

USRP based Cognitive Radio Test-Bed using OpenBTS

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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

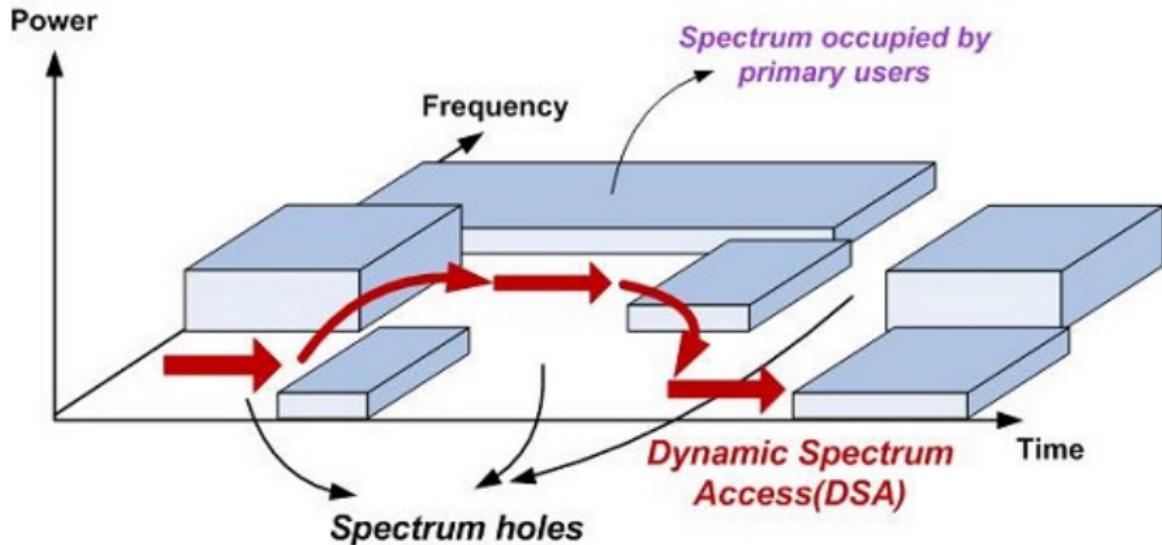


Setup for the 4-frequency test-bed



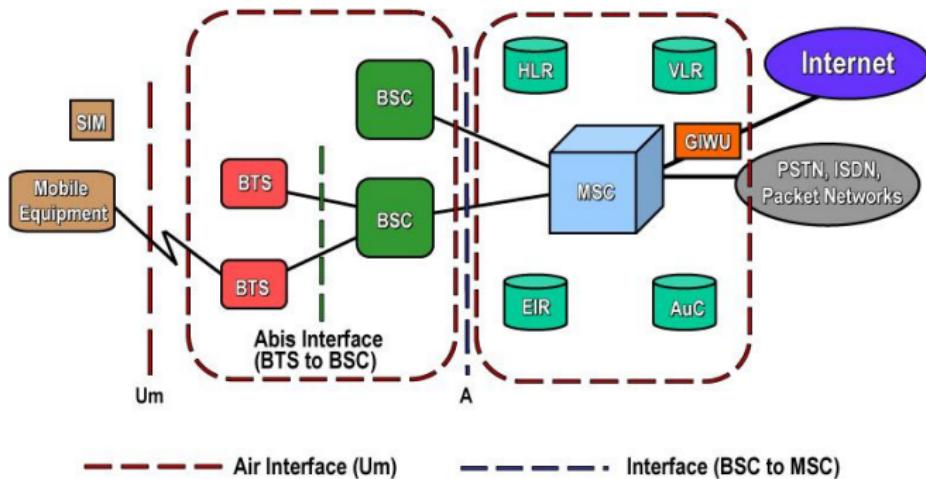
Cognitive Radio

- ▶ What is Cognitive Radio?



Source: http://www.brunel.ac.uk/__data/assets/image/0011/237539/Abdullah-Masrub1.jpg

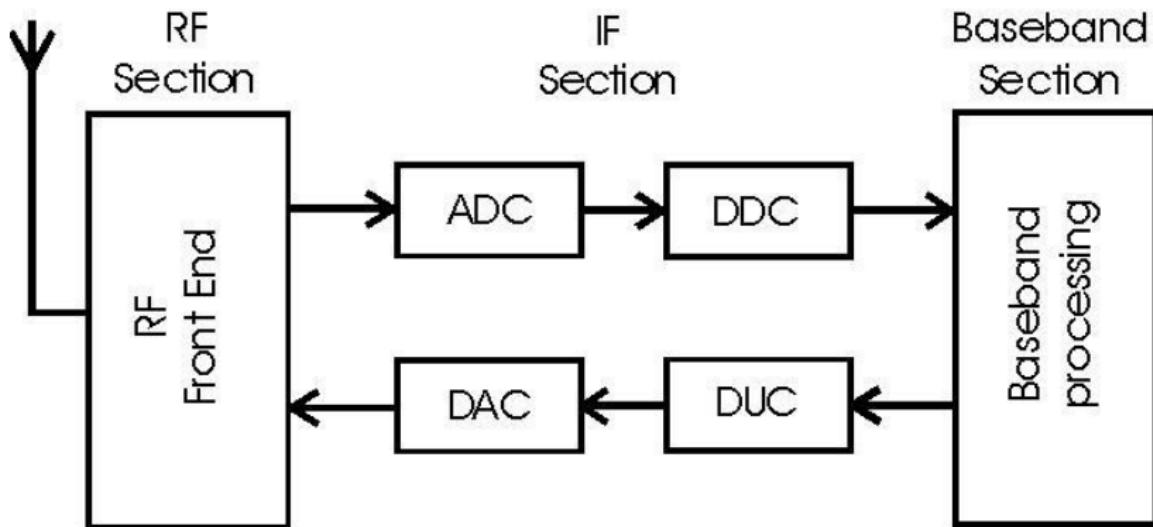
GSM



Source: http://www.hill2dot0.com/wiki/index.php?title=Image:G2407_GSM-Architecture.jpg

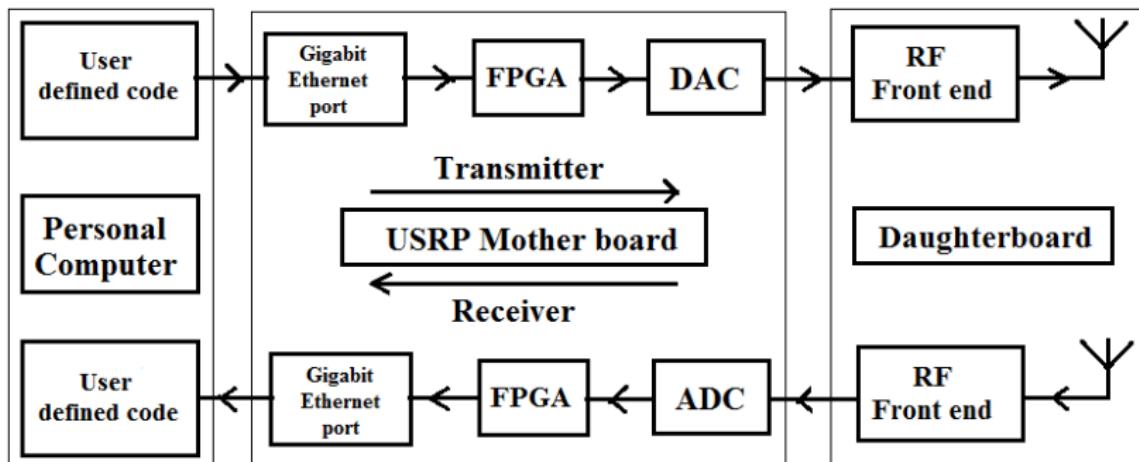
Software Defined Radio

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



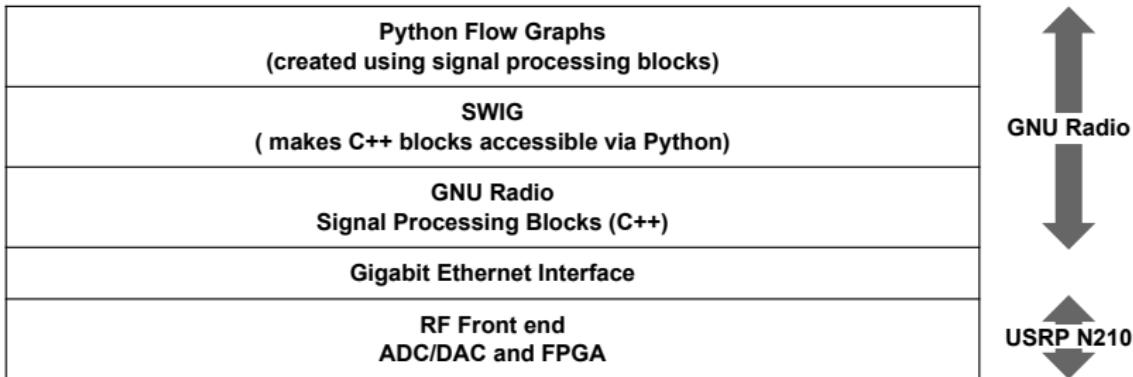
USRP

- ▶ 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

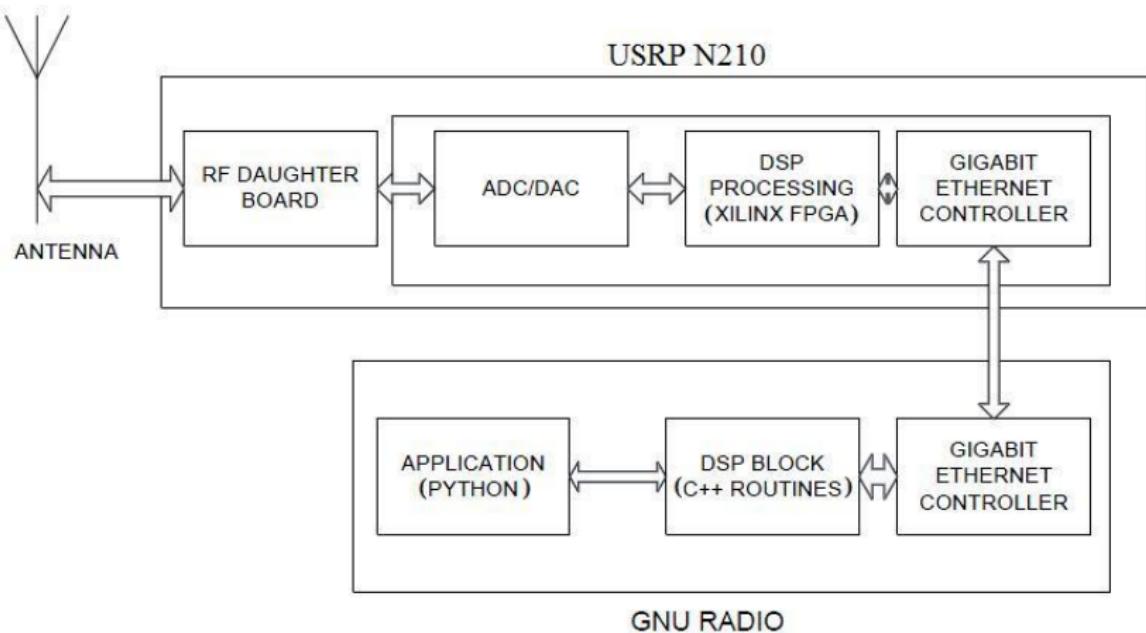


GNURadio

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



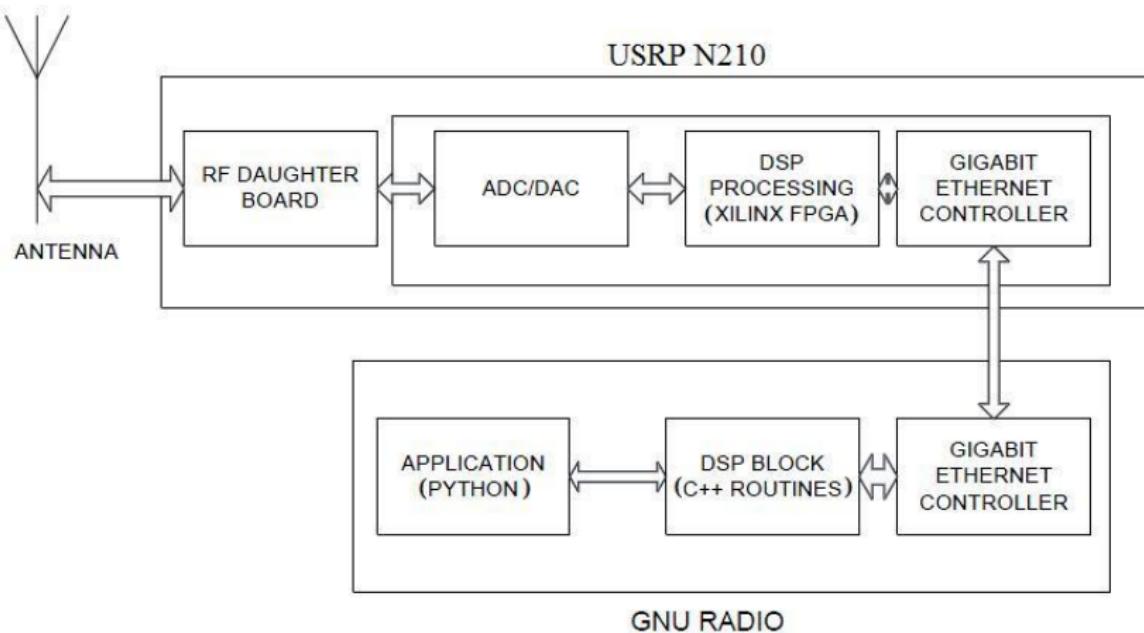
Block diagram of SDR using USRP and GNURadio



OpenBTS

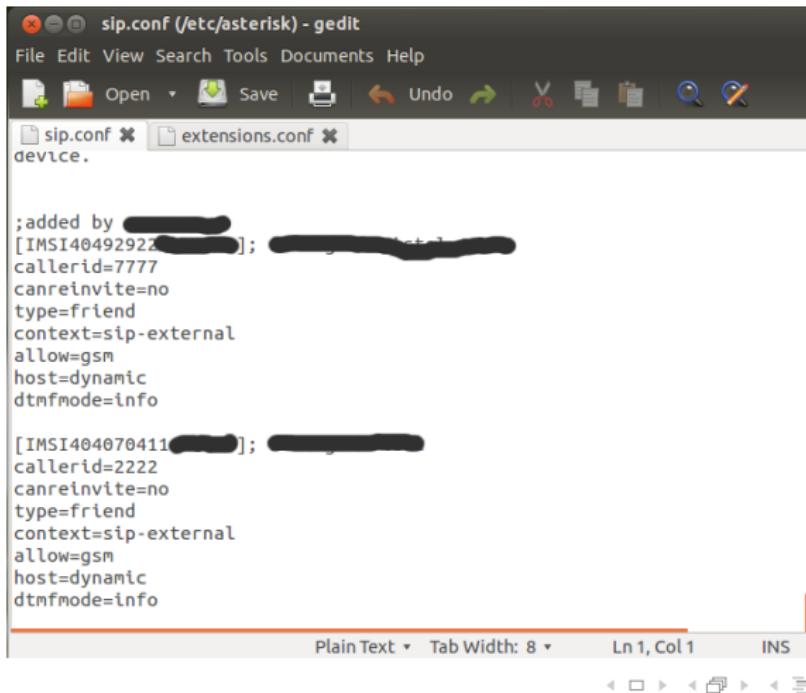
- ▶ Motivation of building OpenBTS
- ▶ What is OpenBTS?
- ▶ The OpenBTS Application Suite
 - OpenBTS
 - Asterisk
 - Smqueue
 - SIPAuthServe (Subscriber Registry)

Block diagram of SDR using USRP and GNURadio



How to register a SIM in the network?

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



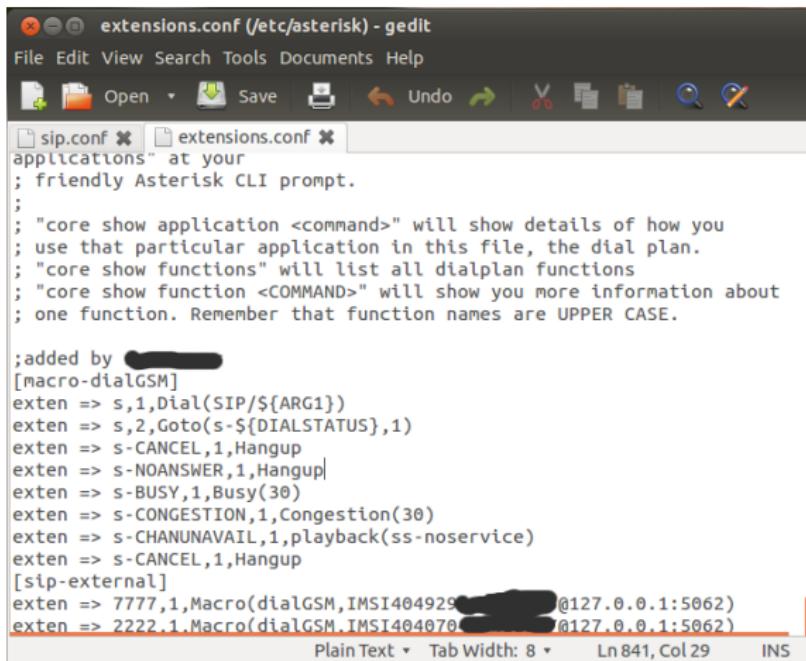
The screenshot shows a Gedit text editor window with the title "sip.conf (/etc/asterisk) - gedit". The menu bar includes File, Edit, View, Search, Tools, Documents, and Help. The toolbar contains icons for Open, Save, Undo, Redo, Cut, Copy, Paste, Find, and Replace. There are two tabs visible: "sip.conf"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

```
; 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)
```

The bottom status bar shows "Plain Text", "Tab Width: 8", "Ln 841, Col 29", and "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.

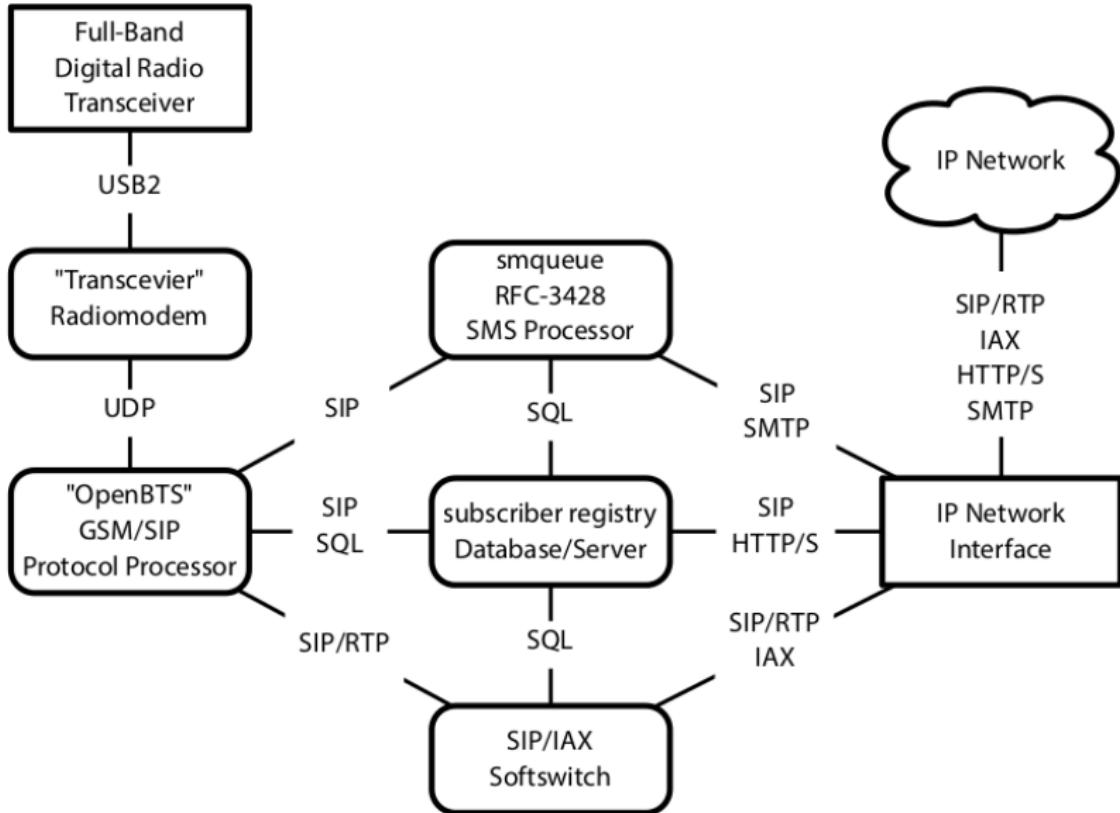
The left pane displays the database schema under the "main" database. A table named "sip bu..." is selected, indicated by a blue selection bar. The table structure includes columns for id, name, context, and callingpres.

The main pane shows the results of a query. The table data is as follows:

| | 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, a message box displays "Query OK Row(s) returned: 2". The bottom right corner shows the SQLite version "Sqlite: 3.7.9".

Network organization for OpenBTS

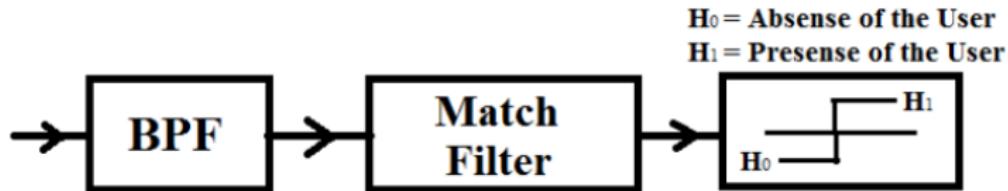


Spectrum sensing

- ▶ 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:



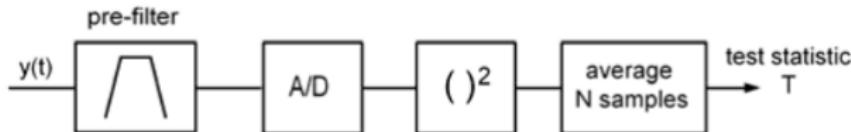
Energy detection technique

- ▶ Hypothesis testing
- ▶ Equations

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

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

- ▶ Block diagram



a)



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 ,

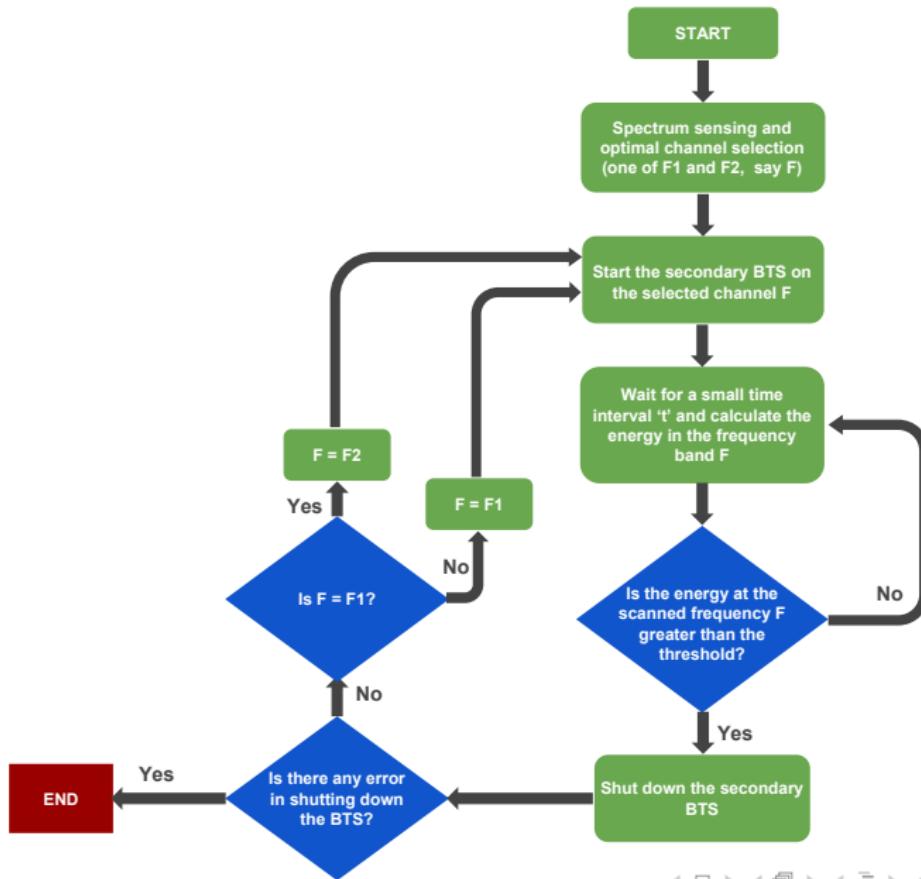
$$I[k] = \frac{1}{M} \left| \sum_{r=0}^{M-1} X_r[k] \right|^2$$

2-frequency system

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



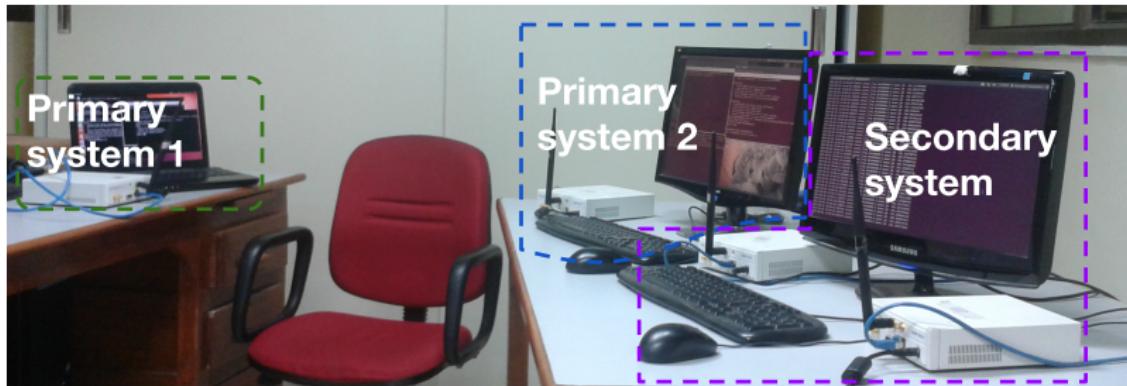
Flow chart for 2-frequency system



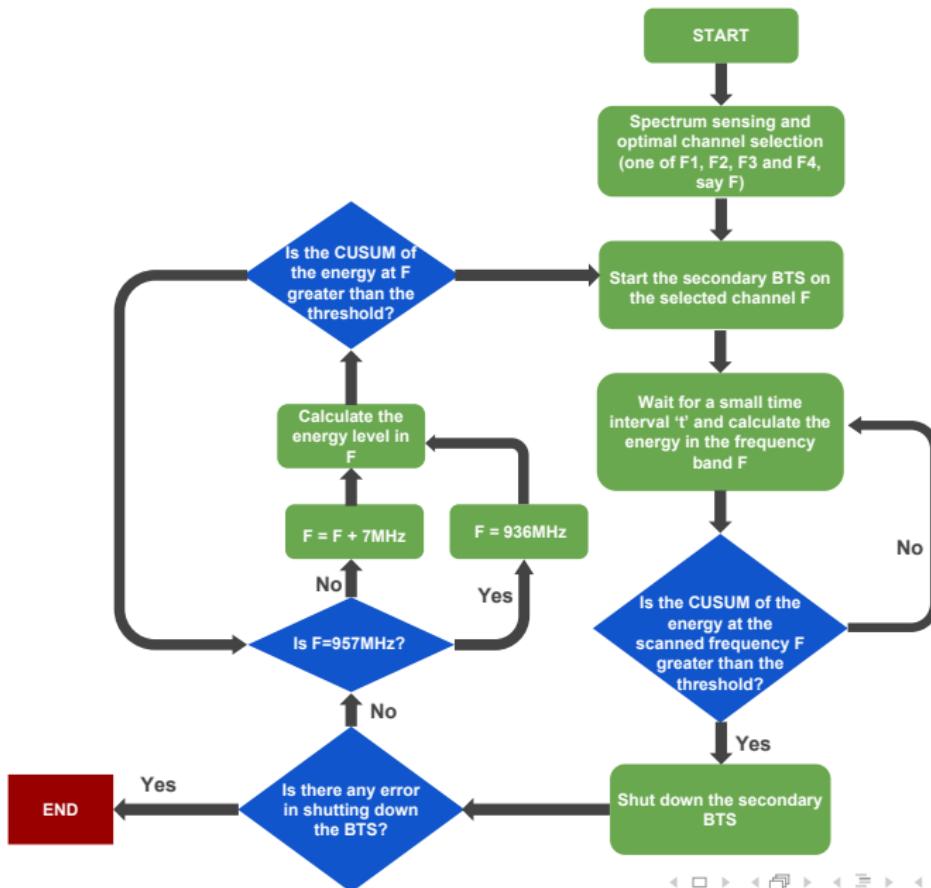
VIDEO for 2-frequency system

4-frequency system

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



Flow chart for 4-frequency system



VIDEO for 4-frequency system