

# 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?

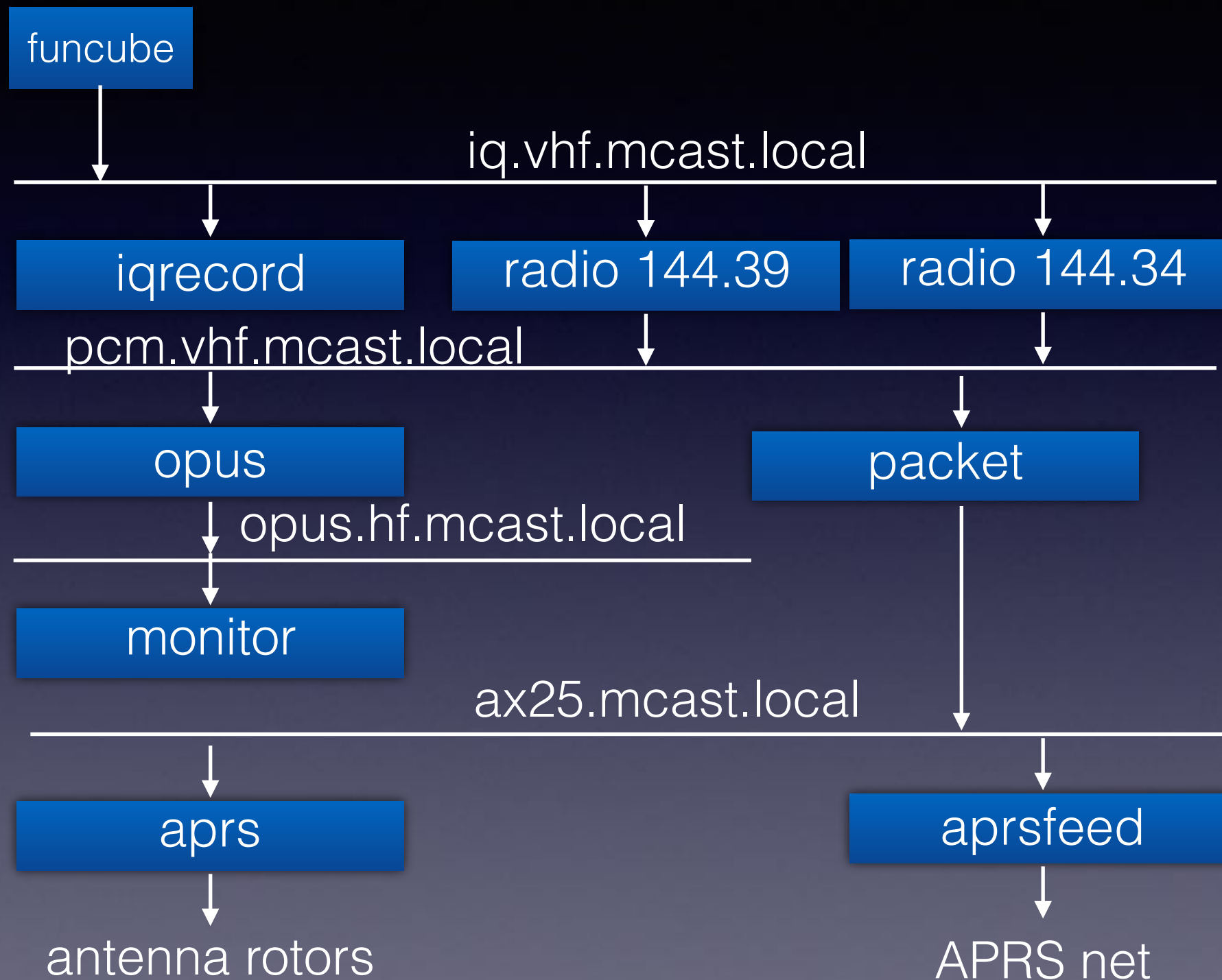
# RTP features

- 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
- pcmcat
- wwv/wwvh/chu sims

# KA9Q-radio for UCSD balloon flights





# Radio screenshot - VHF (HackRF)

ka9q-radio — karn@homer: ~ — ssh homer — 103x32 — 881

Tuning		Signal		Info	
Carrier	147,435,000.000 Hz	IF	-111.4 dB	Receiver profile: FM	
Center	147,435,000.000 Hz	Baseband	-111.5 dB	Band: 2m	
First LO	147,483,000.000 Hz	N0	-181.5 dB/Hz	Emissions: Voice Image Data CW	
IF	-48,000.000 Hz	S/N0	70.0 dBHz	Privs: Extra Adv Gen Tech	
		NBW	42.0 dBHz		
		SNR	27.9 dB		

Filtering		FM demodulator		Options		SDR Hardware		Modes	
Low	-8,000.000 Hz	Loop SNR	28.5 dB	ISB	Samprate	192,000 Hz	<u>FM</u>		
High	+8,000.000 Hz	Offset	+28.503 Hz	PLL	A/D Level	-45.4 dBFS	FMF		
Shift	+0.000 Hz	Deviation	2500.6 Hz	Square	LNA gain	14 dB	AM		
Beta	3.000	Tone	103.5 Hz	<u>Mono</u>	Mix gain	40 dB	CAM		
Blocksize	3,840			Stereo	IF gain	12 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: 192.168.42.4:54957 -> 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 — 103x32 — 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

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Compiled on Sep 11 2018 at 02:48:35

# Audio monitor screenshot

```
karn — ssh maggie.ka9q.net — 108x15 — 2
```

KA9Q Multicast Audio Monitor: opus.hf.mcast.local opus.vhf.mcast.local opus.hackrf.mcast.local

Type	ch	BW	Gain	Pan	SSRC	Queue	Source/Dest
Opus 20 ms	2	20	+0	+0.00	5b978fc8	0.03	homer.local:54638 -> opus.hf.mcast.local packets 14,642
Opus 20 ms	2	20	+0	+0.00	5b978fe6	0.01	homer.local:37317 -> opus.hackrf.mcast.local packets 11,077
Opus 20 ms	2	20	+0	+0.00	5b978fff	-0.20	homer.local:51622 -> opus.vhf.mcast.local packets 5,445

M-b~GM-% select next stream  
d delete stream  
r reset playout buffer  
M-b~F~Q volume +1 dB  
M-b~F~S volume -1 dB  
M-b~F~R stereo position right  
M-b~F~P stereo position left

# 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
  - no need to use computer sound system
- More digital demods: DMR, D\*Star, Fusion
- BPSK satellite modems
- Medium speed UHF terrestrial modem
- Automatic satellite downlink recording

# 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 + multicast
  - 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