QUEUED COMBINED GUARD CHANNEL AND MOBILE ASSISTED HANDOFF CALL ADMISSION IN 5G NETWORKS

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ABSTRACT

The performance of the combined guard channels and mobile handoff call admission control is studied. If a handoff call arrives, and there are not enough channels for its service, it is queued in a finite buffer. Two customer types, narrowband (voice calls) and wideband (data, video and media) are considered. Matrix algorithmic techniques are used to solve the balance equations to calculate the different performance measures of the system. The results indicate that when handoff calls are queued, handoff call dropping is reduced for both types of calls and there is an increase in the bandwidth utilization. There is no noticeable change in the blocking probability of new calls. Increasing the size of the queue, led to further reduction in the handoff call dropping and increase in the bandwidth utilization.

KEYWORDS

Call admission control, Wireless Networks, Mobile Networks, Guard channels, Mobile assisted handoff

1. INTRODUCTION

Wireless 5G networks carry different types of traffic; voice, data and video. Each of these traffic types has different Quality of Service (QoS) requirements; for example voice and video can only tolerate very small delays while when sending data, more delay can be accepted.

Provision for handoff calls is important in wireless 5G networks. Handoff calls are calls which have started service in one cell and moved to another cell before the call is complete. It is generally accepted that it is not acceptable for a user to have a call dropped simply because he/she moved to another cell. Wireless Call Admission Control (CAC) strategies have to prioritize handoff calls so as to decrease the handoff call dropping as much as possible.

Call Admission Control (CAC) strategies in wireless networks are required to guarantee that each of the different traffic types achieves its QoS requirements and at the same time decrease the probability of handoff call dropping as much as possible.

Call admission strategies for prioritizing handoff calls are found in numerous works in the literature [1]–[4] . Guard or Reserve channels strategies, reserve a certain fraction of the bandwidth for handoff. Other strategies limit the number of new originating calls accepted to allow more handoff calls to be serviced. These strategies, called Threshold CAC strategies are

David C. Wyld et al. (Eds): ICDIPV, CBIoT, ICAIT, WIMO, NC, CRYPIS, ITCSE, NLCA, CAIML -2023
pp. 263-272, 2023. CS & IT - CSCP 2023 DOI: 10.5121/csit.2023.131320

presented in [5] and [6]. Still other strategies let handoff calls wait in queues in the hope that bandwidth will become available for their service before they are dropped [7].

The most common WCAC is the Guard Channels (GC) CAC strategy in which a number of channels are reserved for handoff calls. In this way, additional channel resources are made available for handling handoff calls only in the event of common sharable channels being exhausted. This effectively provides a form of prioritization for handoff calls.

In cellular wireless networks, each mobile station (MS) is connected using a radio link to the base station (BS) of the cell where it is currently located. One or more BS's are under the control of a mobile switching center (MSC). The primary function of the MSC is managing mobility. When an MS moves, it is possible that the currently serving BS may no longer be able to provide reasonable service as compared to some other BS. Thus the MSC may decide to handoff this MS to some other better serving BS or in some cases to another MSC. There are a number of handoff techniques. The simplest handoff technique is the one in which the MS is responsible for making handoff decisions. When the received signal strength drops below an acceptable threshold, the MS may decide to choose another BS. Another technique is to allow the network to make the handoff decisions. A third technique combines the two approaches so that handoff decisions are made jointly by the network and the mobile stations [3]. This approach is called mobile assisted handoff (MAHO). In the MAHO scheme, while the network makes the final handoff decisions, it is assisted by the mobile terminal in the handoff process. This assistance takes the form of serving BSS asking the MTs to periodically report their received signal quality (in terms of the RSSI and the BER values) from the surrounding base stations.

In [3], it is suggested that both the guard channel approach as well as the MAHO scheme can individually result in unnecessary loss of handoff calls. For example, in the MAHO scheme, it is possible that the serving base station may end up handing off a call to another base station that has good signal quality, but there are no free channels available in the new base station to accept this handoff call. Similarly, when using the guard channel approach, since the signal strength is not taken into consideration while making handoff decisions, there is a finite probability that the serving base station may hand over call to a new base station that has poor signal quality. To address limitations of single criterion handoff schemes, such as MAHO and guard channel, a combined MAHO and guard channel (M+G) based approach was proposed. In [3] and [8], M+G scheme is analyzed for systems serving one customer type and two customer types respectively.
In [4], a queueing analysis of the M+G strategy is performed for one customer type. In this work, the M+G strategy with a queue two customer types, *n*-type (narrowband customers) and *w*-type (wideband customers) is considered. Handoff calls are queued if there are no enough channels for their service.

2. SYSTEM MODEL

A wireless cell with a total of *m* channels is considered. Arrivals to the system are from 2 customer streams; narrowband, *n*-type and *w*-type. *N*-type customers require $b_n = 1$ channels for their service while *w*-type customers require $b_w > 1$ channels for their service. The arrival process distribution for type *i* ($i = n,w$) customers is Poisson with mean λ_i calls per unit time. The call holding time of type *i* customers is exponentially distributed with mean μ_i^{-1} unit time. Handoff calls for type *i* customers also form a Poisson process with mean rate α_i. The cell residence time (CRT) i.e., the amount of time during which a mobile user of type *i* stays in a cell is assumed to follow the exponential distribution with mean θ_i^{-1}. The queue dwell time, the maximum time that a call can spend in the queue before being dropped is assumed to be exponentially distributed with mean β^{-1}.

3. (M+G) CAC STRATEGY WITH HANDOFF CALL QUEUEING

In the (M+G) CAC strategy, both the guard channels and the signal strength are considered when accepting a handoff call. The channels are divided into active channels, *A* and guard channels, *G*. New calls will only be served from the *A* channels. If there are not enough *A* channels for their service they will be dropped.

When a handoff call of type *i* arrives, its signal strength is compared with a pre-set signal threshold value, S_t, if its signal strength is less than the S_t, it is immediately dropped. If the signal strength of the handoff call is greater than or equal to S_t, and there are enough free *A* channels for its service, it is served otherwise, the balance is taken from the free *G* channels. If there are not enough free *A*+*G* channels, the handoff call is placed in the queue.

Fig.1 gives the 2-D Markov chain representation of the system under study; γ is the probability that the system has accepted a handoff call with good signal quality.

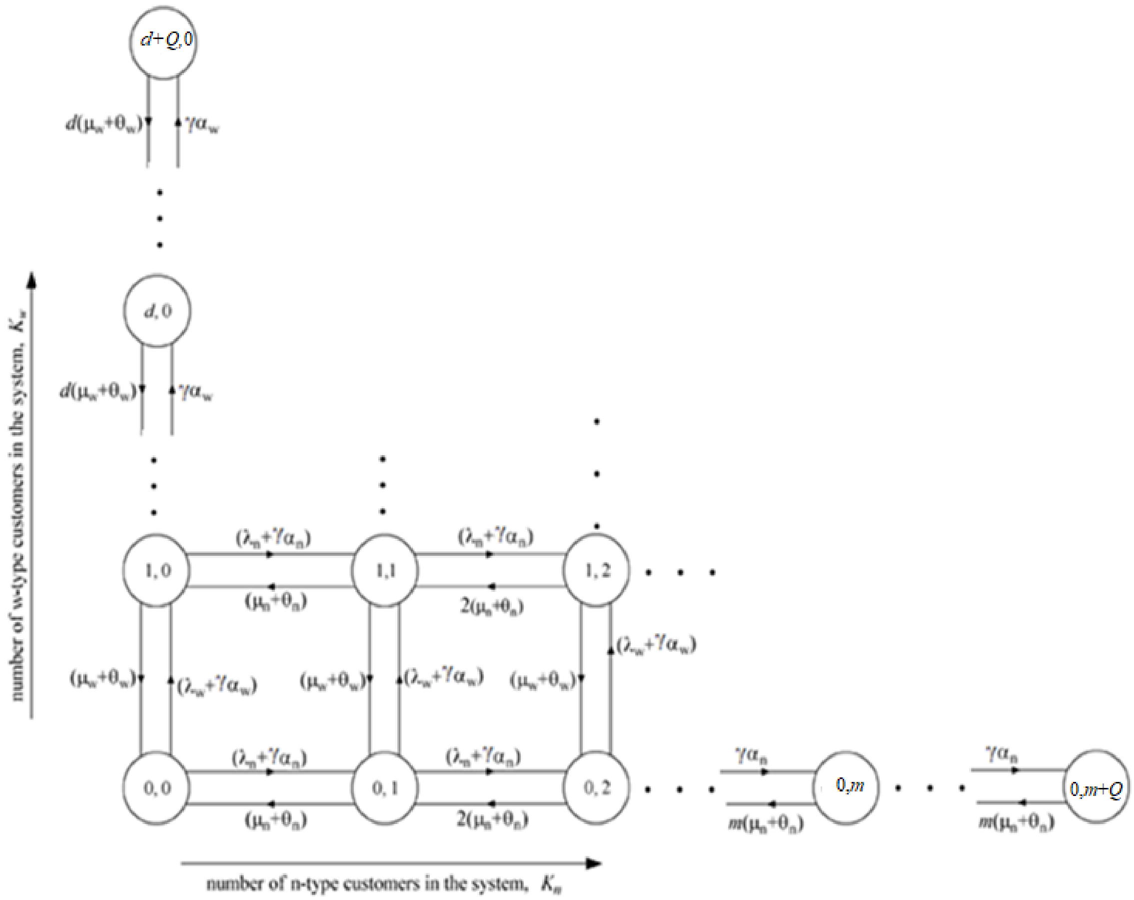

Figure.1: 2-D Markov Chain

The 2-D Markov chain can be mathematically represented as:

$$E = \{\mathbf{K}: K_n = 0,1,\ldots,m+Q; K_w = 0,1,\ldots,d+Q: d = \left[\frac{m}{b_w}\right]\} \tag{1}$$

where *Q* is the size of the queue for handoff calla

In state **K**, we can compute the number of *n*-type and *w*-type calls being served ($S_n(\mathbf{K})$ and $S_w(\mathbf{K})$) using (2)

$$\begin{aligned} &S_n(K) = K_n \ and\ S_w(K) = K_w \quad if\ \ (K_n + K_w b_w) \le m \\ &S_n(K) = 0\ and\ S_w(K) = 0 \quad otherwise \end{aligned} \tag{2}$$

The number of free active channels, f_A (**K**) and the number of free guard channels, $f_G(\mathbf{K})$ are given by (3):

$$\begin{aligned} &f_A(\mathbf{K}) = A - r \ \text{ and } \ f_G(\mathbf{K}) = G \ \ if\ r \le A \\ &f_A(\mathbf{K}) = 0 \ \text{ and } \ f_G(\mathbf{K}) = m - r \ \text{ otherwise} \end{aligned} \tag{3}$$

where

$$r = S_n(\mathbf{K}) + S_w(\mathbf{K}) b_w$$

$f_n(\mathbf{K})$, $f_w(\mathbf{K})$, and $f_H(\mathbf{K})$ are the number of channels which are free for the service of originating n-type, originating w-type and handoff calls respectively. These values are calculated using (4).

$$\begin{aligned} &f_n(K) = f_A(K) \\ &f_w(K) = f_A(K) \\ &f_H(K) = f_A(K) + f_G(K) \end{aligned} \tag{4}$$

From Fig.1, the global balance equations are derived as:

$$\begin{aligned} -\{&\lambda_n \mathrm{I}(f_n(\mathbf{K}) > 0) + \gamma\alpha_n \mathrm{I}(f_H(\mathbf{K}) > 0) + \lambda_w \mathrm{I}(f_w(\mathbf{K}) \ge b_w) + \gamma\alpha_w \mathrm{I}(f_H(\mathbf{K}) \ge b_w) \\ &+ S_n(\mathbf{K})(\mu_n + \theta_n) + S_w(\mathbf{K})(\mu_w + \theta_w) + Q_n(\mathbf{K})(h + hdrop) \\ &+ Q_w(\mathbf{K})(h + hdrop)\} p(\mathbf{K}) \\ &+ \{\lambda_n \mathrm{I}(f_n(\mathbf{K} - \boldsymbol{e}_2) > 0) + \gamma\alpha_n \mathrm{I}(f_H(\mathbf{K} - \boldsymbol{e}_2) > 0)\} p(\boldsymbol{K} - \boldsymbol{e}_2) \\ &+ \{\lambda_w \mathrm{I}(f_w(\mathbf{K} - \boldsymbol{e}_1) \ge b_w) + \gamma\alpha_w \mathrm{I}(f_H(\mathbf{K} - \boldsymbol{e}_1) \ge b_w)\} p(\boldsymbol{K} - \boldsymbol{e}_1) \\ &+ \{S_n(\mathbf{K} + \boldsymbol{e}_2)(\mu_n + \theta_n) + Q_n(\mathbf{K} + \boldsymbol{e}_2)(\theta_n + \beta)\} p(\boldsymbol{K} + \boldsymbol{e}_2) \\ &+ \{S_w(\mathbf{K} + \boldsymbol{e}_1)(\mu_w + \theta_w) + Q_w(\mathbf{K} + \boldsymbol{e}_1)(\theta_w + \beta)\} p(\boldsymbol{K} + \boldsymbol{e}_1) = 0 \end{aligned} \tag{5}$$

where $Q_n(\mathbf{K})$ and $Q_w(\mathbf{K})$ are the number of n-and w-type customers in the queue.

The normalizing equation is given as

$$\sum_{\mathbf{K} \in E} p(\mathbf{K}) = 1 \tag{6}$$

Equations (5) and (6) can be written in matrix form as

$$\begin{aligned} &\mathbf{Q\,p} = \mathbf{0} \\ &\mathbf{e\,p} = \mathbf{1} \end{aligned} \tag{7}$$

Using matrix algorithmic techniques, we can solve for $p(\mathbf{K})$.

The blocking probabilities of the two types of customers (BP_n and BP_w) and the probability of handoff call dropping for the two customer types (HD_n and HD_w) and the average bandwidth utilization can be calculated using (8)-(12).

$$BP_n = \sum_{\mathbf{K} \in E} p(\mathbf{K}) I(f_n(\mathbf{K}) < 0) \tag{8}$$

$$BP_w = \sum_{\mathbf{K} \in E} p(\mathbf{K}) I(f_w(\mathbf{K}) < b_w) \tag{9}$$

$$HD_n = \sum_{\mathbf{K} \in E} p(\mathbf{K}) I(f_H(\mathbf{K}) < 0) \tag{10}$$

$$HD_w = \sum_{\mathbf{K} \in E} p(\mathbf{K}) I(f_H(\mathbf{K}) < b_w) \tag{11}$$

$$E(U) = \sum_{\mathbf{K} \in E} p(\mathbf{K}) \{S_n(\mathbf{K}) + S_w(\mathbf{K})\} \tag{12}$$

4. RESULTS

We consider a wireless cell with $m = 30$ channels, $b_n = 1$ channel and $b_w = 6$ channels. $\mu_w^{-1} = 300$ seconds, $\mu_n^{-1} = 200$ seconds, $\lambda_w = 1/30$ call arrivals/sec, λ_n is varied from 0.05 to 0.5 call arrivals/sec, $\alpha_n = ½\lambda_n$, $\alpha_w = ½\lambda_w$ call arrivals/sec, $\theta_n^{-1} = \theta_w^{-1} = 100$ seconds and $\beta^{-1} = 5$ seconds. The probability of accepting a weak signal, $\gamma = 0.5$, i.e., a weak signal has a probability of 0.5 of being served.

The results obtained are depicted in Figs 2-6. Two cases are considered; the case of handoff call are queued and the case of no queueing for handoff calls.

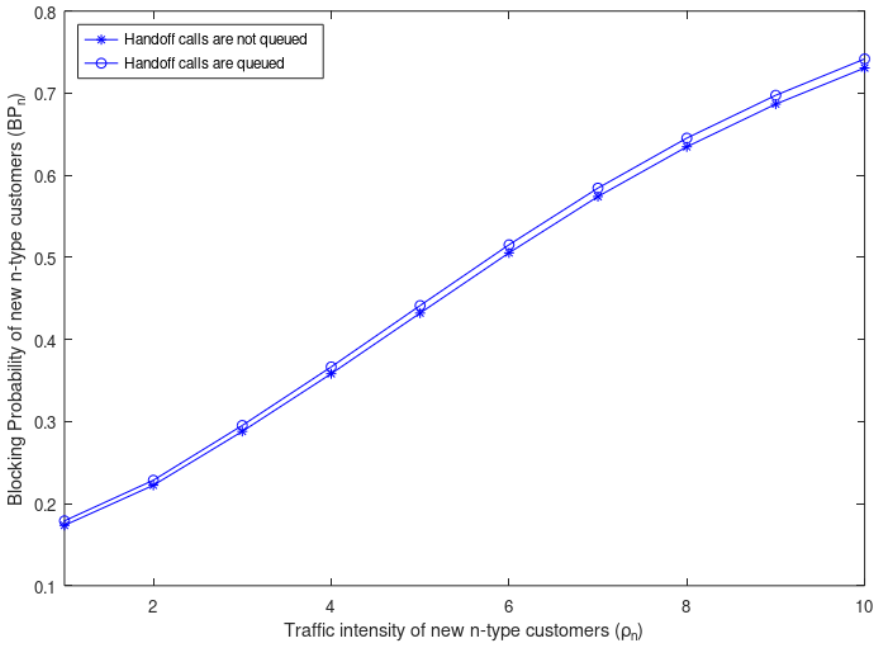

Figure 2: Blocking Probability of originating new n-type calls (BP_n) versus ρ_n

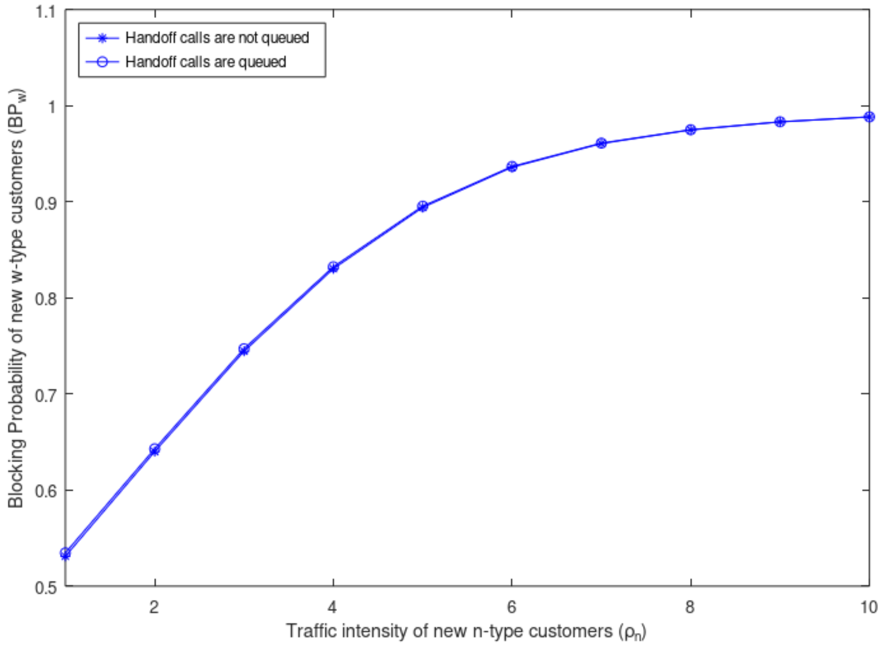

Figure 3: Blocking Probability of originating *w*-type calls (BP_w) versus ρ_n

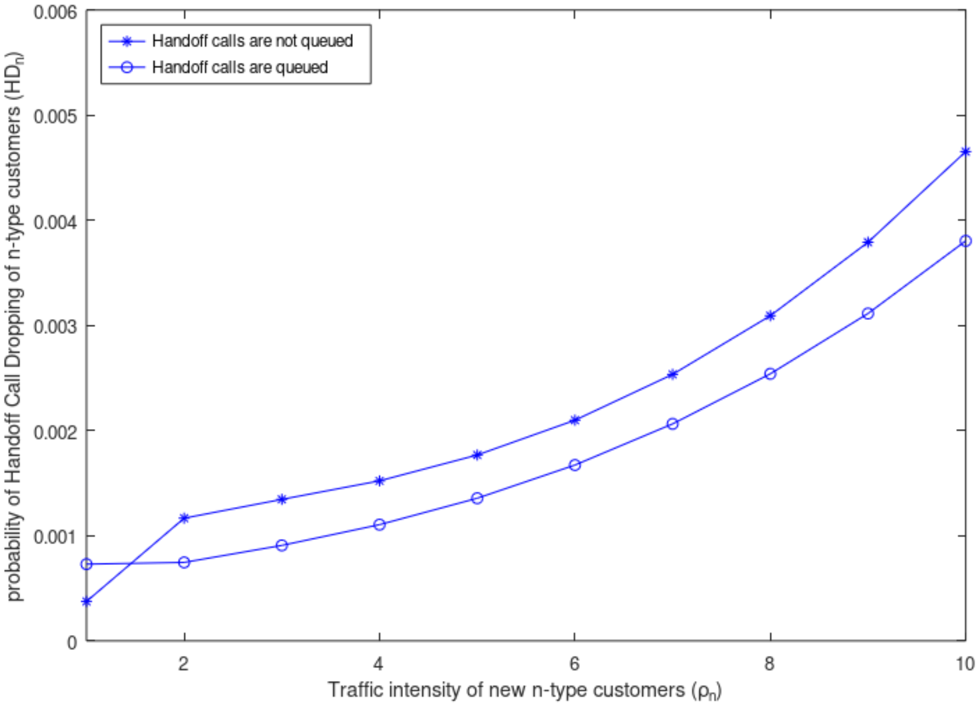

Figure 4: Probability of *n*-type handoff call dropping (HD_n) versus ρ_n

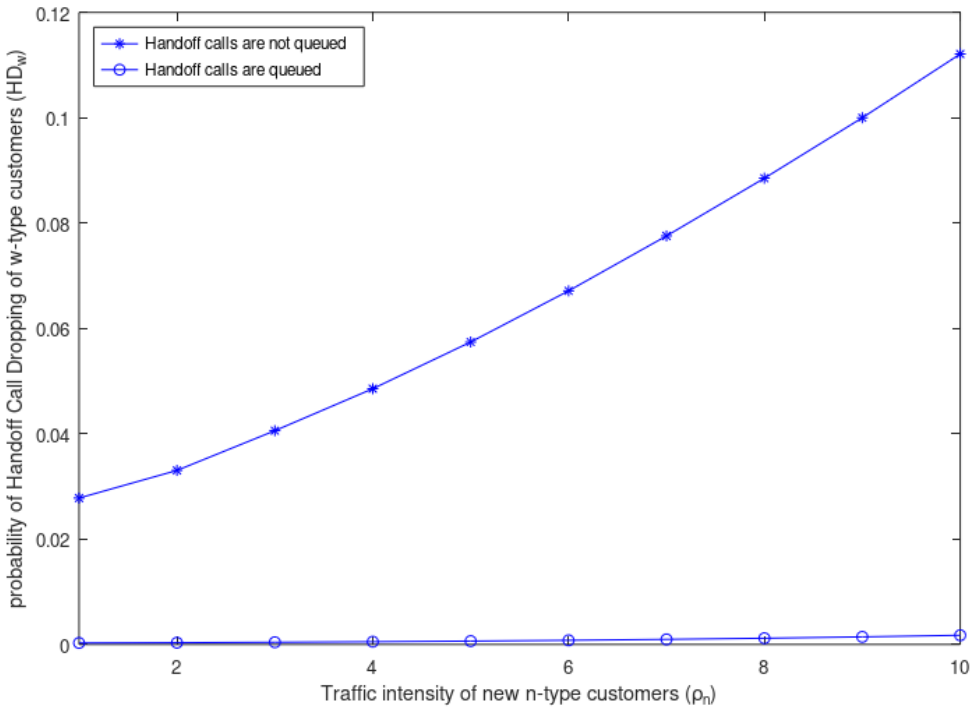

Figure 5: Probability of *w*-type handoff call dropping (HD_w) versus ρ_n

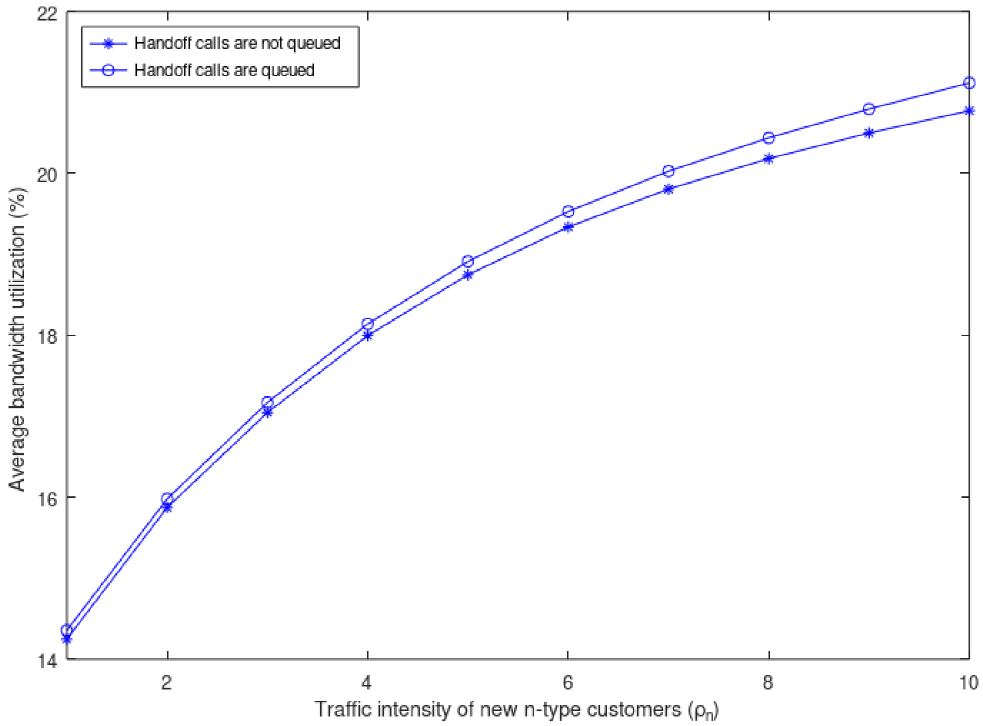

Figure 6: Average bandwidth utilization ($E(U)$) versus ρ_n

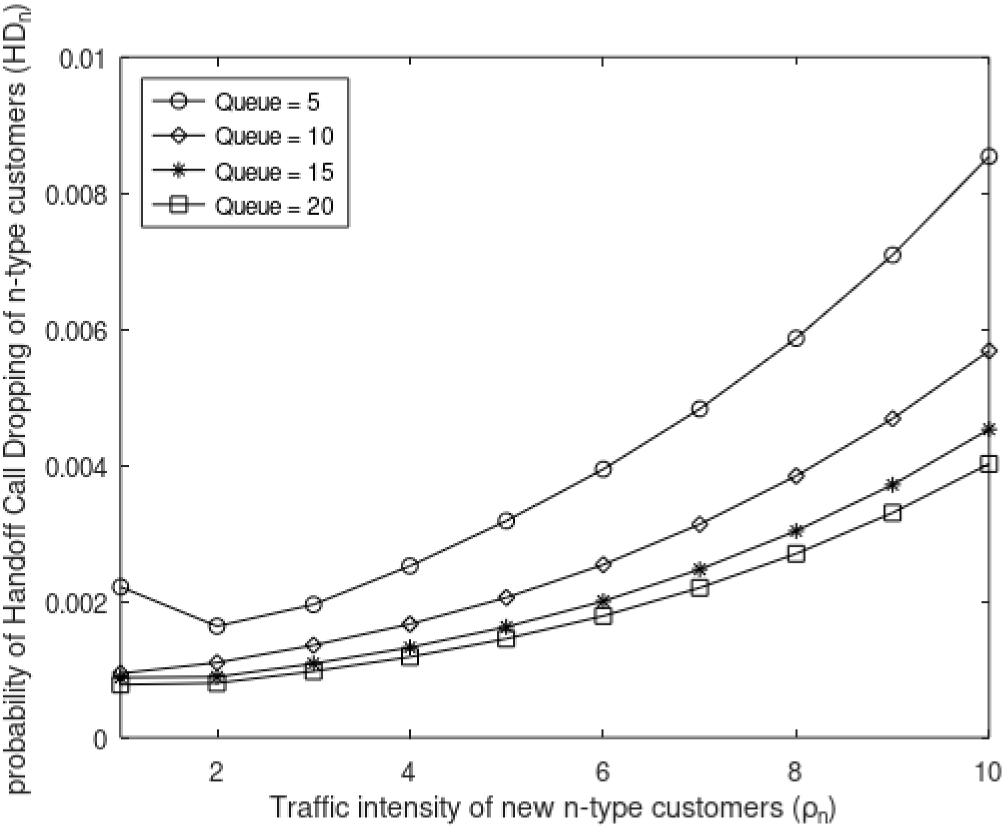

Figure 7: Probability of *n*-type handoff call dropping (*HD*$_n$) versus ρ_n

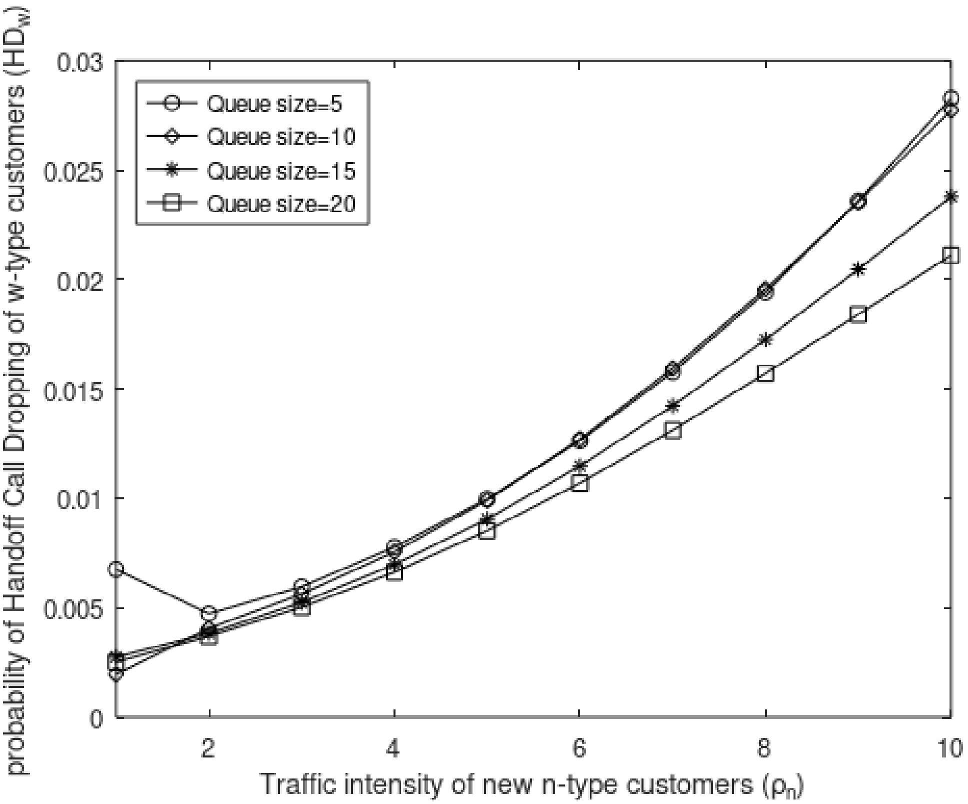

Figure 8: Probability of *w*-type handoff call dropping (HD_w) versus ρ_n

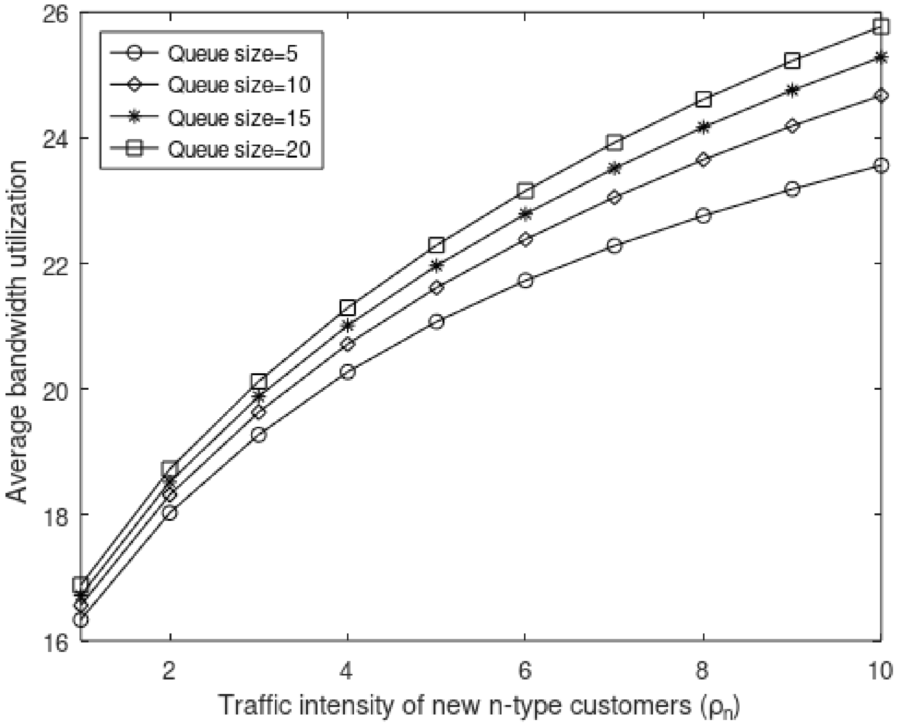

Figure 9: Average bandwidth utilization ($E(U)$) versus ρ_n

5. CONCLUSIONS

Queueing of handoff calls in the (M+G) CAC strategy led to a reduction in the handoff call dropping of both customer types. The blocking probability of new calls was not affected while the average bandwidth utilization was increased.

COMMENTS

The results indicate that the proposed CAC strategy gives better results than the (M+G) strategy. Figures 2 and 3, show that there is no noticeable difference between the queued and non-queued (M+G) strategy (or there is a slight reduction in BP_n) for the queued (M+G) strategy, this is to be expected as the queueing is only for handoff calls.

Figures 4 and 5 indicate that there is a reduction in the probability f handoff call dropping for the 2 call types (*n* and *w*) decreases when there is queueing. In the case of *w*-type handoff call dropping, the reduction is much more than the case of *n*-type handoff call dropping; this means that the improvement for *w*-type handoff calls is more than for *n*-type handoff calls because *n*-type calls are much more likely to be serviced than wait in the queue (they require only one channel for their service) so the presence of the queue favors *w*-type handoff calls more.
Bandwidth utilization is also slightly increased when using the proposed strategy (Figure 6). This is expected since calls are waiting in the queue, and whenever a channels become free a call is immediately served from the queue.

Figures (7-9) depict the different performance measures while the queue size, is increased from 5 to 20. It is noticed that there is an improvement for all performance measures when the queue size increases. So we can conclude that if handoff calls are queued in the (M+G) strategy, the handoff call dropping will be reduced (which is desired in WCAC) and bandwidth utilization will be increased.

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