

# Cognitive Radio Test-Bed using OpenBTS

Swrangsar Basumatary (09d07040)

*Supervisor:* Prof S N Merchant

Department of Electrical Engineering  
IIT Bombay, Powai

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# Problem Statement

- ▶ To develop a test-bed for cognitive radio demonstrating coexistence of primary (licensed) users and secondary (unlicensed users)
- ▶ A 2-frequency test-bed (channels used 945 MHz and 955 MHz)
- ▶ A 4-frequency test-bed (936 MHz, 943 MHz, 950 MHz, 957 MHz)

# Overview of the tasks accomplished in our project

- ▶ Cognitive radio?, spectrum holes?
- ▶ GNURadio
- ▶ Python programming language
- ▶ USRP kit
- ▶ OpenBTS
- ▶ Calls and SMS service on local network
- ▶ Spectrum sensing techniques
- ▶ Defining problem statement

- ▶ Developing a flow chart of the solution to this problem
- ▶ Running GNURadio and OpenBTS on the same computer at the same time
- ▶ Bash scripting ( .sh files)
- ▶ Periodogram analysis
- ▶ Building a 2-frequency cognitive radio test bed
- ▶ Building a 4-frequency cognitive radio test bed

# **Hardware and software used**

- ▶ GNURadio
- ▶ OpenBTS
- ▶ USRP N210 Kits
- ▶ GSM mobile phones with SIM cards
- ▶ Computers

# Setup for the 2-frequency test-bed

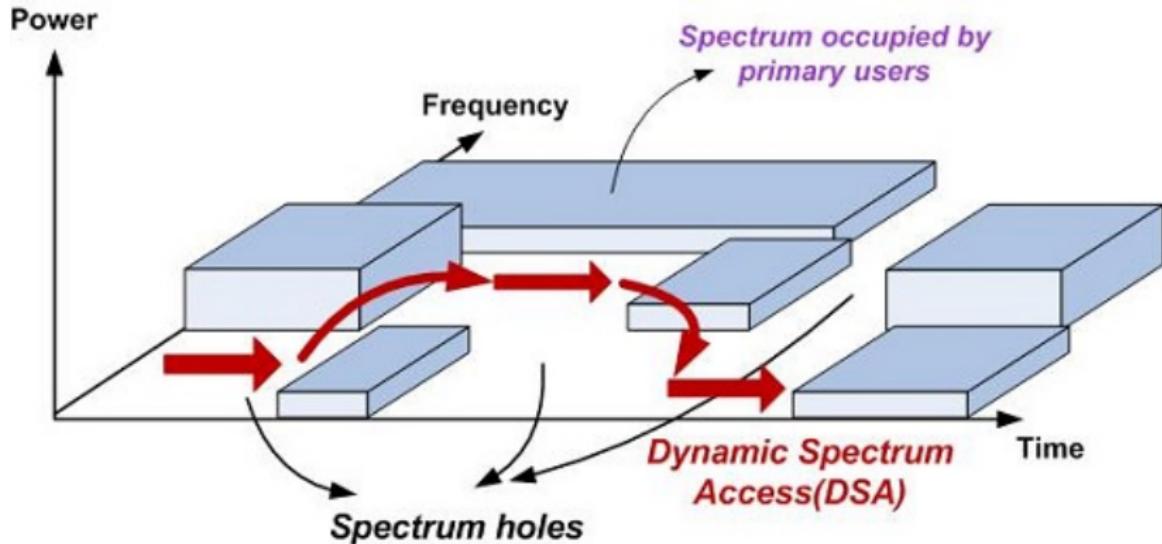


# Setup for the 4-frequency test-bed



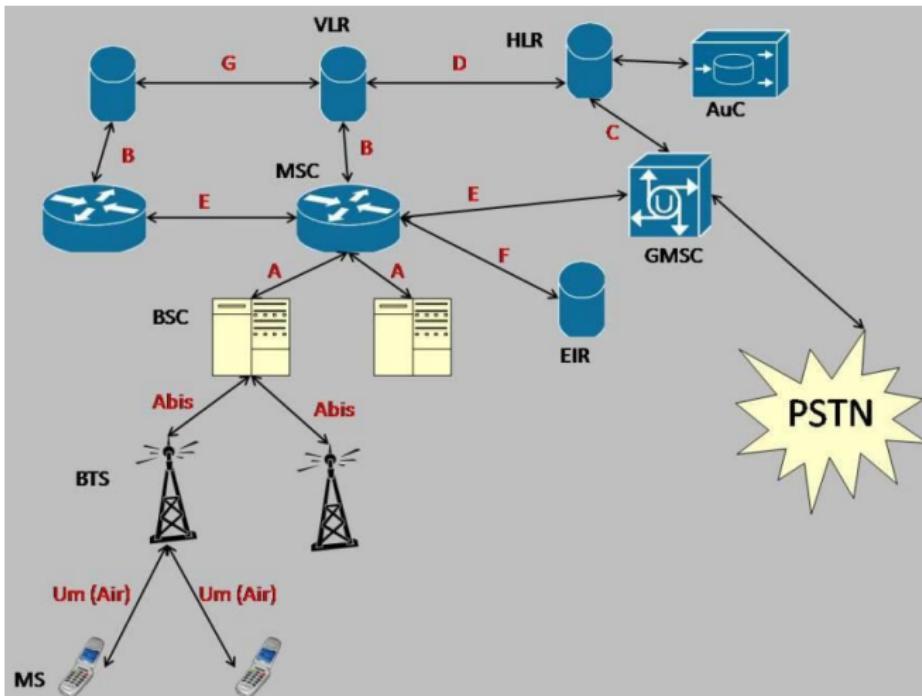
# Cognitive Radio

- ▶ What is Cognitive Radio?



Source: [http://www.brunel.ac.uk/\\_\\_data/assets/image/0011/237539/Abdullah-Masrub1.jpg](http://www.brunel.ac.uk/__data/assets/image/0011/237539/Abdullah-Masrub1.jpg)

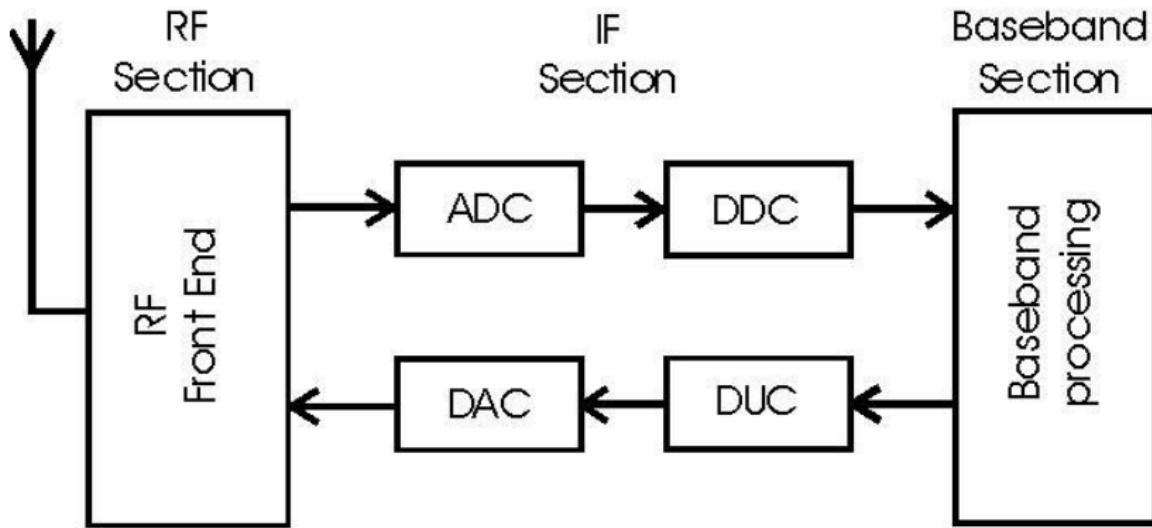
# GSM



Source: <http://gnuradio.org/redmine/attachments/download/156/fullnetwork.jpg>

# Software Defined Radio

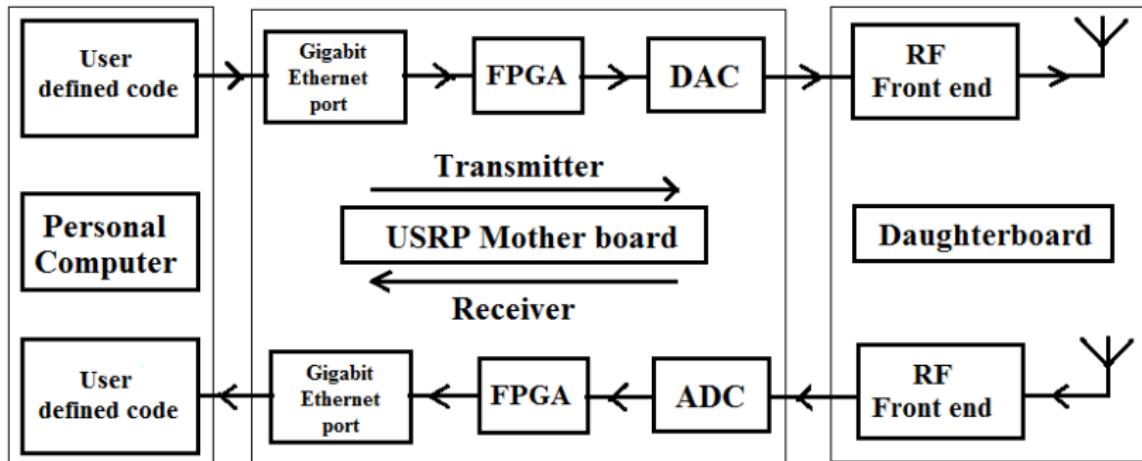
- ▶ What is software defined radio?
- ▶ Block Diagram:



Source: Kranthi Ananthula. *Experimental setup of cognitive radio test-bed using software defined radio*. Master's thesis, Department of Electrical Engineering, 2013.

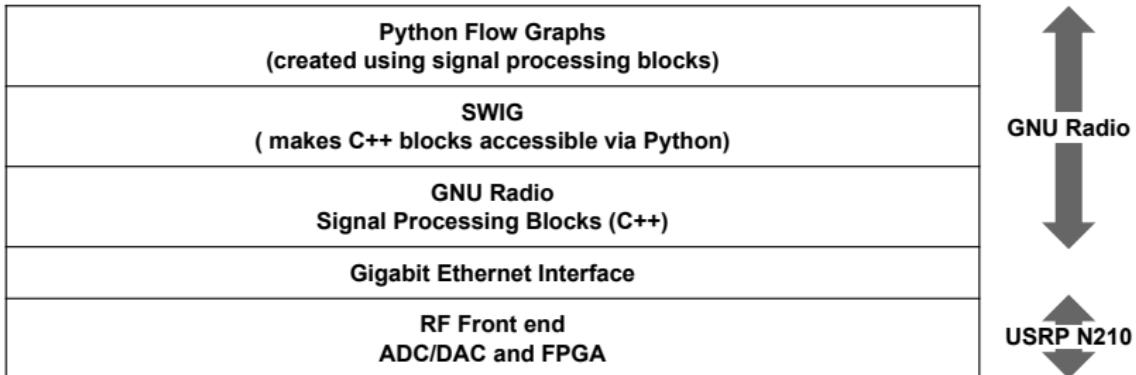
# USRP

- ▶ We have used the USRP N210 kit. It performs the task of: transmission, receiving and sensing
- ▶ The kit is equipped with WBX daughter board which spans a spectrum range of: 50-2200MHz

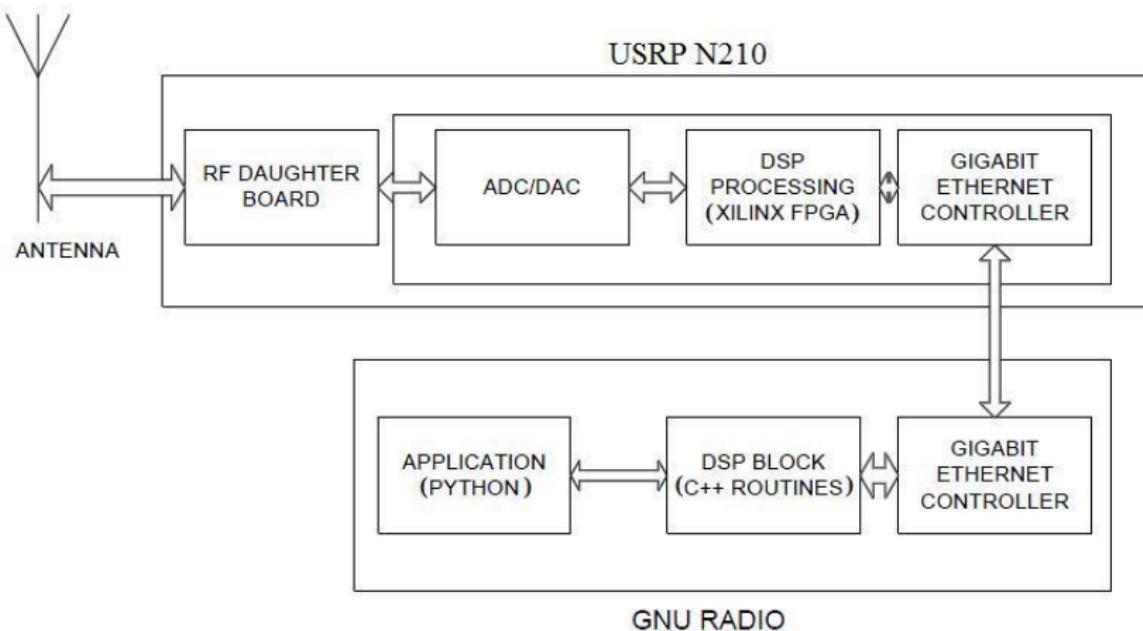


# GNURadio

- ▶ What is GNU Radio?
- ▶ Skeleton code `spectrumsense.py`
- ▶ Block Diagram



# Block diagram of SDR using USRP and GNURadio



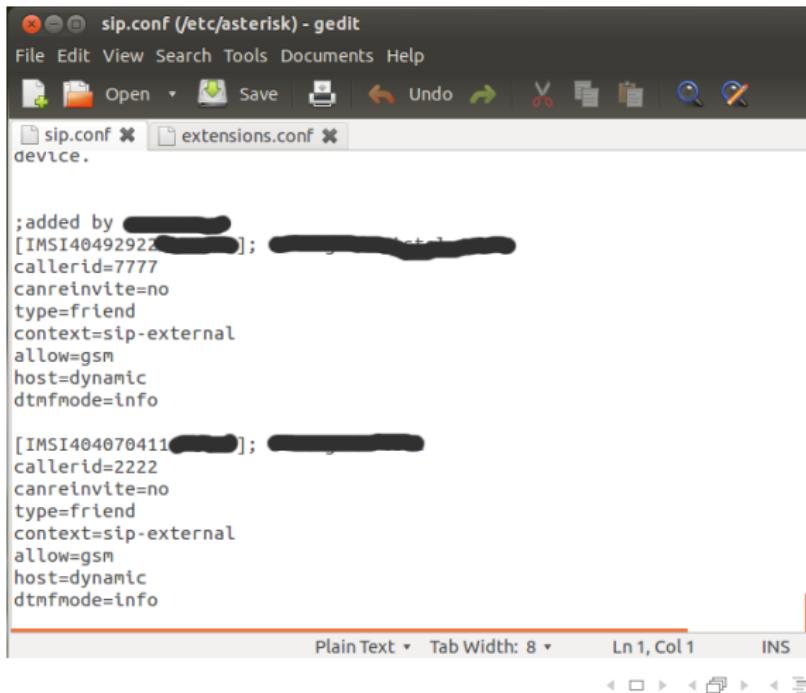
Source: Kranthi Ananthula. *Experimental setup of cognitive radio test-bed using software defined radio*. Master's thesis, Department of Electrical Engineering, 2013.

# OpenBTS

- ▶ Motivation of building OpenBTS
- ▶ What is OpenBTS?
- ▶ The OpenBTS Application Suite
  - OpenBTS
  - Asterisk
  - Smqueue
  - SIPAuthServe (Subscriber Registry)

# How to register a SIM in the network?

- ▶ Sip.conf
- ▶ Extensions.conf
- ▶ Sqlite3.db



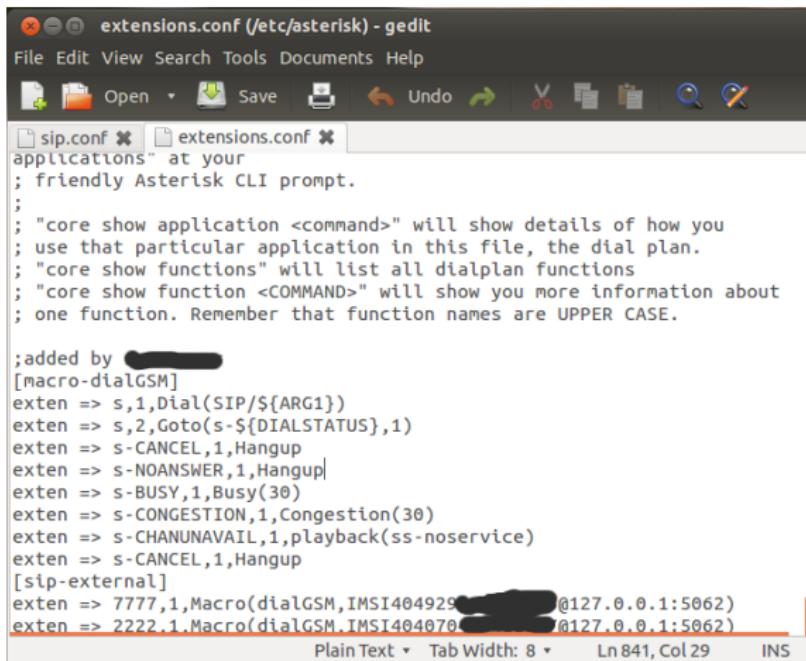
The screenshot shows a Gedit text editor window with the title "sip.conf (/etc/asterisk) - gedit". The menu bar includes File, Edit, View, Search, Tools, Documents, and Help. The toolbar contains icons for Open, Save, Undo, Redo, Cut, Copy, Paste, Find, and Replace. There are two tabs visible: "sip.conf" and "extensions.conf", with "sip.conf" currently selected. The main text area displays configuration parameters for two SIM cards:

```
;added by [REDACTED]
[IMSI40492922[REDACTED]];
callerid=7777
canreinvite=no
type=friend
context=sip-external
allow=gsm
host=dynamic
dtmfmode=info

[IMSI404070411[REDACTED]];
callerid=2222
canreinvite=no
type=friend
context=sip-external
allow=gsm
host=dynamic
dtmfmode=info
```

The status bar at the bottom shows "Plain Text", "Tab Width: 8", "Ln 1, Col 1", and "INS". Navigation arrows are also present at the bottom.

# How to register a SIM in the network?



The screenshot shows a GIMP image of a terminal window titled "extensions.conf (/etc/asterisk) - gedit". The window contains the configuration file for Asterisk's dial plan. The code is as follows:

```
; applications" at your
; friendly Asterisk CLI prompt.
;
; "core show application <command>" will show details of how you
; use that particular application in this file, the dial plan.
; "core show functions" will list all dialplan functions
; "core show function <COMMAND>" will show you more information about
; one function. Remember that function names are UPPER CASE.

;added by [REDACTED]
[macro-dialGSM]
exten => s,1,Dial(SIP/${ARG1})
exten => s,2,Goto(s-${DIALSTATUS},1)
exten => s-CANCEL,1,Hangup
exten => s-NOANSWER,1,Hangup
exten => s-BUSY,1,Busy(30)
exten => s-CONGESTION,1,Congestion(30)
exten => s-CHANUNAVAIL,1,playback(ss-noservice)
exten => s-CANCEL,1,Hangup
[sip-external]
exten => 7777,1,Macro(dialGSM,IMSI404929,[REDACTED]@127.0.0.1:5062)
exten => 2222,1,Macro(dialGSM,IMSI404070,[REDACTED]@127.0.0.1:5062)
```

Plain Text ▾ Tab Width: 8 ▾ Ln 841, Col 29 INS

# How to register a SIM in the network?

The screenshot shows the Sqliteman application interface for an SQLite database named "sqlite3.db".

**Database Tree:** The left pane displays the database schema under the "main" database. It includes tables like "dialdata", "rates", "rrlp", and "sip\_bu".

**Table View:** The central pane shows the contents of the "dialdata" table.

id	exten	dial
1	1	7777 IMSI40492[REDACTED]
2	2	2222 IMSI404070[REDACTED]

**Status Bar:** The bottom right corner indicates "Sqlite: 3.7.9".

**Message:** "Query OK Row(s) returned: 2" is displayed in the bottom pane.

# How to register a SIM in the network?

The screenshot shows the Sqliteman application interface with the title "sqlite3.db - Sqliteman". The menu bar includes File, Context, Database, System, and Help. The toolbar contains icons for New, Open, Save, Import, Export, Paste, Copy, Paste Special, Find, and Refresh.

The left pane displays the database schema under the "main" database:

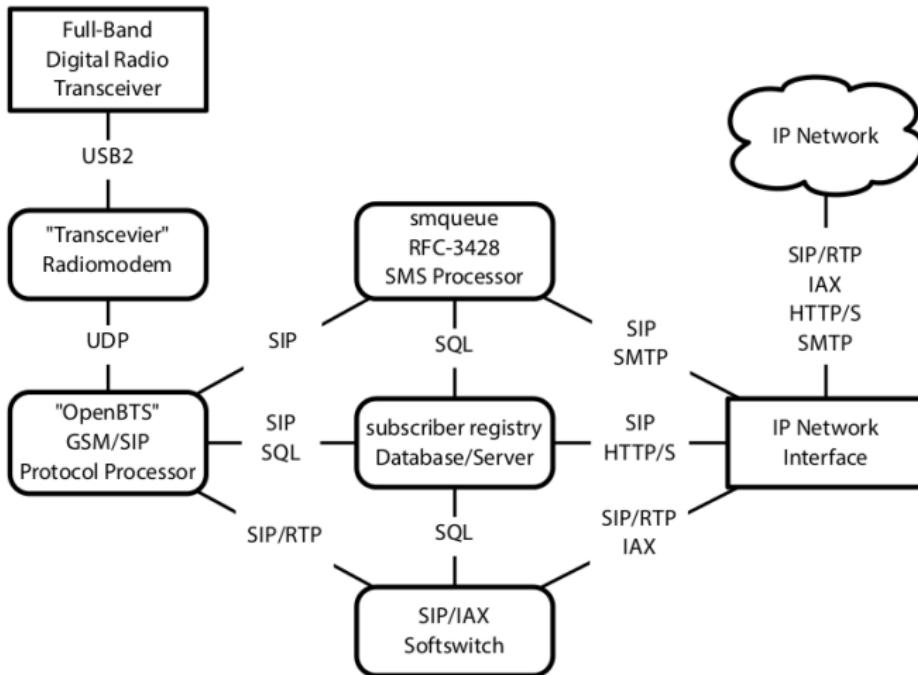
- Tables: dialdata..., rates, rrlp
- Temporary Tables: ...
- Views: ...
- Triggers: ...
- Sync to disk: ...
- Sessions: ...
- System tables: ...

The main pane shows the results of a query in a table format:

	id	name	context	callingpres
1	1	IMSI4049292[REDACTED]	sip-external	allowed_not_screened
2	2	IMSI404070[REDACTED]	sip-external	allowed_not_screened

Below the table, the status message "Query OK Row(s) returned: 2" is displayed. The bottom right corner shows the version "Sqlite: 3.7.9".

# Network organization for OpenBTS



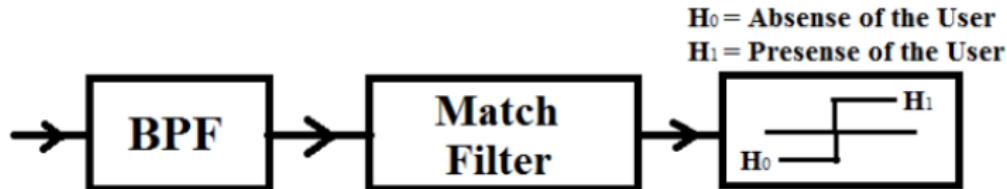
Source: <https://wush.net/trac/rangepublic/attachment/wiki/WikiStart/OpenBTS-4.0-Manual.pdf>. [Accessed on May 27, 2014].

# Spectrum sensing

- ▶ What is spectrum sensing?
- ▶ Various techniques:
  1. Matched filter based technique
  2. Energy detection based technique

# Matched filter detection

- ▶ Correlation with a filter whose response is matched with reference signal
- ▶ Block diagram:



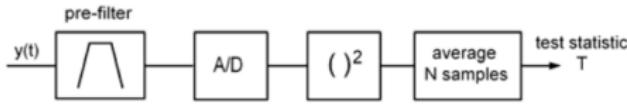
Source: Kranthi Ananthula. *Experimental setup of cognitive radio test-bed using software defined radio*. Master's thesis, Department of Electrical Engineering, 2013.

# Energy detection technique

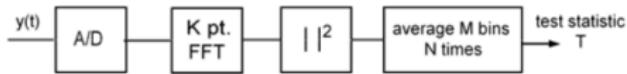
- ▶ Hypothesis testing
- ▶ Equations

$$x(t) = n(t), \quad H_0$$

$$x(t) = h(t)s(t) + n(t), \quad H_1$$



a)



b)

Source: D Cabric, A Tkachenko, and R W Brodersen. Experimental study of spectrum sensing based on energy detection and network cooperation.

In *TAPAS 06 Proceedings of the first international workshop on Technology and policy for accessing spectrum*, August 2006.

# Periodogram Analysis

- $X[n]; n = 0, 1 \dots L - 1$  is divided into  $M$  finite length segments  $X_r[n]; n = 0, 1 \dots N - 1$
- The modified periodogram for the  $r$ th segment is,

$$I_r[k] = \frac{1}{NU} |V_r[k]|^2 \quad k = 0, 1 \dots N - 1$$

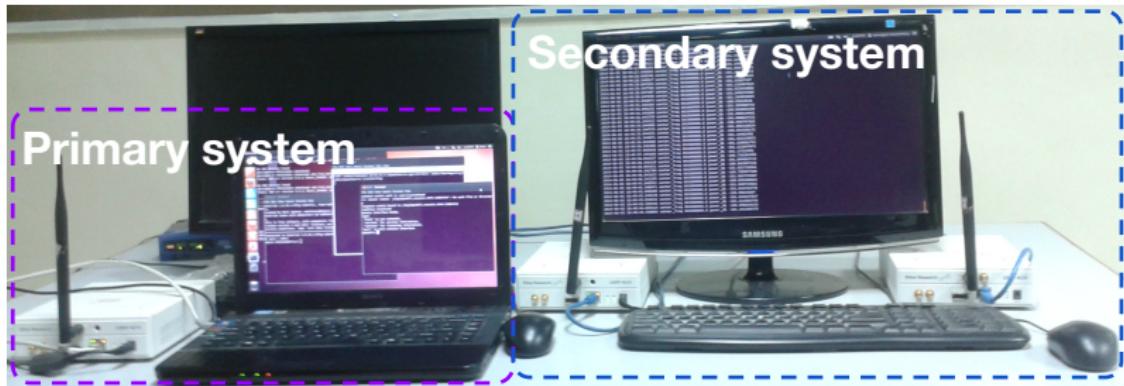
where  $V_r[k] = DFT\{W[n] * X[n]\}$ ,  $N$  point DFT and  $U = \frac{1}{N}(\sum_{n=0}^{N-1}(W[n])^2)$  is the normalization factor.

- The PSD of  $X[n]$  sequence is then the time averaged periodogram estimate ,

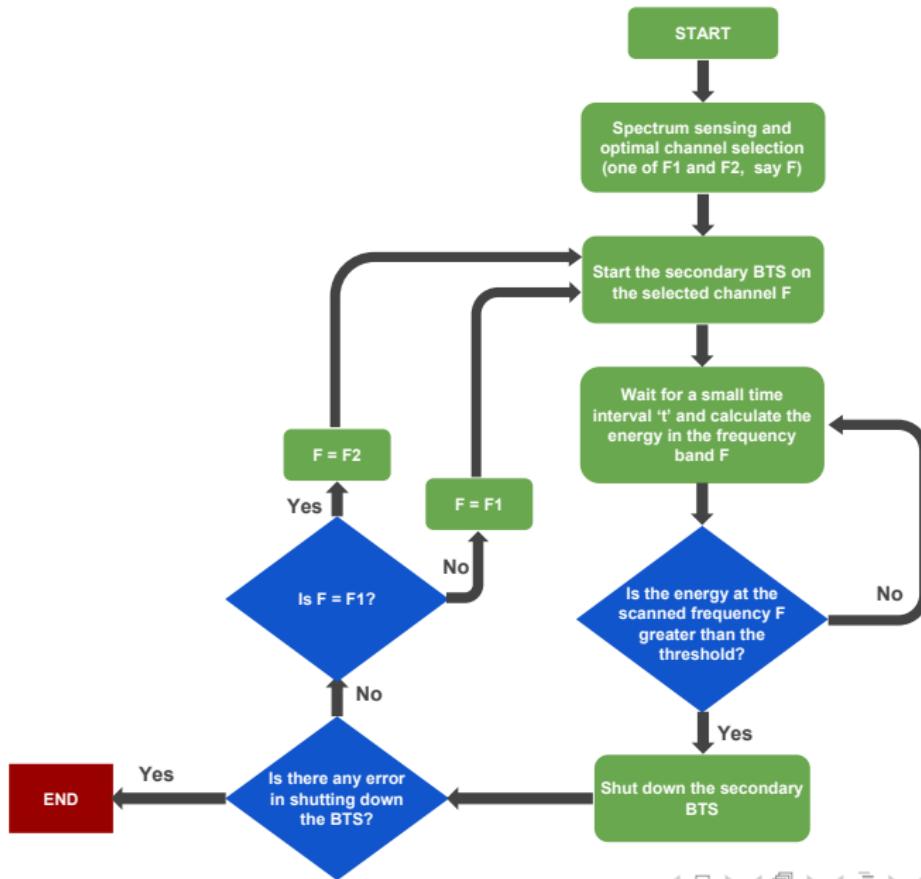
$$I[k] = \frac{1}{M} \left| \sum_{r=0}^{M-1} X_r[k] \right|^2$$

# 2-frequency system

- ▶ Channels used: 945MHz and 955MHz
- ▶ Experimental setup :



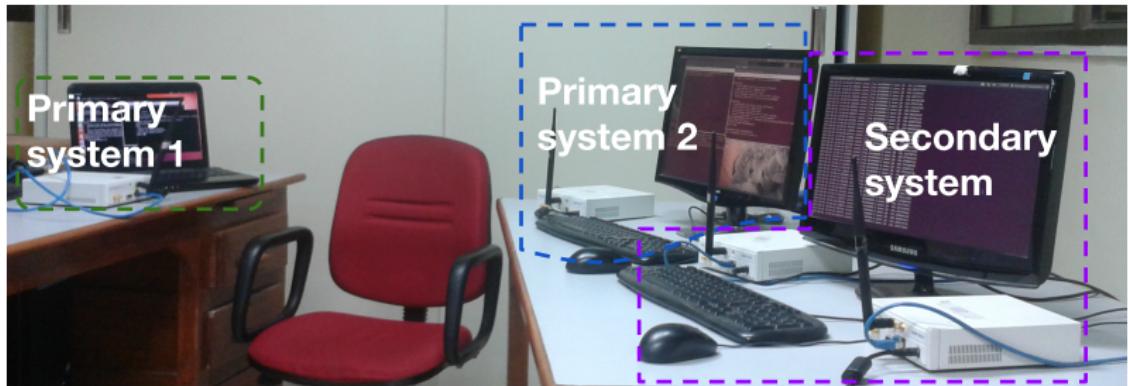
# Flow chart for 2-frequency system



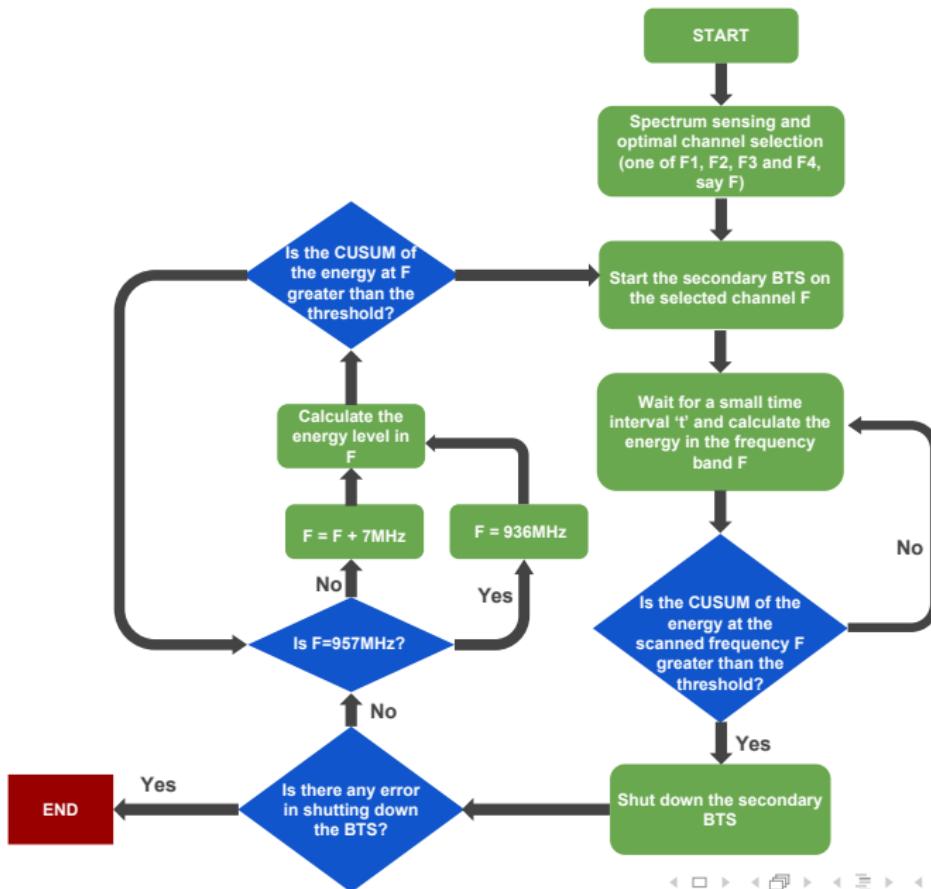
# **VIDEO for 2-frequency system**

# 4-frequency system

- ▶ Channels used: 936MHz, 943MHz , 950MHz , 957MHz
- ▶ Experimental setup :



# Flow chart for 4-frequency system



# **VIDEO for 4-frequency system**