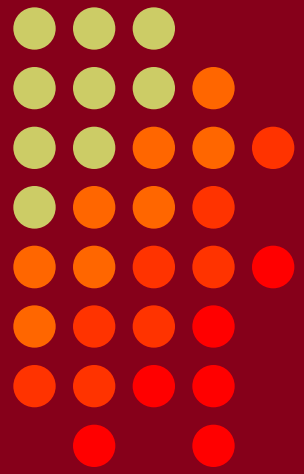
CTU Presents

Contest-Grade Remote

Bill Fehring, W9KKN



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What is this talk about?

- There are an increasing number of reasons we're operating contests remotely
  - **Station Location -** A contest station wants to be as far away from society as possible (QRM/RFI, neighbors/HOAs, etc.)
  - **Staffing**
    - It's increasingly difficult to get everyone to travel to a multi-op station
    - Aging operators / Competing priorities
    - Health Concerns
    - Expensive/Difficult Travel (great stations usually far away from large cities with airports)
    - XYL Support (A huge team invading a QTH might be a tall ask)
  - **Testing a station before you get there!**
    - Checking propagation
    - Planning what tools / parts to bring

What is this talk NOT about?

- This is not a presentation trying to generically describe how to build a remote ham radio station
- There is a wide solution space for remote operating
  - Not all of it is “contest grade” (yet)
- When I say ”contest-grade” I mean high expectations with few compromises
  - It shouldn’t affect your operating
  - It shouldn’t affect your score
  - The other side of the QSO shouldn’t know that you’re a remote operator

Question

- If you had equal stations (antennas, QTH, etc.), with similar teams (capability/skill), who would win between an all-remote or all-in-person operation?
  - I think the all-in-person team still has an edge
- Why?
  - Because this isn't easy to get right.
- But Bill, …

Some big names doing this…

- There are a few stations doing remote contesting quite successfully:
  - NJ4P (FlexRadio)
  - ZF5T (Mumble) / ZF1A (K3 + RemoteRig)
  - W2SC / 85PA (K3 + WriteLog)
  - K1LZ (Yaesu RCU / Icom RS-BA1 / Mumble / RemAud)
  - W2FU (RRC)
  - N6RO (RRC + K3 & RRC + Flex)
  - K6MTU (Flex)
  - W7RN (K3 + RRC)
  - WA6TQT/NO6T/K5ZO/KI6RRN (K3 + RRC)
  - numerous others…
- They have VERY different approaches to the problem

What is this talk about?

- You have to get all of these right…
  - Connectivity Quality (latency/jitter/packet loss)
  - Audio latency outside of the network
  - Operator Experience
  - Strategy
  - Contest Rules (don’t get yourself DQed)

What are some of the different approaches to remote contesting?

- External Hardware
  - RemoteRig (aka the gold standard) K3 “Twin”

  - Works with several different radios
  - Very hard to find/obtain – almost entirely on the secondary market
  - Requires that each side have the hardware
  - A little complicated to set up if you aren’t used to low-level stuff

What are some of the different approaches to remote contesting?

- Built into the radio + software / hardware
  - Elecraft K4

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  - Flex Radio

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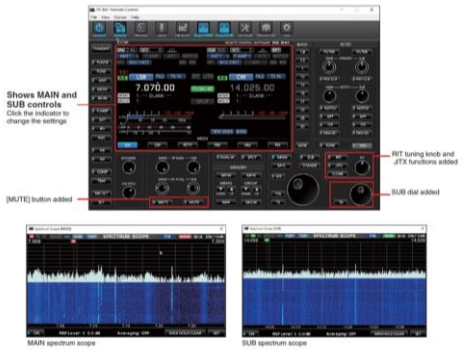
What are some of the different approaches to remote contesting?

- Built into the radio + software / hardware
  - Icom
    - RS-BA1 (Windows)
    - DL8MRE SDR-Control (Mac / iPad)



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What are some of the different approaches to remote contesting?

- Built into the radio + software / hardware
  - Yaesu
    - SCU-LAN10 Hardware
    - Yaesu Remote Control Software (Windows)
    - DL8MRE FT-Control for Yaesu (Mac / iPad)

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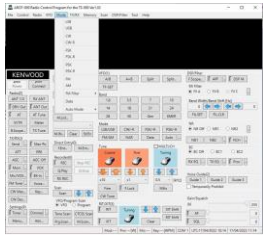
What are some of the different approaches to remote contesting?

- Built into the radio + software / hardware
  - Kenwood
    - TS-890
    - ARCP-890 Remote Control Software (Windows)
    - DL8MRE TS-Control for Kenwood (Mac / iPad)



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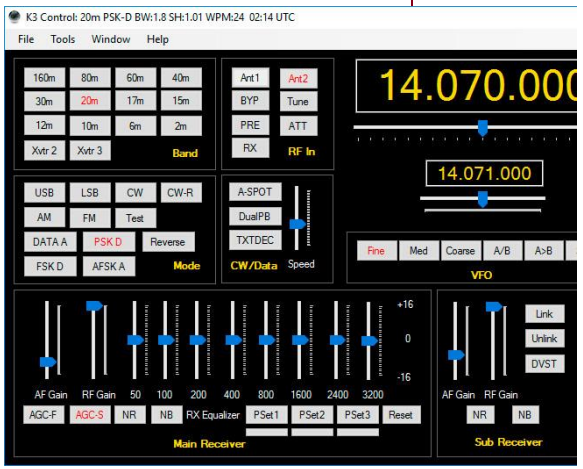
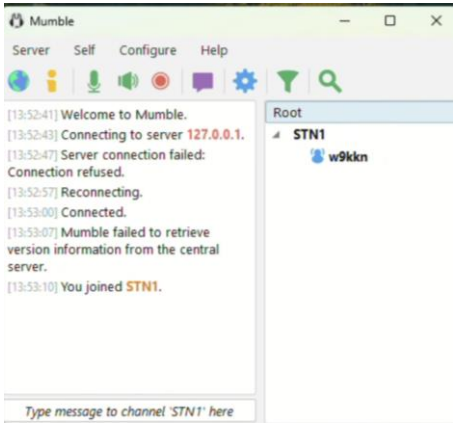
What are some of the different approaches to remote contesting?

- Software + Soundcard approach
  - Mumble
    - Self-hosted servers
    - Gerry's servers
  - Sonobus – Peer to peer
  - Writelog
  - RemAud
- Remote Operators mostly plug and play
- Multiple operators can usually listen in at the same time…
- Usually the "Radio Control" part is handled by something like Win4K3 (VA2FSQ) or just the logging program
- Usually the audio keying is handled by VOX and the CW keying is a local Winkeyer





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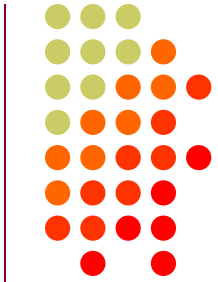
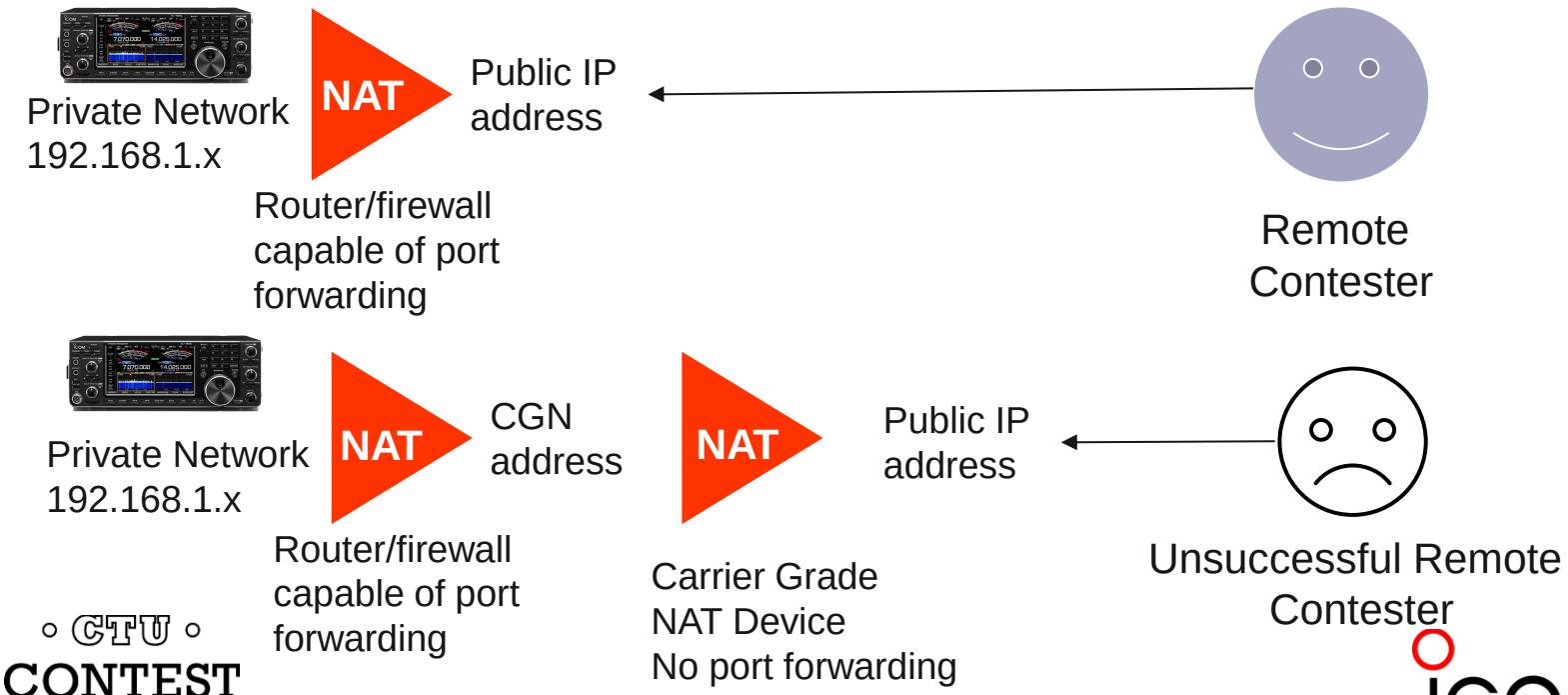
What kind of Internet do I want for ”contest-grade” remote?



- Latency – Keep it under 50ms
- Loss – ZERO.
- Jitter -- 20ms or less (note, it is part of total system latency)
- Bandwidth budget
  - 64-128kbps per audio channel
  - 1-2 mbps per waterfall
  - 1-50 mbps per remote desktop
  - Headroom to absorb anything else happening on the network
- Public IP address

What kind of Internet do I need for ”contest-grade” remote?

- Public IP address vs Carrier Grade NAT
  - Carrier grade NAT means that your ISP is making you share a public IP address with other users and you won’t be able to host anything.
    - 100.64.0.0/10 address space
    - Common in Satellite / LTE / 5G / Rural WISPs
    - Many times, a real IP public address is available for more money



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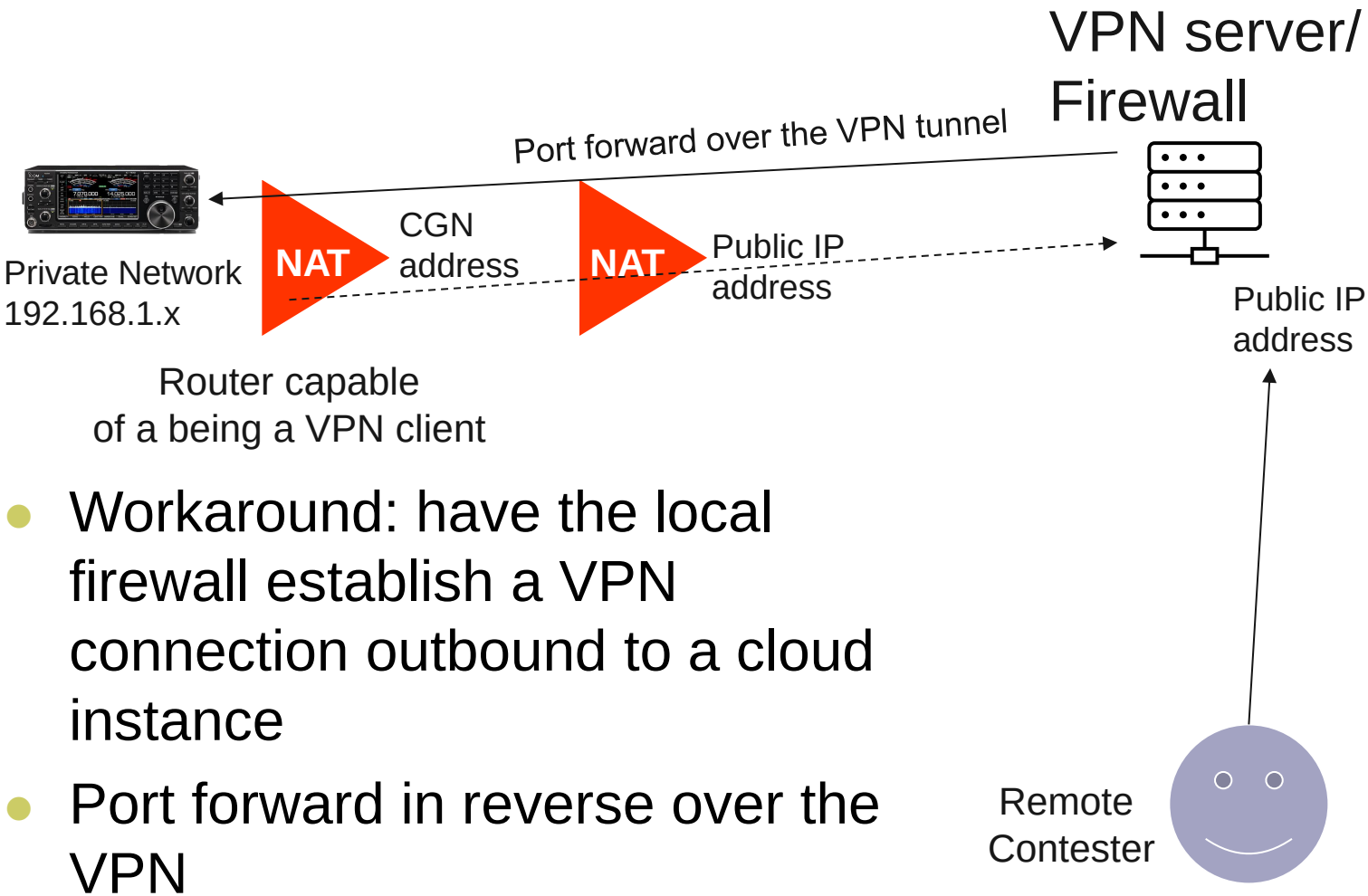
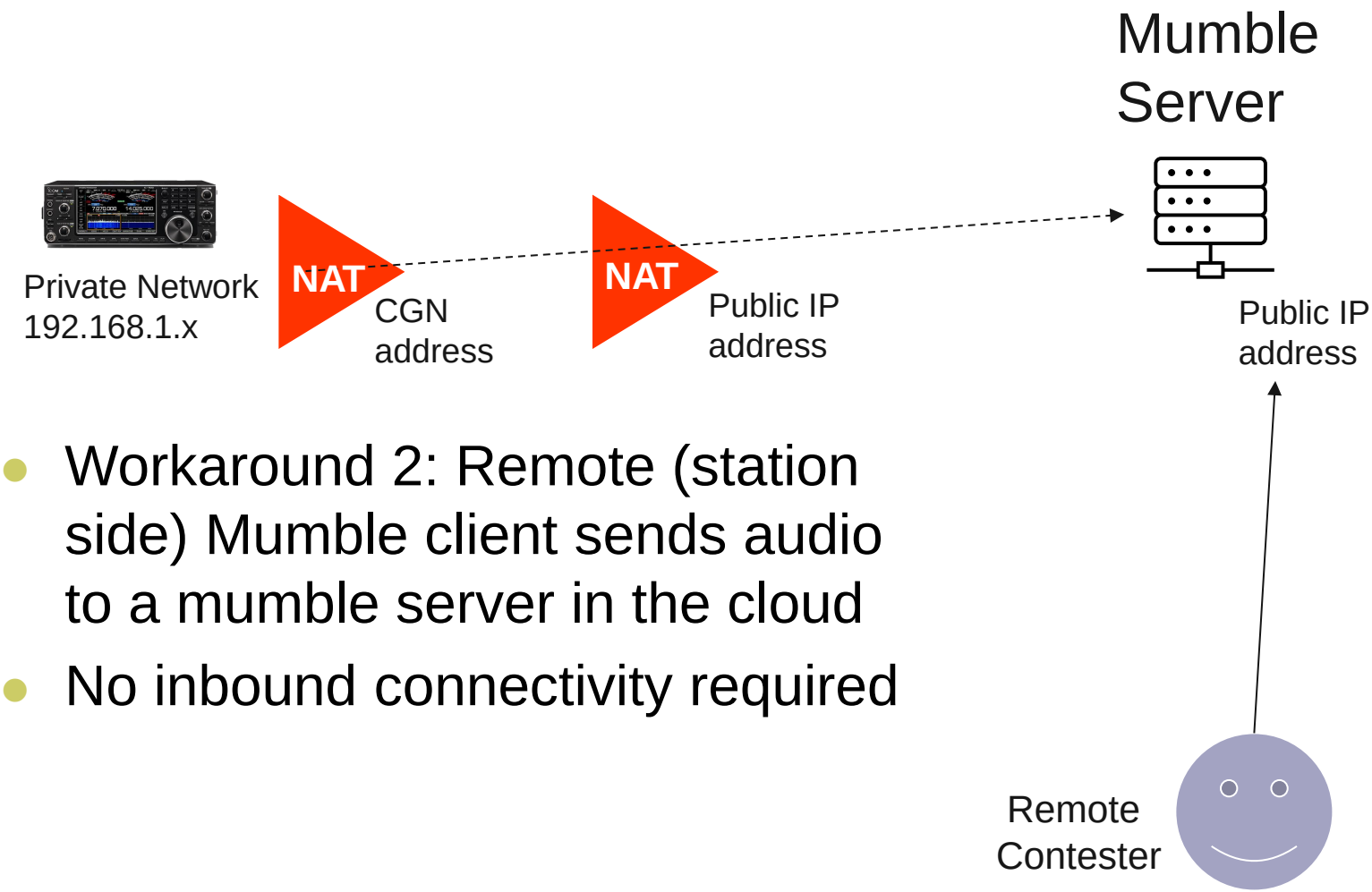
What if I can't get a public IP address?



- Workaround: have the local firewall establish a VPN connection outbound to a cloud instance
- Port forward in reverse over the VPN

What if I can't get a public IP address?



- Workaround 2: Remote (station side) Mumble client sends audio to a mumble server in the cloud
- No inbound connectivity required

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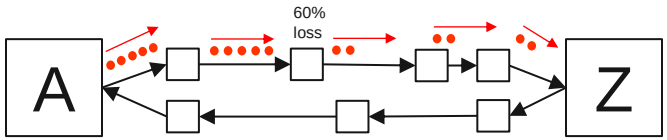
Concepts: Internet Latency

- **Latency** - the measurement of time it takes for a packet to arrive from the source to the destination.
  - It is often NOT symmetrical on the Internet (A to B is not necessarily equal to B to A).. and probably doesn't even traverse the same physical path
  - Can be caused by
    - Speed of light (inversely proportional to its refractive index in mediums such as fiber optics)
    - Network congestion / buffering either locally, or at any point along the network path
      - Many home modems / routers will buffer excessively instead of dropping packets – Known as "buffer bloat"
  - It may vary over time – such as during periods of heavy use
    - Evening online streaming usage (Netflix, Hulu, etc.)
  - When you use "ping" you are measuring the round-trip time.

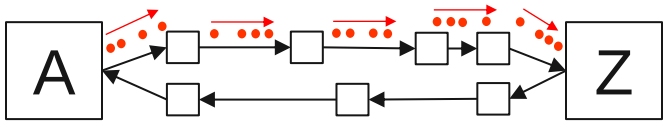
Concepts: Internet Packet Loss

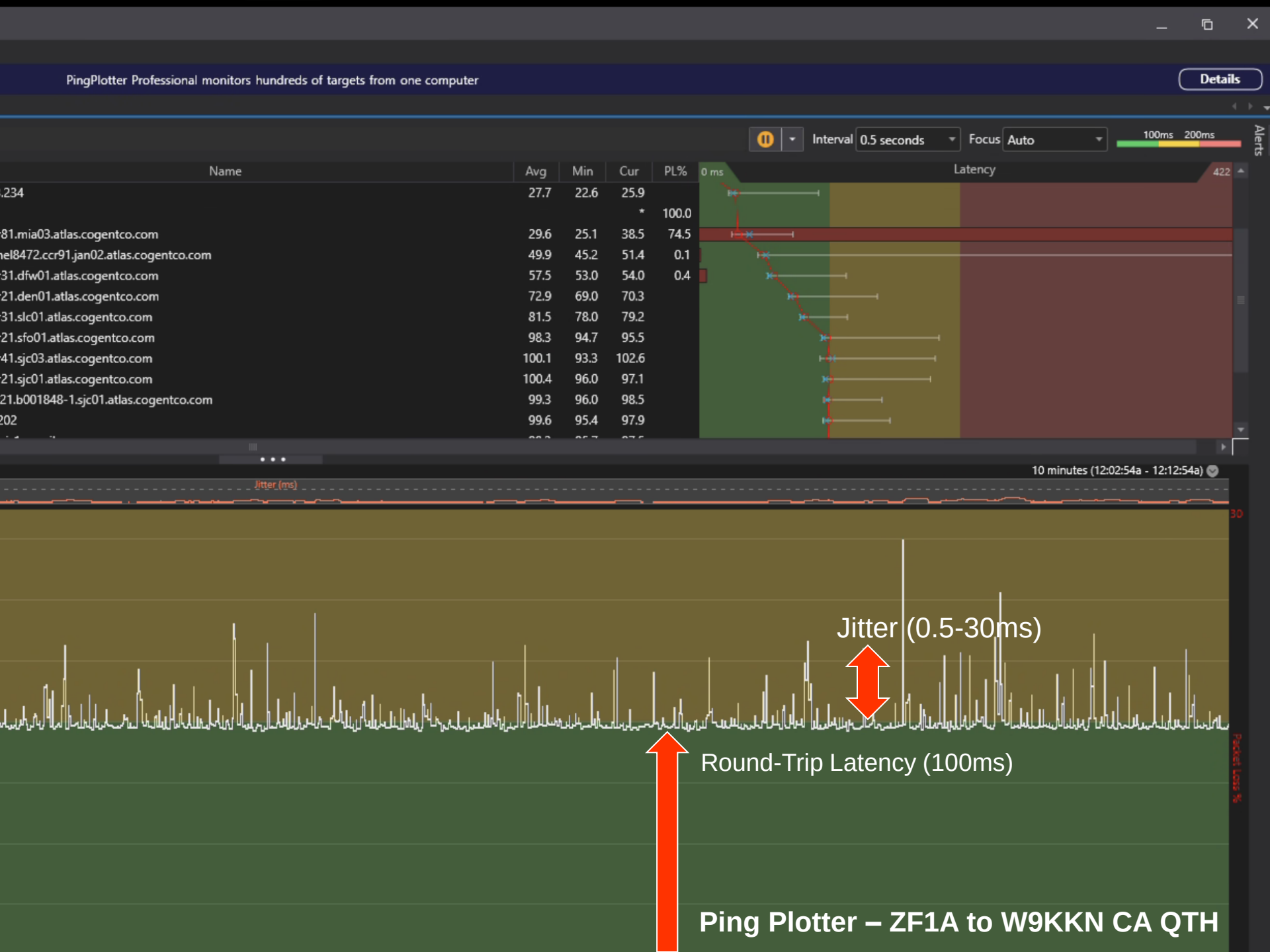
- **Packet loss** – Packets that didn't make it to the other side
  - Usually caused by congestion and preceded by latency
  - Could also be caused by link errors or
  - Could be occurring at any point between you and the remote station
    - Local interference (wifi, etc.)
    - Local downstream / upstream bandwidth
    - ISPs downstream / upstream bandwidth (x several diverse paths)
    - ISP to ISP connectivity
    - ISP to Peer / Customer connectivity



Concept: Internet Jitter

- **Jitter** -- The inconsistency of latency from packet to packet
  - Usually caused by attributes of the transport medium
    - Modulation changes (wireless)
    - Retransmissions (wireless)
    - Time division / airtime fairness algorithms (wireless, optical TDMA)
    - Wired almost always better than wireless
  - Could also be caused by “microbursts” of traffic/momentary congestion along the network path
  - Could be caused by load balancing (Unequal-Cost-Multi-Path) (rare)
  - End device must either buffer to “smooth” out or just assume loss if data doesn’t arrive on time.

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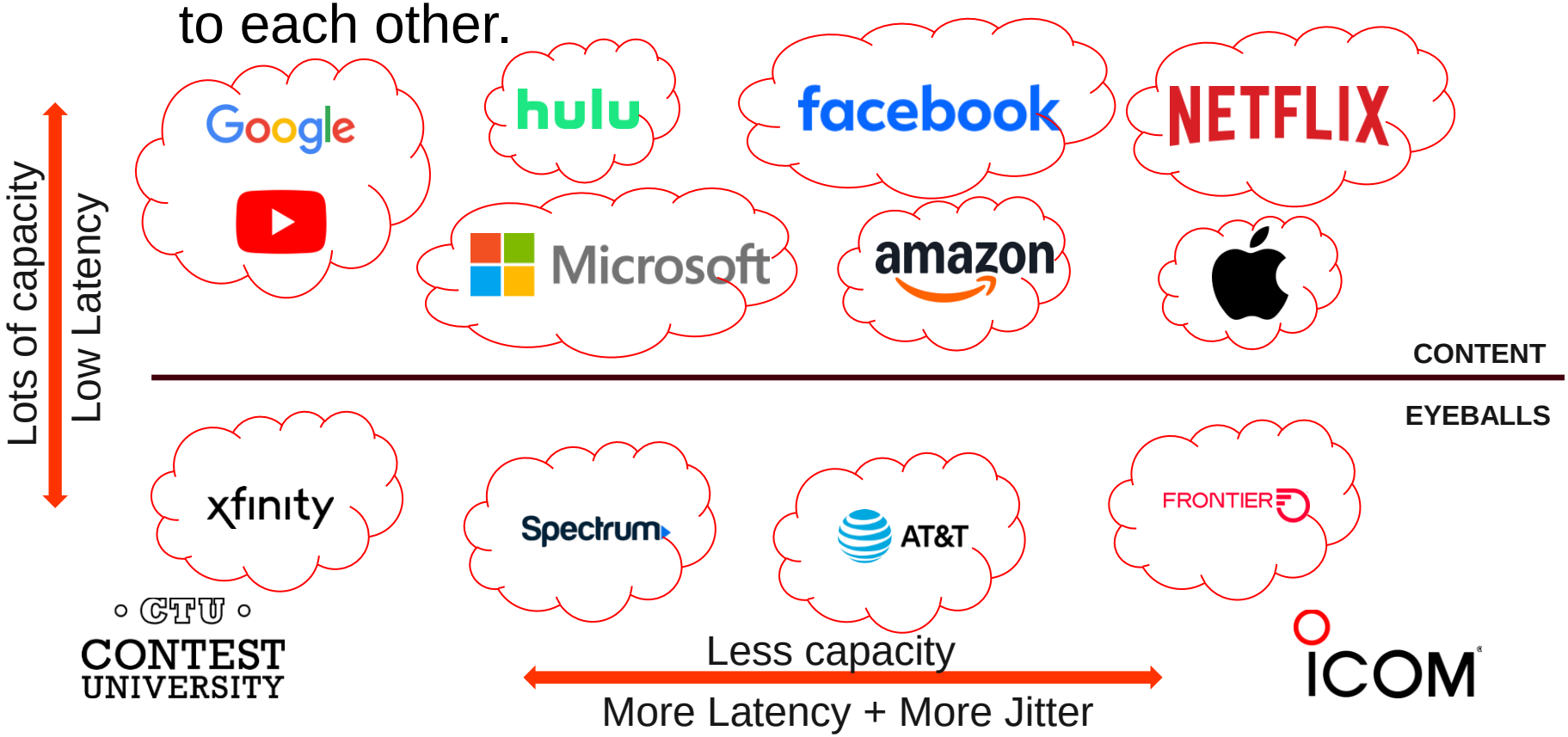
202 99.6 95.4 97.9
10 minutes (12:02:54a - 12:12:54a)
Jitter (ms)
30
Packet Loss %
Jitter (0.5-30ms)
Round-Trip Latency (100ms)
Ping Plotter – ZF1A to W9KKN CA QTH

Concepts: Internet Peering 101

- Eyeball networks versus content networks
  - Home internet service providers (ISPs) usually have more capacity to/from content networks than they do to each other.



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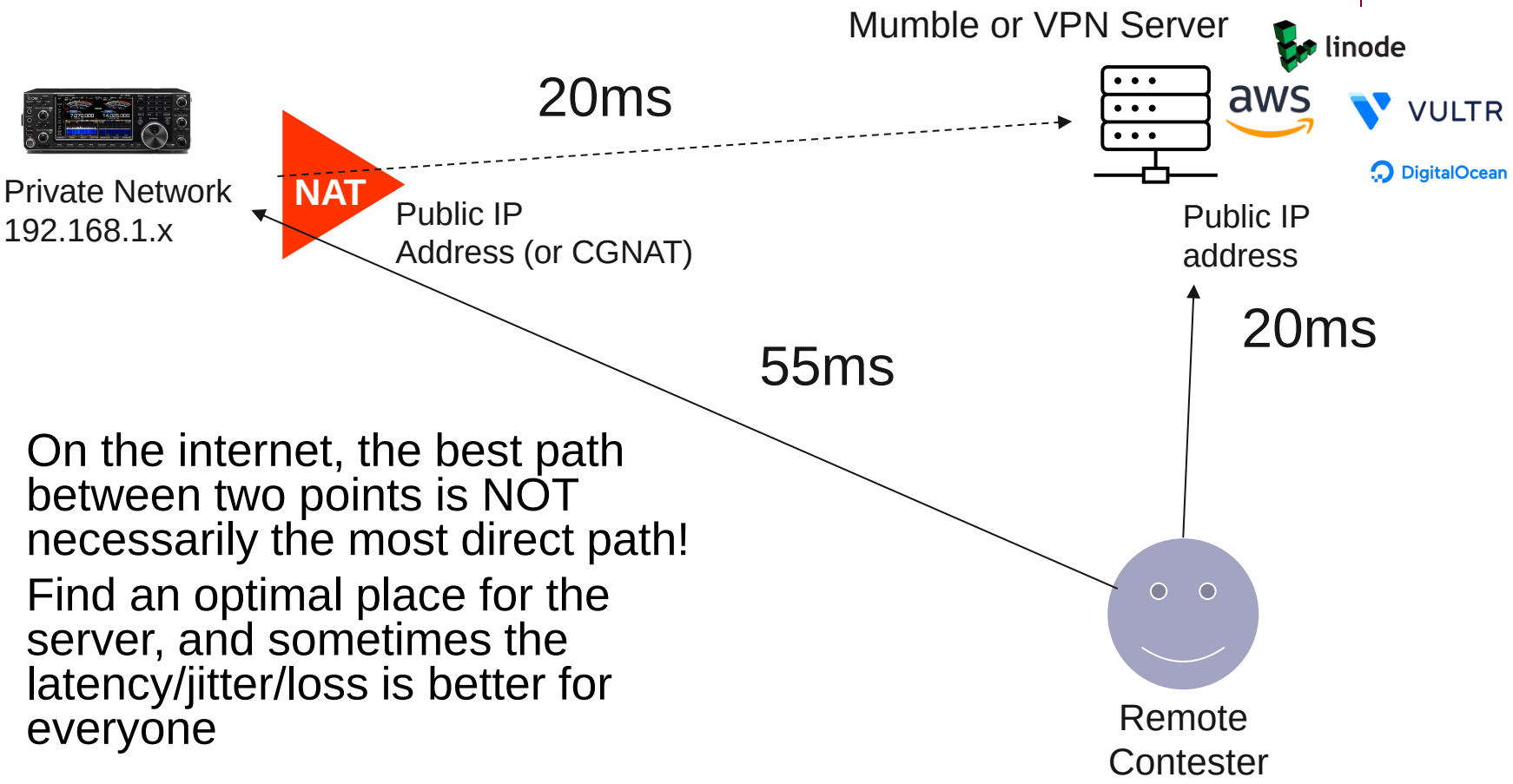
One other advantage to this setup…



- On the internet, the best path between two points is NOT necessarily the most direct path!
- Find an optimal place for the server, and sometimes the latency/jitter/loss is better for everyone

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Contest Rules and Remote Ethics

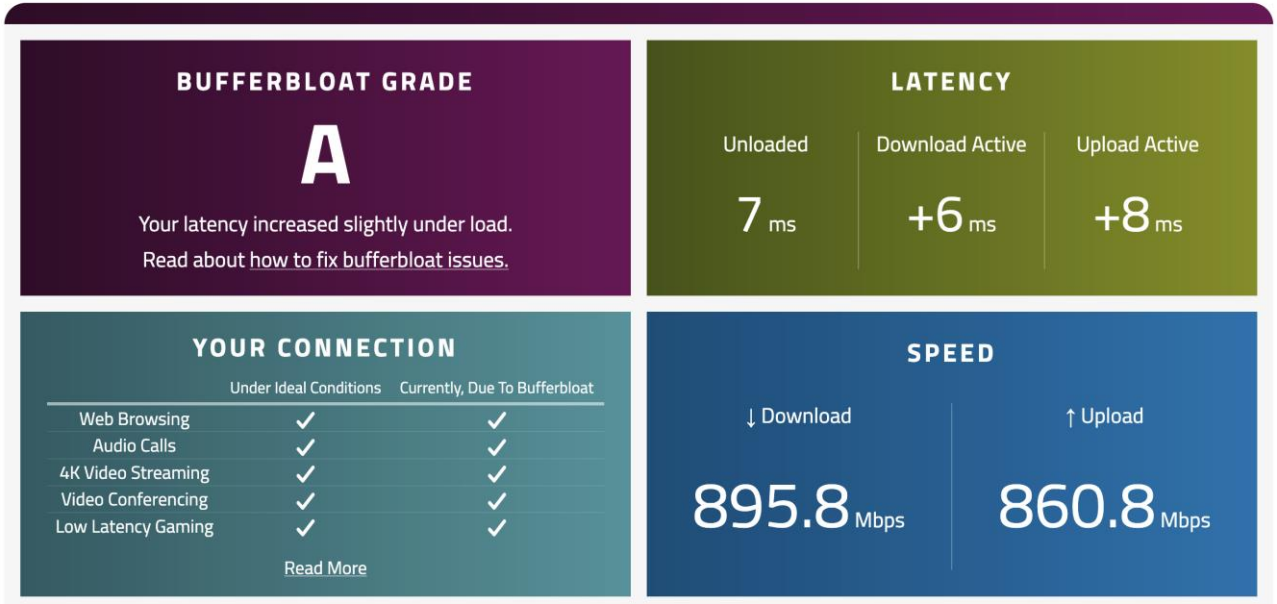
- In order to use remote in many places, you may need to be LICENSED in that country (US / Canada for sure.)
- Your US CEPT privileges don't apply if you are not a US Citizen.
- A foreign national may not operate a U.S. station by remote control under CEPT, IARP, or some other reciprocal authorization
  - Must have a US license
  - These only apply to local control
- Don't get on and work only yourself (or almost only yourself) from a multiplier.
- https://www.arrl.org/contest-remote-station-operation

Characterize your networks

- To see if it is suitable for ”contest-grade” remote, we need to measure the internet connections of both the remote and local sides
- How do we do that?
- Tools:
  - https://speed.cloudflare.com/
  - https://www.waveform.com/tools/bufferbloat

Finding Bufferbloat

- Bufferbloat – Looking for increased latency during download/upload
- Latency during active download or upload 200ms+++



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Fixing Bufferbloat / Packet Loss

- Activate “smart queuing” QoS features of your router
  - CoDel algorithm
- IQrouter / Ubiquiti

- Artificially limit bandwidth (~80%) of everything EXCEPT for the remote audio stream
- Note: If a lot of traffic is already queued by your ISP before you can slow it down, it might be too late to apply QoS

Latency – the silent rate killer

Let's take our "average" SO1R CW QSO:

=

8.482 seconds/QSO

=

7 Q's/minute

=

420 Q's/hour

… but there's more!

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Momentary aside:

- What is your reaction time to an audio stimuli?
- https://playback.fm/audio-reaction-time

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Latency – the silent rate killer

Let's take our "average" SO1R CW QSO wo/remote:

~2107ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

~1147ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

~2374ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

~987ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

~1894ms @45wpm

=

9.882 seconds/QSO

=

6.1 Q's/minute

=

420 -> 364 Q's/hour

*Not including Skywave Propagation Time or RF delay

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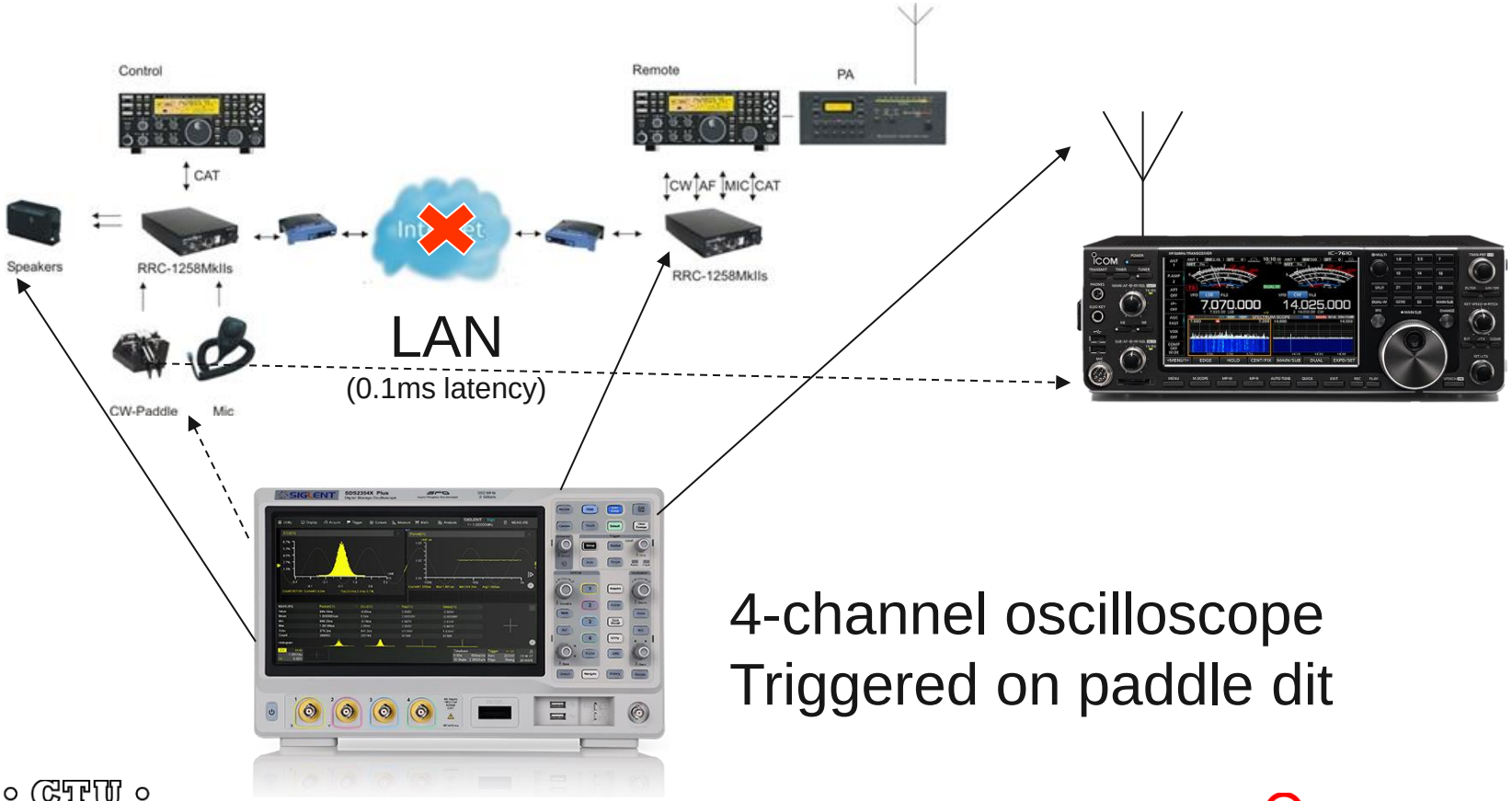
End to End Latency – Test Setup

So, let's bring in some remote. We'll start with the "gold standard" of the K3-Twin via RemoteRig 1258MkIIs's



4-channel oscilloscope
Triggered on paddle dit

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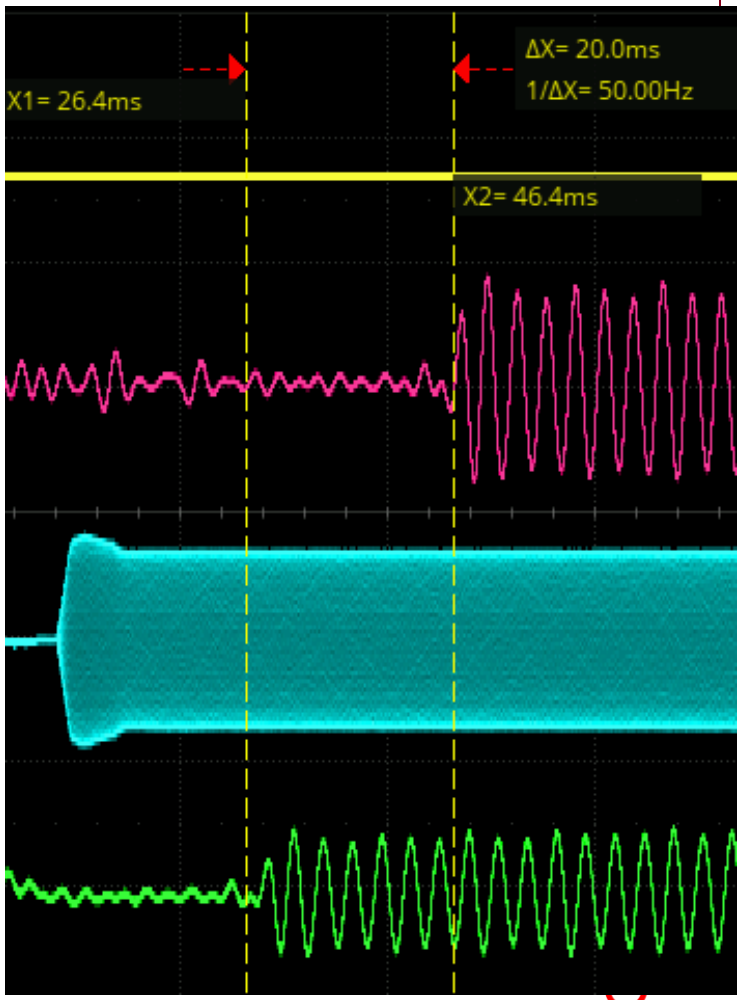
End to End Latency – RRC K3 Twin RX

- RRC-1258mkII K3-Twin RX
  - End to end RX latency of the K3-Twin setup (including DSP) is around ~41ms
  - It turns out about half of that is the DSP though.
  - So, the real end-to-end delay from the RRC is about 20ms…



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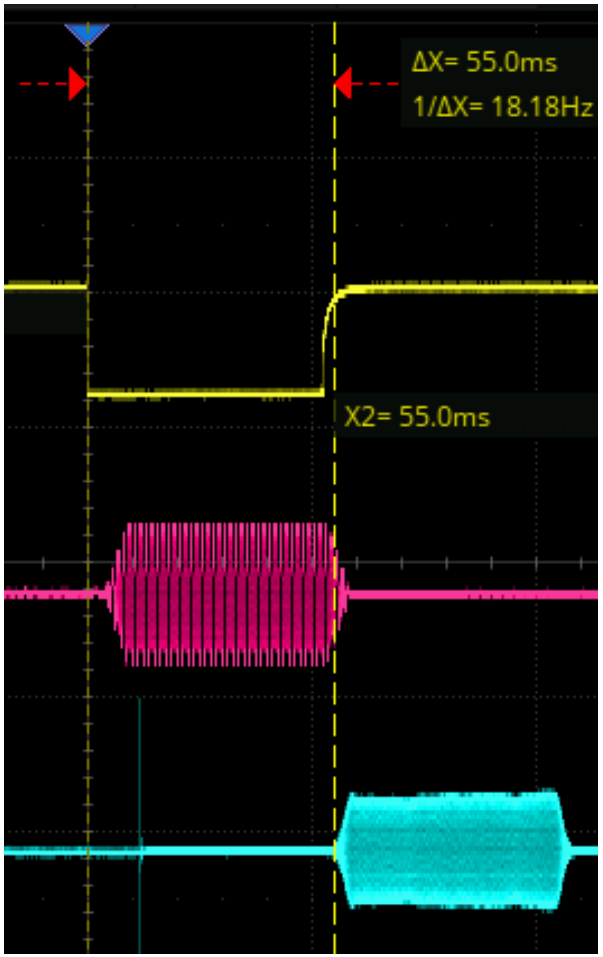
End to End Latency – RRC K3 Twin TX

- RRC-1258mkII K3-Twin TX
  - TX consistently reproduced at the remote end at the end of the first element.



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Latency – Other Remote Solutions

- What about other remote solutions?

Setup	RX E2E (incl. DSP)	TX E2E
K3-Twin (RRC)	41ms	55ms
FlexRadio 6600 + Maestro-B	55ms-320ms*	60-90ms (inconsistent)
K4-K4	140ms-1200ms**	134ms
Mumble (through K4)	113ms-117ms	113-117ms (symmetrical)
SonoBus (through K4)	60ms***-110ms	60ms***-110ms

*Depends on the filter sharpness setting, worst latency was default “auto” setting
** DSP ~ 33ms; Depends on remote buffering level RX0-RX7
*** Minimal jitter buffer settings

Latency – the silent rate killer

Let's take our "average" SO1R CW QSO w/remote:

TEST ZF1A → ND7K → ND7K ENN 8 → ENN 3 → TU ZF1A

~2107ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

+60ms Internet Latency

+20ms Remote Latency TX/RX

~1147ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

+60ms Internet Latency

+20ms Remote Latency TX/RX

~2374ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

+60ms Internet Latency

+20ms Remote Latency TX/RX

~987ms @45wpm

+30ms DSP

+250ms Human Auditory Stimuli Reaction Time

+60ms Internet Latency

+20ms Remote Latency TX/RX

~1894ms @45wpm

9.941 seconds/QSO = 6 Q's/minute =
360 Q's/hour = 4 Qs/hr lost (from non-remote rate of 364/hr)
192 Qs lost over 48 hours (1.1%)

*Not including Skywave Propagation Time or RF delay

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Latency – the silent rate killer

Let's take our "average" SO1R CW QSO w/remote:

TEST ZF1A → ND7K → ND7K ENN 8 → ENN 3 → TU ZF1A

~2107ms @45wpm
+30ms DSP
+250ms Human Auditory Stimuli Reaction Time
+60ms Internet Latency
+85ms Remote Latency TX/RX

~1147ms @45wpm
+30ms DSP
+250ms Human Auditory Stimuli Reaction Time
+60ms Internet Latency
+85ms Remote Latency TX/RX

~2374ms @45wpm
+30ms DSP
+250ms Human Auditory Stimuli Reaction Time
+60ms Internet Latency
+85ms Remote Latency TX/RX

~987ms @45wpm
+30ms DSP
+250ms Human Auditory Stimuli Reaction Time
+60ms Internet Latency
+85ms Remote Latency TX/RX

~1894ms @45wpm

10.209 seconds/QSO = 5.87 Q's/minute =
352 Q's/hour = 12 Qs/hr lost (from non-remote rate of 364/hr)
576 Qs lost over 48 hours (3.2%)

*Not including Skywave Propagation Time or RF delay

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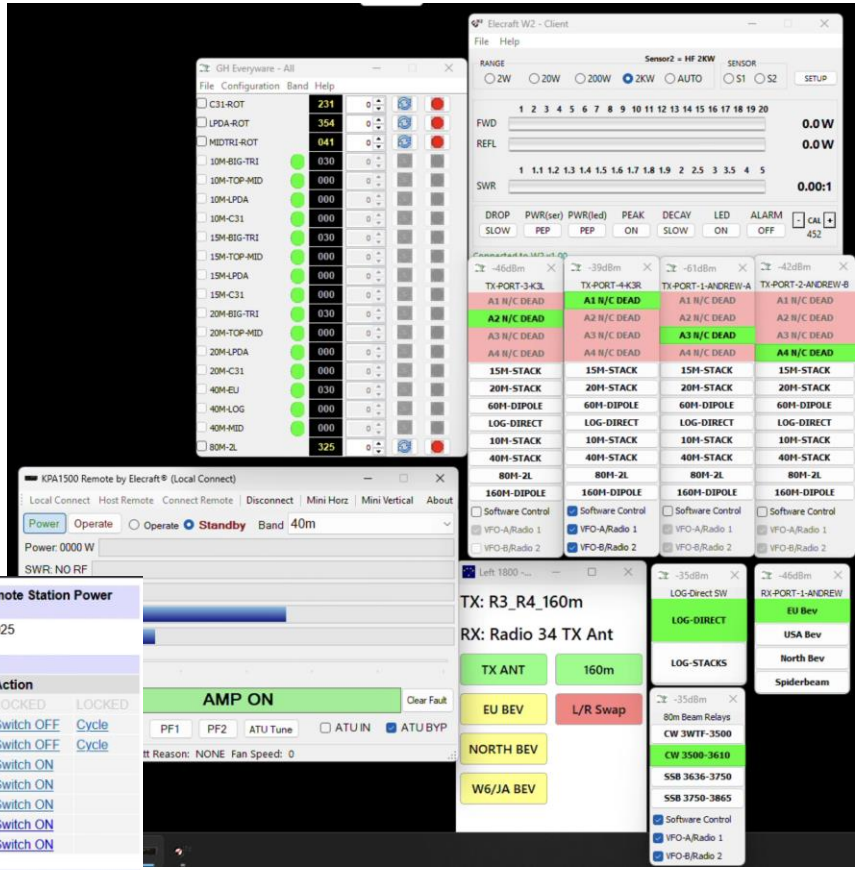
Operator Experience: Remote Desktop

- Remote desktop vs running the logger locally
- Preference towards running the logger remotely for multi-ops
  - Makes the handoff easier
- Main issues with locally running the logger
  - Do all of the keyboard shortcuts work through a remote desktop program?
  - Do I have something that makes a lot of screen updates (SmartSDR, MMTTY/2Tone, etc.)
  - With a multi-op, you'll have to use a VPN or similar to link the network the programs – you'll see all kinds of quirkiness with this – everyone needs to leave their logger open. You need to make sure VPN traffic doesn't include extra-curricular activities using all of the bandwidth
  - Entirely reliant on remote transport of CW/RTTY keying and decoding
- Many use Anydesk or Teamviewer (nagware, free for non-commercial use)
- My preference: RustDesk (open-source) or Parsec (paid)
  - Run your own RustDesk Relay server!
  - Parsec is exceptional at streaming (used to remotely game)
  - Parsec has an explicit bandwidth limit per session
  - Parsec can handle multiple virtual screens on the remote side even if they don't exist
- Less inclined to use VNC or RDP due to security issues.

Operator Experience: Station Automation

- Need to be able to control almost every aspect of the station
- Rotators
- Stack Matches
- Antenna Switches
- Power Monitoring
- Amplifiers
- There are many solutions
  - MOAS
  - Green Heron Everywhere
  - MicroHam Station Manager / ARCO
  - PSTRotator
  - 4O3A “Genius” Line
  - Node Red
- Power Control
  - DLI



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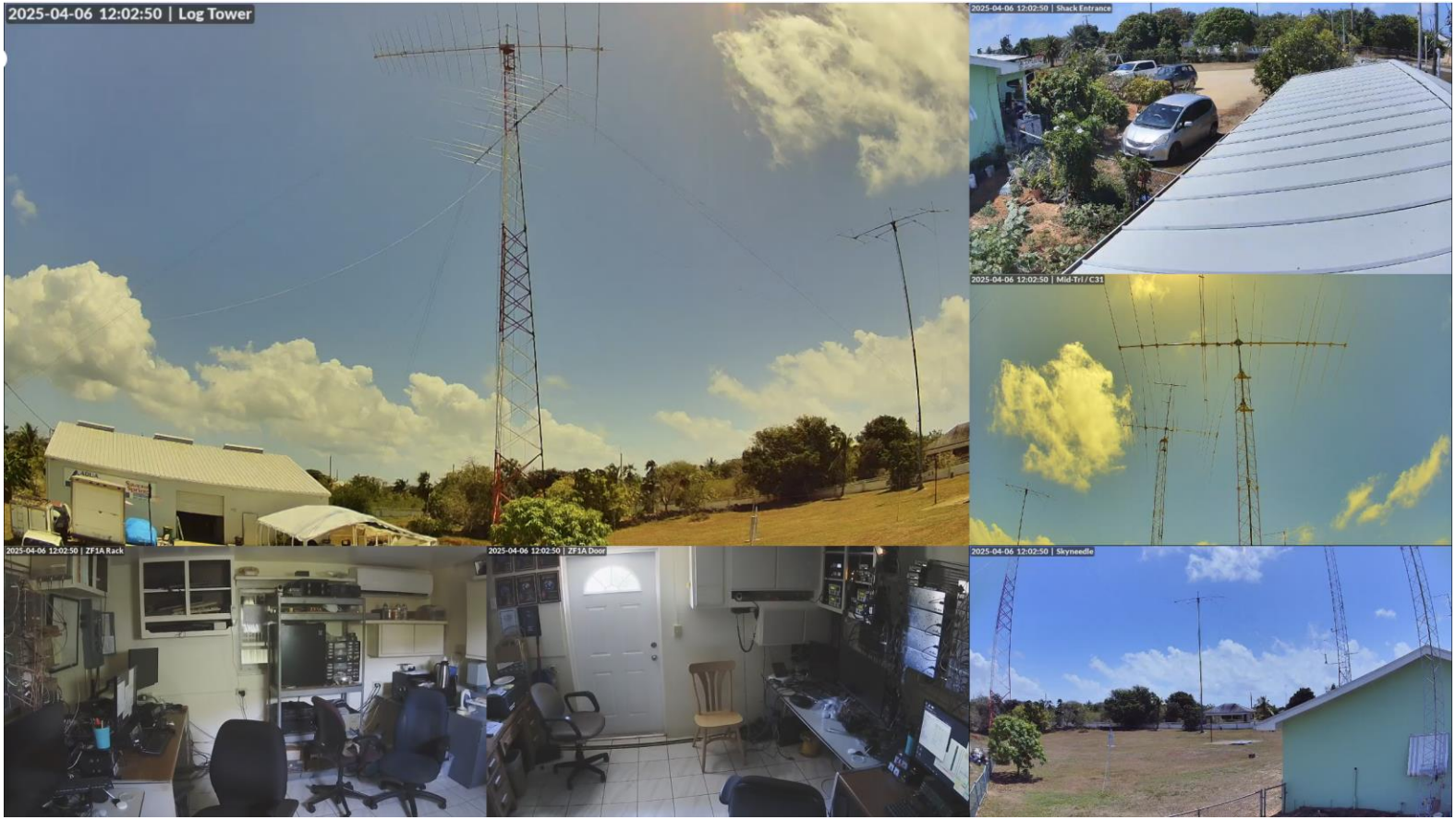
Operator Experience: Station Monitoring

- Cameras to monitor in and outside of the shack…



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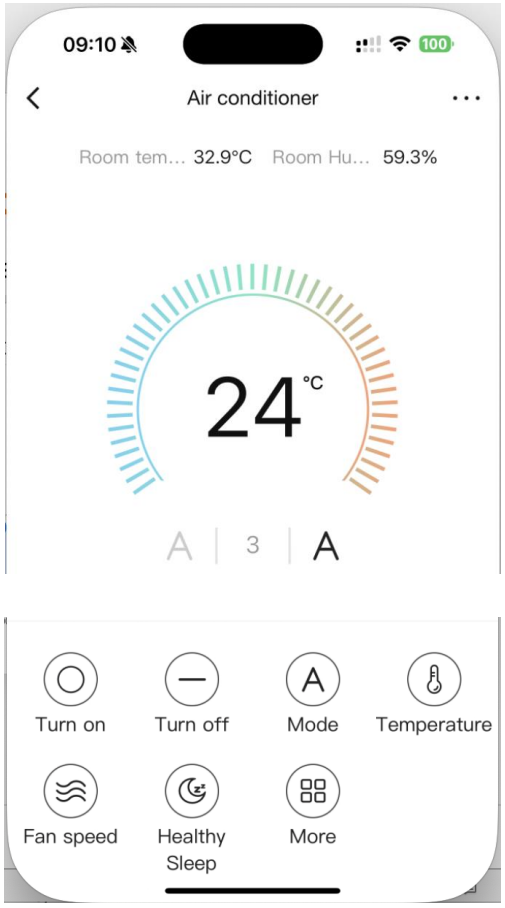
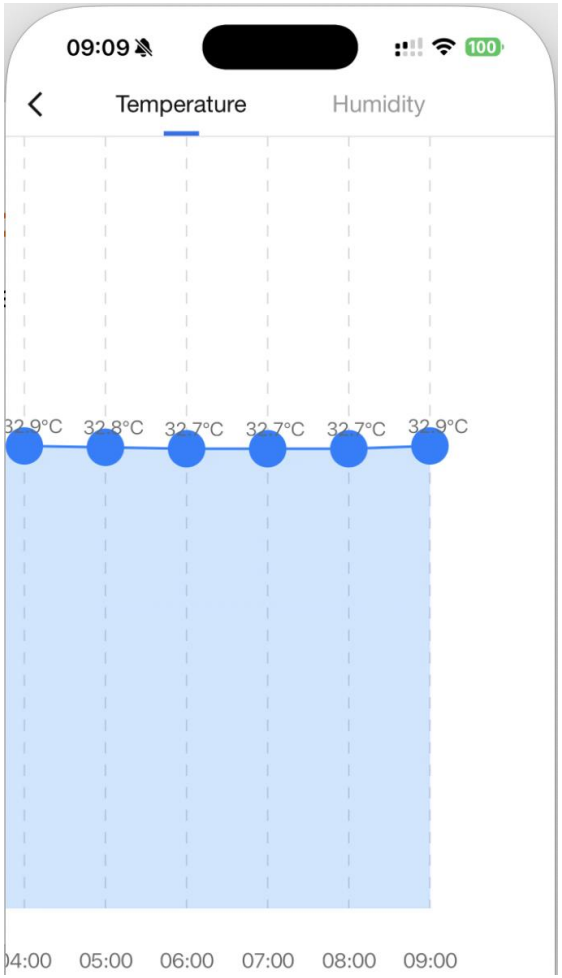
Operator Experience: Remote AC Control





- Air conditioner control and temperature monitoring

BroadLink RM4

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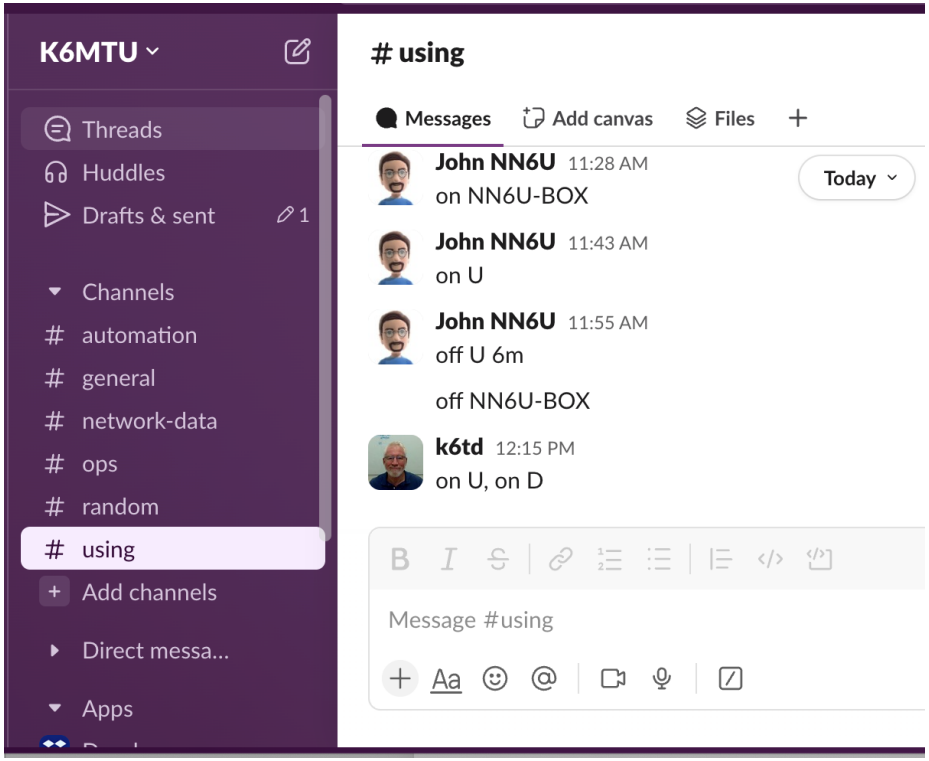
Operator Experience: Remote AC Control

Operator Experience: Team Communication

- Almost every remote contest station I'm involved with has a chat room in Slack or Discord
- It really helps to coordinate things between operators
- Establish a protocol for your team such that you don't step on each other or surprise the station owner
- Per-contest "rooms" often helpful



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Some other practical tips

- This should be obvious, but… if you're going to have guest contest operators, have them try it out with supervision BEFORE the contest and work out the setup issues.
- Build a station diagram and survival guide, keep it up to date, distribute it to the operators
- Publish known issues with the station somewhere

Contest Rules and Remote Ethics

- In order to use remote in many places, you may need to be LICENSED in that country (US / Canada for sure.)
- Your US CEPT privileges don't apply if you are not a US Citizen.
- A foreign national may not operate a U.S. station by remote control under CEPT, IARP, or some other reciprocal authorization
  - Must have a US license
  - These only apply to local control
- Don't get on and work only yourself (or almost only yourself) from a multiplier.
- https://www.arrl.org/contest-remote-station-operation

Questions?

- Work me, spot me, see you on the bands
- bill@w9kkn.net
- Contribute your logs to Super Check Partial!
  - logs@supercheckpartial.com

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