



Dept. of Electrical Engineering

IIT BOMBAY

DUAL DEGREE PROJECT STAGE 1

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# OpenBTS with cognitive capabilities

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## **Abstract**

Our goal is to set up an OpenBTS system with cognitive capabilities. We have a predefined frequency band to run our cognitive OpenBTS system in. First we sense the presence of primary users in that particular frequency band by detecting the presence of ongoing calls. If it turns out that the calls made by primary users end, then we start our secondary OpenBTS system thus allowing secondary users to make calls.

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# Chapter 1

## Introduction

### 1.1 Cognitive Radio

A cognitive radio is an intelligent radio that can be programmed and configured dynamically. Its transceiver is designed to use the best wireless channels in its vicinity. Such a radio automatically detects available channels in wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. This process is a form of dynamic spectrum management[1].

### 1.2 Motivation

Studies have shown that most of the spectrum allotted to licensed networks remain unused most of the time[2]. To utilize these unused spectral resources we can make use of dynamic spectrum management. We can allow secondary (unlicensed) users to utilize the spectrum whenever that particular spectrum becomes available. For this we need cognitive capabilities to sense the availability of the spectrum.

### 1.3 Organization



# **Chapter 2**

## **Software Defined Radio**

### **2.1 Introduction**

### **2.2 USRP**

USRP (Universal Software Radio Peripheral) is a hardware kit developed by Ettus, Inc. to run software defined radio applications.

### **2.3 GnuRadio**

### **2.4 OpenBTS**





# Chapter 3

## Spectrum Sensing

3.1 Matched filter detection

3.2 Energy based detection



# Chapter 4

## A cognitive base station using GnuRadio and OpenBTS

### 4.1 Motivation



# Appendix A

## Codes

### A.1 senseUplinknStartBTS.py

```
#!/usr/bin/env python
#
# Copyright 2005,2007,2011 Free Software Foundation,
# Inc.
#
# This file is part of GNU Radio
#
# GNU Radio is free software; you can redistribute it
# and/or modify
# it under the terms of the GNU General Public License
# as published by
# the Free Software Foundation; either version 3, or (
# at your option)
# any later version.
#
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# useful,
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# GNU General Public License for more details.
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```

```

# You should have received a copy of the GNU General
  Public License
# along with GNU Radio; see the file COPYING.  If not,
  write to
# the Free Software Foundation, Inc., 51 Franklin
  Street,
# Boston, MA 02110-1301, USA.
#

```

```

from gnuradio import gr, eng_notation
from gnuradio import blocks
from gnuradio import audio
from gnuradio import filter
from gnuradio import fft
from gnuradio import uhd
from gnuradio.eng_option import eng_option
from optparse import OptionParser
import sys
import math
import struct
import threading
import time
import sqlite3
import os
import subprocess
from datetime import datetime

```

```

sys.stderr.write("Warning: this may have issues on some
machines+Python version combinations to seg fault
due to the callback in bin-statitics.\n\n")

```

```

class ThreadClass(threading.Thread):
    def run(self):
        return

```

```

class tune(gr.feval_dd):
    """
    This class allows C++ code to callback into python.
    """
    def __init__(self, tb):
        gr.feval_dd.__init__(self)

```

```

self.tb = tb

def eval(self, ignore):
    """
    This method is called from blocks.
    bin_statistics_f when it wants
    to change the center frequency. This method
    tunes the front
    end to the new center frequency, and returns
    the new frequency
    as its result.
    """

    try:
        # We use this try block so that if
        # something goes wrong
        # from here down, at least we'll have a
        # prayer of knowing
        # what went wrong. Without this, you get a
        # very
        # mysterious:
        #
        # terminate called after throwing an
        # instance of
        # 'Swig::DirectorMethodException' Aborted
        #
        # message on stderr. Not exactly helpful
        ;)

        new_freq = self.tb.set_next_freq()

        # wait until msgq is empty before
        # continuing
        while(self.tb.msgq.full_p()):
            #print "msgq full, holding.."
            time.sleep(0.1)

        return new_freq

    except Exception, e:
        print "tune:_Exception:_", e

```

```

class parse_msg(object):
    def __init__(self, msg):
        self.center_freq = msg.arg1()
        self.vlen = int(msg.arg2())
        assert(msg.length() == self.vlen * gr.
               sizeof_float)

        # FIXME consider using NumPy array
        t = msg.to_string()
        self.raw_data = t
        self.data = struct.unpack( '%df' % (self.vlen),
                                   t)

class my_top_block(gr.top_block):

    def __init__(self):
        gr.top_block.__init__(self)

        usage = "usage: %prog [options] [down_freq]"
        parser = OptionParser(option_class=eng_option,
                              usage=usage)
        parser.add_option("-a", "--args", type="string",
                          , default="",
                              help="UHD device device [
                                address args [default=%
                                default]")
        parser.add_option("", "--spec", type="string",
                          , default=None,
                              help="Subdevice of UHD device
                                where appropriate")
        parser.add_option("-A", "--antenna", type="
            string", default=None,
                              help="select Rx Antenna where
                                appropriate")
        parser.add_option("-s", "--samp-rate", type="
            eng_float", default=10e6,
                              help="set sample rate [
                                default=%default]")

```



```

parser.add_option("-g", "--gain", type="
    eng_float", default=None,
                    help="set_gain_in_dB_(default
                        _is_midpoint)")
parser.add_option("", "--tune-delay", type="
    eng_float",
                    default=0.25, metavar="SECS",
                    help="time_to_delay_(in_
                        seconds)_after_changing_
                        frequency_[default=%
                        default]")
parser.add_option("", "--dwell-delay", type="
    eng_float",
                    default=0.25, metavar="SECS",
                    help="time_to_dwell_(in_
                        seconds)_at_a_given_
                        frequency_[default=%
                        default]")
parser.add_option("-b", "--channel-bandwidth",
    type="eng_float",
                    default=9.7656e3, metavar="Hz
                    ",
                    help="channel_bandwidth_of_
                        fft_bins_in_Hz_[default=%
                        default]")
parser.add_option("-l", "--lo-offset", type="
    eng_float",
                    default=0, metavar="Hz",
                    help="lo_offset_in_Hz_[
                        default=%default]")
parser.add_option("-q", "--snr-threshold",
    type="eng_float",
                    default=None, metavar="dB",
                    help="snr_threshold_in_dB
                        _[default=%default]")
parser.add_option("-F", "--fft-size", type="int
    ", default=None,
                    help="specify_number_of_FFT_
                        bins_[default=samp_rate/
                        channel_bw]")

```

```

parser.add_option("", "--real-time", action="
    store_true", default=False,
                    help="Attempt_to_enable_real-
                        time_scheduling")

(options, args) = parser.parse_args()
if len(args) != 1:
    parser.print_help()
    sys.exit(1)

self.channel_bandwidth = options.
    channel_bandwidth

self.down_freq = eng_notation.str_to_num(args
    [0])
self.up_freq = self.down_freq - 45e6

if not options.real_time:
    realtime = False
else:
    # Attempt to enable realtime scheduling
    r = gr.enable_realtime_scheduling()
    if r == gr.RT_OK:
        realtime = True
    else:
        realtime = False
        print "Note:_failed_to_enable_realtime_
            scheduling"

# build graph
self.u = uhd.usrp_source(device_addr=options.
    args,
                                stream_args=uhd.
                                stream_args('fc32')
                                )

# Set the subdevice spec
if (options.spec):

```

```

        self.u.set_subdev_spec(options.spec, 0)

# Set the antenna
        if(options.antenna):
            self.u.set_antenna(options.antenna, 0)

        self.u.set_samp_rate(options.samp_rate)

        self.usrp_rate = usrp_rate = self.u.
            get_samp_rate()

        self.lo_offset = options.lo_offset

        if options.fft_size is None:
            self.fft_size = int(self.usrp_rate/self.
                channel_bandwidth)
        else:
            self.fft_size = options.fft_size

        self.squelch_threshold = options.
            squelch_threshold

        s2v = blocks.stream_to_vector(gr.
            sizeof_gr_complex, self.fft_size)

        mywindow = filter.window.blackmanharris(self.
            fft_size)
        ffter = fft.fft_vcc(self.fft_size, True,
            mywindow, True)
        power = 0
        for tap in mywindow:
            power += tap*tap

        c2mag = blocks.complex_to_mag_squared(self.
            fft_size)

        tune_delay = max(0, int(round(options.
            tune_delay * usrp_rate / self.fft_size))) #
            in fft_frames

```

```

dwell_delay = max(1, int(round(options.
    dwell_delay * usrp_rate / self.fft_size))) #
    in fft_frames

self.msgq = gr.msg_queue(1)
self._tune_callback = tune(self)           # hang
    on to this to keep it from being GC'd
stats = blocks.bin_statistics_f(self.fft_size,
    self.msgq,
                                self.
                                _tune_callback
                                , tune_delay
                                ,
                                dwell_delay)

# FIXME leave out the log10 until we speed it
up
#self.connect(self.u, s2v, ffter, c2mag, log,
    stats)
self.connect(self.u, s2v, ffter, c2mag, stats)

if options.gain is None:
    # if no gain was specified, use the mid-
    point in dB
    g = self.u.get_gain_range()
    options.gain = float(g.start()+g.stop())
        /2.0

self.set_gain(options.gain)
print "gain =", options.gain

def set_next_freq(self):
    target_freq = self.up_freq

    if not self.set_freq(target_freq):
        print "Failed to set frequency to",
            target_freq
        sys.exit(1)

return target_freq

```

```

def set_freq(self , target_freq):
    """
        Set the center frequency we're interested in.

        Args:
            target_freq: frequency in Hz
            @rypte: bool
    """

    r = self.u.set_center_freq(uhd.tune_request(
        target_freq , rf_freq=(target_freq + self.
        lo_offset),rf_freq_policy=uhd.tune_request.
        POLICY_MANUAL))
    if r:
        return True

    return False

def set_gain(self , gain):
    self.u.set_gain(gain)


def main_loop(tb):

    # use a counter to make sure power is less than
    threshold
    lowPowerCount = 0
    lowPowerCountMax = 10
    print 'fft_size' , tb.fft_size
    N = tb.fft_size


    while 1:

        # Get the next message sent from the C++ code (
        blocking call).
        # It contains the center frequency and the mag
        squared of the fft

```

```

m = parse_msg(tb.msgq.delete_head())

# m.center_freq is the center frequency at the
#   time of capture
# m.data are the mag-squared of the fft output
# m.raw_data is a string that contains the
#   binary floats.
# You could write this as binary to a file.

center_freq = m.center_freq
bins = 10
power_data = 0

for i in range(1, bins+1):
    power_data += m.data[N-i] + m.data[i]
power_data += m.data[0]
power_data /= ((2*bins) + 1)

power_db = 10*math.log10(power_data/tb.
    usrp_rate)
power_threshold = -95

if (power_db > tb.squelch_threshold) and (
    power_db > power_threshold):
    print datetime.now(), "center_freq",
        center_freq, "power_db", power_db, "in_u
        se"
    lowPowerCount = 0
else:
    print datetime.now(), "center_freq",
        center_freq, "power_db", power_db
    lowPowerCount += 1
    if (lowPowerCount > lowPowerCountMax):
        down_freq = center_freq + 45e6
        startOpenBTS(down_freq)
        break

def startOpenBTS(downFrequency):

```

```

arfcn=int((downFrequency-935e6)/2e5)
if (arfcn < 0):
    print "ARFCN_must_be_>_0_!!!"
    sys.exit(1)
print 'ARFCN=', arfcn
#DB modifications
t=(arfcn,)
conn=sqlite3.connect("/etc/OpenBTS/OpenBTS.db")
cursor=conn.cursor()
cursor.execute("update_config_set_valuestring=?_
    where_keystring='GSM.Radio.C0'",t)
conn.commit()

#start the OpenBTS
f=subprocess.Popen(os.path.expanduser('~'/ddp-stage
    -1-and-openbts/runOpenBTS.sh'))
f.wait()

if __name__ == '__main__':
    t = ThreadClass()
    t.start()

    tb = my_top_block()
    try:
        tb.start()
        main_loop(tb)

    except KeyboardInterrupt:
        pass

```





# Bibliography

- [1] [http://en.wikipedia.org/wiki/Cognitive\\_radio](http://en.wikipedia.org/wiki/Cognitive_radio).
- [2] Federal Communications Commission. Spectrum policy task force. *ET Docket No. 02-135*, November 2002.