* state and this becomes a new *arrival*.

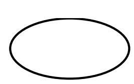


Figure 3. States of requests

Figure 3 shows the state transition scenarios. We represent the session mobility scenario of Figure 2 using state diagram. Obviously, an ongoing data session is represented by the *successful* state of a request. The state transition from *successful* state to next states depends on the type of user initiating a request. For backup users, the *successful* state can transit to any one of three states as shown in Figure 2. For a UMTS-only user, the *successful* state can transit either to *completion* or to *HHR arrival* state because this user cannot initiate VHR in WLAN. For a hotspot user, the *successful* state can transit either to *completion* or to *VHR arrival* state because this user cannot initiate horizontal handoff from WLAN to WLAN. For a WLAN user, the successful state can transit to only *completion* state because a WLAN user cannot access UMTS.

Traffic model: Conversional and interactive are the two most important classes of services which are defined for UMTS [12]. A real-time service having two way communications is called conversional class. A non-real time service is called interactive class. Voice and elastic data services (e.g. web browsing and file transfer) are the typical conversional and interactive classes of services, respsinversi.15.3(si)l-hz51(nv)-5.1(er05.1(a9vi6(onc-5.1(er)4.9UM)45.e8.1(n1(er)4.

quality of service (QoS) is the number of logical channels. When a user gets access in WLAN, one logical channel is occupied.

IV. State Transition Probabilities

The session mobility scenarios (Section III B) have been represented using states of reqeusts (Section II C). This helps estimation of traffic loads of new and handoff traffic which is given in Section V. Figure 5 presents the state transition scenarios for back-up and hotspot users.

For back-up users

b_2 -Probability that an HHR or a VHR is blocked on its arrival in in UMTS-only coverage. So, it is the probability that an *HHR arrival* state transits to *blcoked* state.

b_1' -Transition probability from *NR arrival* to *NR successful* state. $b_1' = (1 - b_1)$.

b_2' -Transition probability from *HHR arrival* to *HHR successful* state. $b_2' = (1 - b_2)$. It is also the transition probability from *VHR arrival* to VHR successful.

g - It is the probability that a data session moves from UMTS-only coverage to WLAN coverage in a mixed cell (Section IIIA). This gives the transition probabilities from *NR successful* or *HHR successful*, or *VHR successful* in UMTS to *VHR arrival* in WLAN.

g' -Probability that a data session of a backup user will not enter WLAN. $g' = (1 - g)$.

P_{ns}^u - Probability that an NS moves from a pure UMTS cell to neighbor UMTS cell and initiates HHR.

P_{hhs}^u -Probability that an HHS moves from a pure UMTS cell to neighbor UMTS cell and initiates HHR. $P_{hhs}^u = (r^u)^{-1} h^u P_{ns}^u - 1$.

P_{vhs}^u -Probability that a VHS moves from a pure UMTS cell to neighbor UMTS cell and the MS initiatres HHR. $P_{vhs}^u = (r^u)^{-1} h^u P_{ns}^u - 1$.

P_{ns}^u, P_{hhs}^u and P_{vhs}^u can be expressed in terms of r^u and h^u . Derivations are given in APPENDIX II.

$g' P_{ns}^u$ - Transition probability from *NR successful* to *HHR arrival (*in neighbor cell).

$g' P_{hhs}^u$ - Transition probability from *HHR successful* to *HHR arrival* (in neighbor cell).

$g' P_{vhs}^u$ - Transition probability from *VHR successful* to *HHR arrival* (in neighbor cell).

Assume b is the blocking probability of any request in WLAN. P_{ns}^w and P_{vhs}^w are the probabilities and an NS and a VHS initiate VHR in UMTS-only coverage, respectively. We can state the transsition probabilites as follows.

b - It is the blocking probability of any request in WLAN. So, it is the probability that an *NR arrival* in WLAN transits to *blcoked* state or a *VHR arrival* in WLAN transits to *blocked* state.

All blocked NRs in WLAN initiates NRs in UMTS. So, transition probability from *NR blocked* (in WLAN) to *NR arrival* (in UMTS) is 1. All blocked VHRs in WLAN are in *successful* states in UMTS i.e., *NR successful*, *HHR successful* and *VHR successful*. So, these states will transit to HHR arrival in neighbor UMTS with the probabilities $g' P_{ns}^u$, $g' P_{hhs}^u$ and $g' P_{vhs}^u$, respectively, which are represented by $\{g' P_{ns}^u \;\; g' P_{hhs}^u \;\; g' P_{vhs}^u\}$

V. TRAFFIC ESTIMATION AND STEADY STATE PROBABILITY

A. *Traffic estimation*

The transition probability from one state to any other state is given by the product of the probabilities of transitions that take place from that state to other state. Probabilities that *NR arrival*, *HHR arrival* and *VHR arrival* in UMTS generate *HHR arrival* in neighbor are $(1-b_1)(1-g(1-b))P_{ns}^{u}$, $(1-b_1)(1-g(1-b))P_{hhs}^{u}$ and $(1-b_2)(1-g(1-b))P_{vhs}^{u}$, respectively. Probabilities that *NR arrival*, *HHR arrival* and *VHR arrival* in UMTS generate *VHR arrival* in WLAN are $b_1' g$, $b_2' g$ and $b_2' g$, respectively. We assume that λ_{nr}^{u}, λ_{hhr}^{u} and λ_{vhr}^{u} represent the NR, HHR and VHR arrival rates , respectively, in UMTS under steady state conditions. The VHR and NR arrival rates in WLAN are λ_{vhr}^{w} and λ_{nr-hp}^{w}, respectively. λ_{hhr}^{u}, λ_{vhr}^{u} and λ_{vhr}^{w} are generated from λ_{nr}^{u} and λ_{nr-hp}^{w} due to mobility of the users. . λ_{hhr}^{u}, λ_{vhr}^{u} and λ_{vhr}^{w} are unknown parameters and λ_{nr}^{u} and λ_{nr-hp}^{w} are known parameters. We estimate λ_{hhr}^{u}, λ_{vhr}^{u} and λ_{vhr}^{w} in terms of λ_{nr}^{u} and λ_{nr-hp}^{w} .

HHR Arrival Rate in UMTS-only Coverageragerageragku35 60.22 Tm604fTjTT2 1Tf4fTjTT2 978 Tm6001T9()T UM01 s2902T

$b'P^{w}_{ns}$ - It is the probability that an *NR arrival* state in WLAN reaches to *VHR arrival* state in UMTS-only coverage.

$b'P^{w}_{vhs}$ - It is the probability that a *VHR arrival* state in WLAN will reach to *VHR arrival* state in UMTS-only coverage.

So, VHR arrival rate in UMTS-only coverage is obtained as follows.

$$ {}^{u}_{vhr} \qquad {}^{w}_{nr} \;\; {}_{hp}(1 \quad b)P^{w}_{ns} \qquad {}^{w}_{vhr}(1 \quad b)P^{w}_{vhs} $$

$$P^u(0,0,0) = \left[\sum_{i=0}^{m} \frac{\left(\lambda_{nr}^u T_{ns}^u\right)^i}{i!} \sum_{j=0}^{M-i} \frac{\left(\lambda_{hhr}^u T_{hhs}^u\right)^j}{j!} \sum_{k=0}^{M-i-j} \frac{\left(\lambda_{vhr}^u T_{vhs}^u\right)^k}{k!} \right]^{-1} \quad (20)$$

From [22], we write, $T_{nds}^u = \frac{1}{h^u} - \frac{r^u}{(h^u)^2}\left(1 - f_{R^u}^*(h^u)\right)$, $T_{hhds}^u = T_{vhds}^u = \frac{1}{h^u}\left(1 - f_{R^u}^*(h^u)\right)$

$$T_{hhs}^u = T_{vhs}^u = \frac{1}{r^u}\left(1 - h^u T_{ns}^u\right)$$

VI. PERFORMANCE ANALYSIS

A. Blocking Probabilities in UMTS

Blocking of an NR: An NR may be blocked in two cases.

*Case 1: A*n NR is blocked when there are already m ongoing NSs (i.e., *NR successful* states) in a cell. In this case, $i = m$, $j \le (M - m)$ and $k \le (M - m - j)$. In this case, $(j + k) \le (M - m)$ and $(i + j + k) \le M$. From equation (19), the probability that there are m ongoing NDSs in a UMTS cell , i.e., b_1^m is given by,

$$\sum$$

B. Blocking Probability in WLAN

There are two events in WALN, *NR arrival* and *VHR arrival*. Blocking of an NR or a VHR in WLAN occurs when all WLAN channels are busy. Using Erlang loss formula for two dimensional steady state Markov chain the probability that there will be i *NR successful* and k *VHR successful*

Dropping Probability of HHR: In UMTS-only coverage, an HHR occurs with probability $(1-g)$ i.e., g'

50% increase in WLAN coverage. The analytical results show an almost exact match with the simulation results given in [8] (Fig. 6).

Figure 6: System Capacity Versus hotspot coverage.

We compare the request dropping performance betw

Figure 8 shows the change in dropping probability of NR in a mixed cell with increasing new traffic with the effect of g. As g increases this dropping probability decreases. At NR arrival rate of 14 per sec and $g = 0.40$, the dropping probability decreases by 67.4% with respect to a pure UMTS cell (i.e., $g = 0$). To provide this performance level the UMTS-first access scheme [7] needs at least 10 reserved WLAN channels. Our scheme additionally permits NRs to access WLAN and supports session-handover from UMTS to WLAN, its request dropping performance is quite comparable with UMTS-first scheme without reserving WLAN bandwidth for handoff handling. Similar performance is obtained for handoff dropping also which is not provided due to limited scope.

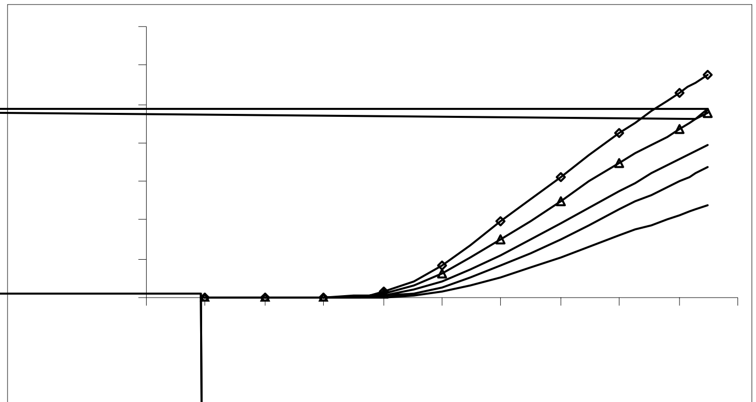


Figure 8: Dropping probability of NR in a mixed cell with increasing new traffic

VIII. CONCLUSION

WLAN-first access scheme supports handover of ongoing session between UMTS and WLAN. The results of system capacity are useful to quantify the requisite WLAN coverage to maintain threshold blocking performance of a UMTS cell The proposed under increasing traffic load. Model provides the effect of both WLAN and UMTS traffic on the dropping probability of a request. It mitigates the effect of increasing WLAN traffic on request dropping probability by transferring the blocked request of WLAN towards to UMTS system.

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[15]

since $A << 1,\ \frac{1}{A} >> 1$.

o, pot users / kup users or, backup users $\approx [\mathrm{Ad}]^{-1}$(hotspot users) (ii)

From the defi g v

spot users / xed users $= \frac{\text{hotspot users}}{\text{hotspot users} + \text{backup users}}$ (iii)

om eq) and (ii $g \approx \frac{1}{1+[\mathrm{Ad}]^{-1}}$

A II. P^u_{nds} =

P^u_{nd} s is the prob NDS in UMTS initiates HHR in a neighbor UMTS c initi HHR if the s e (SHT) is greater than the residual cell residence prob ity of HH e probability that the SHT is greater than th $P^u_{nds} = P(H^u > R$ igure i. shows the event space given by s the rang of H^u and R^u_r. Replacing H^u b wi

So, P^u_{nds} i

Under

Using re

(3.19)

From equati (3.19)

R^u $\int_0^{\infty}\int_t^{\infty} r^G (1-F_{R^u}(t))($

$$= r^u \int_0^\infty 1 - \int_0^t f_{R^u}(t)dt \;\; e^{-h^u t}dt \quad ;$$

where, $F_{R^u}(t) = \int_0^t f_{R^u}(t)dt$.

$$P^u_{nds} = r^u \int_0^\infty e^{-h^u t}dt - \int_0^\infty \int_0^t f_{R^u}(t)dt \;\; e^{-h^u t}dt$$

Using integration property of Laplace transform [201] with the variable h_G , following can be written.

$$P^u_{nds} = r^u \int_0^\infty e^{-h^{uG} t}dt - \frac{f^*_{R^u}(h^u)}{h^u} = \frac{r^u\left(1 - f^*_{R^u}(h^u)\right)}{h^u} \qquad (3.20)$$

Similarly, $P^u_{hhds} = P(H^u_r > R^u) = P(H^u > R^u)$; since $H^u_r = H^u$ from the memory less property of exponential distribution.. $P^u_{hhds} = \int^*_{R^u}(h^u)$. So, $P^u_{hhds} = (r^u)^{-1}h^u P^u_{nds} - 1$ and $P^u_{vhds} = P(H^u > R^u) = \int^*_{R^u}(h^u) = (r^u)^{-1}h^u P^u_{nds} - 1$.

Similarly, $P^w_{nds} = \frac{r^w\left(1 - f^*_{R^u}(h^w)\right)}{h^w}$ and $P^w_{vhds} = (r^w)^{-1}h^w P^w_{nds} - 1$

So, gp is the fraction of hotspot users out of total users in a mixed cell. We assume that request arrival rate from a particular class of users occurs in proportion with number of users. λ_{nr-t}^{m} is NR arrival rate from *total us*ers in a mixed cell.

Request arrival rate from *mixed user* (from equation (x)) = $p\lambda_{nr-t}^{m}$

Request arrival rate from hotspot users (from equation (xii)), $\lambda_{nr-hp}^{w} = gp\lambda_{nr-t}^{m}$ (xiv)

Request arrival rate from backup users, $\lambda_{nr-bu}^{u} = (1-g)\,p\lambda_{nr-t}^{m} = g'p\lambda_{nr-t}^{m}$ (xv)

All blocked calls of hotspot users also initiate NRs in UMTS. So, to NR arrival rate, λ_{nr}^{u} is given by,

$$\lambda_{nr}^{u} = \lambda_{nr-bu}^{u} + b\lambda_{nr-hp}^{w} = g'p\lambda_{nr-t}^{m} + bgp\lambda_{nr-t}^{m} \quad \text{(xvi)}$$