Realtime Multicast for SDR Interconnect

- Phil Karn, KA9Q

Some background

- Retired from Qualcomm Sept 2011
- Second career as volunteer mentor to San Diego high school and university ham clubs
  - ham licensing
  - high altitude balloons
  - cubesats

KA9Q-radio

- Set of general purpose SDR modules
  - multicast proof of concept
- Minimum cost (I work with students)
  - RPIs, Funcube dongles, HackRF, etc
    - must be open, cheap and available
- Balloon APRS, satellite operations

Is it real time?

- “Real Time” != “audio and video” !!
- Real time is **real time** — *is the stream being generated right now? Is latency important?*
  - Use RTP for real time data, too: AX.25, etc.
  - Just use TCP for recorded video/audio

RTP

- Stable Internet standard for real time streams
  - multicast or unicast
  - VoIP, IPTV
- Why not use it for SDR interconnection?

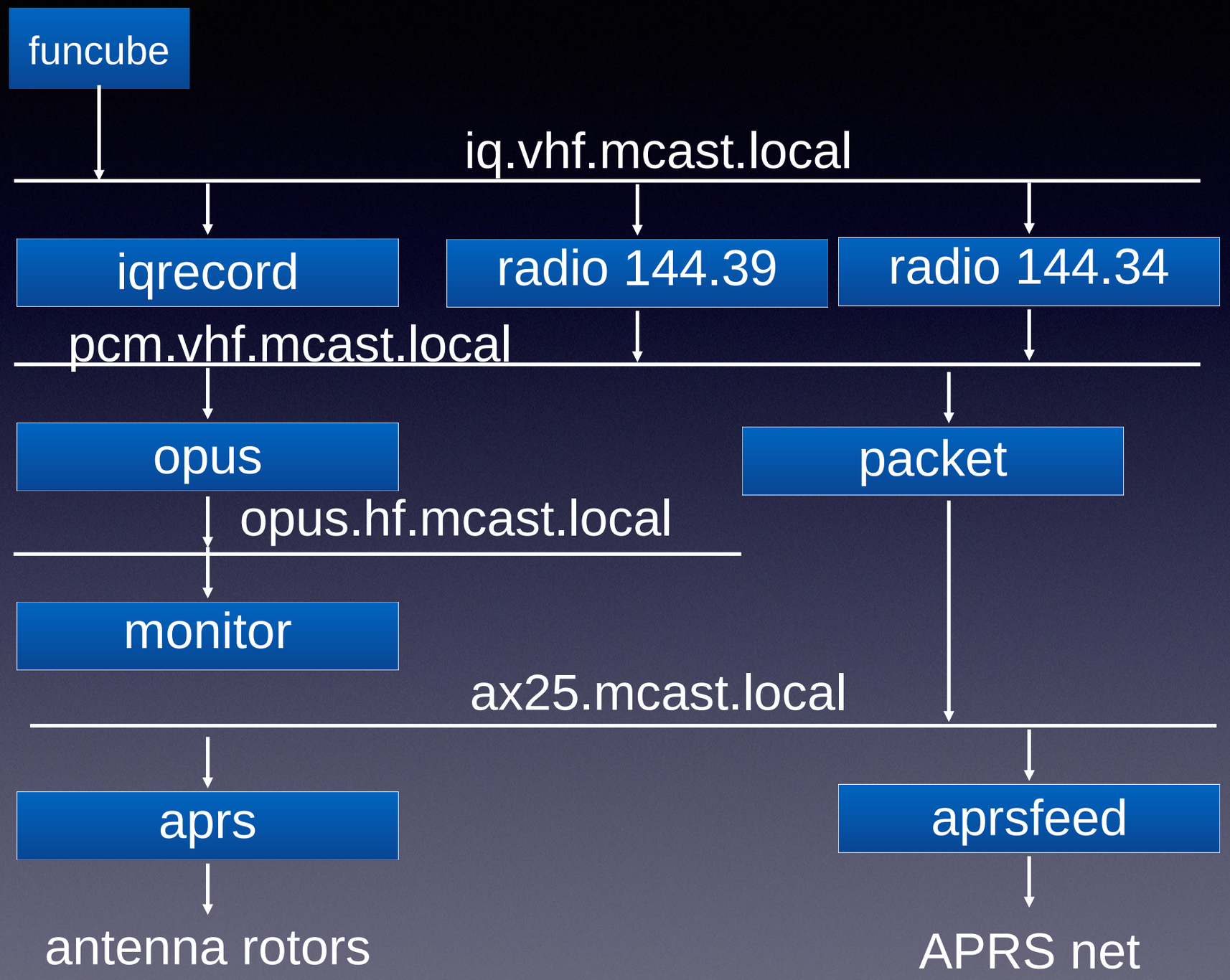
RTP features

- Runs above User Datagram Protocol (UDP)
- Sequence number
  - detect packet loss
- Timestamp - counts samples, frames, etc
  - can be discontinuous
- Payload type, stream source ID, mark flag

KA9Q-radio modules

- funcube
- hackRF
- radio
- opus
- monitor
- packet
- aprs
- aprsfeed
- iqplay/iqrecord

KA9Q-radio for UCSD balloon flights



Radio screenshot - VHF (HackRF)

ka9q-radio — karn@homer: ~ — ssh homer — 103×32 — ⌘1

```
Tuning
Carrier       147,435,000.000 Hz
Center        147,435,000.000 Hz
First LO      147,483,000.000 Hz
IF                -48,000.000 Hz

Signal
IF              -111.4 dB
Baseband        -111.5 dB
N0              -181.5 dB/Hz
S/N0              70.0 dBHz
NBW               42.0 dBHz
SNR               27.9 dB

Info
Receiver profile: FM
Band: 2m
Emissions: Voice Image Data CW
Privs: Extra Adv Gen Tech

Filtering
Low     -8,000.000 Hz
High    +8,000.000 Hz
Shift       +0.000 Hz
Beta          3.000
Blocksize     3,840
FIR           4,353
Freq bin     23.438 Hz
Delay        31.333 ms
Interpolate        1
Decimate           4

FM demodulator
Loop SNR         28.5 dB
Offset         +28.503 Hz
Deviation       2500.6 Hz
Tone             103.5 Hz

Options
ISB
PLL
Square
Mono
Stereo

SDR Hardware
Samprate    192,000 Hz
A/D Level     -45.4 dBFS
LNA gain           14 dB
Mix gain           40 dB
IF gain            12 dB

Modes
FM
FMF
AM
CAM
DSB
IQ
ISB
CISB
CWU
CWL
USB
LSB
AME

I/O
Source: 192.168.42.4:54957 -> iq.hackrf.mcast.ka9q.net SSRC 5b97a610
IQ pkts 153,496,504 samples 53,723,776,750 drops 1
Time: Fri Sep 14 17:08:44.521391 UTC 2018
Sink: pcm.hackrf.mcast.ka9q.net; ssrc 5b978fe6; TTL 1
PCM 48,000 Hz; pkts 13,587,643

KA9Q SDR Receiver v1.0; Copyright 2017-2018 Phil Karn
Compiled on Sep 11 2018 at 02:48:35
```

Radio screenshot - HF (WWV)

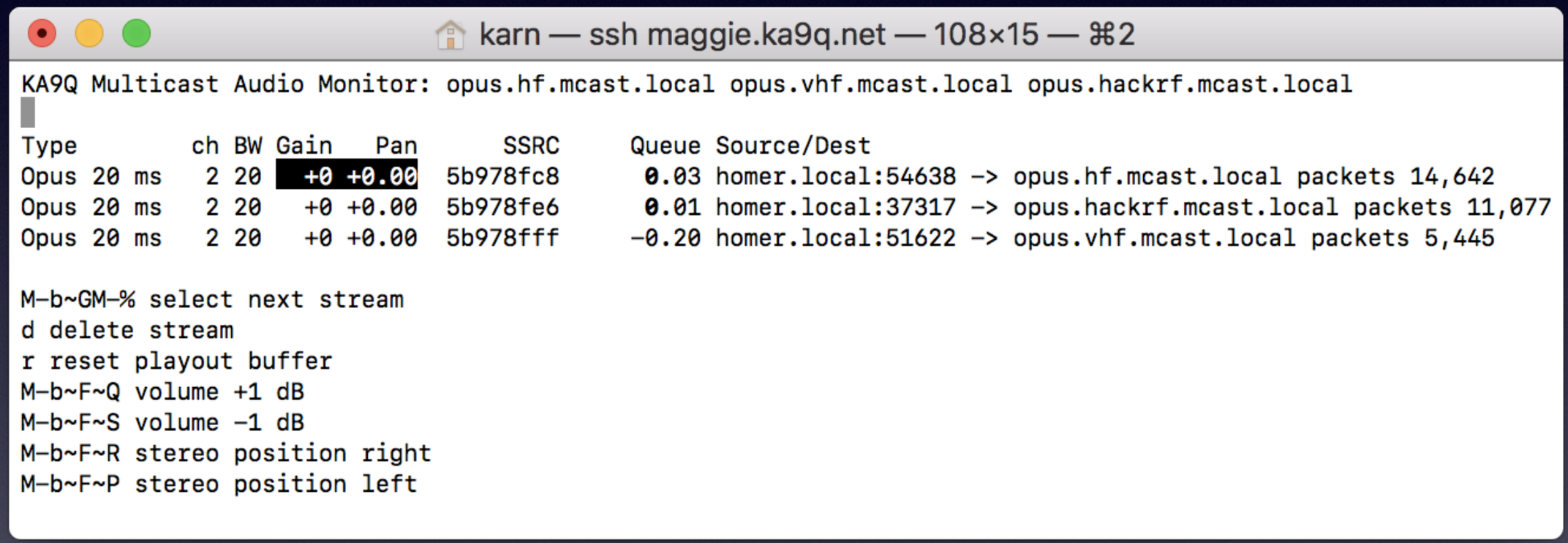
ka9q-radio — karn@homer: ~ — ssh homer — 103×32 — ⌘1

```
┌──────────────Tuning──────────────┐ ┌──────────Signal──────────┐ ┌──────────────────────Info──────────────────────┐
Carrier        10,000,000.000 Hz  IF          -82.7 dB  Receiver profile: cam
Center         10,000,000.000 Hz  Baseband    -85.5 dB  Band: WWV 10 MHz
First LO        9,951,999.850 Hz  N0         -136.5 dB/Hz
IF                 48,000.150 Hz  S/N0          50.8 dBHz
                                  NBW           37.8 dBHz
                                  SNR           13.0 dB
└──────────────────────────────────┘ └─────────────────────────┘ └────────────────────────────────────────────────┘

┌──────Filtering──────┐ ┌─────Linear demodulator─────┐ ┌─Options──┐ ┌──────SDR Hardware──────┐ ┌─Modes─┐
Low     -3,000.000 Hz  Loop SNR        17.5 dB  ISB      Samprate   192,000 Hz  FM
High    +3,000.000 Hz  AF Gain         62.9 dB  PLL      A/D Level    -38.7 dBFS  FMF
Shift       +0.000 Hz  Offset       +11.637 Hz  Square   LNA gain           0 dB  AM
Beta          3.000    Phase           +0.2 deg  Mono     Mix gain          19 dB  CAM
Blocksize     3,840    Spare         48000.0     Stereo   IF gain           25 dB  DSB
FIR           4,353                                                              IQ
Freq bin     23.438 Hz                                                           ISB
Delay        31.333 ms                                                           CISB
Interpolate       1                                                              CWU
Decimate          4                                                              CWL
└─────────────────────┘ └────────────────────────────┘ └──────────┘ └────────────────────────┘ └─────────┘ USB
                                                                                                  LSB
                                                                                                  AME
                                                                                                  └─────┘
┌──────────────────────────────────────────I/O──────────────────────────────────────────┐
Source: 192.168.42.67:59971 -> iq.hf.mcast.local SSRC 5b977b87
IQ pkts 228,559,539 samples 54,854,290,320 drops 222 dupes 218
Time: Fri Sep 14 17:11:51.212577 UTC 2018
Sink: pcm.hf.mcast.local; ssrc 5b978fc8; TTL 1
PCM 48,000 Hz; pkts 28,569,890
└──────────────────────────────────────────────────────────────────────────────────────┘

KA9Q SDR Receiver v1.0; Copyright 2017-2018 Phil Karn
Compiled on Sep 11 2018 at 02:48:35
```

Audio monitor screenshot



Opus Codec

- Xiph + Skype merged algorithms
- IETF standard, many players
- 6 - 510 kb/s: comm voice to high fi
- Excellent reference implementation
- **Free and open!**

Wifi: a show stopper?

- Many consumer access points roll over and die when they see fast multicast streams, even with no WiFi clients listening

- *sigh*

Multicast & WiFi

- Ever-growing list of modulation and coding schemes (MCS) and MIMO (lots of antennas)
- unicast works great: dynamic MCS + acks
- multicast: slow and unacked
  - very poor performance - can kill an AP!

Fixing WiFi multicast

- IGMP snooping in switches
- Multicast-to-unicast conversion
  - AP sends acked unicast to each group member
- Radio is no longer a broadcast medium!

Observations

- Successful experiment: RTP works well
- Small modules with simple text UIs
- Multicast over small wired LANs works great
- Multicast over WiFi is a serious problem
- Wide area multicast is difficult
  - tunneling, routing often required

- Code is on https://github.com/ka9q/ka9q-radio
- All open source (of course)
- C, some Intel SIMD (eg. decimation)
- Runs on Linux (x86-64, RPi) & OSX
- Collaborators welcome!

Near-term ideas

- Turnkey APRS iGate (Rx only)
- Multicast inputs for WSJT, etc
- More digital demods: DMR, D*Star, Fusion
- BPSK satellite modems
- Medium speed UHF terrestrial modem
- Automatic satellite downlink recording

- Ham comm programs (WSJT, etc) can accept multicast streams
  - no need to use computer sound system!
- APRS needs a *serious* overhaul
- We can do much better than DMR/Fusion/D*Star
- IP multicast ideal for “tactical” (round table)
- We can build one!

Longer-term ideas

- We can do *much* better than DMR/D*/Fusion
- Proprietary codecs are evil!
  - Inflexible network layers
  - C4FM is inexcusably inefficient
    - 1200 Hz spacing @ 4800 baud??!?!?!
- APRS badly needs an overhaul

Ham Multicast?

- Digital voice with CODEC2 + Opus
  - vary data rate with available capacity
- Round table operation
  - A multicast group is a “talkgroup”
  - Much better user interfaces are possible
- Easily support metadata: e.g., positioning