

RPi4 and OP25

Rich Lucente





Who am I?

Husband, Dad, Technical professional

Over 30 years in the industry as developer, software engineer, manager, consultant, sales engineer

Like to tinker with technology

Also spend free time with family, trips to Disney world (probably too much), tabletop games, Legos, fantasy and sci/fi books, shows, and movies

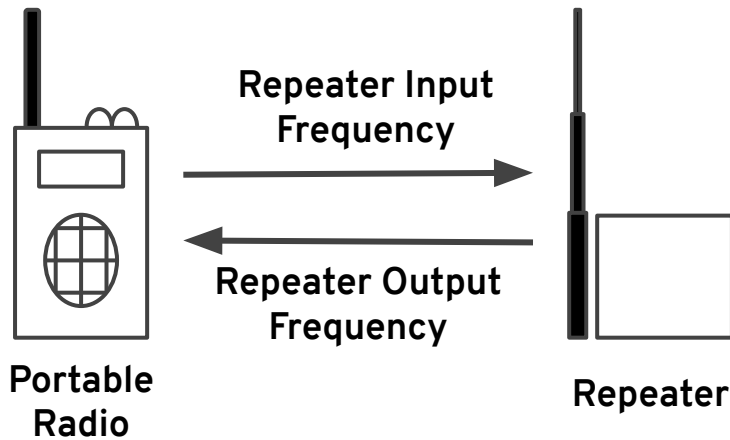




What is digital trunked radio?



Scale and Interoperability Challenges

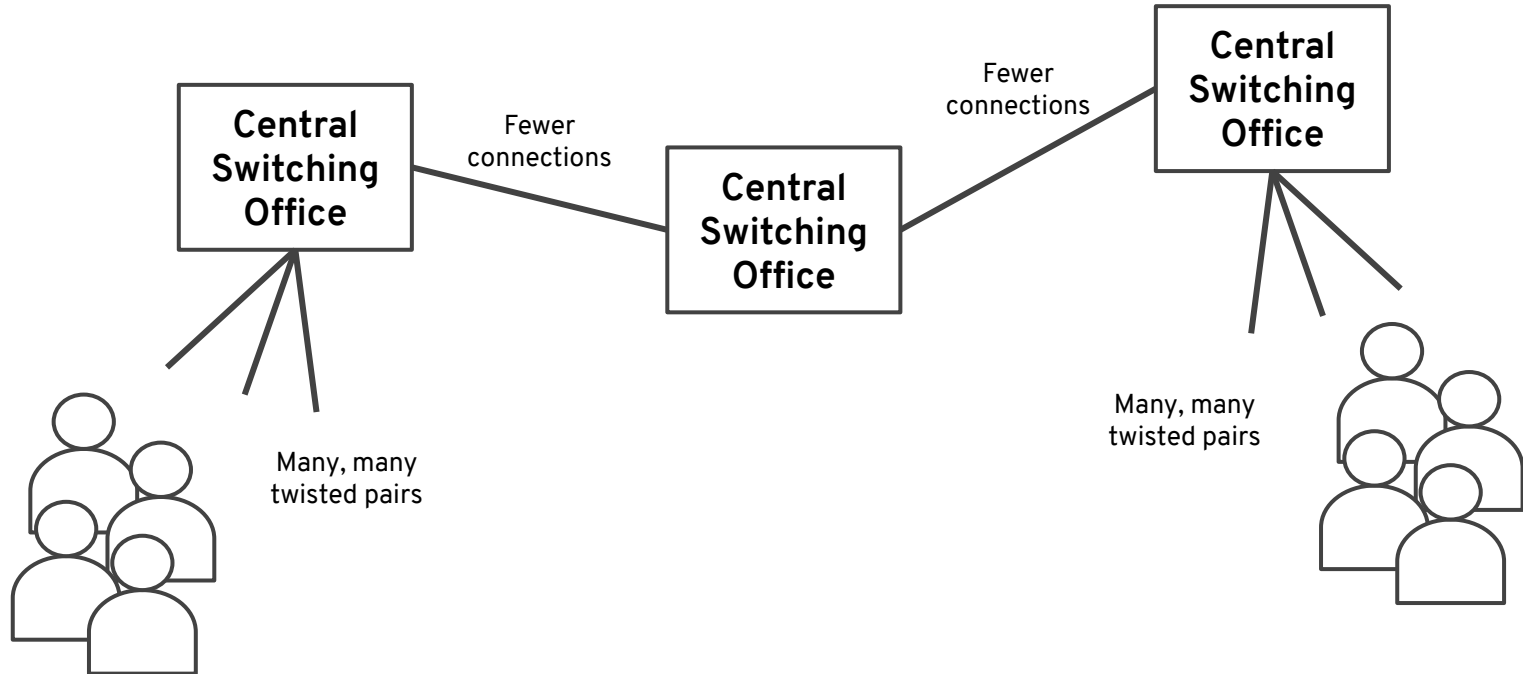


Conventional

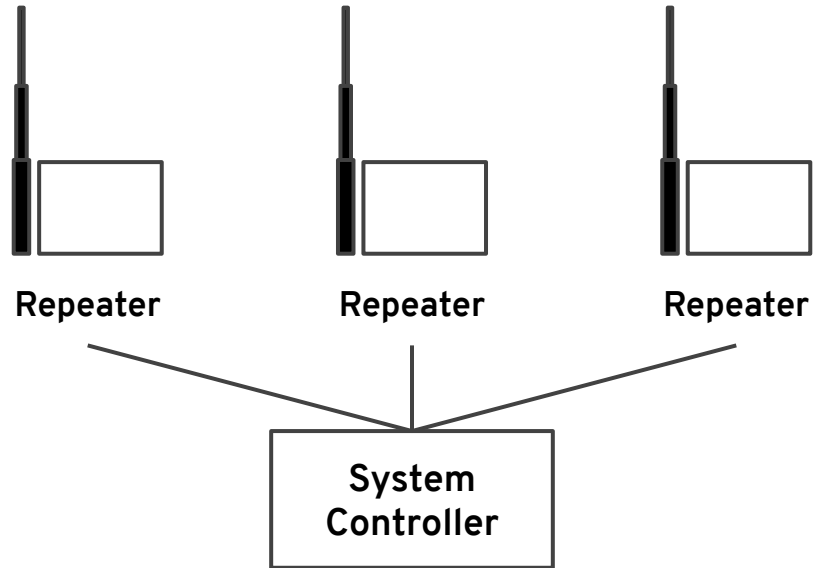
- Limited number of users
- Fixed set of frequencies
- Everyone hears everyone
- Wait your turn to talk
- Scale by
 - Adding frequencies
 - Adding repeaters
 - Splitting by geography

Trunking, or “Sorry, all circuits are busy”

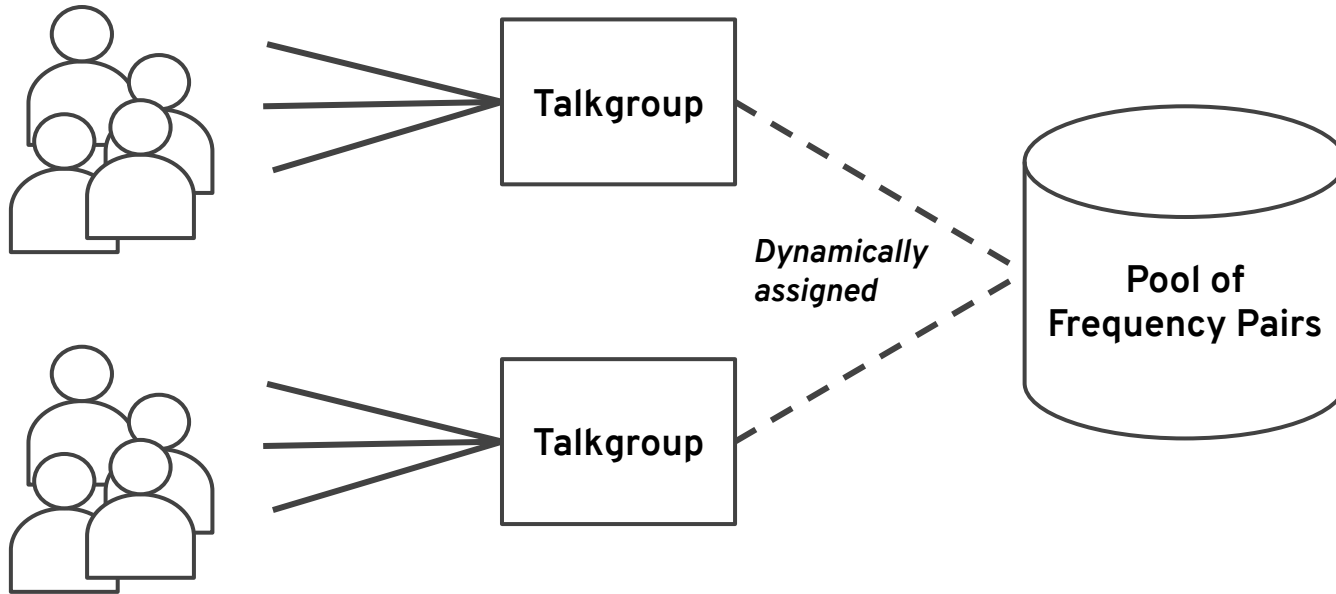
Example of POTS, not PANS



Trunked Radio



Trunked Radio





Trunking process

Control channels carry instructions and status (in digital form)

Traffic channels carry encoded voice

Steps for speaking on a talkgroup:

This all takes less than a second

1. **Idle state** - all portable radios tuned to control repeater output frequency
2. Portable radio PTT button pressed
3. Portable radio sends request on repeater control frequency with talkgroup identifier
4. Controller assigns available traffic channel to talkgroup and marks channel “in use”
5. Controller broadcasts talkgroup active on assigned traffic channel
6. All portable radios in talkgroup tune that traffic channel
7. Portable radio may emit some “go ahead” tone to user
8. User talks then releases PTT button
9. Portable radio sends “finished” to controller
10. Controller broadcasts on assigned traffic channel that talkgroup no longer active
11. Portable radios tuned to assigned traffic channel retune to control channel
12. Controller releases assigned traffic channel and marks it as “not in use”



Project 25

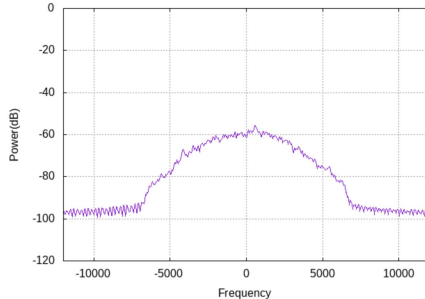




Basic Concepts

Modulation/Demodulation

- Adds *symbols* to a carrier frequency
- Creates sidebands



Encoding/Decoding

- Symbols map to binary values
- Mapping binary values to understandable concepts

Human speech, Unicode, Telemetry

Encryption/Decryption

- Scrambling binary streams to prevent unwanted listeners
- Algorithms and keys are used to map between plaintext and ciphertext



APCO Project 25

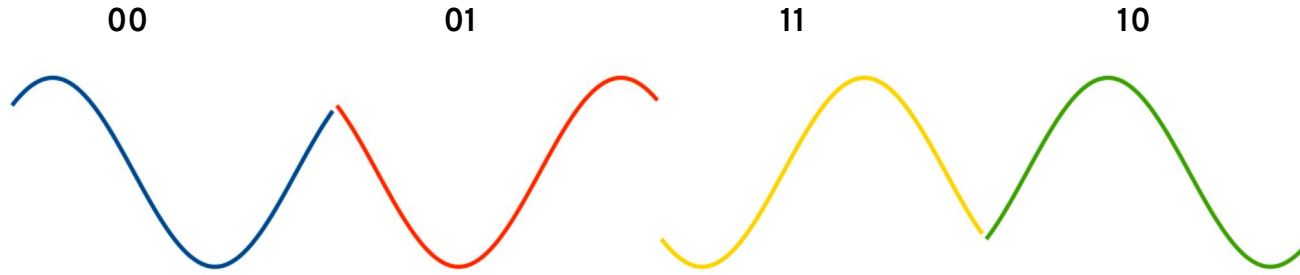
Association of Public-Safety Communication Officials (APCO) created a set of standards for digital public-safety radio in the late '80s

Standards collectively known as *Project 25*

Phase 1 Systems

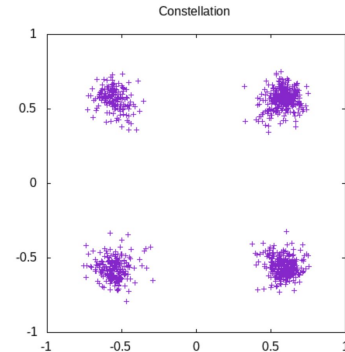
- 12.5 kHz digital mode, single user per channel
- Continuous 4 level FM (C4FM) or compatible quadrature phase-shift keying (CQPSK)

QPSK Demodulation



Quadrature phase-shift keying

- Each symbol is phase shifted 90° from the previous symbol
- Grey code typical so adjacent symbols differ by only one bit
- Constellation diagram helps visualize how well demodulation is working





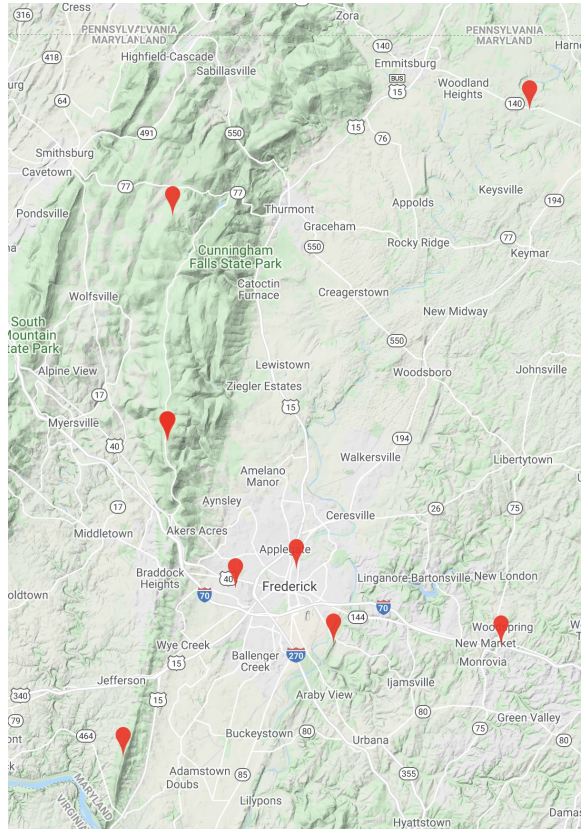
What's in the signal?

4800 symbols per sec (baud) with two bits per symbol = 9600 bps

- Standards define content in binary stream
- Project 25 phase 1 systems
 - 4400 bps voice in improved multi-band excitation (IMBE) codec
 - 2800 bps forward error correction
 - 2400 bps signalling and control

This is intended only as background since the software handles all the demodulation and decoding

Frederick County P25 Phase 1 System



Many repeaters in Frederick County, MD

List of [FCC licenses](#)

<https://www.radioreference.com> is your friend

[Frederick County Data](#)

- Primary control frequency at 854.9875 MHz
- Network Access Code 0x441
- Over 100 talkgroups

Lots of channels are *encrypted*

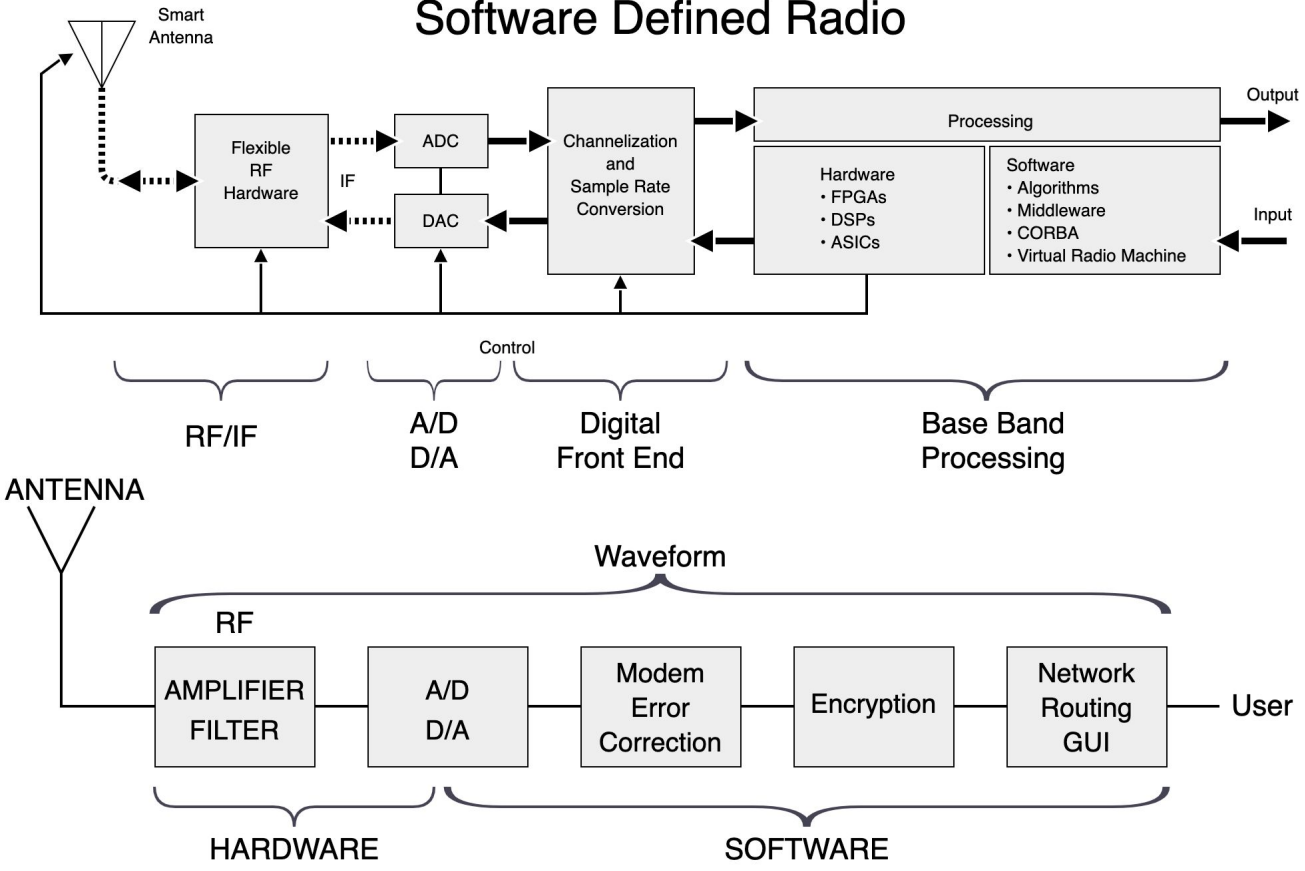
- Criminal investigations
- Narcotics
- SWAT



Software-defined radio



Software Defined Radio



https://en.wikipedia.org/wiki/Software-defined_radio

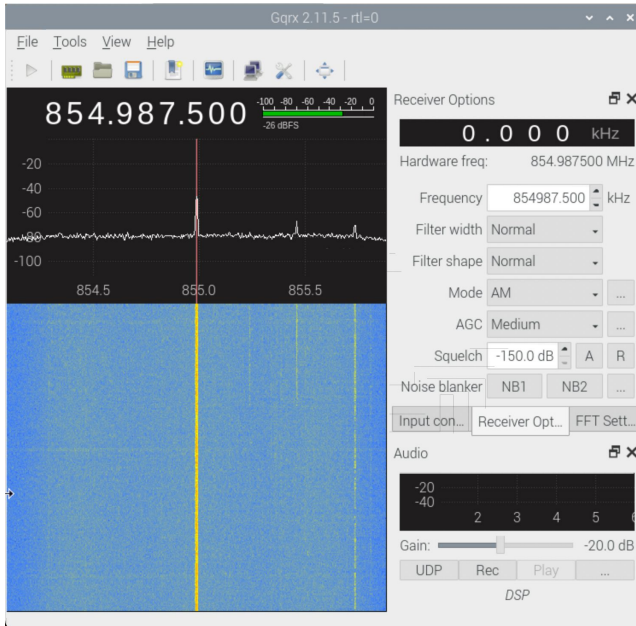
SDR Hardware



RTL-SDR.com
< \$40
But shipping took
over six weeks



SDR Software

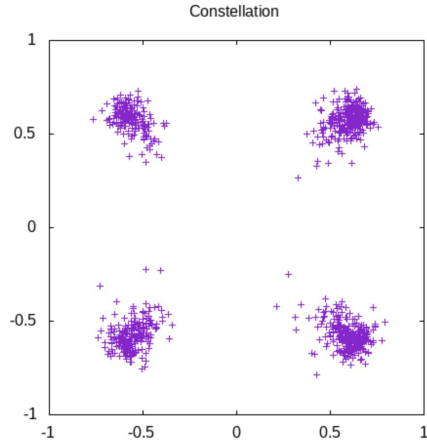


Gqrx is an open source software defined radio receiver (SDR) powered by the [GNU Radio](#) and the [Qt](#) graphical toolkit.

Install pulls in needed software dependencies for ...

SDR Software (cont)

Home	Plot	About	© 2017-2020 Max H. Parke & Graham J. Norbury [boatbod version]						
FFT	Con	Sym	Dat	Mix	Tune	<<	<	>	>>
Frequency:	854.987500	fcs0							
Talkgroup:									
Group Addr:									
Source Addr:									



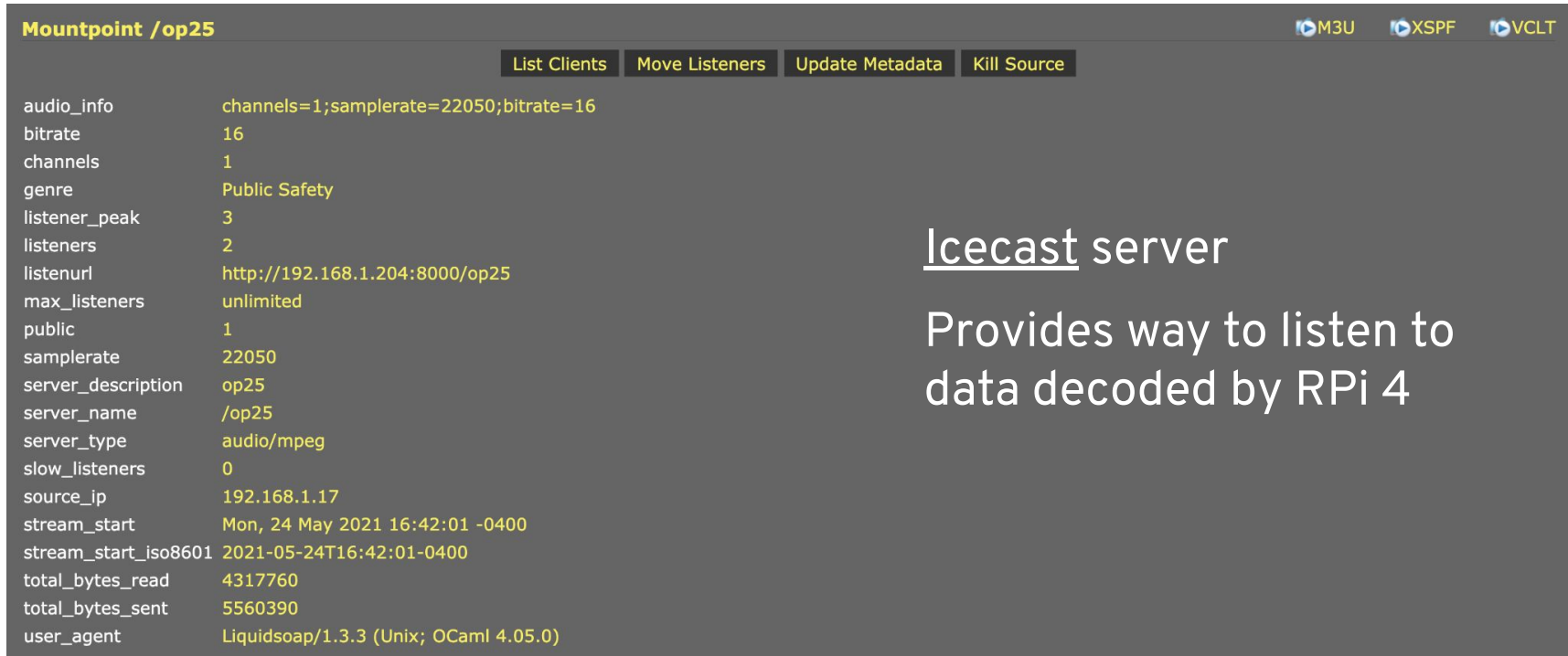
[OP25](#) project

Project 25 receiver
written in python

Compiles on RPi 4

Can stream to shoutcast
servers

SDR Software (cont)



The screenshot shows the Mountpoint /op25 web interface. At the top right, there are icons for M3U, XSPF, and VCLT. Below these are four buttons: List Clients, Move Listeners, Update Metadata, and Kill Source. The main area displays a list of server parameters and their values.

audio_info	channels=1;samplerate=22050;bitrate=16
bitrate	16
channels	1
genre	Public Safety
listener_peak	3
listeners	2
listenurl	http://192.168.1.204:8000/op25
max_listeners	unlimited
public	1
samplerate	22050
server_description	op25
server_name	/op25
server_type	audio/mpeg
slow_listeners	0
source_ip	192.168.1.17
stream_start	Mon, 24 May 2021 16:42:01 -0400
stream_start_iso8601	2021-05-24T16:42:01-0400
total_bytes_read	4317760
total_bytes_sent	5560390
user_agent	Liquidsoap/1.3.3 (Unix; OCaml 4.05.0)

Icecast server

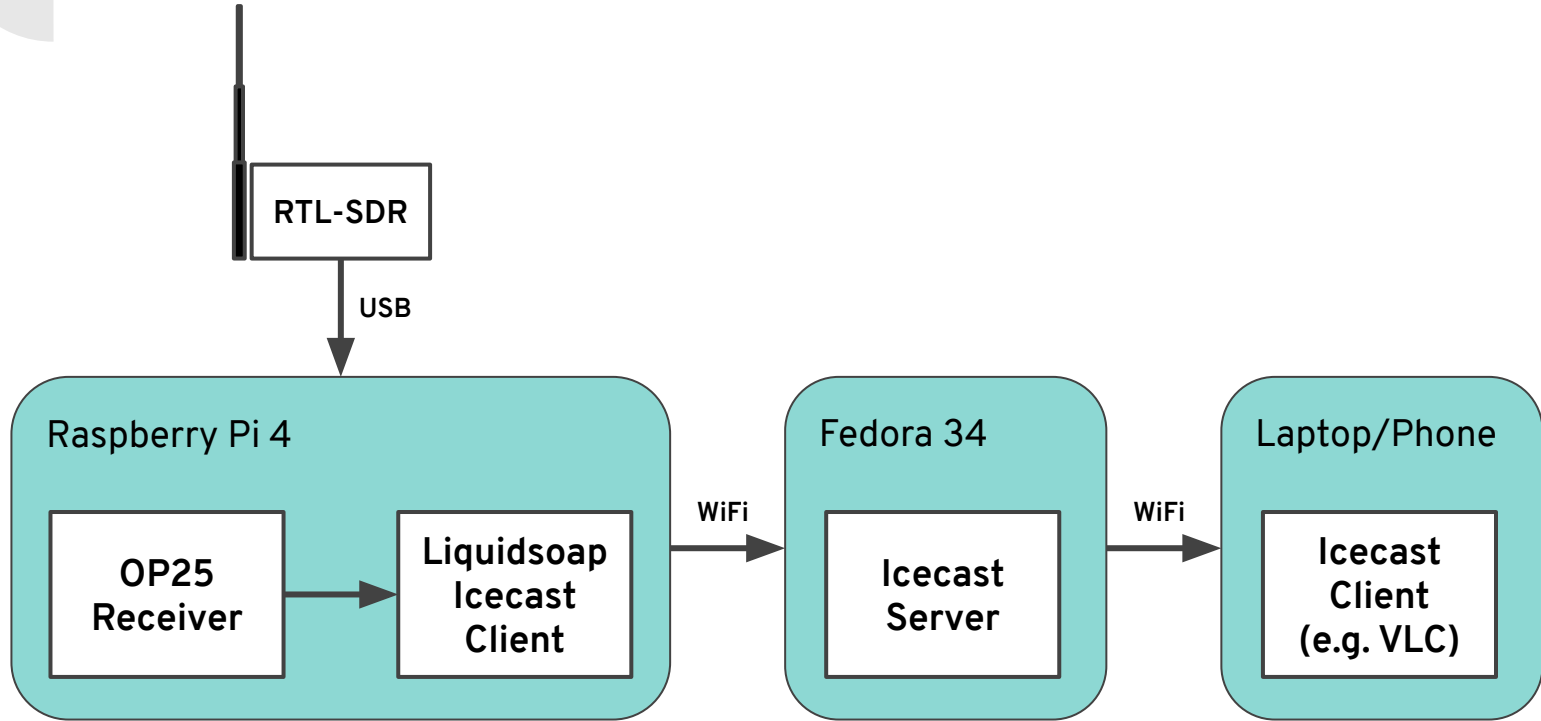
Provides way to listen to
data decoded by RPi 4



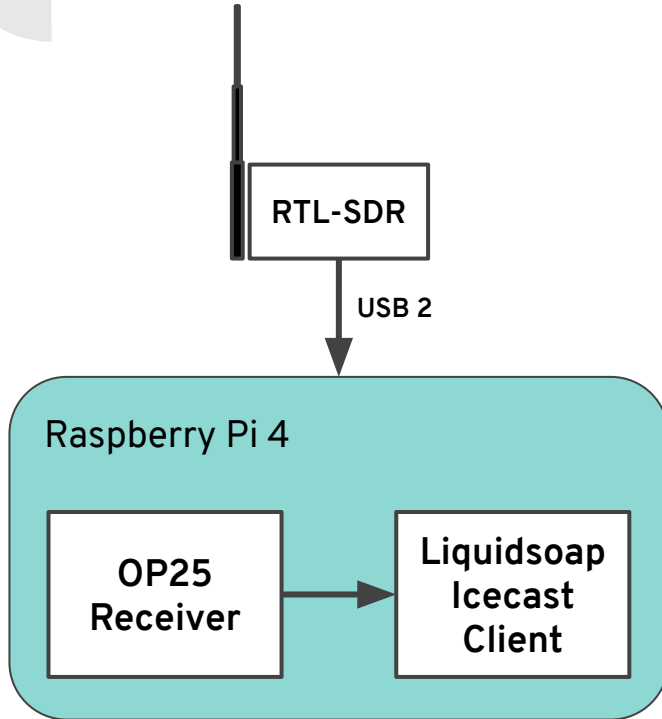
My setup



Big picture



Raspberry Pi 4



OP25 receiver and Liquidsoap source client running as rootless systemd services

Receiver provides web interface to view P25 decoding and signal characteristics

libusb issues ...

- Use the USB 2 ports and **NOT** the USB 3 ports
- Increase the size of usbfs memory buffers

Liquidsoap source client forwards decoded voice streams to Icecast server

OP25 web interface

Home	Plot	About	© 2017-2020 Max H. Parke & Graham J. Norbury [boatbod version]
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SKIP	HOLD	GOTO	B/LIST	W/LIST	LOG	<<	<	>	>>
-------------	-------------	-------------	---------------	---------------	------------	-----------------	-------------	-------------	-----------------

Frequency: **854.987500** **fcso**
Talkgroup:
Group Addr:
Source Addr:

NAC 0x441 WACN 0xbee00 SYSID 0x441 854.987500/809.987500 tsbks 157676

RFSS ID: 1 Site ID: 1

Secondary control channel(s): **851.612500 851.912500 853.475000**

Frequency error: **-41 Hz. (approx)**

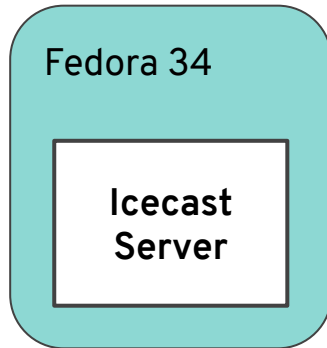
Fine tune offset: **-24**

System Frequencies			
Voice Frequency	Last Used	Active Talkgroup Id	Count
853.750000	56.1	-	1748
856.137500	83.5	-	1821
856.487500	64.2	-	1440
857.487500	0.1	5541	1240
858.087500	155.9	-	1876
858.487500	88.1	-	1875
859.487500	1.2	-	1493

Adjacent Sites			
Frequency	RFSS	Site	Uplink
774.881250	1	2	804.881250



Fedora 34 server



Icecast server receives source client stream, offers playlist to clients, and streams content

Systemd timers/services

- Archive streams at top and bottom of hour using curl
- Remove streams older than 14 days

Icecast web interface

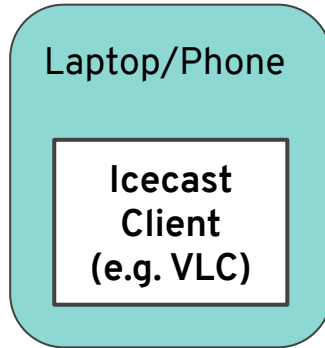


The screenshot displays the Icecast web interface for a specific mountpoint. At the top left, the title is "Mountpoint /op25". On the top right, there are three icons: M3U, XSPF, and VCLT. Below the title, there are four buttons: "List Clients", "Move Listeners", "Update Metadata", and "Kill Source". The main content area shows a list of server statistics and configuration parameters in a key-value format.

audio_info	channels=1;samplerate=22050;bitrate=16
bitrate	16
channels	1
genre	Public Safety
listener_peak	3
listeners	1
listenurl	http://192.168.1.204:8000/op25
max_listeners	unlimited
public	1
samplerate	22050
server_description	op25
server_name	/op25
server_type	audio/mpeg
slow_listeners	0
source_ip	192.168.1.17
stream_start	Mon, 24 May 2021 21:55:03 -0400
stream_start_iso8601	2021-05-24T21:55:03-0400
total_bytes_read	165239151
total_bytes_sent	187034908
user_agent	Liquidsoap/1.3.3 (Unix; OCaml 4.05.0)



Streaming client



Lots of streaming clients to choose from
or just use phone browser

VLC works great on multiple platforms
including mobile phones



Demo





All source code and instructions

<https://github.com/rlucente-se-jboss/rpi4-op25>

The background is a solid orange color. In the top-left corner, there are three vertical bars of varying heights, each composed of several overlapping semi-transparent orange circles. In the bottom-right corner, there are four vertical bars of increasing height from left to right, each also composed of several overlapping semi-transparent orange circles.

Questions (and thanks!)