A Brief Look at Internet Networking Over Amateur Radio
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Abstract

Amateur digital networking using the standard Internet Protocol (IP) suite allows the ham radio operator to take advantage of the vast array of facilities and communication methods developed for use on the wired Internet whilst using ham radio for independence from the commodity Internet. The AMPRNet network provides the Internet address and routing resources to make possible the construction of an experimental worldwide ham radio Internet-compatible network. Unlike wifi, which provides short-range wireless connectivity, the AMPRNet enables both community and long-haul ham networking.

Introduction

Internet networking is everywhere in modern life. Web sites, email, voice over IP, instant messaging, and social networking are but a few of the many applications based on the Internet.

In ham radio, besides direct keyboard-to-keyboard realtime "chat" communications (eg, PSK31[1]), there are several ham-specific computer-to-computer radio networking schemes — the packet BBS forwarding network, APRS[2], etc. Each of these has developed its own specialized communication protocol. However, application-specific protocols often lack a generality that allows them to be efficiently adapted to different uses, and many are dependent on specific features of the underlying transport mechanism. It can be difficult to add new features to an existing narrowly-defined protocol.

Ham IP networking offers a flexible advantage over these by allowing hams to directly link computers together using the standard Internet Protocol (IP)[3] and associated higher-level protocols, upon which can be built a multitude of applications without modification of the IP suite itself. The result is that many of the Internet's vast collection of applications are immediately available for ham radio experimental use, and new applications, when they are developed, do not require development of a new network. In addition, in countries where it is permitted, limited network interaction with non-ham Internet resources may be possible.[4]

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[1] <http://en.wikipedia.org/wiki/Psk31>

[2] <http://www.aprs.org/>

[3] IPv4. The future use of IPv6 in ham radio is more properly the subject of a separate paper.

[4] Subject to second- and third-party-communication treaties, rules, and regulations, and the no-commercial-use restrictions of amateur radio.

The Internet Protocols

Briefly, the Internet Protocol suite provides a common transparent format for carrying data so that underlying transport mechanisms (radio, wireline, optical fibre, Ethernet, etc) need not have any specialized knowledge of the data itself. Communication over IP requires only that the transport medium can carry IP packets from a source address to a destination address. In turn, the IP packet carries the data without regard to the format or meaning of the data contained within the packet. Applications and higher-level protocols build upon IP in layers as needed, but underneath, the transport happens via IP. No matter how many networks or transport types the packet has to transit, it remains an IP packet and the data in the IP packet travels along.

IP packets are rarely sent raw; generally the media transporting the IP packets has a transport-specific protocol adapted to that medium. Examples are PPP for dial-up modems, DOCSIS/PPPOE for cable modems, ATM for wideband telephone circuits, IEEE 802.3 for Ethernet, 802.11 for wifi, and AX.25 for point-to-point ham radio links.

AX.25

In ham packet radio, the most common air protocol is **AX.25**[5]. AX.25 offers several advantages for the point-to-point link aspect of ham radio networking: it identifies the station callsign, it provides retries at the link connection level for damaged or lost packets when in "connected mode", and in some jurisdictions its use permits the station to operate unattended. It should be kept in mind that AX.25 is a point-to-point link protocol; unlike IP, it was not designed to operate in end-to-end multiple hops nor to provide non-radio data transport. It is a highly suitable transport for IP packets on ham radio.

AX.25 has a protocol ID ("PID") in its packet header to indicate what kind of data is being carried in the AX.25 packet; for ordinary plaintext or keyboard communications this is set to 0xF0, but if the packet contains another protocol, the PID is set to something else to differentiate the transmissions from plain traffic.[6] For IPv4 traffic, the value **0xCC** is used.

AMPRNet

In the early 1980's, before the Internet became a household word, Hank Magnuski, KA6M[7], had the foresight to obtain an allocation of Internet addresses for the use of experimenters in the ham radio community. Known as the **AMPRNet**, this is the network resource that hams currently use for IP-based experimentation.

As hams, we have a unique ability to experiment with radios and radio-based networking. A primary goal of AMPRNet experimentation is to achieve a world-wide network based on ham radio, *as independent of the landline-based commodity Internet as our voice communications are independent of the public telephone system.* Because Amateur Radio is an experimental service, we have here an opportunity to experiment with truly large scale cooperative networking, of which the current AMPRNet is only the beginning.

The links which form the network are varied: some are medium-speed FSK links using commodity ham rigs, some are converted commercial radios; there are higher-speed data radios specifically designed for ham use; casual ham participants can connect using the traditional 1200 bps AFSK or 9600 bps FSK packet radio equipment. Recently, the availability of commercial high-speed wireless endpoints[8] at quite affordable prices and that are easily adapted for ham use has

[5] <http://www.tapr.org/pub_ax25.html>

[6] When monitoring an AX.25 radio channel, it is often necessary to enable a special setting in the TNC or packet software to make non-text-PID traffic visible.

[7] <http://en.wikipedia.org/wiki/Hank_Magnuski>

[8] Typically these operate in the amateur or license-free 2.4 GHz or 5.8 GHz bands. Such devices

made it economical to construct fast links with good bandwidth between communities. Good connectivity enables a number of applications that were not previously practical to experiment with due to bandwidth requirements; among these could be digital voice repeater linking, digital quality facsimile picture transmission, television (D-ATV), Web-SDR, multimedia, and so on.

IP Tunnels

Within regional communities, ham IP experimenters communicate with each other by radio. However, wider-area connectivity in the AMPRNet is as yet rather sparse. In many areas, there is only the localized community radio connectivity, forming an "island" where neighboring stations can communicate with each other but there is as yet no inter-community radio link. In order to allow those islands to participate in the network, a scheme has been developed of connecting communities, where permitted, via "tunnels"[9] through the commodity Internet. These tunnels provide a mechanism for transporting AMPRNet IP packets across the Internet as though there were a radio link between the two tunnel endpoints. Since each island community may have a gateway system with a complete table of tunnels it can set up to other islands[10], development of networking techniques with a working connected network may procede even before the planned radio links are in full operation. Each tunnel connects directly between each pair of island gateways; the resulting connectivity is therefore independent of any single point of failure that could impact the network as a whole. Of course, a goal is to eventually replace the tunnels with radio links, and have all AMPRNet connectivity be by means of ham radio.

Because tunnel gateway systems are of necessity connected to both radio and an ISP-based connection to the Internet, it is mandatory that they institute appropriate firewalls and other access control mechanisms to restrict access to their radio equipment in accordance with the regulations governing non-ham traffic in their jurisdictions and in accord with their ISP terms of service[11].

IP Addressing

Administratively, the AMPRNet IP address space is divided into blocks of addresses which are allocated to regional volunteer coordinators[12] who in turn assign the addresses to hams who request them. Each coordinator is also responsible for updating the central DNS database when an address assignment is recorded.

Domain Name Service (DNS)

The mechanism for turning Internet domain names such as *WWW.EXAMPLE.COM* into the actual IP address of the desired destination is by means of a distributed database called the Domain Name System ("DNS")[13]. Early on TAPR[14] registered the domain name AMPR.ORG for ham IP use.

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can transfer data at 10 Mbps or faster, and are particularly well suited for medium-range applications such as community-wide networking and the interconnection of adjacent communities.

[9] <http://en.wikipedia.org/wiki/IP_tunnel>

[10] For more on the AMPRNet tunnels, see <http://www.ampr-gateways.org>. The administration of the tunnels routing database is managed by James Fuller, N7VR.

[11] There is also a limited provision to allow packets addressed to AMPRNet gateways to be forwarded one-way from the Internet, permitting access to Internet resources should the tunnel gateway operator choose to allow it. This one-way forwarding also supports an academic cybersecurity research project (funded by the National Science Foundation and the Deparment of Homeland Security) which relies on routing to the AMPRNet address space through the forwarder.

[12] A list of regional coordinators can be found at <http://www.ampr.org/amprnets.txt>. Hams in regions without a current coordinator are encouraged to work together to select one. Regions without a current block allocation may request one. Contact the author.

[13] <http://en.wikipedia.org/wiki/Domain_Name_System>

[14] <http://www.tapr.org/>

Entries in that domain are primarily callsigns, forming fully qualified domain names such as **W1AW.AMPR.ORG** or **WWW.W6ABC.AMPR.ORG,** and these can be looked up in the DNS to yield that station's assigned IP address. There are several redundant ("secondary") AMPR.ORG DNS servers operated by volunteers worldwide (currently in the USA, Germany, and Australia), each with complete copies of the database. There is also an associated PTR or "reverse lookup" DNS zone that translates the AMPRNet IP addresses back to the associated callsign/name. Updates to the DNS are made when an address coordinator makes an address assignment.

Current Usage

At the time of writing, there are more than 250 blocks of addresses allocated to more than 140 countries. Over the past twenty years, thousands of addresses have been assigned to hams around the world. Many of these are still active.

There have been more than 150 tunnel gateways registered, with more than 90 in current operation.

Groups in Austria[15], Belgium, France, Germany[16] and elsewhere in central Europe are developing advanced national and international network structures utilizing high-speed intercity links.

Hams are experimenting with using AMPRNet resources to link repeaters using various voice-over-IP schemes[17] and to remotely control stations.

There are ham station web pages with details of equipment, QSL information, and contest logging data.

BBS mail and bulletin forwarding, DX-clusters, conferencing, and APRS have become Internet-aware and are capable of using IP and AMPRNet.

Setting up a station

A ham station wishing to begin IP networking will need a computer and software to do so; most advanced experimenters use the Linux operating system which often has ham radio IP networking built in, but with appropriate software, Windows computers may also participate in the network. The same equipment (TNC or sound card and radio) that most packet stations use is also suitable for ham IP networking. Applications such as telnet, e-mail, file exchange, or messaging may use the same programs that operate on the Internet, although there are amateur-radio-specific programs that enhance ham IP networking.

The **JNOS**[18] program for Linux offers a complete suite of Internet applications with a strong emphasis on ham IP networking including serving as a tunnel gateway; Windows users should consider **PC/Flexnet**[19] or the **SV2AGW**[20] suite of programs. Some years ago, Ian Wade, G3NRW, wrote the book *NOSINTRO TCP/IP Over Packet Radio: An Introduction to the KA9Q Network Operating System* about setting up an AMPRNet station using the pioneering **KA9Q NOS** [21] program. Although that book is now out of print[22], copies may be available in libraries or from used book stores, and much of the original source material is available on the author's web

[15] <http://wiki.oevsv.at/index.php/Kategorie:Digitaler_Backbone>

[16] <http://db0fhn.efi.fh-nuernberg.de/doku.php?id=projects:wlan:hamnet>

[17] ICOM D-Star repeaters are readily able to use IP connectivity to link between sites. <http://en.wikipedia.org/wiki/D-STAR>.

[18] <http://www.langelaar.net/projects/jnos2/about.html>.

[19] <http://www.afthd.tu-darmstadt.de/~flexnet/>

[20] <http://www.sv2agw.com/ham/>.

[21] <http://www.ka9q.net/code/ka9qnos/>

[22] ISBN 978-1897649008

site[23]. See also the excellent instructions at the DB0FHN web page[24]. Many AMPRNet regional address coordinators are quite knowledgeable and often can help the newcomer to ham IP networking get their station running.

To avoid tying up a general-usage computer, some hams have elected to construct dedicated tunnel gateway routers from commodity residential gateways by replacing the standard firmware, and in some wireless models there is the additional capability of moving the wireless section into the 2.4 GHz ham band.[25]

Summation

In its more than twenty years of existence, the AMPRNet has provided hams with an unparalleled opportunity to experiment with radio-based computer networking on both large and small scales, and will continue to do so for the future. Interested amateur radio operators are encouraged to join the hundreds of fellow hams who have helped develop this unique network.

Areas for further experimentation include higher-speed data radios, long-haul links over HF, microwave circuits, data compression to lessen occupied bandwidth, Forward Error Correction (FEC) to reduce the need for retransmission of damaged packets, and ham satellite operations.

There is much to be done by those who want to try new things.

[23] <http://homepage.ntlworld.com/wadei/nosintro>

[24] <http://db0fhn.efi.fh-nuernberg.de/doku.php?id=doc:db0fhn:tcpip>

[25] <http://db0fhn-i.ampr.org/wrt54gs/>,