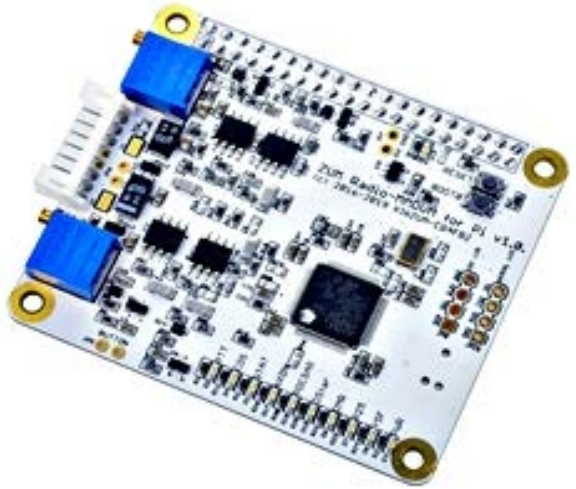
Internet-based Ham Radio

& HOT SPOTS



Registrations and Acknowledgements

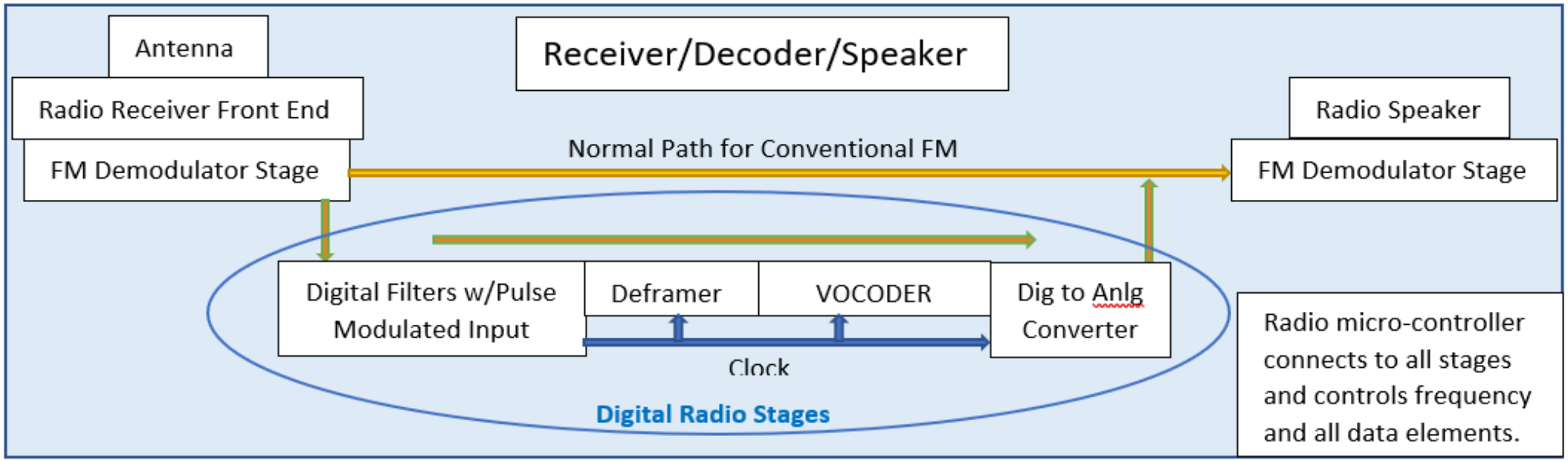
- D-STAR® is a registered trademark of Icom Inc.
- System Fusion® is a registered trademark of Yaesu Musen Co., Ltd.
- NXDN® is a registered trademark of JVC Kenwood Corp. and Icom Inc.
- APRS® is a registered trademark Bob Bruninga, WB4APR
- MMDVM® is a registered trademark of Shenzhen HKCNMA Co., Ltd.

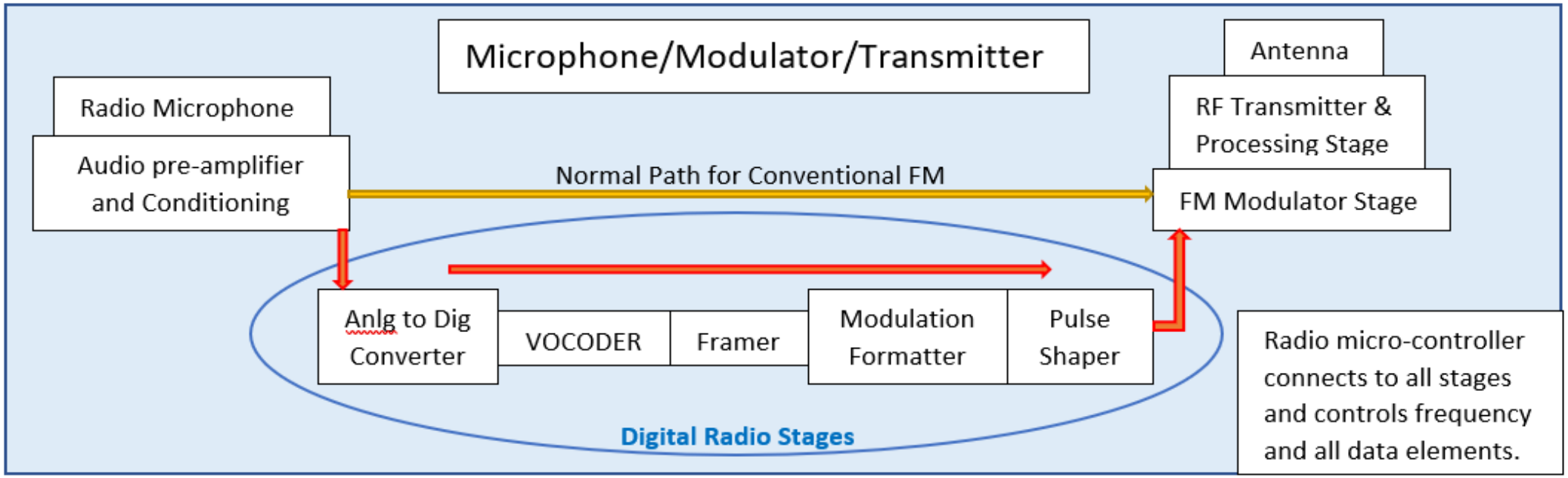
- A huge thank you goes out to all the amateur radio operators who have contributed video to You Tube and who those who have contributed to the effort of educating the masses about hot spots with web-based articles.
- This presentation is a summary of various pieces of documentation found on the web, vendor information and You Tube videos that too numerous to list individually. Rather than miss an acknowledgement – Thank You!
- And last but not least, our member who join in the discussion and show me session tonight.

First, A Review of Terms

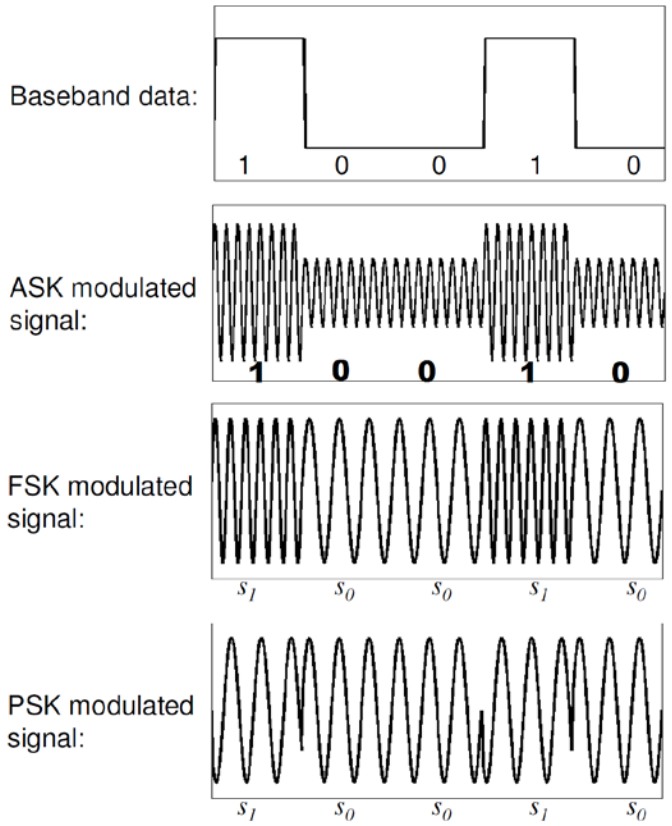
- Analog FM – Frequency Modulation
- DMR – Digital Mobile Radio
- C4FM – Continuous Four Level Modulation
- D-Star® – Digital as used by Icom & Kenwood
- NXDN® – Dual Channel 6.5 kHz FM, Kenwood
- System Fusion® – Yaesu (form of C4FM)
- YSF & FCS – Internet-based C4FM reflectors
- Talk Group – DMR and P25 channelization
- Vocoder – A to D and D to A converter
- PCM – “Radio over IP” (no single standard)
- Node – Hardware creating RF to Internet
- Room – Virtual connection point for C4FM
- AMS – Auto Mode Select is the method used by Yaesu to choose analog or digital use
- Hot Spot – Interfaces the radio’s air interface via the Internet to selected servers
- IMRS – Internet-Linked Multi-site Repeater System, a protocol to link Yaesu repeaters via the Internet
- WIRES-X – Yaesu’s method of Internet linking

Inside Digital Radios





Modulation/Digital - Visuals



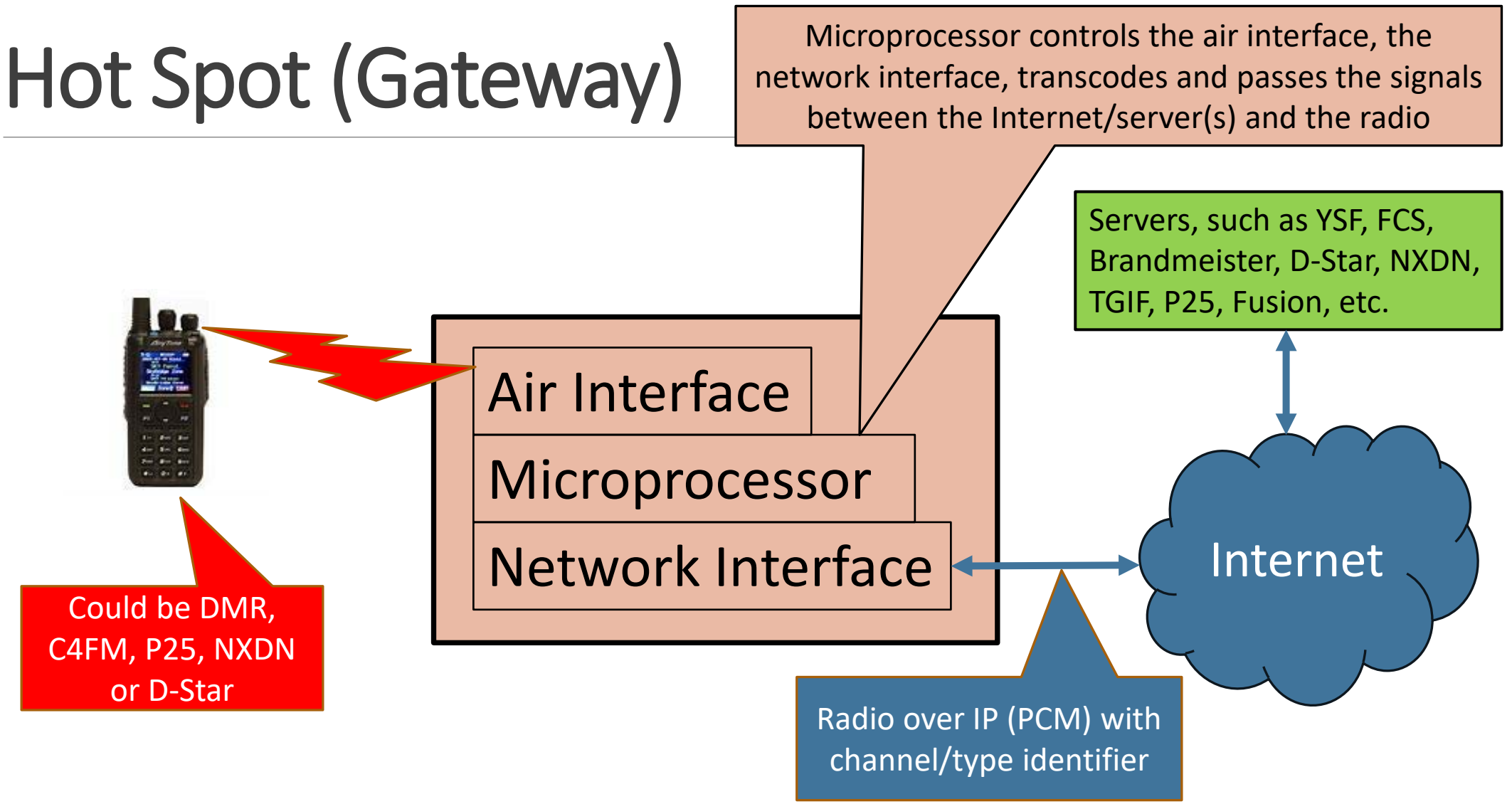
- C4FM (System Fusion) has four distinct frequencies (four symbols) used to send bits of data: 01, 00, 10, 11
  - ✓ Each of the four bits is represented by a preset distinct frequency: 01 +1.8 kHz, 00 +0.6 kHz, 10 -0.6 kHz, 11 -1.8kHz
  - ✓ No amplitude modulation
- DMR and NXDN® uses 4 level Frequency Shift modulation sends four bits of on/off data
  - ✓ Each of the four bits is related to present deviation from the carrier, though not definitively defined as C4FM does
  - ✓ No amplitude modulation
- D-Star® makes use of 0.5 GMSK, like GSM cell phones, where a 1 or 0 is each represented by a different frequency
  - ✓ No amplitude modulation

Voice Channels and Vocoding

❖ Analog	> One per 25 kHz BW	- No digital coding, standard FM	Voice Only
❖ D-Star®	> One per 12.5 kHz BW	- DVSI AMBE-2000 vocoder	Voice/Data
❖ C4FM / Fusion	> One per 12.5 kHz BW	- DVSI AMBE+ vocoder	Voice/Data/Image
❖ P25 (Phase 1)	> One per 12.5 kHz BW	- DVSI AMBE+ vocoder	Voice
❖ DMR, P25 P2	> Two per 12.5 kHz BW	- DVSI AMBE+ vocoder	Two Voice paths
❖ NXDN	> Two per 12.5 kHz BW	- DVSI AMBE+ vocoder	Two Voice paths
❖ PCM	> Digital voice formatted for streaming via the Internet		One stream

NOTE: As shown before, analog microphone audio is coded to digital bits, ie., vocoding. This same method is then used in reverse to convert these digital bits to analog to be heard via the speaker.

Hot Spot (Gateway)



Basic Hot Spot Types Found Today

- MMDVM® – Pi Star-based devices and least expensive
  - Zumspot
  - SKYBRIDGE
  - JumboSpot
  - NEX-JEN
- DVMega
  - w/Raspberry Pi / MMDVM® Software
  - w/Bluestack / BlueDV Software
- Shark RF: OpenSpot, OpenSpot2 & OpenSpot3
- DV4Mini on Raspberry Pi or Windows

Yaesu Wires-X® is not supported via Hot Spots

What is RoIP?

- RoIP, as a generic description and as there is no standard, is a means of carrying Pulse Code Modulation (PCM) voice packets via an IP connection which may be the Internet.
- RoIP PCM traffic is UDP (and not TCP, thus there is no resend).
- Call set up generally uses TCP, just as a Web Browser connects to a server and once the connection is made, data is exchanged such as IP addresses and network forwarding.
- Push the radio PTT button, Hot Spot (gateway) converts to RoIP and uses TCP to set up a connection. Once connection is made then IP UPD exchanges support the PCM voice packets.
- The servers such as Brandmeister, YSF, FCS, XLS, etc. accept the TCP connection and sets up the connection to a bridge where gateways “meet” and exchange voice associated PCM packets.
- Some Hot Spots are able to accept one RoIP protocol and convert it to another for transmission which is defined as transcoding. (More on this later.)

Ham Radio Hot Spots

- **Converts a radio's air interface (RF) to/from "RoIP" via the Internet**
  - Serves as a "gateway" between radio air interface (RF) and the Internet
  - Converts DMR, P25, D-Star®, NXDN® or C4FM -to- RoIP
  - Converts RoIP -to- DMR, P25, D-Star®, NXDN® or C4FM
- **Some hot spots are capable of transcoding between digital modes**
  - Hardware/software "transcoding" supports use of:
    - ✓ DMR radio to connect via a hot spot a selected D-Star® reflector
    - ✓ C4FM/Fusion radio to connect via hot spot and server to a selected DMR talk group
    - ✓ D-Star® radio to connect via hot spot to selected DMR number or C4FM reflector
- **Private radio to radio via Internet using a Brandmeister ID No.**

Hot Spot Transcoding – Higher Cost!

- **What is cross mode?** – It is the ability for a hot spot to support one digital mode radio's RF and for the connection to the Internet via PCM to operate on a different mode server or reflector.
- To cross mode between D-Star® and System Fusion®/C4FM, DMR, P25 or NXDN servers (reflectors) via the Internet, the Hot Spot must have a DVSI AMBE+ vocoder firmware chip. $$$$
- Remember, the Hot Spot transceiver connects with the desired radio, decodes the RF signal and connects via the Internet to a selected server or reflector.
  - If the desire is to allow a DMR or System Fusion® C4FM to connect with Brandmeister TGs then a server in the cloud can take care of the transcoding.
  - If the radio is a D-Star® and the server/reflector non-D-Star®, then the PCM voice packets must first be decoded and then transcoded for the desired server or reflector such as with a OpenSpot3.
  - Software on a MMDVM-based Pi-Star hot spot can translate between System Fusion® C4FM(DN), DMR, and NXDN® without an on-board DVSI AMBE+ chip because they all us this chip inside the radio.

Possible Protocols Supported by Hot Spot

Possible compatible digital radio protocols and networks you may want to verify:

- **DMR** — BrandMeister, DMRplus, DMR-MARC, Phoenix, XLX, TGIF
- **D-STAR®** — DCS, REF/DPlus, XRF/DExtra, XLX
- **System Fusion® / C4FM** — FCS, YSF Reflector **{Not WIRES-X}**
- **NXDN®** — NXDN Reflector
- **APCO P25 / C4FM** — P25 Reflector
- **POCSAG®** — DAPNET {Pagers}
- **APRS® messaging and location data forwarding**

Notes:

- Not all of the above listed features are available with every available hot spot.
- Not all hot spots offer internal transcoding

Special Connectivity Notes: DMR vs. Fusion

- **DMR** – RF Channels consist of two Time Slots supporting two Talk Groups
  - ✓ DMR radios can connect to a repeater, a hot spot or operate simplex
  - ✓ The repeater or hot spot is the means to utilize the Internet for wide are connectivity
  - ✓ Smarts to determine the selected path of a voice exchange is in the radio by sending special codes
  - ✓ DMR, in the WAN (Internet) make use of Servers such as Brandmeister for all connections
- **Yaesu System Fusion®** - RF Channels consist of one path supporting Nodes/Rooms/Reflectors
  - ✓ C4FM / System Fusion® radios can connect to a repeater, hot spot or operate simplex
  - ✓ The repeater (via an HRI-200) or hot spot is the means to utilize the Internet for RoIP connectivity
  - ✓ Fusion radios can connect directly to the Internet via a PC and PDN software/cable interface
  - ✓ WIRES-X® is the method used by Yaesu to interconnect repeaters, establish Rooms and support WANs
  - ✓ Fusion radios can remotely change repeaters to move between WIRES-X® Nodes and/or Rooms
  - ✓ Some Hot Spots are able to utilize Fusion commands to also connect/set up YSF/FCS/XLS connections

Hot Spot – Things to Remember

>> All radio traffic is ultimately transported via the Internet <<

- The gateway decodes the modulation and formats PCM for transport
- Microprocessor, via IP, establishes connection to a server
  - Brandmeister Master Servers and BM DMR Talk Group Servers
  - Brandmeister Redirects via TCP followed by connections via UDP
    - ✓Digital Servers: YSF, FCS, XLS, D-Star® and NXDN® Reflectors {YSF is not Yaesu}
    - ✓P25 Talk Group Servers
    - ✓Transcoding software/firmware can convert AMBE+ <> AMBE 2000, then PCM

>>> Yaesu Wires-X® is not directly supported by any Hot Spot though some are able to use the radio's Wires-X® commands to change rooms via YSF, FCS, XLS <<<

Reminders: DMR TG Servers, YSF/FCS, P25, NXDN® and D-Star® Reflectors

- **A Hot Spot must connect to one of the following "servers" just as one connects to a web server. TCP/IP makes the connection and UDP carries the voice packets**
  - **A Master (List) Server** – This server acts like a directory that hands out IP addresses of active servers
  - **DMR TG Servers** – These servers each host a DMR talk group allowing multiple radios to communicate
  - **FCS Reflectors** – A server capable of hosting up to 99 modules (each an FCS Room).
  - **YSF Reflectors** – A single reflector supporting a single YSF Room and generally set up at a home.
  - **D-Star® Reflectors** – There are many hundreds of reflectors across the world.

- **Connecting to Yaesu System Fusion Wires-X® {Only with a bridge}**
  - A dedicated Yaesu System Fusion Radio connected via Wires-X® to a Yaesu Wires-X® Node/Room
  - A dedicated Hot Spot RF connected to the dedicated Yaesu radio and connected to a YSF/FCS Room

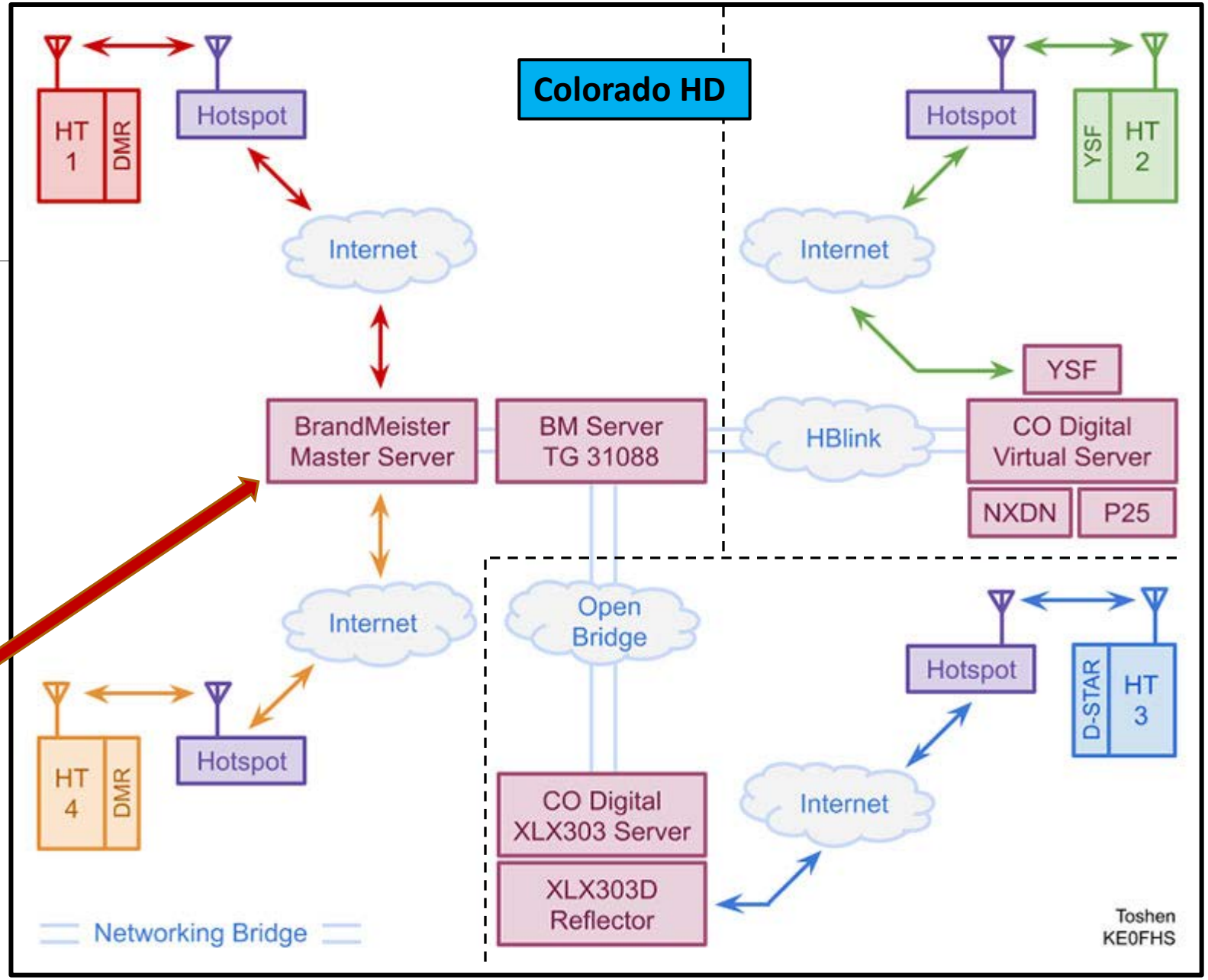
The Basic Chain of Connectivity

- User radio is programmed with frequency(s) the hot spot has been programmed to operate on
- Some hot spots can be set up with different frequencies to support different radio types
- The air interface decodes the channel information it receives and sends it to the microprocessor
- The microprocessor decodes addressing information and the voice payload, then packetizes the vocoded voice to be sent via the internet to the prescribed server (such as Brandmeister)
- The call set up is completed for each PTT using TCP which makes a connection to the server.
- Once the connection is established, the voice packets are sent via UDP to the prescribed server
- At the server the UDP packets are sent to all pre-determined locations (repeater and hot spots) to be decoded and sent to a radio and the speaker
- The connection is maintained for a “hang time” to allow for a response from the called radio(s)

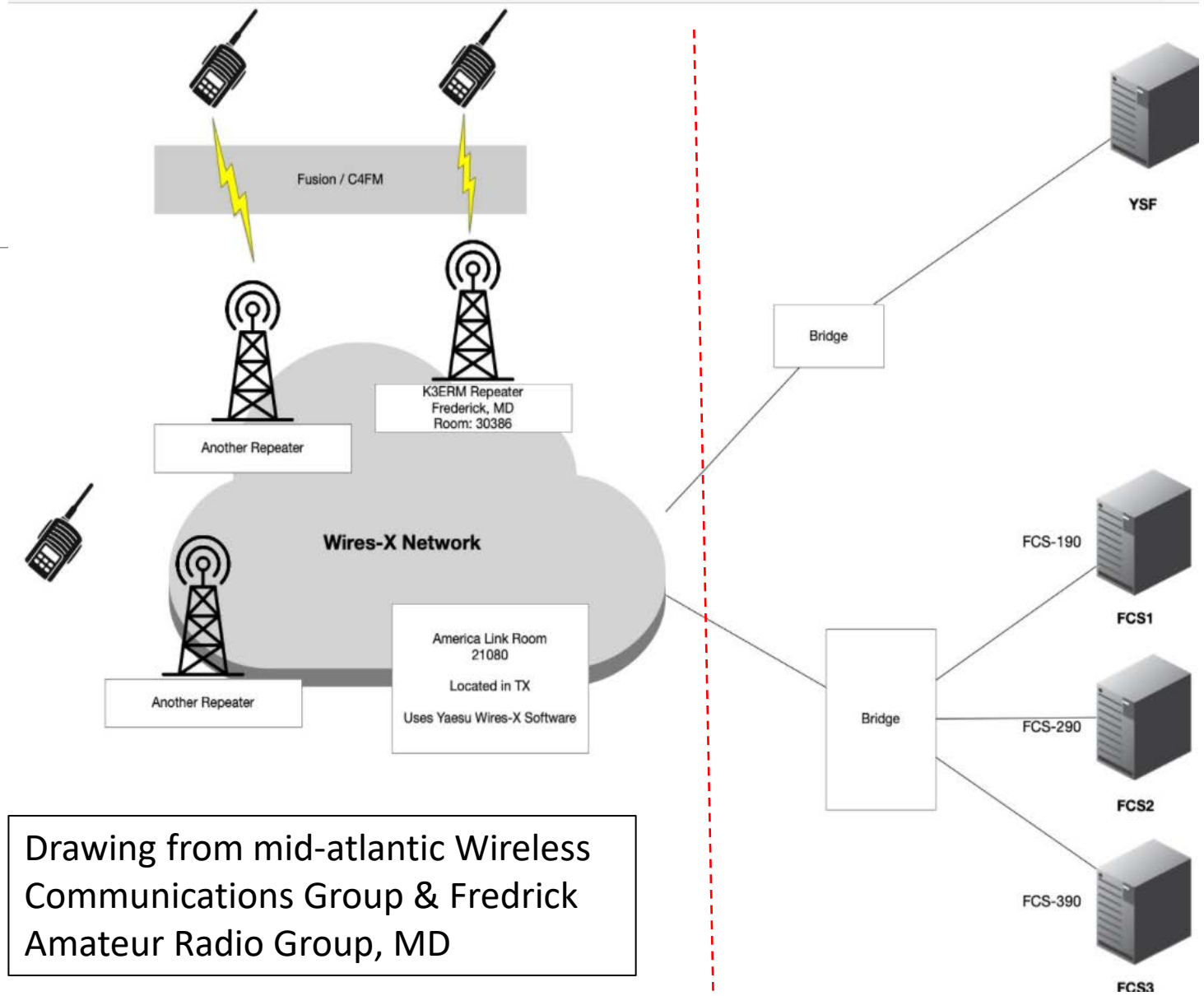
Internet Connectivity

- **Far Left:** The basic DMR network
- **Upper Right:** YSF, NXDN and P25 via Internet network
- **Lower Right:** D-Star via Internet network
- **Brandmeister Master Server is the key element here!**
- HBlink and Open Bridge provide for a gateway to BM

http://www.w0dmr.org/

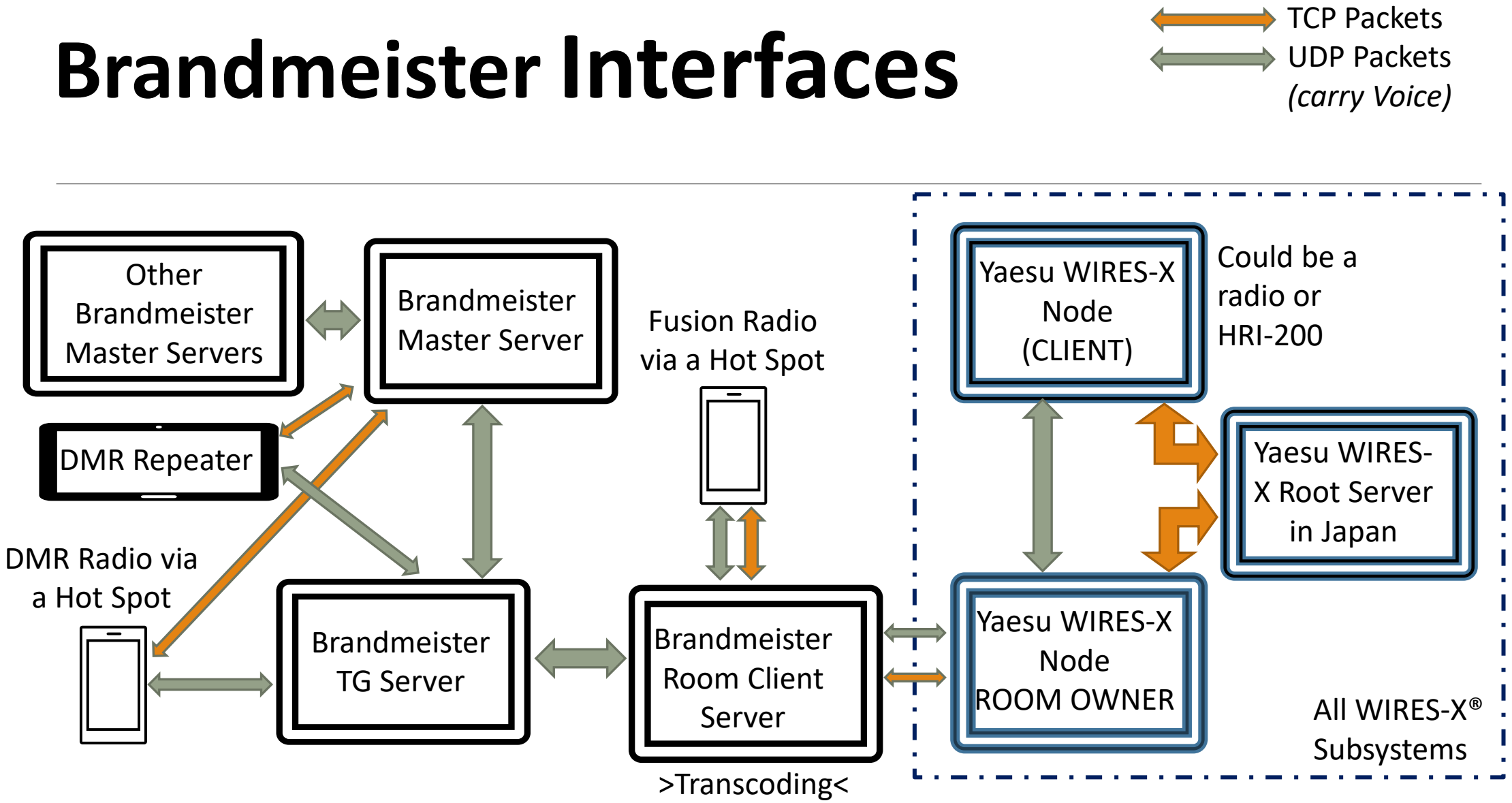


Another Combined Network of Wires-X, FCS and YSF Rooms



Drawing from mid-atlantic Wireless Communications Group & Fredrick Amateur Radio Group, MD

Brandmeister Interfaces



Hot Spot Connectivity 101 - Review

1. A NODE uses the Internet to a selected Reflector Server such as Brandmeister, YSF, FCS, TGIF, etc. (A LISTSERVER acts as traffic cop for these Internet connections.)
2. DMR: PTT on radio is used to send out a connection request for the desired Talk Group
   a. Connection occurs via air interface to hot spot or repeater and Internet to LISTSERVER
   b. A UDP connection is established between radio (via hot spot or repeater) and a TG Server
   c. Connection is made and is ready to support voice created digital packets to desired TG and receive packets from the TG to decoded to audio to the speaker – QSO begins
3. C4FM System Fusion via hot spot (or repeater) via a YSF or FCS Server **>>NOT WIRES-X® <<**
   a. Connection occurs via air interface to hot spot or repeater and Internet to REFLECTOR SERVER
   b. Hot Spot establishes UDP connection to selected Reflector Server
   c. Connection is made and is ready to support voice created digital packets to desired Room and receive packets from the Reflector to decode audio to the speaker – QSO begins

So then, What is Yaesu WIRES-X®

- WIRES-X®:
  - ✓ ROOT SERVER, operated by Yaesu, collects and pushes out all WIRES-X Nodes (users) in their database who are connected. This LISTSERVER operates somewhat like an active phone book.
  - ✓ Hot Spots are <u>not</u> directly supported
  - ✓ Yaesu's wide area connectivity via the Internet interlinks Wires-X® Nodes and (virtual) Rooms
  - ✓ A WIRES-X® Node: Yaesu HRI-200 or a PC connected to a radio using a PDN interface
    - The HRI-200 is the Wires-X® interface to the internet for repeaters or radios
    - PDN is a feature whereby a Yaesu radio can connect to a PC and the PC to the Internet
  - ✓ Nodes connect to Nodes and/or Rooms, plus some Nodes can support a Room
  - ✓ Multiple Nodes (radios and repeaters) can connect to a selected Room
  - ✓ Some Yaesu System Fusion radio are able to remotely control a Node
- **The only way Wires-X® can connect to YSF or FCS is via a specialized gateway where linking occurs between DMR, D-Star®, NXDN®, YSF, FCS and P25.**

Bridging to Yaesu System Fusion Wires-X

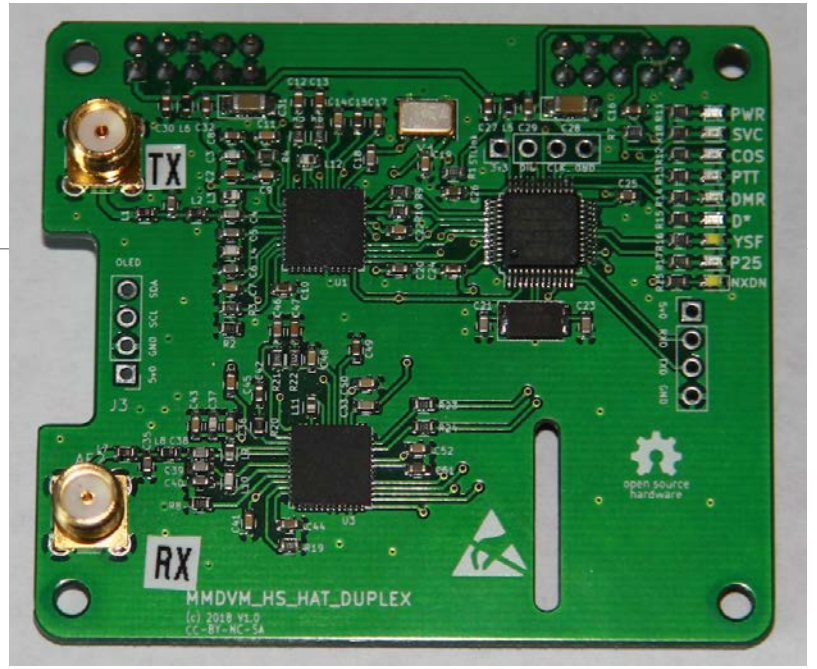
Here is how K0RQ has been able to bridge the digital modes:

The CQ-NODAK WIRES-X® Room (#62208) that I manage. I created a WIRES-X® to YSF bridge for this room, allowing users to come in on YSF Reflector #62208 (hosted by me in the cloud) and can be heard on WIRES-X®.

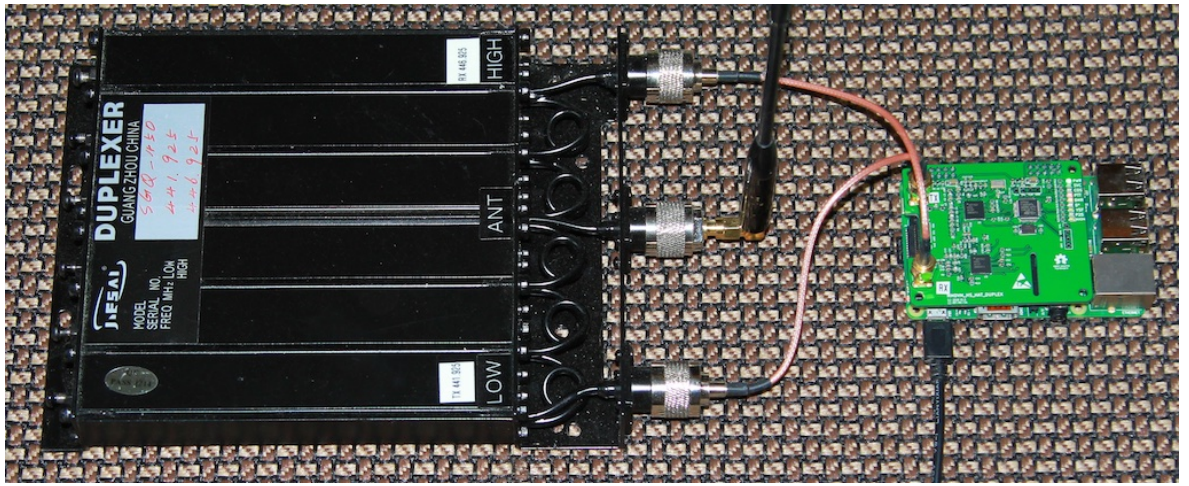
To accomplish this, I had to get an FTM100 (luckily, I had an extra one that used to be in my mobile) which I put into PDN mode. This also required computer. I then had to set a frequency split for transmit and receive into TWO different Pi-Star hotspots, as recent Yaesu updates have blocked the Pi-Stars callsign decoding for remote gateways, basically meaning I couldn't use a single Pi-Star on a simplex frequency. The bridge works very well, but it was a lot of work and there are a lot of moving pieces.

WIRES-X vs. YSF vs. FCS – K0RQ

An Option: A Full Duplex High Power Hot Spot



- Digital Mobile Radio (DMR), including MotoTrbo®, D-Star® (Icom's digital protocol that is now supported by some Kenwood models)
- System Fusion® C4FM (Yaesu's digital protocol)
  Note: Not Wires-X®
- P25 (the standard protocol for LMR Part 90 public safety, form of C4FM)
- NXDN® (an open standard developed by Kenwood and also used by Icom)
- MMDVM® Multi-Mode Duplex Hotspot (commswg.site)



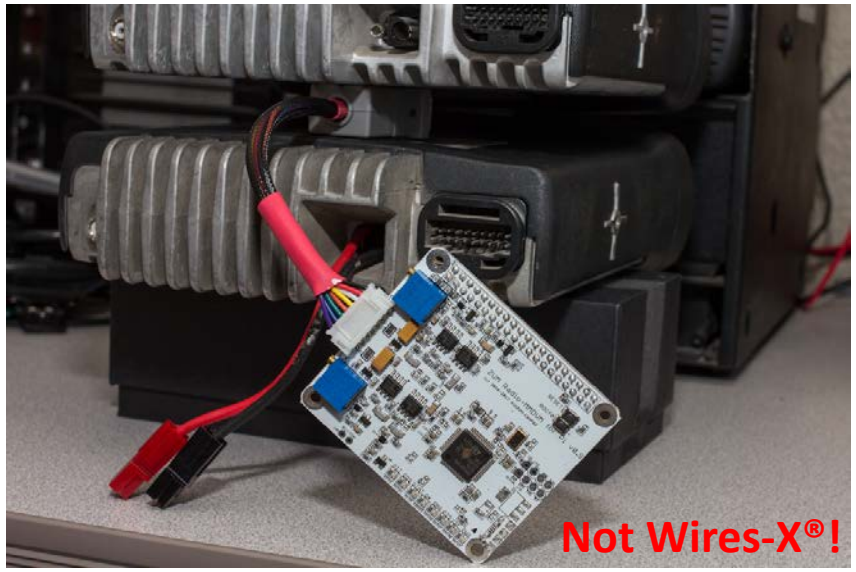
Higher Power “Hot Spot” A Repeater Interface

The MMDVM-Repeater board is a lot like a hotspot, except no onboard RF. Cables wire directly into the I/O pins of the radio or repeater. The MMDVM®/Raspberry-Pi combo will turn a single analog radio into a high-powered simplex hotspot or two radios into a fully featured digital voice repeater and this board becomes the controller.

The MMDVM® Host software counterpart is opensource and feature rich giving users access to the following digital modes in a single repeater:

- D-star®
- DMR (both time slots)
- Yaesu System Fusion® (C4FM)
- P25 Phase I (not TDMA)
- NXDN® 4800
- POCSAG® (paging)

NOTE: One can order a Bridgecom repeater using this board.



Setting Up a Hot Spot per BrandMeister

The following is the general steps to connecting a hotspot (MMDVM® Host, Pi-Star, OpenSpot, DVMega) to BrandMeister. For specific settings/configurations visit the corresponding information as noted in red with links to the individual articles.

1. **Have a 7-digit Radio ID assigned** to you and your call sign. See http://radioID.net to setup a radio ID.
2. **Setup your BrandMeister Dashboard Account** by registering at http://brandmeister.network and clicking on Register at the top right. See Register for an Account.
3. **Set your Hotspot Security password** for the Radio ID you will use on your hotspot in BrandMeister SelfCare. See HotSpot Security.
4. **Configure your Hotspot** by selecting the master, entering in your hotspot password. See specific hotspot connection information (Pi-Star, OpenSpot, BlueDV)
5. **Configure your DMR Radio** to communicate with the hotspot. Generally, Radio and Hotspots need to be set to the same frequency, color code and talk groups setup you wish to communicate on using the CPS and uploading it into the radio.

Questions

Want to learn more? Great You Tube video.

https://youtu.be/TuEpFJbXNq4?t=2

Brandmeister, the “Glue”

- There are Brandmeister Master Servers and Talk Group Servers
- The Brandmeister Master Server is somewhat like a Call Director in the IP Phone arena
- Talk Group Servers act like Conference Bridges
- Brandmeister Primarily Interconnects DMR Repeaters and Hot Spots
- Brandmeister has become the means of interconnecting hot spots and other gateway bridges
- Gateway Bridges, such as Colorado Digital, support the interconnect of D-Star® DCS/XRF303D, NXDN 31088, P2531088 and YSF 31088 servers to a Brandmeister Talk Group Server such as DMR TG31088

BrandMeister was Developed by Hams for Hams

BrandMeister is an operating software for Master servers participating in a worldwide infrastructure network of amateur radio digital voice systems. If you are an amateur radio operator working in digital voice modes like D-Star, DMR, C4FM, APCO P25 or others (not all are supported yet!!).

What is BrandMeister - BrandMeister - **PD0ZRY**

bm.pd0zry.nl/index.php/What_is_BrandMeister

The Brandmeister Network was born from several worldwide hams and software engineers who joined together to create a digital repeater network consisting of master servers and peer repeaters all over the world. The network has over 1300 repeaters and more than 3000 hotspots across the globe and it's growing every day!

https://www.dmrfordummies.com/brandmeister-network

BrandMeister News

May 23, 2019 · **DMR: Brandmeister servers** and connectivity issues. The best possible connections for all users and the repeaters will occur if you all use the same **Brandmeister server** to communicate.

Jul 01, 2021 · Oliver F4BWG. The **BrandMeister** DMR development team has been working on a new web-based talkgroups audio streaming platform, known as “Hoseline”. It has been re-programmed from scratch and packs a lot of new jaw-dropping features.

Jul 01, 2021 · New and upgraded features are expected to include much improved audio quality. BM’s developer has a new secret sauce for stunning and unmatched audio quality, a Real-Time Vu Meter, support for multi-browsers, Volume Normalizing and Auto-Reconnect.

Checkout BrandMeister Nets: Brandmeister DMR Nets – W0WC

YSF, FCS, NXDN® and D-Star® Reflectors

- There are nearly 1200 individually listed YSF Reflectors as of August 2021, with many cross-linked to other digital voice reflectors and talk groups. YSFReflector-Registry
- The number of FCS reflectors is well past thousands on the PI-STAR website with all listed linked to a DMR TG number. They can be found at FCS Reflector List - pistar.uk
- With NXDN®, the number of relectors on the PI-STAR website is about 100. NXDN Reflector List - pistar.uk
- D-Star® D-Plus reflectors number only 30 today though there are another 90+ in the master list in the USA, as of August 2021. D-Star-Online Reflectors