An Algorithm towards QoS Improvement of Cognitive Mobile Users

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Why Cognitive Radio Networks?

- Problem: Bandwidth is a Limited and Costly Resource and the demand for bandwidth is ever increasing.
- Solution: Cognitive Radio Networks. Secondary or opportunistic users can access the channels which are not being used by the licensed users [1,2].
- Considering two types of Cognitive Radio Users - Handoff Secondary Users (HOSUs) and New Secondary Users (NSUs).

Problem Statement

A probabilistic study on the proposed infrastructure-based Cognitive Radio Network modelled using a Continuous Time Markov Chain which aims at improving the Quality of Service (QoS) of opportunistic users by reducing their call blocking probabilities.

Related Work

- Channel reservation policies are adopted to reduce the forced termination probability at the cost of higher dropping probability [4,5].
- PU prioritized Markov approach for dynamic spectrum access has also been considered [6].
- A number of efforts have been devoted to channel sensing for CRNS [7-13].
- Most of the research objectives mentioned have concentrated on efficient utilization of the spectrum.
- We propose a cognitive channel allocation algorithm which not only enhances the spectrum utilization but improves the QoS of the SUs by lowering their blocking probabilities.

System model

- Infrastructure based CRN with C channels and two homogeneous FIFO queues- HQ to accommodate Handoff Secondary Users and NQ to accommodate New Secondary Users.
- Each channel has a fixed bandwidth.
- Arrival rates are modelled as Poisson distributions as they are independent, discrete and proportional to the time interval considered.
- Service rates are modelled as Exponential distributions as they are independent, memory-less and non-uniformly distributed.
- Secondary User devices have perfect channel sensing capabilities.

The system is modelled using a 5-dimensional CTMC with the following transitions upon arrival of a call.

Table 1: TRANSITIONS FROM A GENERIC STATE (i,j,k,l,m) UPON ARRIVAL OF A CALL

	Activity	Destination	Transition Rate	Condition
PU Arrival	A vacant channel exists	(i+1,j,k,l,m)	λ_P	$(i+j+k) < C, l = 0, m = 0$
	No vacant channel, NSU pre-empted	(i+1,j,k-1,l,m)	λ_P	$(i+j+k) = C, k > 0, l = 0$
	No vacant channel, HOSU pre-empted	(i+1,j-1,k,l,m)	λ_P	$(i+j) = C, j > 0, k = 0$
HOSU Arrival	A vacant channel exists	(i,j+1,k,l,m)	λ_{SHO}	$(i+j+k) < C, l = 0, m = 0$
	No vacant channel, NSU pre-empted	(i,j+1,k-1,l,m)	λ_{SHO}	$(i+j+k) = C, k > 1, l = 0$
	No vacant channel, HOSU in queue	(i,j,k,l+1,m)	λ_{SHO}	$(i+j) = C, l < S_{HOQ}, k = 0$
NSU Arrival	A vacant channel exists	i,j,k+1,l,m	λ_{SN}	$(i+j+k) < C, l = 0, m = 0$
	No vacant channel, NSU in queue	(i,j,k,l,m+1)	λ_{SN}	$(i+j+k) = C, m < S_{NQ}$

The system is modelled using a 5-dimensional CTMC with the following transitions upon departure of a call.

Table 2: TRANSITIONS FROM A GENERIC STATE (i,j,k,l,m) UPON DEPARTURE OF A CALL

	Activity	Destination	Transition Rate	Condition
PU Departure	No calls in queue	(i-1,j,k,l,m)	$i\mu_P$	$(i+j+k) < C, l = 0, m = 0$
	No calls in HOQ	(i-1,j,k+1,l,m-1)	$i\mu_P$	$(i+j+k) = C, m > 0, l = 0$
	Calls present in HOQ	(i-1,j+1,k,l-1,m)	$i\mu_P$	$(i+j+k) = C, k > 0$
HOSU Departure	Calls in both queues	(i,j,k,l-1,m)	$j\mu_{SHO}$	$(i+j+k) = C, l > 0, m > 0$
	No calls in queue	(i,j-1,k,l,m)	$j\mu_{SHO}$	$(i+j+k) < C, m = 0, l = 0$
	No calls in HOQ	(i,j-1,k+1,l,m-1)	$j\mu_{SHO}$	$(i+j+k) = C, k > 0$
NSU Departure	No calls in queue	(i,j,k-1,l,m)	$k\mu_{SN}$	$(i+j+k) < C, l = 0, m = 0$
	Calls present in NQ	(i,j,k,l,m-1)	$k\mu_{SN}$	$(i+j+k) < C, l = 0, m > 0$

Arrival of Calls

Vacant Channel is present

When a caller of any type requests access and a vacant channel is present, the caller is granted access.

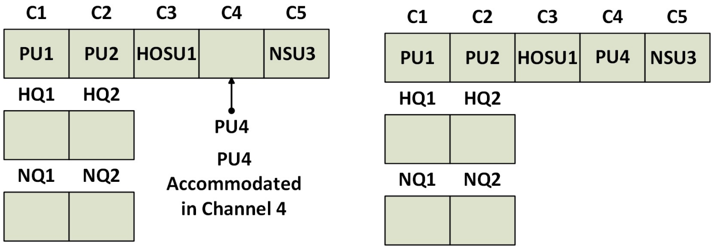

Figure: PU accommodated in channel

Case I: New Secondary User (NSU) pre-empted to accommodate Primary Users and Handoff Secondary Users(HOSUs).

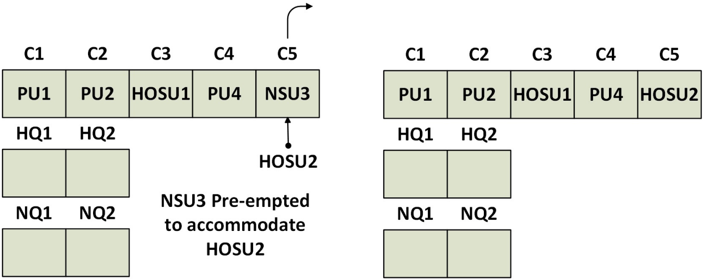

Figure: NSU3 pre-empted to accommodate HOSU2

Case II: No New Secondary Users present. Handoff Secondary User (HOSU) pre-empted to accommodate Primary User (PU).

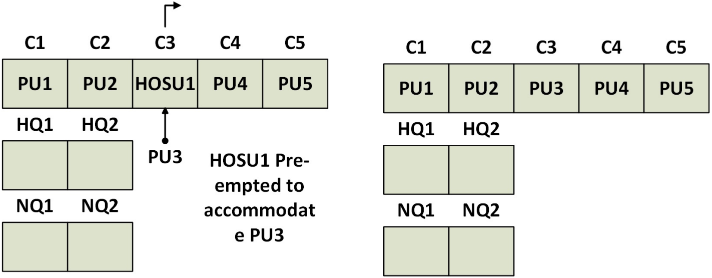

Figure: HOSU1 pre-empted to accommodate PU2

Case III: No pre-emption possible. New Secondary User (NSU) accommodated in the New Call Queue(NQ), Handoff Secondary User accommodated(HOSU) in the Handoff Call Queue(HQ).

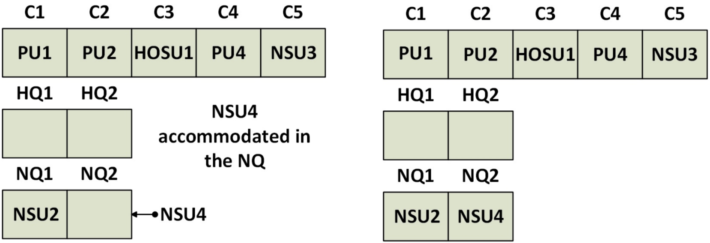

Figure: NSU4 is added to the NQ

Arrival of Calls

No Vacant Channel Present

Case IV: No space to accommodate the secondary caller in its queue. Call is blocked.

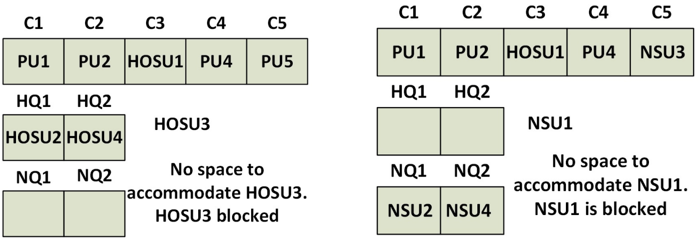

Figure: HOSU1 and NSU1 are blocked

Departure of Calls

HandOff Call Queue is Non-Empty

When any call vacates a channel, a call from the Handoff Call Queue is given access to the channel, irrespective of the status of the New Call Queue.

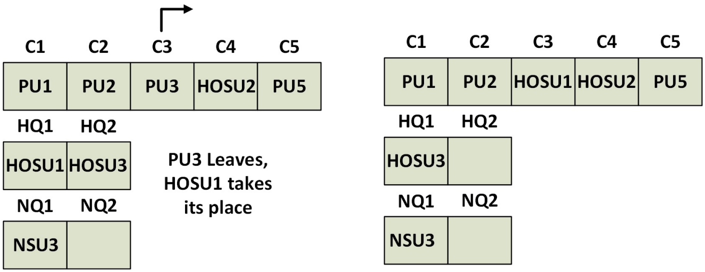

Figure: A HOSU is moved to the vacated channel.

Case I: A caller from the New Call Queue is granted access to the channel.

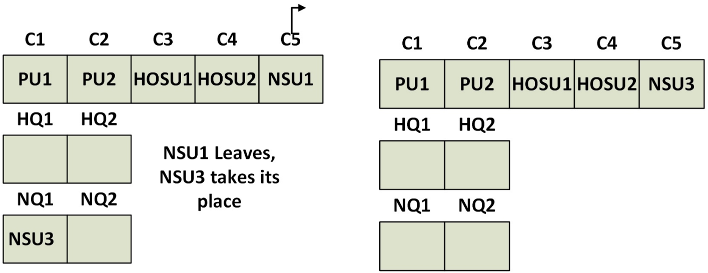

Figure: A call from NQ is moved to the vacated channel.

Case II: New Queue is empty, channel is left vacant.

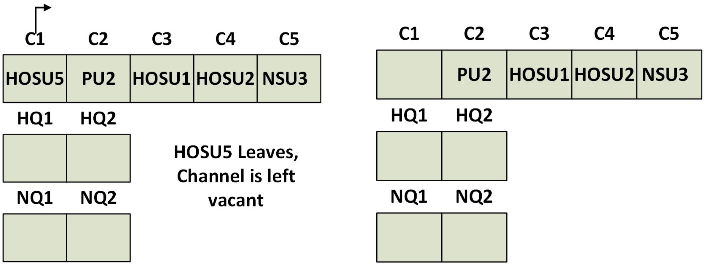

Figure: Channel is left vacant.

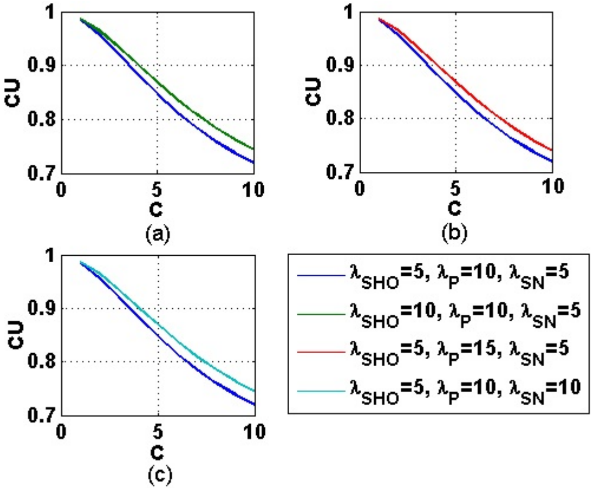

Figure: Channel utilization variations with respect to (a) arrival rate of handoff SUs (b) arrival rate of PUs (c) arrival rate of new SUs

Results

Blocking Probabilities

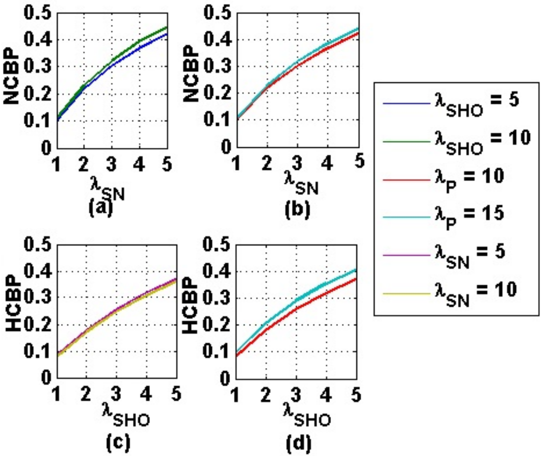

Figure: Call blocking probability (a) NCBP with respect to arrival rate of HSUs (b) NCBP with respect to arrival rate of PUs (c) HCBP with respect to arrival rate of NSUs (d) HCBP with respect to arrival rate of PUs

Results

Blocking Probabilities

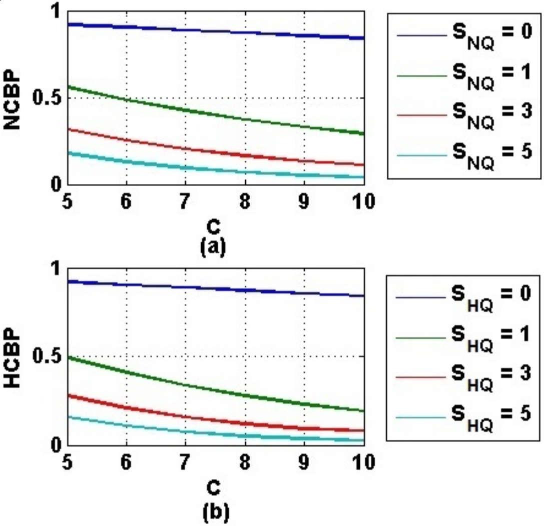

Figure: Call blocking probability with respect to queue size (a) New call (b) Handoff call.

Results

Dropping Probabilities

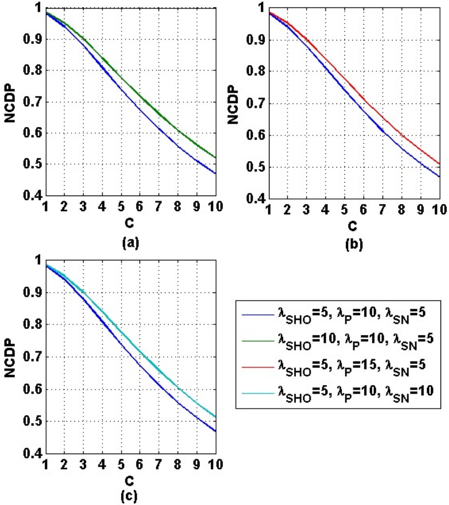

Figure: New call dropping probability variations with respect to (a) arrival rate of HOSUs (b) arrival rate of PUs (c) arrival rate of NSUs

Results

Dropping Probabilities

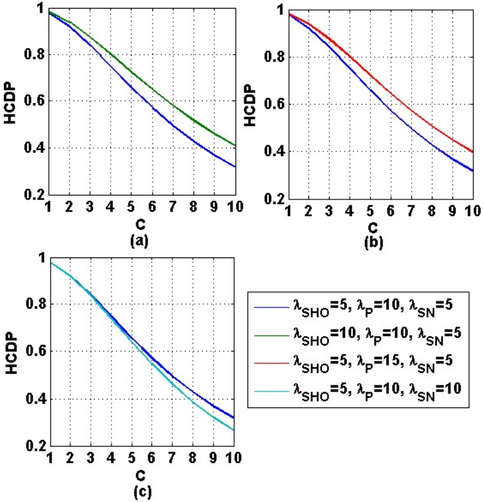

Figure: Handoff call dropping probability variations with respect to (a) arrival rate of HOSUs (b) arrival rate of PUs (c) arrival rate of NSUs

Some more results...

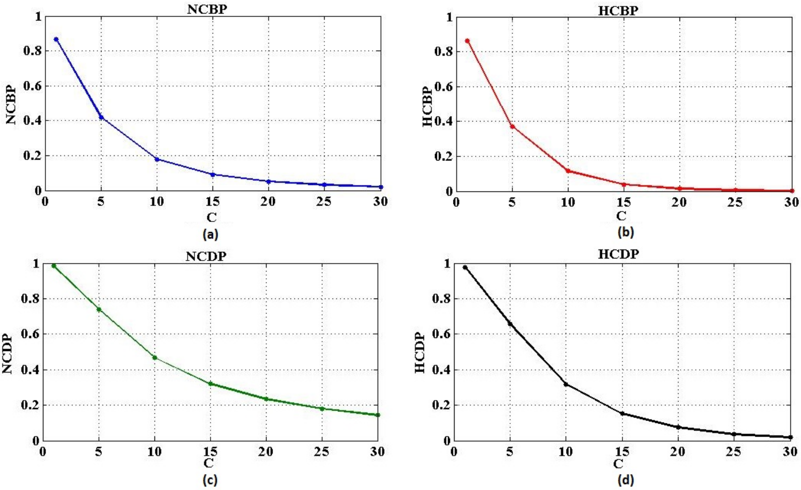

Figure: Variations with respect to number of channels (a) NCBP (b) HCBP (c) NCDP (d) HCDP

Future Work

- To reduce the dropping probabilities for the cognitive mobile users, introduction of buffer(s) to accommodate the pre-empted calls.
- To observe the implications by varying the priority based on call durations of the various types of users
- Consider the implications of variable bandwidth channels.

Conclusion

- Cognitive Radio Networks accommodate larger number of users in limited bandwidth.
- Two homogeneous, FIFO queues have been employed to lower the blocking probabilities for the Secondary Users.
- Lower blocking probabilities ensure better Quality of Service for Secondary Users.
- Blocking and Dropping Probabilities are higher for New Secondary Callers due to their lower priority.

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Thank You!

Questions?