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On the Evaluation of Handover Exchange Schemes Between Two Cognitive Radio Base Stations with and without Buffers

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***Abstract*—This article investigates and evaluates a handover exchange scheme between two secondary users (SUs) moving in different directions across the handover region of neighboring cell in a cognitive radio network. More specifically, this investigation compares the performance of SUs in a cellular cognitive radio network with and without channel exchange scheme. The investigation shows reduced handover failure, blocking, forced and access probabilities respectively, for handover exchange scheme with buffer as compared to exchange scheme without buffer. It also shows transaction within two cognitive nodes within a network region. The system setup is evaluated through system simulation.**

***Keywords*—Cognitive radio networks, channel handover exchange scheme, blocking probability, force termination, handover failure**

I. INTRODUCTION

SPECTRUM handover is an area of interest in cognitive radio networks presently. Handover is the passage of request/call from one user or node to the other. A spectrum handover occurs when the licensed/primary users (PUs) and SUs collide on the same spectrum hole [1]. The collision could still be among SUs especially when the PUs has vacated the spectrum. Therefore, efficient radio resource in cognitive cellular network is essential to determine the Quality of Service (QoS). Key metrics for evaluating the QoS are but not limited to; the handover call blocking and dropping/handover failure probability respectively [2]. Cognitive cellular networks comprise of several cells in which its sizes depend on the physical area. High density areas require smaller sizes than larger sizes thus, the reason is to accommodate the large number of SUs. Large cell size often causes more blocking for two class of SUs (real and non-real-time traffic) due to the frequent hand-off from one cell to another [3]. A well-planned handover procedure is crucial in sustaining continuity of ongoing calls. However, maintaining minimum likelihood of dropping/blocking new calls, processing and traffic exchanging on the network is a challenge. Hence, it is worthwhile to investigate and compare strategies that eases the undesired dropping of calls, reduces the signaling traffic on the network and invariably improve the QoS of the network against schemes without no-exchange (no handover).

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II. HANDOVER TYPES AND DECISION

There are basically two types of handover regime, which could be precisely categorized as soft and hard handover respectively. A hard handover is an open before close type of configuration controlled by the Mobile Switching Centre (MSC) for a traditional cellular network. However, in the cognitive radio setting, the Cognitive Radio Base Station (CRBS) transfers the SUs request to alternative cell (base station) and hands off the request. In this type of protocol, the connection preceding the CRBS is ended earlier or as the user is reassigned to the new cells CRBS. Furthermore, the SU is linked to not more than one CRBS at any given time [4], [5]] though, in this investigation, two CRBS were considered for simplicity. In these schemes, it is assumed that individual users are allocated to one or several channels to avoid channel meddling. When a SU changes direction between two CRBS, it becomes difficult to mutually interconnect with CRBS because of the utilization of separate band.

In soft handover protocol, several connections can be established with neighbouring and adjacent cells. Although, the nested handover is faced with several challenges. Particularly on developing handover protocols for all-inclusive thus, to solve these challenges, fast moving SUs are allotted to the macro cell while pedestrian to the micro cell (mini-base station). However, macro cell can still serve low speed SUs depending on the present load each is it is carrying at that pointing time. The received signal to noise ratio seen by two neighbouring CRBS determines the handover decision [6]. Furthermore, handover, decision process could be centrally controlled handover, network-controlled handover, mobile assisted handover and the mobile controlled handover [7], [8].

The rest of the paper is organised as follows: Section II briefly discussed handover types and decisions. Section III summarizes related work, Section IV presents the system/network model of the the handover exchange, Section V deals with performance measures while numerical results and discussion is in Section VI. The paper is concluded in Section VII.

III. RELATED WORK

Several handovers prioritizing procedures are deployed to reduce the forced termination of ongoing calls. However, this result to rise in new call blocking probability and the total accepted traffic [9]. [10] developed a swift and smart nested network layer controller as a new handover strategy to select the optimal network among other networks, while Quality of Service, delays and improved spectral efficiency can be attained. In [11],a buffer regime using guard channels is employed such that, both new calls and handover calls are queued. In this scenario, a number of guard channels are reserved for handover calls and when the new calls are congested, a channel from the guard channels is used if it is available. The key contributions of this work are:

- 1. To compare the performance of a channel handover exchange scheme with queue against no-channel handover exchange scheme through a simulation framework in a cognitive radio network scenario when the PUs is absent.
- 2. To evaluate the system using some key performance metric.

IV. Network and System Model for Handover Exchange

The following assumptions where made:

1) The channel sensing is perfect and accurate.
2) The interaction/transaction process is between two CRBS within a define coverage area (a cell/region).
3) As at the time of this interaction/transaction, the PUs are assumed absent from the spectrum.
4) A slow arriving PUs is assumed.
5) SU is used interchangeably used with mobile station (MS) as shown in Fig. 1.
6) The holding time is exponentially distributed.

The network/system model consists of a handover area between neighbouring cells shown in Fig. 1 Both base stations are separated through the borderline $c_{1,2}$, with lines c_1 and c_2, represent the assignment region. Outside the right line c_1, the signal strength received by a mobile SU from CRBS is inadequate to assure good connections. The symbol $SU_i(j,k)$ indicates that, the i^{th} SU utilizing a frequency owned by $CRBS_j$ and approaching another base station $CRBS_k$. Assuming that in an event corresponding to Fig. 2, where both $CRBS_1$ and $CRBS_2$ channels are occupied. If the condition remains same after a duration, and the $SU_1(2,1)$ trespasses b_2, a handover failure will occur and the channel hands off in $CRBS_2$. The CRB_{s2} will formerly allocate this frequency to the $SU_2(1,2)$, if it is within the handover region. The mobile SU are serviced in the same vain in a traditional resource sharing policy. However, in the handover exchange scheme, the SUs mobiles are permitted to interchange their resources when travelling in reverse directions within handover space. Therefore, with Fig. 2, the channels held by SUs (mobiles), $SU_2(1,2)$ and $SU_1(2,1)$ are exchanged. This results in handover success for both SUs (mobiles) unlike the conventional scheme. In channel handover exchange scheme, there is a mutual interaction between neighbouring cells such that, $CRBS_i$ buffer handover calls from a SU travelling from $CRBS_i$ to $CRBS_j$ in different duffer q_{ij}. Also, the $CRBS_j$ maintains a queue q_{ji} for handover request from SUs travelling from region i to j.

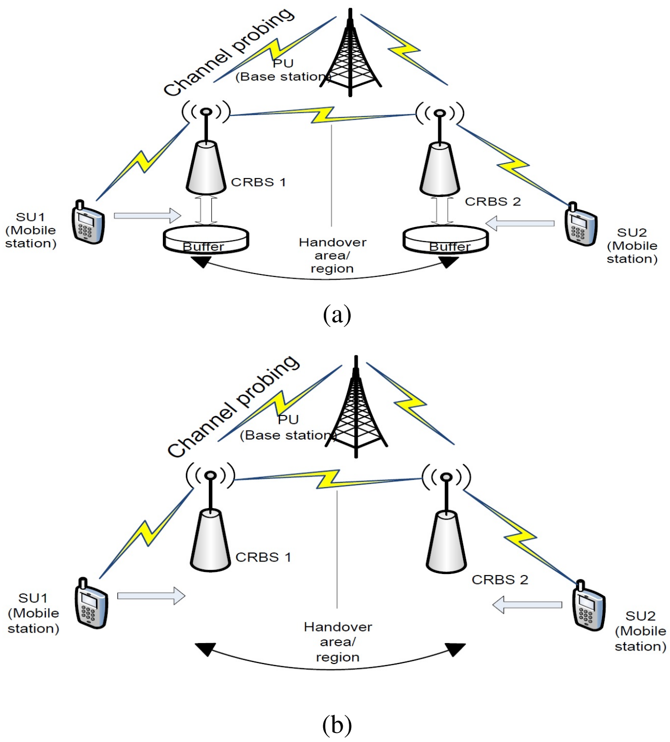

Fig. 1. Network model for the handover between CRBS, (a) with buffer and (b) without buffers.

Both $CRBS_i$ and $CRBS_j$ together blocks request/calls if free channels are not available. However, idle frequency is allocated to new request if the buffer is unfilled. In this scheme, request/calls in the buffer are serviced with priority hence, both buffers will always be filled. The procedure for hand over from the mobile user in cell i to the CRBS of cell j is captured Fig. 3 in the following ways:

1) When an idle frequency is found in cell j, it is allocated to the SU seamlessly; this outcome is a successful handover.
2) If an idle channel slot is occupied in cell j and buffer q_{ij} is unoccupied, then the handover request is pushed to the buffer in q_{ij} for later service.
3) If an idle channel slot is occupied in cell j and q_{ij} is full, then the SU is forced to exchange its channel with the channel held by the SU whose handover request has the top priority in buffer q_{ij}.

As soon as the call enqueued, a handover call translates to successful delivery of the calls, when a slot (channel) is handed off in the equivalent coverage area or when a slot is swapped by a SU of that cell as shown in Fig 3. Nevertheless, if a channel is not vacant to a handover as shown in Fig. 2, during the crosses of the handover region, its effects is a handover failure. However, queued handover calls are occasionally ranked as a result of the signal to noise ratio (SNR) from the SUs (mobiles). When a free channel-slot is vacant, it is allocated to the highest urgent SU (mobile).

Likewise, if a priority channel interchange commenced in the buffer. Delayed handover calls, in the queue which link to handover failures are intermittently removed from the buffer stack. However, here are the three procedures in handover exchange. Firstly, SUs whose call attempts are rejected depart and never come back. Secondly, SU request dropped attempt over again within a predefine time, and lastly, the network permits secondary users to be added to a queue in a buffer until slot are allocated.

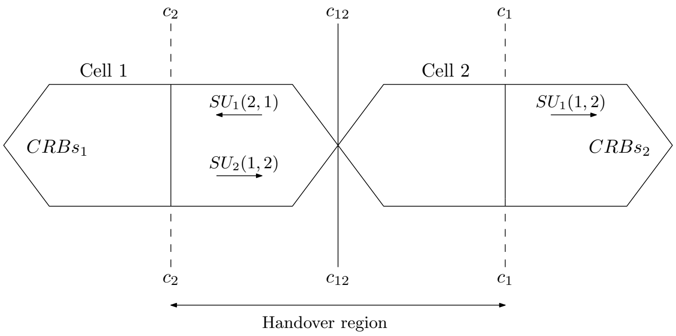

Fig. 2. Diagram illustrating of handover region between CRBS cell.

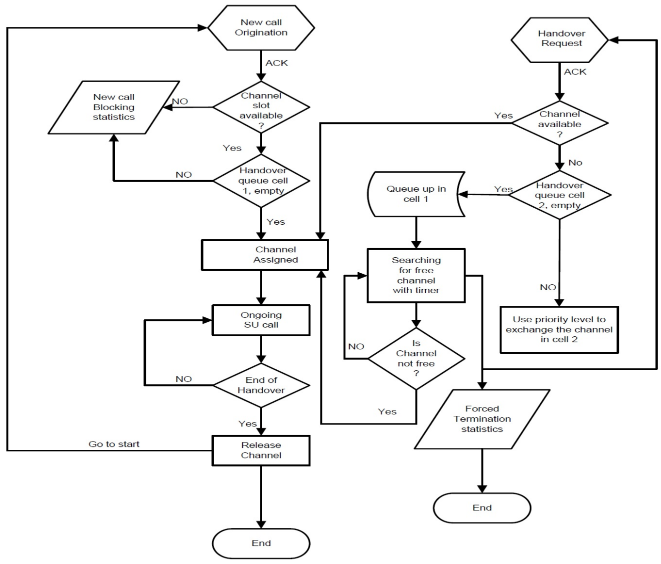

Fig. 3. Flow chart of the handover protocol/procedure.

V. PERFORMANCE MEASURES

The terminologies for this simulation are as follows:

1) The dwelling time t_{dl} is the duration within which, a call continues without any handover exchange.
2) Holding time t_h is the entire duration a call can last. The rest are found in Table II.

Let P be the likelihood that the t_{dl} of a request is allotted. A channel terminates before its call t_h. Then it can be expressed as

$$P = \frac{\mu_d}{\mu_d + \delta_h} \tag{1}$$

Note that, a request is exchanged only when $t_h > t_{dl}$. The likelihood of a new call been successful is $(1 - P_{nc})$. So, $\lambda_{nc}(1 - P_{nc})$ is the ratio to which incoming request are allocated. Assuming an incoming call is created in cell i, the likelihood that is successful is $(1 - P_{nc})$. It is formerly exchanged to cell 2, if $t_h > t_{dl}$ with a likelihood of $(1-P_{nc})P$.

VI. FLOW CHART/ALGORITHM

This section presents the simplified pseudocode for this system model followed by the algorithm

Therefore, probability that access is granted or successful to a handover is expressed as

$$(1 - P_{hf}) \tag{2}$$

Thus, the likelihood of an incoming request from cell i to successfully exchange with cell j is expressed as

$$(1 - P_{nc})(1 - P_{hf})P \tag{3}$$

On bases that a call can be exchanged numerous time before dropping, then λ_{hoc} can be expressed as

$$\lambda_{hoc} = \frac{\lambda_{nc}(1 - P_{nc})P}{(1 - P_{nc})P} \tag{4}$$

The carried traffic α_{ct}, is the simultaneous call supported by the network or cell. It is mostly estimated as the average of an interval which could be an hour or less. In this paper, it denotes a portion of the accessible traffic ω_{ot}. It is expressed as

$$\alpha_{ct} = \omega_{ot}(1 - P_{nc}) \tag{5}$$

Incoming call blocking probability P_{nc}, is the fraction of the number of obstructed SU calls to the number of incoming SU calls. It can be expressed as

$$P_{nc} = \frac{\textit{(Number of blocked SU calls/request)}}{\textit{(Number of new SU calls/request)}} \tag{6}$$

The offered traffic ω_{ot} is defined as the new call arrival rate divided by the average cell dwelling time. It is expressed as,

$$\omega_o t = \frac{\lambda_{nc}}{\mu_d} \tag{7}$$

Handover failure probability P_{hf} is defined as the fraction of SU calls been forced to terminate to the number of successful new SU calls. It can be expressed as,

$$P_{hf} = \frac{\textit{Number of SU calls been forced to terminate}}{\textit{Number of successful new Su calls/request}} \tag{8}$$

VII. RESULTS AND DISCUSSION

The numerical results are presented from simulations run in Matlab platform. Table III shows the simulation values that were used. A comparative result is presented in this section through various performance metrics.

In Fig. 4, the two schemes are compared. From the result, as new calls arrive, the bocking probability increases as expected. However, the scheme with the handover exchange protocol has a better performance and with the buffer which accommodates request that has not been serviced.

Fig. 5 implies that once a request/call cannot be serviced, or queued it is dropped. On the other hand, when a call is being serviced and a more superior (high priority users) call comes in, if it cannot be queued, then it is forced to terminate. The difference is that for forced termination, access would

TABLE I
SYSTEM MODEL ALGORITHM

	Pseudo code for new call origination
1.	*The CRBS scans the channel/spectrum*
2.	*New call initiates and acknowledge*
3.	*Is channel slot available*
4.	*If no*
5.	*New call blocking statistics initiated*
6.	*If yes (Else)*
7.	*Is handover queue in cell 1 empty*
8.	***Go to step 4 (If no)***
9.	***Go to step 5***
10.	***Go to step 6 (If yes)***
11.	*Allocate/Assign channel*
12.	*Ongoing SU calls/request*
13.	*Is handover ended*
14.	***Go to step 4***
15.	***Go to step 6***
16.	*Release the channel*
17.	***Go to step 1***
18.	*Else end*
	Handover request procedure
19.	*Handover request and acknowledge*
20.	***Go to step 3***
21.	***Go to step 6***
22.	***Go to step 11***
23.	***Go to step 4***
24.	*Is handover queue in cell 2 empty*
25.	***Go to step 4***
26.	*Use priority level to exchange the channel in cell 2*
27.	***Go to step 6***
28.	*Queue up in cell 1*
29.	*Start searching/probing for free channel with timer set*
30.	***Go to step 3***
31.	***Go to step 4***
32.	***Go to step 29***
33.	***Go to step 6***
34.	***Go to step 11***
35.	*If no free channel slot after probing*
36.	*Drop/forcibly terminate or* ***Go to step 18***
37.	**Else, end**

TABLE II
PERFORMANCE PARAMETERS

λ_{nc} :	New (incoming) call arrival rate.
λ_{hoc} :	Handover call arrival rate.
μ_d^{-1} :	Average cell dwelling time.
δ_h^{-1} :	Average cell-holding time.
P_{nc} :	Incoming call blocking probability.
P_{hf} :	Handover failure probability.
μ_d :	Average call duration.
δ :	Mean delay.

TABLE III
SIMULATION PARAMETERS

Numbers of channels:	10
Handover queue:	2
New call arrival rate, λ_{nc} :	1 call/sec
Average cell dwelling time, μ_d^{-1}:	120 sec
Average call holding time, δ_h^{-1}:	240 *sec*
Mean delay:	2-5 sec

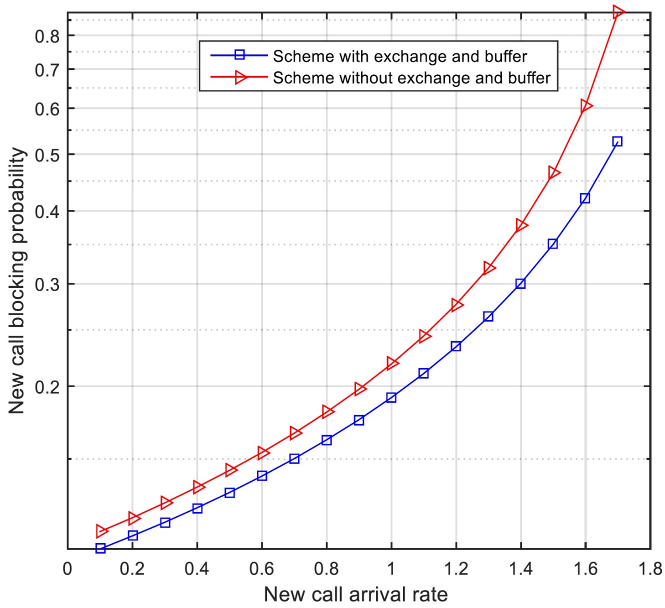

Fig. 4. New call blocking probability vs. new call arrival rate.

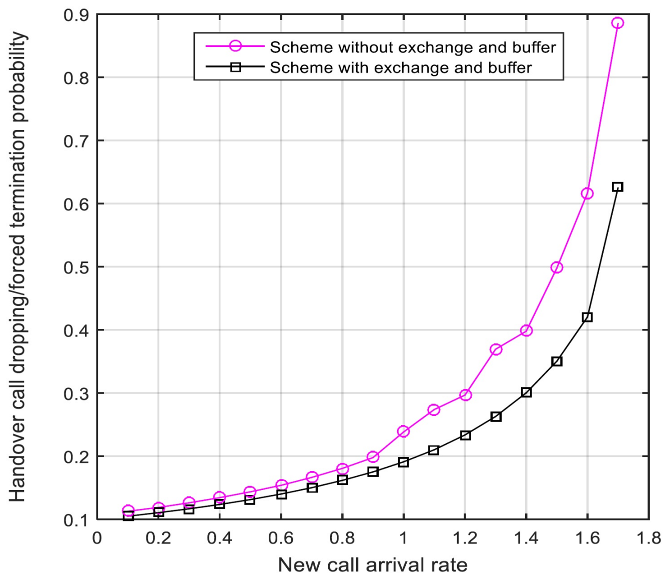

Fig. 5. Dropping/forced termination probability vs. call arrival rate.

have been granted. However, the scheme with both the buffer regime and exchange protocol outperformed the conventional scheme with these robust techniques.

When a new call arrives from a user, because of mobility, there is a tendency of handing over that call form one cell to another. However, if there is a buffer, the handover will be more successful in the sense that instead of dropping the call or request, it is queued in a buffer [12], [13]. This has been illustrated in our result in Fig. 6. It is showed that as new call arrives, it is expected that the handover procedure will be more successful for the scheme that incorporates queuing.

Fig. 7 shows the impact of a queuing regime on the access or admission probability. This gives SUs the leverage (avenue to wait) to access the channel whenever it is interrupted or if the SU experiences insufficient or no resources/channel. As the queue length increases, the probability of SU accessing the resources increases as well, and at a certain point, begins to saturate due to fixed buffer capacity. However, because of space constrain, more results would have been presented but will be considered in future investigation. Fig. 8 illustrates

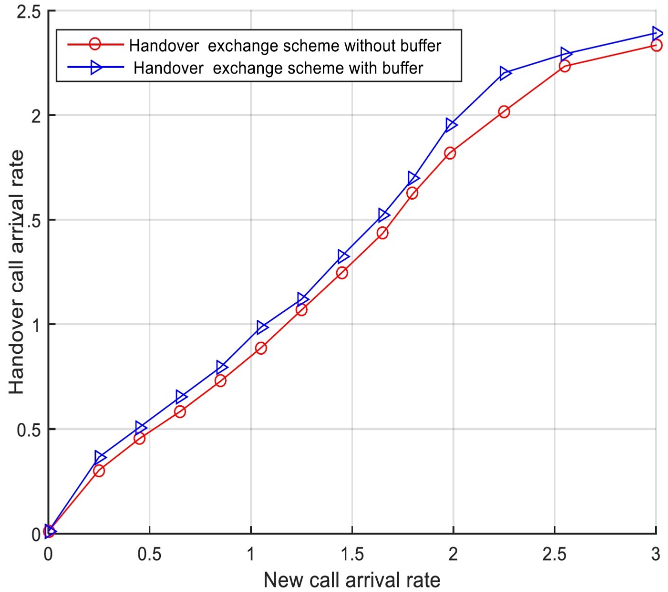

Fig. 6. Handover call arrival rate vs. new call arrival rate.

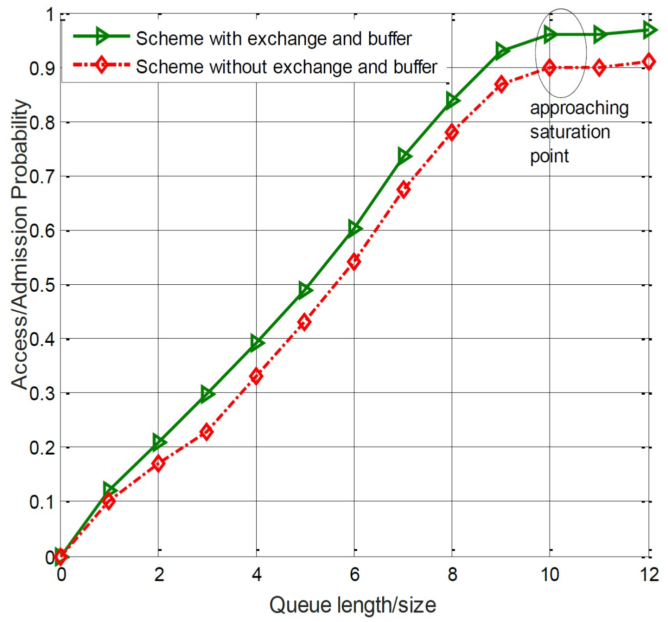

Fig. 7. Access/Admission prob. vs. Queuing length.

the significance of integrating a queuing regime into cognitive setup, this is to allow services that would have been blocked, to be served or better put enhance handover procedure. However, there is extra delays which the SUs experience in the buffer, as it waits for service. Thus, this by no means could be compared to a system which has no buffer system. It shows the outcome of queue size on the delay, precisely on both scheme and SUs. The interrupted SUs can be rerouted back into the queue to reduce instant forced termination/handover failure while the new arriving SUs can be buffered to wait in order to ensure successful handovers. On the long run a buffered system is far superior to unbuffered system without exchange since more failure is likely to occur.

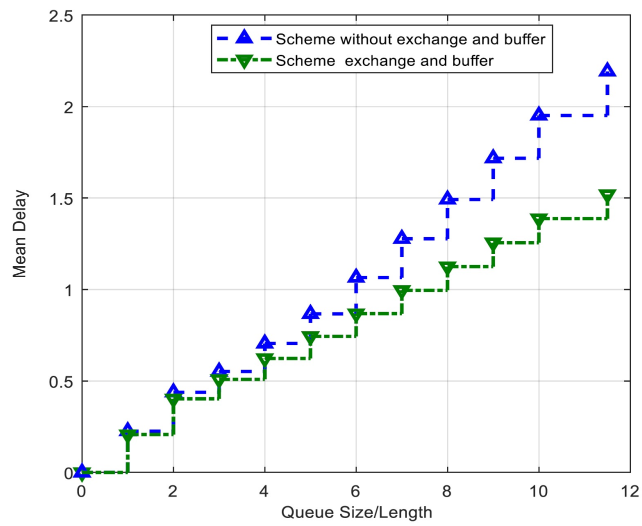

Fig. 8. Mean delay vs. Queue size/length.

VIII. Conclusion

This paper investigated through a comparative study the impact of a queuing regime of a handover exchange scheme. The role a buffer/queuing regime plays that makes handover a success (reduced handover failure) cannot be overemphasized especially when new calls arrive in batches. Our future work will include a detail performance analysis of the scheme investigated using Markovian model. Also, the class of secondary traffic/users will be considered.

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