THE P25 NETWORK EXCHANGE – LINKING AMATEUR P25 DIGITAL REPEATERS WORLDWIDE

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Abstract

Digital voice modes have become widespread on the amateur radio VHF and UHF bands. Many different formats are in use, but the one used in most public safety applications, P25, seemed to languish for lack of an inexpensive linking system. The P25 Network Exchange (P25NX) was designed to bring this mode into the fold and unite pioneering amateurs across the world.

Introduction

There are plenty of digital voice modes being used in Amateur repeaters. D-Star, DMR and System Fusion are the most well-known, but the sleeper is the granddaddy of them – Project 25[1] It should be noted that P25 phase 1, which is what P25NX supports, uses C4FM modulation, which a particular amateur system vendor has now adopted as a marketing term for their systems, making it appear it is something they invented – but it was around long before they starting using it. Some version of P25 is used by nearly every public safety agency with digital radios, and there is a wide variety of commercial radios available for this mode. Prices have been coming down as surplus gear hits the market when agencies upgrade to newer versions. Because of this, the most popular repeater that is used on P25 became available for a reasonable cost. The Motorola Quantar. (Figure 1)

The Quantar is a workhorse repeater, available in VHF, UHF, and 900 MHz versions usable on the amateur bands. Power outputs range from 25 watts to 350 watts in the similar Quantro. The Quantar was never intended for wide area, multipoint linking, but this is exactly what was needed for Amateur Radio use.

Figure 1 -Motorola Quantar

Getting to the root of the problem

Some Quantars included a "V.24" interface for limited, site-to-site linking or receiver voting. The first problem was converting the Quantar data interface into something useable. V.24 is a standard that defines what is essentially a synchronous RS232 connection. In addition to the normal transmit, receive, and ground lines, there are two additional lines, one for transmit clock and one for receive clock. This port is available on an add-on card that was sometimes installed in the Quantar, but not as often as one would hope. The protocol for the data that runs over the V24 interface is High Level Data Link Control, or HDLC. HDLC was an early standard for data communications, but is not used much anymore. Fortunately, it was found that Cisco routers support this standard on their serial interface cards, using the Serial Tunneling (STUN) protocol…and old Cisco routers are very inexpensive on eBay.

Next came decoding enough of the protocol to determine what was going on. Much of the credit for this work goes to John Yaldyn, ZL4JY. His years of experience with Quantars and expert deductive abilities really broke down the protocol and allowed for understanding of the connections from one Quantar to another. Before long, ZL4JY and a few others had figured out how to connect 2 routers together over the internet for point-to-point communications. That was pretty much the end of it for quite a while. If you wanted to do multipoint linking, you needed a very expensive Astro-Tac Comparator device, and enough line cards to accept connections from each repeater, plus a router or at least a serial card for each one. That gets expensive and cumbersome very quickly, although a few folks did do exactly that. One such system still links the Hawaiian Islands.

In August 2014, I found all of the information which had been developed to that point on the "communications.support"[2] forum on the Internet (previously P25.ca), and used this to write a server software package that could act as a hub. This package, written in C# using Visual Studio, uses a central server which is configured to accept TCP/IP connections from each repeater site. From the repeater's point of view, it's connecting to one other repeater. The central server accepted the STUN connections from the routers, did some post-processing to pull out some of the more interesting pieces of data, and then reflected the data stream to all the connections except the sender. This was initially tested with ZL4JY, and then a few others. Before long, a post was made on the communications.support forum announcing this breakthrough. Full worldwide linking was now possible.

The reaction was swift and positive. Soon 10 systems were online, then 20, and now over 30. While small compared to the number of D-Star or DMR repeaters, it is still finding new repeater owners who had no idea it was possible. Repeaters are located in many mainland US states plus Hawaii, and also internationally in Canada, Australia, New Zealand, France, Austria, and Germany.

One problem mentioned earlier was the lack of availability of the V.24 board. Another forum user made a replacement circuit board, but it was very difficult to make work due to many tiny surface mount components. ZL4JY again came to the rescue with a simple one-chip design, and I designed a PC board for it. The complete assembled version of the board and adapter cable was placed for sale at a very reasonable cost on the P25NX website[3], and over 50 units have been purchased to date. That problem was at least solved.

The long road to Version 2

Before long, people began asking about being able to segregate their traffic from the one worldwide talkgroup. A patch was put in to allow local traffic to take place, but it still "bled though" onto the network, causing interference with any conversations there. Several attempts were made to modify the software to support multiple talkgroups, but none were particularly successful. It was a difficult problem to solve, and lack of adequate time to work on it dragged the process out for well over a year. I knew that I wanted it to be very flexible – several of the other modes limited you to one talkgroup (room, reflector) with no easy way to dynamically switch between them. Others gave priority to larger talkgroups over smaller ones, which I believed is backwards from the way it should be.

In version one, the system relies on a central server, which is a single point of failure, and a single person to maintain it. This was not desirable from a reliability or wife-happiness standpoint – the latter being more pressing. Something had to be done to distribute the network. One day while working on a project at work, I realized that that what I was doing could conceptually be applied to the network, and solve both problems at the same time.

The multicast solution

The solution is something called "IP Multicast". This technology has been available for a long time, but is not supported over the internet for various technical reasons. Essentially, each endpoint tells its local router it wants to join a particular multicast group. The routers talk to each other and have knowledge of which endpoints are on which groups. When a repeater site that has joined a particular group transmits, the network routes the data to the places it needs to go… no more central server is needed. In this system, the network does what it is meant to do – route data. As mentioned earlier, IP Multicast is not supported over the Internet. This is true, but DMVPN is.

What is DMVPN?

Dynamic Multipoint Virtual Private Network[4] is a method to establish "tunnels" over the internet, within which you can run other protocols. DMVPN in this case is set up as a mesh network, with geographically distributed hub routers through which traffic can flow. Single point of failure can be eliminated with two hub routers in each region, and each of them can take the traffic if there is a hub router failure. In addition, if configured correctly, some connections can even bypass the hubs and go directly from site to site. The best part of this is that intra-regional traffic stays within that region. A conversation between Germany and France stays within Europe. Inter-region talkgroups are routed though the US with high speed backbone links between the regional hub routers. While this is a complicated setup, it works very well. P25 Talkgroups are converted to multicast groups by using an inexpensive Raspberry PI or BeagleBone Black at each site. The PI also converts the unicast STUN data from the repeater to multicast and vice-versa. This approach is different than any other ham radio linking protocol that I know of. It eliminates reflectors, while allowing for almost unlimited talkgroups on demand.

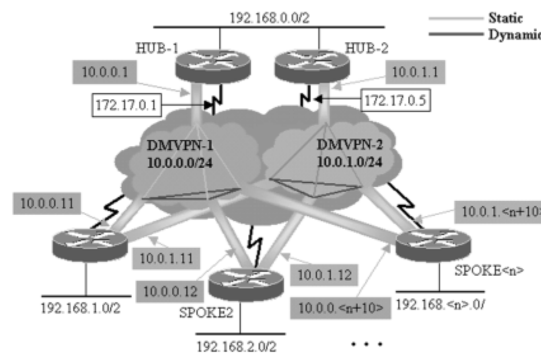

Figure 2- Dynamic Multipoint VPN

Where we are today

Version one is still active and carries most of the network traffic at this time. Version two is still in beta test but slowly being rolled out to more users. A bridge between the two is online to ease the transition. This year, for the first time, the system was shown at the Dayton Hamvention in the TAPR booth. Several P25 inclined amateurs have come online, and more are working on it. The biggest surprise for people when they hear P25 for the first time? How good it sounds.

[1] http://www.project25.org/
[2] http://communications.support
[3] http://p25nx.com
[4] http://www.cisco.com/c/en/us/support/docs/security-vpn/ipsec-negotiation-ike-protocols/41940-dmvpn.html

Bio:

David Krauss, NX4Y, holds an amateur extra class license and has been licensed continuously since 1979. He has worked with repeater systems the entire time, and currently operates 8 P25/Analog repeaters on the Florida west coast, supporting the Florida Statewide Amateur Radio network. Mr. Krauss is employed by Gannett Fleming Project Development Corporation as a Sr. intelligent transportation systems (ITS) technical manager.

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