On the Handover Performance of a Tri-threshold Bandwidth Reservation CAC Scheme

Hoi Yan Tung, Kim Fung Tsang, Lap To Lee, Ka Lun Lam, Yu Ting Sun,
Shiu Keung Ronald Kwan, and Sammy Chan

ABSTRACT—A dynamic tri-threshold call admission control scheme has been developed. This scheme supports voice, data, and multimedia services and it complies with the universal mobile telecommunications system. The performance of the proposed scheme is evaluated under varying handover rates. The QoS performance–including channel utilization, call dropping probability, and blocking probability–is investigated. The performance of the developed scheme is found to be encouraging.

Keywords—Call admission control (CAC), quality of service (QoS), wideband mobile cellular network.

I. Introduction

In this letter, the tri-threshold bandwidth reservation (TTBR) scheme depicted in Fig. 1 is proposed and developed. The TTBR scheme supports multi-class services bearing differentiated QoS requirements. In this context, QoS is quantified by the channel utilization (CU), the conversational call blocking probability (CCBP), the weighted blocking probability (WBP), and the weighted handover dropping probability (WHDP). The specific QoS requirement for each of the three data services defined by the Universal Mobile Telecommunication System (UMTS) is achieved by adjusting the corresponding threshold value. The relationship between the QoS and the handover rate is investigated to determine the optimal performance of the network. For wideband mobile cellular networks, data and multimedia services are provided. These service classes have much longer call holding times and their characteristics vary significantly from conversational calls (CCs). When there are increasing call-holdings, the number of handover calls also increases. Therefore, it is important to evaluate the performance of the TTBR scheme under different handover rates. The performance of the TTBR should preferably be evaluated from the simulation model since the analytical model cannot fully account for the wideband characteristics of the mobile network.

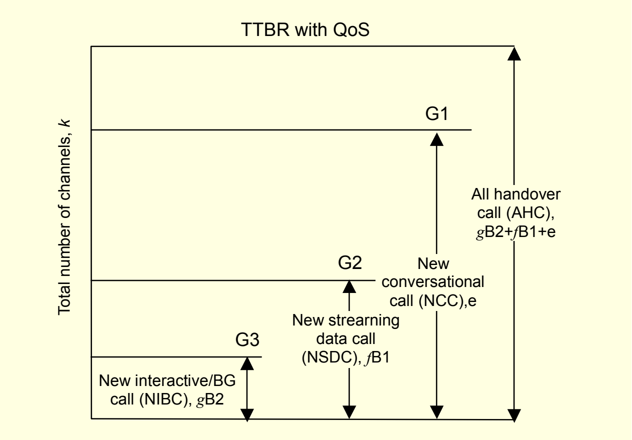

Fig. 1. TTBR priority scheme.

II. The Model

In the TTBR model, all-handover calls (AHCs) are assigned the highest priority in which conversational handover calls (CHCs), streaming data handover calls (SDHCs), and interactive/background handover calls (IBHCs) will have

---

Manuscript received July 14, 2006; revised Dec. 18, 2006.

Hoi Yan Tung (phone: + 852 2788 7806, email: Candy.tung@student.cityu.edu.hk), Kim Fung Tsang (email: ee330015@cityu.edu.hk), Lap To Lee (email: jackylee@cityu.edu.hk), Ka Lun Lam (email: 50325576@student.cityu.edu.hk), Yu Ting Sun (email: 50655344@student.cityu.edu.hk), and Sammy Chan (email: schan@ee.cityu.edu.hk) are with the Department of Electronic Engineering, City University of Hong Kong, Hong Kong, China.

Shiu Keung Ronald Kwan (email: 50648691@student.cityu.edu.hk) is with the Department of Manufacturing Engineering & Engineering Management, City University of Hong Kong, Hong Kong, China.

equally high priority. The remaining prioritizations are as follows in descending order: new conversational calls (NCCs), new streaming data calls (NSDCs), and new interactive/background calls (NIBCs). The priority assignment is based on the UMTS recommendation that CCs are delay sensitive and do not tolerate service degradation, whereas interactive/background calls (IBCs) are delay insensitive [1].

In the TTBR scheme, it is assumed that each cell has a total of k channels and that the bandwidth requirement for CCs, streaming data calls (SDCs), and IBCs are 1, B1, and B2, respectively (with B1 >1, B2 >1). Let n denote the number of busy channels. As shown in Fig. 1, k channels of each cell are partitioned into four regions by three thresholds, namely G1, G2, and G3, with priority G1 > G2 > G3. When n < G3, CCs, SDCs, and IBCs are admitted into the network upon request. When n > G3, all NIBCs will be rejected. When n > G2, both NIBCs and NSDCs will be rejected while AHCs and NCCs will be admitted to the system. If n > G1, only AHCs will be admitted. Finally, AHCs will be surrendered when the network lacks sufficient channels for service.

The arrival traffic patterns of IBCs and SDCs are still a hot topic of research pending final conclusion. Nevertheless, Poisson distribution is one of the most common and rational candidates since it describes human behaviour satisfactorily, especially regarding CCs. In order to gain more insight, a comparison with the results from [2] and [4] will be made in later contexts (see Fig. 2). It is assumed that the call arrivals of NCCs, CHCs, NSDCs, SDHCs, NIBCs, and IBHCs are Poisson distributed with arrival rates of λ_{vn}, λ_{vh}, λ_{sn}, λ_{sh}, λ_{bn}, and λ_{bh}, respectively. The call holding times of CCs, SDCs, and IBCs are assumed to follow an exponential distribution with means $1/\mu_v$, $1/\mu_s$, and $1/\mu_b$, respectively. In addition, the residence time for CHCs, SDHCs, and IBHCs are exponentially distributed with means m_v, m_s, and m_b, respectively. Based on [2], and by performing a three-dimensional Markov Chain analysis, a general equation for each state is obtained as

$$\begin{aligned}&(\hat{\lambda}_v + e\hat{\mu}_v + f\,\mathrm{B}1\hat{\mu}_s + \hat{\lambda}_s + g\,\mathrm{B}2\hat{\mu}_b + \hat{\lambda}_b)P_{e,f,g}\\ &= (e+1)\hat{u}_v P_{e+1,f,g} + \hat{\lambda}_v P_{e-1,f,g} + (f+1)P_{e,f+1,g}\\ &+ \hat{\lambda}_s P_{e,f-1,g} + (g+1)\,\mathrm{B}2\hat{\mu}_b P_{e,f,g+1} + \hat{\lambda}_b P_{e,f,g-1},\end{aligned} \tag{1}$$

where $P_{e,f,g}$ denotes the steady state probability under e number of CCs, f number of SDCs, and g number of IBCs; $\hat{\mu}$, defined as $\mu + 1/m$ denotes the total effective call departure rate; and $\hat{\lambda}$ denotes the total effective call arrival rate, that is, $\lambda_n + \lambda_h$.

All steady state probabilities are then obtained by using the recursive technique. The boundary state probabilities are determined by solving the remaining independent equations using normalization. Then, steady-state probabilities, $P_{e,f,g}$, are obtained, the global state probabilities, P_z, are given by

$$P_z = \sum_{e+f\,\mathrm{B}1+g\,\mathrm{B}2=z} P_{e,f,g}. \tag{2}$$

III. Numerical Results

The performance of TTBR is evaluated under different handover rates using an OPNET simulation model. In order to compare with the performance in [2]-[4], the settings shown in Table 1 are used.

It is known from [3] that uneven distribution of traffic will lead to a drop in CU, hence the traffic loadings are chosen to be identical in all cells. The handover rates for each class of service are chosen from 1 call/min to 5 call/min, at an increment of 1 call/min [3]. Hence, five cases need to be considered.

Two QoS requirements (referred as 2QR thereafter) are now discussed. According to [3], the first QoS requirement (2QR-1) is that CCBP should be less than 1%. The second QoS requirement (2QR-2) is that WHDP should also be less than 1%. The 2QR-1 is a typical QoS requirement for research and 2QR-2 guarantees call contingency adopting a user friendly approach. In this investigation, the total number of channels used to fulfill the captioned 2QR, k, is given by

$$k = 8(n-1) - 1, \tag{3}$$

where n is the number of frequency carriers required to achieve 2QR without using any CAC scheme (with one control channel removed).

The scheme using TTBR is denoted as w-TTBR and the scheme without using TTBR is denoted as wo-TTBR. The QoS of TTBR under different handover rates is shown in Fig. 2. It is seen that the CU of TTBR drops slightly when the handover rate, $1/m$, is increased. Increase in the handover rate causes more handover calls into a cell. This also causes an increase in the departure rate, hence provoking more termination calls and handover calls (out of the cell). Such an environment under an increasing arrival rate is referred as a bursty environment. The bursty background, in turn, causes a higher overall BP (new call blocking and handover blocking), thus leading to lower efficiency. In order to examine the

Table 1. Setting of simulation for scenarios 1-5.

Service	CC	SDC	IBC
Bandwidth	1	2 (B1)	4 (B2)
$1/\mu$ (min)	2	3	4
λ_n (call/min)	2	0.75	0.6

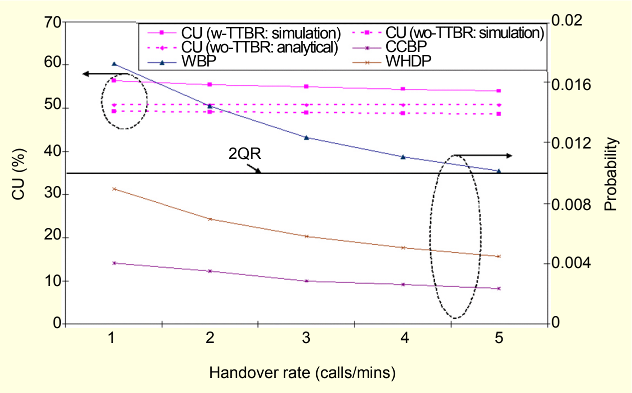

Fig. 2. QoS evaluation of TTBR versus handover rate.

network performance under bursty traffic, the CU, CCBP, WBP, and WHDP will be investigated.

The accuracy of the simulation model is very good. The simulation and the analytical results of CU for wo-TTBR are shown in Fig. 2. The average percentage of difference is found to be 3.61%. This difference is attributed to both the handover effect and random factors [3]. It is also noted that the discrepancy increases as the handover rate increases because the analytical model is insensitive to the change of handover rate and is only sensitive to traffic loadings. The characteristics of w-TTBR are also shown in Fig. 2. The worst discrepancy between the simulated and analytical results (w-TTBR) is 9.31%. This difference is due to the fact that the analytical model is not sensitive enough to cater for the increasing blocked new calls, thus yielding a drop in handover calls (since λ_{hv} is kept constant for all possible states in the Markov chain). Once the simulated data has initially been calibrated by using data from the analytical model, the simulation model is used thereafter. From Fig. 2, it is seen that under the condition of less resources (eight channels less) the w-TTBR scheme still fulfills the 2QR condition and achieves a better CU, typically 6% under all scenarios, than its wo-TTBR counterpart. Since the traffic loading is kept constant, each channel can serve more calls, thereby enhancing efficiency. Figure 2 also demonstrates that w-TTBR, under all scenarios, does not impose any negative effect on the CU as the handover rate is increased.

It was documented [2] that the DTBR has better CU when the call arrival rates of handover calls are increased. This is accurate only when the traffic loads are configured under different traffic intensities. In the case of equal traffic loads, the outcome can be very different.

The relationships of CCBP, WBP, and WHDP to handover rate are also shown in Fig. 2. It is important to stress that the evaluation is based on the condition that eight channels have been removed (refer to (3)). It is seen that the CCBP and the WHDP still meet 2QR. This is simply because the TTBR scheme employs three adjustable thresholds which cater for the adjustment of QoS for each class of service independently and hence will adapt to the changes in traffic load. The WHDP drops by 50% as the handover rate is increased. Since the total traffic is kept constant in this investigation, the number of AHCs increases as the number of new calls decreases. When the number of AHCs is increased, these calls can nevertheless manage the surplus resource resulting from the reduction of new calls since the AHCs are assigned the highest priority. Moreover, the WBP drops by 40% as the handover rate is increased. The increase in handover rate implies that the occupancy of a channel is shorter, leaving more room for the calls to handover to another cell; therefore, the WBP drops. Based on the findings, it is predicted that the TTBR scheme caters for heavy traffic and high mobility. It is found that the scheme has a low BP of CCs, low WHDP as well as a high CU.

IV. Conclusion

We investigated the effect of handover rate on the performance of the TTBR scheme. In this investigation, the total traffic load was kept constant and the ratio of new and handover calls was varied. It was found that the TTBR scheme can maintain CU as handover calls are increased. This finding is different from the conclusion drawn in a former investigation. The former scheme [2] improves the CU under a high arrival rate of handover calls. More importantly, it was found that the TTBR scheme improves the WHDP and the WBP by 50% and 40%, respectively. It is vital to point out that after removing eight channels, TTBR can still maintain both the CCBP and the WHDP to below 1%. We conclude that TTBR is appropriate for application at a high handover rate; therefore, the TTBR caters to the needs of wideband mobile cellular networks.

References

[1] 3GPP TS 23.107: *Quality of Service (QoS) Concept and Architecture.*

[2] Bin Li, L. Li, Bo Li, K.M. Sivalingam, and X.R. Cao, “Call Admission Control for Voice/Data Integrated Cellular Networks: Performance Analysis and Comparative Study,” *IEEE J. Selected Areas in Commun.*, vol. 22, no. 4, May 2004, pp. 706-718.

[3] L.H. Pang and M. Zukerman, “Efficiency Comparison of Channel Allocation Schemes for Digital Mobile Communication Networks,” *IEEE Trans. on Vehicular Technology*, vol. 49, no. 3, May 2000, pp. 724-733.

[4] D.Z. Deniz and N.O. Mohamed, “Performance of CAC Strategies for Multimedia Traffic in Wireless Networks,” *IEEE J. Selected Areas in Commun.*, vol. 21, no. 10, Dec. 2003, pp 1557-1565.