THE EFFECT OF ACCEPTED HANDOFF SIGNAL QUALITY ON THE QUEUED COMBINED GUARD CHANNEL AND MOBILE ASSISTED HANDOFF CALL ADMISSION IN 5G NETWORKS

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ABSTRACT

The effect of handoff call signal strength on the performance of the combined guard channels and mobile assisted handoff with handoff queueing is studied. If a handoff call arrives and it has an acceptable signal quality, and there are not enough channels for its service, it is queued in a finite buffer. If during its dwell time in the queue, enough channels become available, it is immediately serviced, otherwise if its dwell time is completed, and no channels are available for its service it is dropped. 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 the handoff calls with good signal strength have higher probability of being accepted, the blocking probability of new calls of both types increase much more than for the handoff call dropping. Average channel utilization is also increased. Increasing the size of the queue, led to further reduction in the handoff call dropping and increase in the bandwidth utilization. When both the probability of accepting a handoff call with good quality and the queue size is increased, the blocking probability of new calls is not affected while the handoff call dropping in reduced. In all cases, it is noticed that the handoff call dropping of wideband calls is less than the handoff call dropping of narrowband calls.

KEYWORDS

Call admission control, Wireless Networks, Mobile Networks, Guard channels, Mobile assisted handoff, handoff call signal strength

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 completed. It is not acceptable for a user to have a call dropped simply because he/she moved to another cell.

Dropping an ongoing connection is highly undesirable. For voice calls, it not only causes annoyance to the users, dropped calls also imply increased wireless bandwidth consumption, since a dropped call has to be re-established, leading to unavoidable consumption of time and bandwidth. Dropping a wideband call may have even more serious consequences.

Wireless Call Admission Control (WCAC) strategies have to prioritize handoff calls so as to decrease the handoff call dropping as much as possible.

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Therefore, 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.

Wireless Call admission strategies for prioritizing handoff calls are found in numerous works in the literature . Guard 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 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 BS may end up handing off a call to another BS 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 the probability that the serving BS may handover call to a new BS that has poor signal quality. To address the limitations of single criterion handoff schemes, such as MAHO and GC, a combined MAHO and GC (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, a study of the queued (M+G) strategy for two customer types, *n*-type (narrowband customers) and *w*-type (wideband customers) with handoff calls that have different signal is performed.

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}. A queue of size, Q is available for handoff calls. 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. If during its dwell time in the queue, enough channels become available, it is immediately serviced, otherwise if its dwell time is completed, and no channels are available for its service it is dropped.

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.

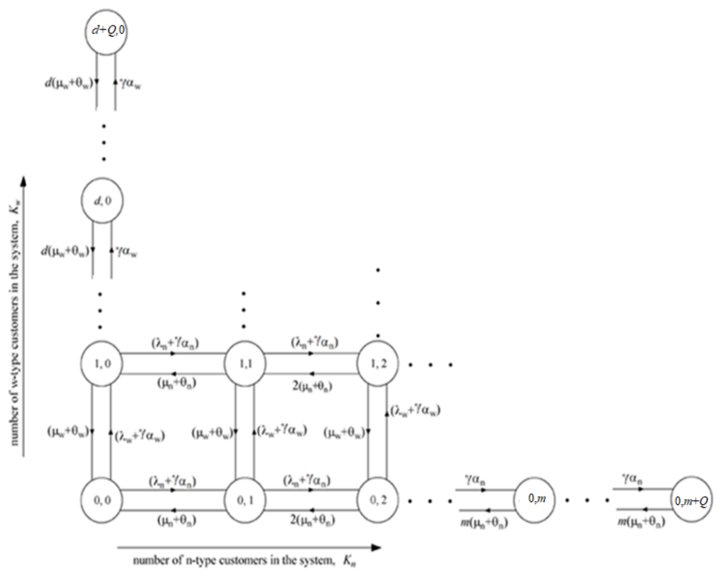

Figure.1: 2-D Markov Chain

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

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

where Q is the size of the queue for handoff calls.

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)

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

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

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

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).

$$\begin{gathered} f_n(K) = f_A(K) \\ f_w(K) = f_A(K) \\ f_H(K) = f_A(K) + f_G(K) \end{gathered} \quad (4)$$

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

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

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

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

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

$$\mathbf{Q\,p} = \mathbf{0}$$
$$\mathbf{e\,p} = \mathbf{1} \tag{7}$$

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 channel utilization E(U) 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. μ_w^{-1} =300 seconds, μ_n^{-1} =200 seconds, λ_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 β^{-1} = 5 seconds. Q=10. The probability of accepting a weak signal, γ, is varied from γ =0.1 to γ = 0.9.

The results obtained are depicted in Figs 2-6. Figures 7-9 depict the case of varying the Queue size, while the signal strength is fixed. While Figures 10-14 show the case of varying the signal strength and the queue size while the traffic intensity of new n-type calls is fixed at ρ_n=1.

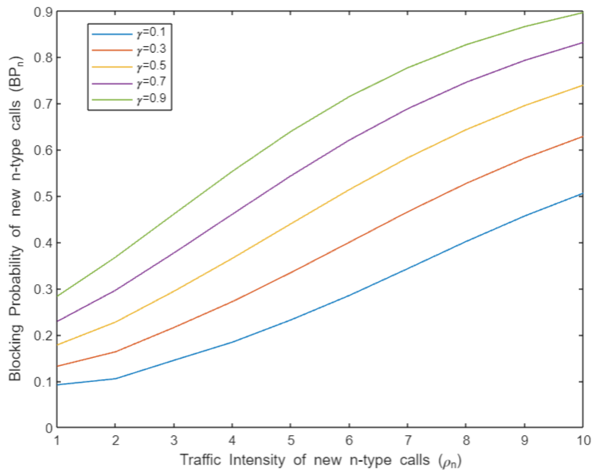

Figure 2: Blocking Probability of new n-type calls (BP_n) versus ρ_n while varying γ

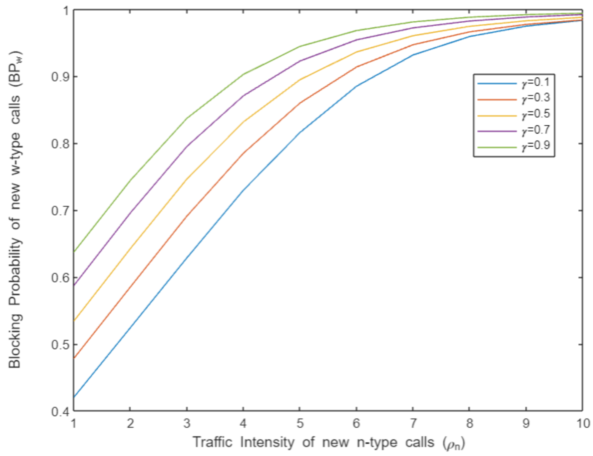

Figure 3: Blocking Probability of new w-type calls (BP_w) versus ρ_n while varying γ

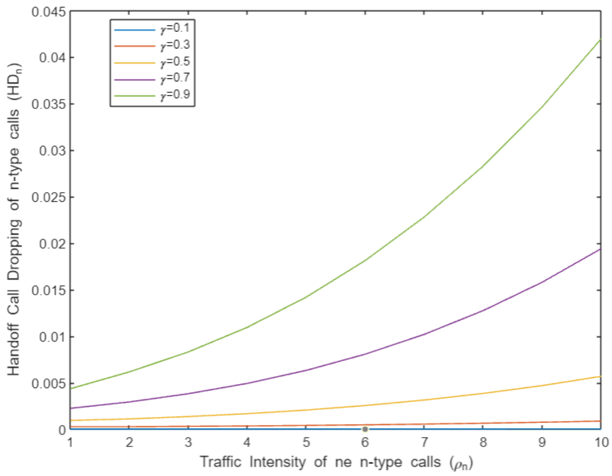

Figure 4: Handoff call Dropping of n-type calls (BP_n) versus ρ_n while varying γ, the probability that the system has accepted a handoff call with good signal quality.

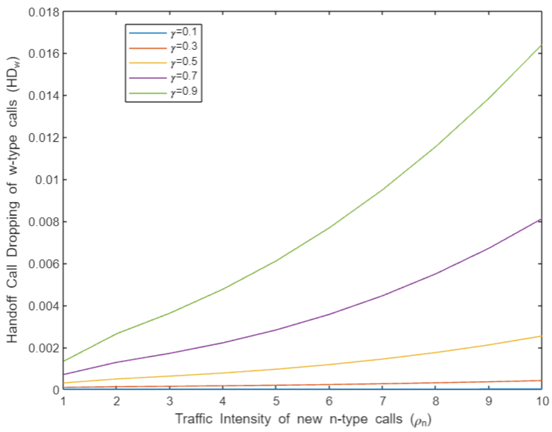

Figure 5: Handoff call Dropping of w-type calls (BP_w) versus ρ_n while varying γ

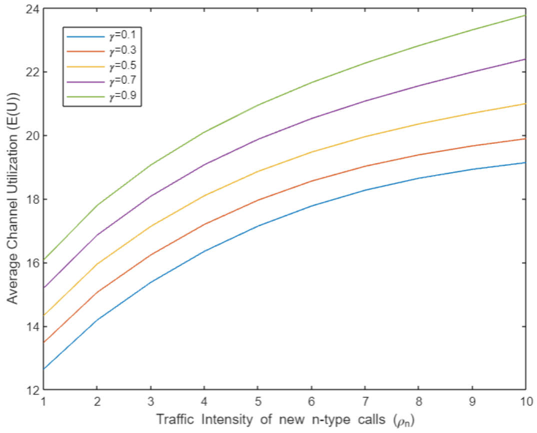

Figure 6: Average Channels Utilization (E(U)) versus ρ_n while varying γ

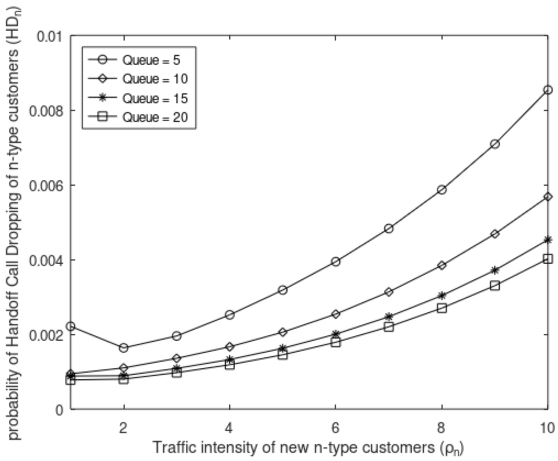

Figure 7: Probability of *n*-type handoff call dropping (HD_n) versus ρ_n

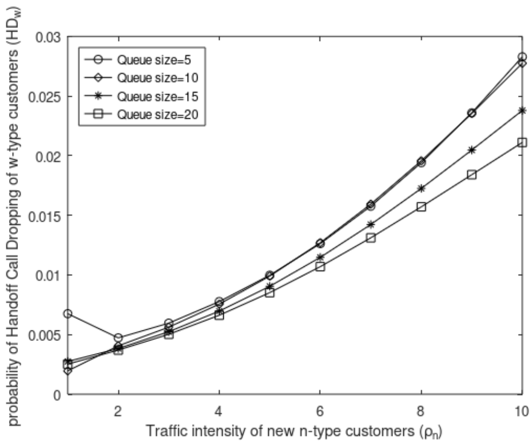

Figure 8: Probability of *w*-type handoff call dropping (HD_w) versus ρ_n

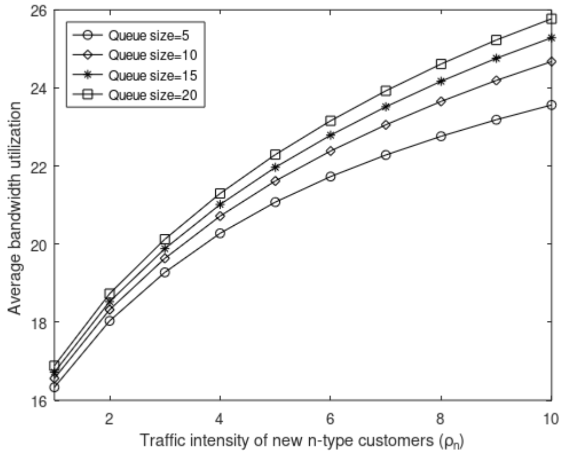

Figure 9: Average bandwidth utilization ($E(U)$) versus ρ_n

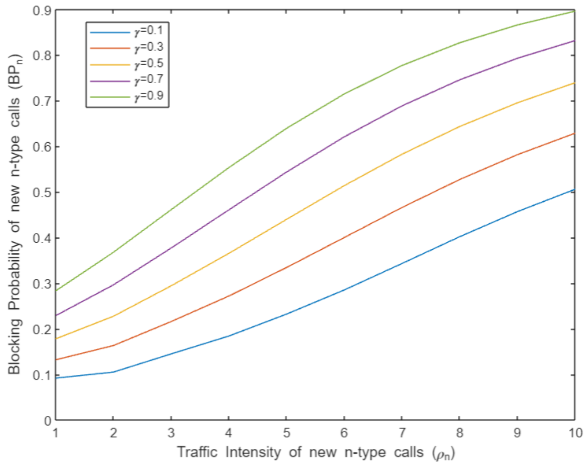

Figure 10: Blocking Probability of new n-type calls (BP_n) versus Queue Size, Q while varying γ,

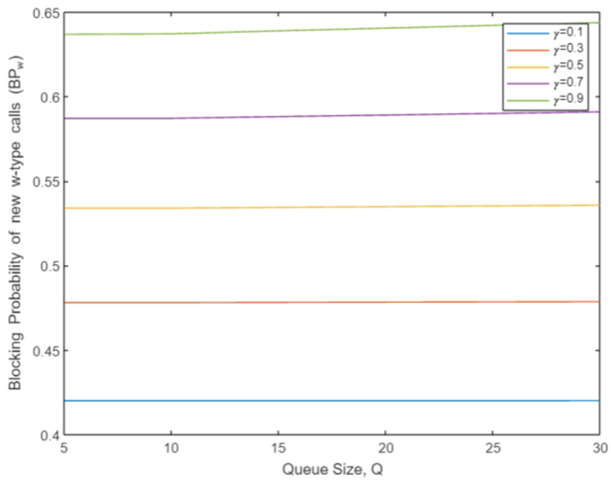

Figure 11: Blocking Probability of new w-type calls (BP_w) versus Queue Size, Q while varying γ

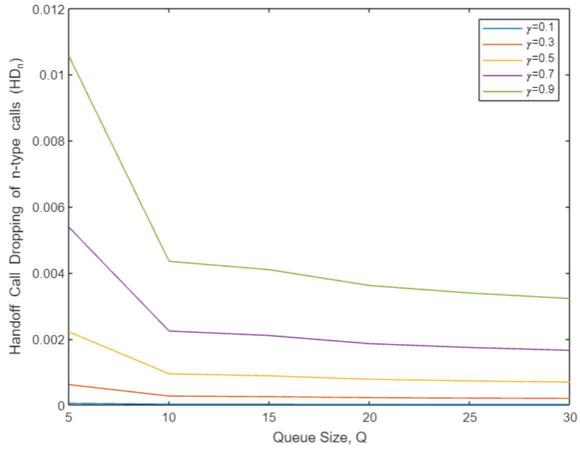

Figure 12: Handoff Call Dropping of n-type calls (HD_n) versus Queue Size, Q while varying γ

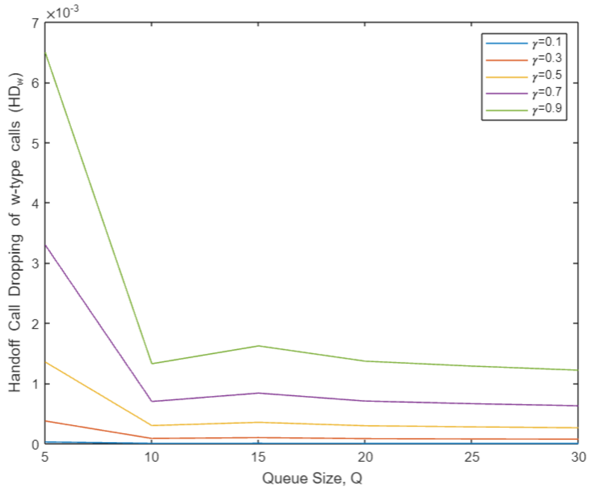

Figure 13: Handoff Call Dropping of w-type calls (HD_w) versus Queue Size, Q while varying γ

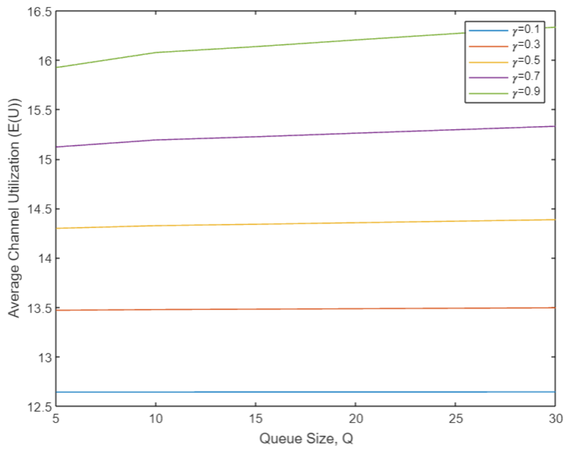

Figure 14: Average Channels Utilization (E(U)) versus Queue Size, Q while varying γ

5. DISCUSSION

Figures 2-3 show that increasing the probability of accepting a signal with good quality will lead to an increase in the blocking probability of new calls of both types. From Figures 4-5, the handoff call dropping of both types of calls also increases when the probability of accepting a signal with good strength is increased. The increase in BP_n and BP_w is much higher than for HD_n and HD_w. It is noticed from Figures 4 and 5, that the handoff call dropping for w-type (wideband) calls is less than for n-type (narrowband) calls. This is the opposite effect to what happened to the blocking probability; as in that case BP_w increases much more than BP_n. From this it can be deducted that queueing of handoff calls, favors wideband calls over narrowband calls, this is an advantage as dropping a wideband handoff call is much worse than dropping a narrowband handoff call.

Figures 7-9 depict the different performance measures while the queue size, is increased from 5 to 20, while the probability of accepting a good signal call is fixed at $\gamma=0.5$. 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.

Figures 10-14 show the performance of the system, when the probability of accepting a strong signal is increased from $\gamma=0.1$ to $\gamma=0.9$. Figures 10 and 11 show that with increasing signal strength, the blocking probability of new calls of both types is almost constant as the queue size is increased. This means that BP_n and BP_w are not affected by increasing the queue size as γ is increased, this is a desired result as we are not concerned with improving BP_n and BP_w. Figures 12 and 13 indicate that handoff call dropping of both types (HD_n and HD_w) are decreased as the queue size is increased and γ is increased. This is also a desired result. Also it is noticed that HD_w is less than HDn which means that adding the queue for handoff calls favors wideband calls. Figure 14 shows that an increase in queue size does not affect the channel utilization much as the signal strength of accepted handoff calls is increased.

6. CONCLUSION

The (M+G) with handoff call queueing, gave good results; the blocking probability of new calls was not much affected, handoff call dropping is decreased while average channel utilization is increased. With increased signal strength, the blocking probability of new calls was increased, the handoff call dropping was reduced while the average channels utilization was increased. It is also concluded that the handoff call dropping of wideband calls is much less than the handoff call dropping of narrowband calls in all cases.

Increasing acceptance of handoff calls with good signal quality leads to increased blocking probability and the handoff call dropping of all types of new calls. Average channel utilization was also increased. Giving more queue space to handoff calls as the probability of accepting a handoff call with good signal strength is increased, did not affect blocking of new calls of all types, while it lead to a reduction in handoff call dropping in all call types. Average channel utilization was also not affected.

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