Experimental Study for Interference on Cognitive Radio Test-bed using Asynchronous Mode

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Introduction

- Why Cognitive Radio ??
  - Scarcity of Spectrum Resource.(Ex : WLAN)
  - Efficient usage for under – utilized spectrum.
  - Capable of reconfiguring their behavior based on physical environment

- Development of Cognitive Radios using Software Defined radios(SDR)
  - Flexibility of changing operating parameters of the device.
  - Easily Reconfigured to different broadband technologies

Motivation and Objective

- Asynchronous Mode of operation between Primary and Secondary Users

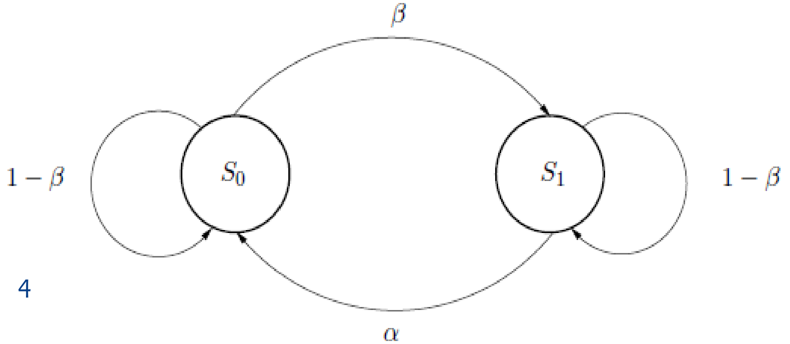
- Evaluation of metrics for Primary and Secondary users with variations in Secondary user Parameters.

Test – Bed Architecture

- Hardware: USRP version1 (Universal Software Radio Peripheral)
  - low cost commercial radios; provided by Ettus Research LLC
  - provides interface to various daughter-boards.

- Software : GNU Radio
  - Free software that provides signal processing blocks
  - Architecture based on hybrid python/C++ programming.

- Hidden - Semi Markov Traffic for PUs
  - S_1 : Primary Traffic ON – Uniform Distribution
  - S_0 : Primary Traffic OFF – Depends on former ON or OFF period.



Spectrum sensing for PUs

- Energy detection using periodogram analysis

  $x[n]\,; n = 0,1,\ldots..N-1 \;\; and \;\; w[n\,]; \;\; n = 0,1\ldots.N-1$

  Periodogram $I[k] = \frac{1}{NU}|V[k]|^2$, *where*

  $V[k] = DFT\{x[n]w[n]\} \; and \; U = \frac{1}{N}\sum_{n=0}^{N-1} W$

  Average Periodogram $\bar{I}[k] = \frac{1}{K}\sum_{n=0}^{K-1} I[k]$

- Wide –band Spectrum Analyzer in USRP
  - Piece – wise spectrum analysis
  - Tune delay(t_t) and Dwell delay (t_d)
  - Frequency overlap

$$P_{avg} = \frac{I_0[k] + I_1[k] + I_2[k]}{3 * \text{size of FFT bin}}$$

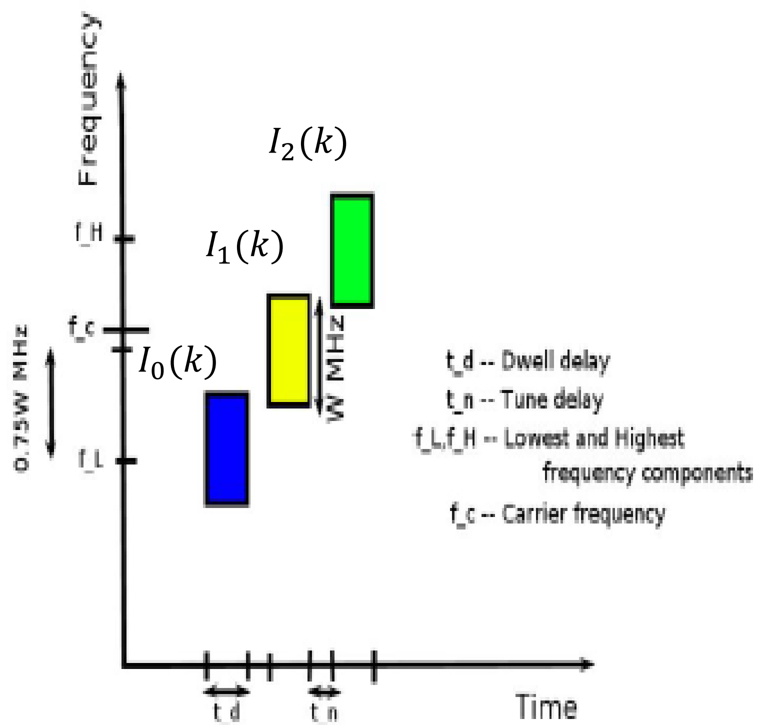


Fig: 2D- Illustration for periodogram analysis

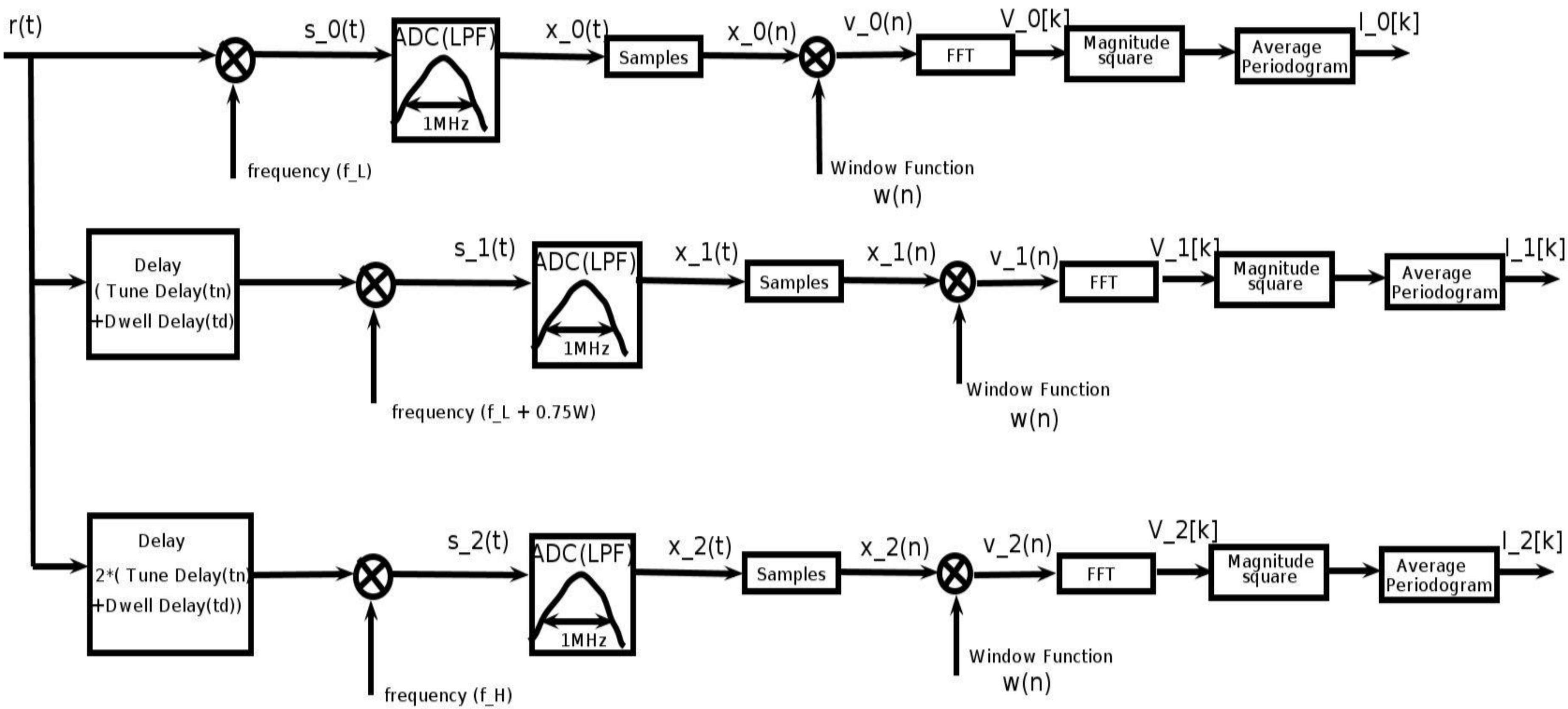


Fig : Block Diagram for Piece-wise periodogram analysis

Decision Statistics

- Average Power Statistics (P_{avg}) are crucial for radio behavior

- MAP Testing
  - H_0 - Primary Traffic OFF
  - H_1 - Primary Traffic ON
  - Experimental Statistics - Density function of P_{avg} for H_0 and H_1 has gaussian distribution

$$P(\underline{P_{avg}}/H_0) = \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp^{-\frac{(P_{avg}-\mu_0)^2}{2\sigma_0^2}}$$

$$P(\underline{P_{avg}}/H_1) = \frac{1}{\sqrt{2\pi\sigma_1^2}} \exp^{-\frac{(P_{avg}-\mu_1)^2}{2\sigma_1^2}}$$

- Decision Threshold

$$\frac{P(P_{avg}/H_0)}{P(P_{avg}/H_1)} \underset{H_1}{\overset{H_0}{\gtreqless}} \frac{\pi_1}{\pi_0}; \qquad \text{where, } P(H_0) = \pi_0 \text{ and } P(H_1) = \pi_1$$

Experimental Set-up

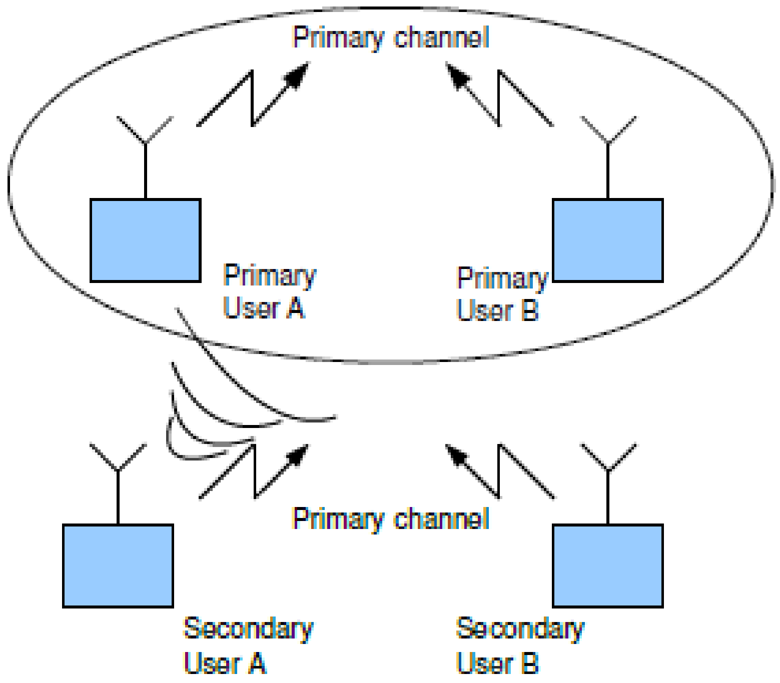


Fig : Test-bed model for Primary and Secondary Users

Parameters

Primary User

- Modulation
- Probabilities of packets in semi-Markov model

Secondary Users

- Modulation
- Sensing period

$$T_s = 3 * (t_d + t_n)$$

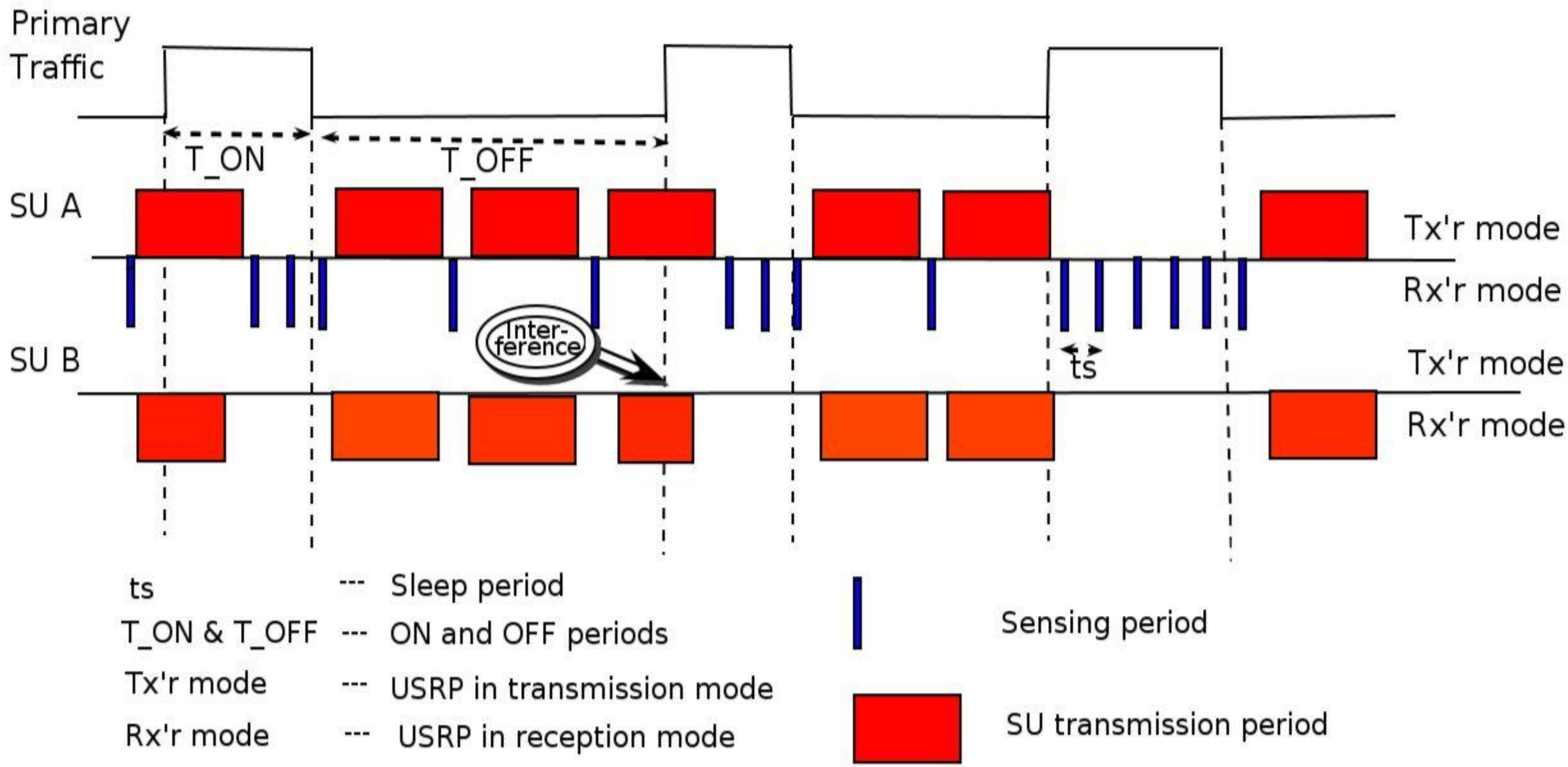


Fig : Duty – cycle for Primary and Secondary Traffic

Performance Evaluation

➢ Metric for Primary and Secondary Users

$$\text{Throughput} = \frac{\textit{Number of Correctly Received Packets}}{\textit{Transmission Time for all Packets}} \quad {}^{Packets}/_{sec}$$

➢ Secondary Transmitter Parameters

a. Size of Communication Window
  - Varied by changing the number of packets (P)

b. Sensing Frequency
  - Varied by changing sleep time (t_s)

c. Modulation
  - coded OFDM, un-coded OFDM and GMSK

Results

TABLE I
SCENARIO 1: UNCODED OFDM WITH QPSK MODULATION

Communication window (secs) \ Sleep time (secs)		0.05	0.45	1.0	1.5
0.312	PUs	22.82	22.63	25.288	24.95
	SUs	18.62	17.49	16.64	16.42
0.624	PUs	20.51	22.50	18.84	23.31
	SUs	25.14	24.15	22.96	21.10
1.04	PUs	20.97	19.59	22.96	18.64
	SUs	35.53	33.43	31.58	29.03
1.56	PUs	20.30	20.04	19.92	18.35
	SUs	37.20	34.39	32.23	30.48

TABLE II
SCENARIO 2:CODED OFDM WITH QPSK MODULATION AND CODE RATE = 1/2

Communication window (secs) \ Sleep time (secs)		0.05	0.45	1.0	1.5
0.312	PUs	24.03	22.20	21.34	20.13
	SUs	14.62	14.58	14.48	13.39
0.624	PUs	18.60	18.76	23.72	21.60
	SUs	18.95	18.41	16.93	16.12
1.04	PUs	16.79	19.08	18.64	17.86
	SUs	20.74	19.78	19.60	19.16
1.56	PUs	16.73	18.06	16.56	14.45
	SUs	22.14	19.88	19.78	19.45

Observations

- For a particular sensing frequency, the Primary User throughput decreases as communication window increases and vice versa for Secondary User throughput

- Secondary User throughput decreases as sensing frequency decreases for a particular communication window

Observations

TABLE III
SCENARIO 3: UNCODED GMSK MODULATION

Communication window (secs) \ Sleep time (secs)		0.05	0.45	1.0	1.5
0.312	PUs	23.12	22.34	23.89	26.68
	SUs	16.67	16.30	15.98	14.84
0.624	PUs	21.29	21.37	21.90	22.45
	SUs	27.13	25.52	24.60	22.35
1.04	PUs	22.20	24.70	22.60	22.54
	SUs	36.24	34.31	32.32	29.06
1.56	PUs	22.12	21.85	22.42	24.53
	SUs	39.56	37.84	34.31	32.16

- Longer Communication Window, GMSK perform better than un-coded or coded OFDM.

- Shorter Communication Window, un-coded OFDM performs better than coded OFDM or GMSK for Secondary user throughput.

Conclusion

- Primary and Secondary Users in Asynchronous mode with Hidden Semi- Markov traffic model.

- Empirical solution for primary and secondary users throughput by varying secondary transmitter parameters.

- Concerns for OFDM implementation on current test-bed provides frequency offset and trade-off issues for coded and un-coded OFDM.

Demo Video

THANK YOU