

From Ether to Ethernet

The merging of wired networks with radio has resulted in a more flexible, reliable and portable radio system. Make DX contacts and enhance your emergency communications with a hand-held radio.

It was the last night in December of 2002. Stations in many different time zones were being worked from North America, while amateurs worldwide were bringing in the New Year. Tony, VK3JED, in Melbourne, Australia was celebrating on the air at 6 o'clock in the morning (my time). As midnight approached in India, Sam, VU2SBB, was busy talking to North America, followed by South Africa; then Belgium and the UK. It was a thrill to talk to the world from home on a hand-held radio. Yes, talk to the world with a battery-powered VHF/UHF FM transceiver!

Amateur Radio has seen many technological changes in the last 85 years. First, the shift from spark to CW in the '20s; next, AM in the early '30s; followed by SSB in the '50s. In the '60s, when hams started to convert discarded taxi and police radios to 2 meters, VHF-FM became the rage, with repeaters following.

Change does not occur without controversy. "Spark Forever!" was heard in the '20s as crystal control and CW ushered in the then-new wireless technology. When AM first appeared, "brass pounders" felt their frequencies were being pirated by the new "upstart." Now that Internet linking of VHF/UHF Amateur Radio repeaters is becoming popular, change is again occurring, but not without controversy.

Early experiments linking FM repeaters using the Internet with Voice Over IP (VoIP) were, for the most part, unsuccessful and none (*iPhone* was one example) ever became popular. Then, in 1998, a ham in Vancouver, Canada designed a better, more reliable way to do that and it has rapidly embraced a worldwide following.

Dave Cameron, VE7LTD, of Vancouver, British Columbia began experimenting with what he called the Internet Radio Linking Project or simply IRLP. Dave and Michael Illingby, VE7TFD, of Vernon, British Columbia, became frustrated with the unreliable operation of *Windows*-based *iPhone*, VoIP software. At that time, all *Windows*-based Amateur

Radio linking software used voice control (VOX) and it wasn't secure from non-amateur access.

Dave designed and developed the new IRLP system using *Linux*, resulting in an ultra-stable operating platform for the new software. It now has an installed base that is approaching 1000 active nodes and is worldwide in scope. With the release of Version 3.0 hardware and greatly enhanced software, IRLP continues to grow rapidly. (When the author first ordered IRLP interface hardware in February 2001, there were only 63 nodes.)

What is Voice Over IP?

Telephone system companies and network infrastructure suppliers, such as Lucent and Nortel, have started promoting Voice Over Internet Protocol (VoIP). The telephone companies recognized that VoIP was an efficient way to merge their telephone voice and data traffic using the TCP/IP protocol. With an IP-based network, the telephone audio is sampled, compressed and wrapped into data packets that can be routed, bridged and switched alongside other data packets flowing through private networks and the Internet. With the great advances in computer soundcard-based software applications, it was just a matter of time before reliable VoIP applications would be generally available.

IRLP is not the only VoIP application making its way into Amateur Radio. Systems such as EchoLink, eQSO and Yaesu Wires II allow computer-to-computer or computer-to-radio links. IRLP continues to build on a philosophy that insists that a radio be at each end of an IRLP contact. Having said that, there is a need for PC-radio based networks that the other technologies provide.

Using IRLP

The technology allows amateurs within range of a repeater or simplex station, equipped with an IRLP interface, to easily link a local repeater to one or more IRLP-equipped stations around the world. The lo-

cal user simply requires a radio with DTMF capability and local access information.

The local linking station is termed a *node*. It's a good idea to contact the station operator before trying to use that station, as some nodes require a pre-access code, similar to a phone patch access. One should also support the local club or organization providing the IRLP link. Refer to the list of active nodes at status.irlp.net to find a node close to your location.

The default access requires dialing the destination node number. Within a second or two, the called node will identify in plain voice with its call sign and location. If the target node is connected, you will receive a recording telling you what node or reflector the repeater is connected to. Optionally, if the target node has enabled its Call Waiting feature, a form of voice enabled call display will announce that a call has been attempted from your node number.

Multiple repeaters can be linked utilizing one of over a dozen multi-channel

What is a Reflector?

A reflector is nothing more than a robust PC accessing a large amount of bandwidth and used for a node connector or a bridge. These machines allow many nodes to be linked together in the form of a round table or a conference bridge. Only one node can talk at a time, although all connected nodes receive a copy of the received audio. No "doubling" is possible on an IRLP system, as the first packet to arrive "wins" and all other IP packets are ignored until the initial station drops the PTT circuit. The main reflectors have a primary channel and nine sub-channels, each with enough capacity for a large number of simultaneous connections. The main international calling channel reflector is 9200 in Indianapolis, Indiana. See status.irlp.net for a full listing of available reflectors.

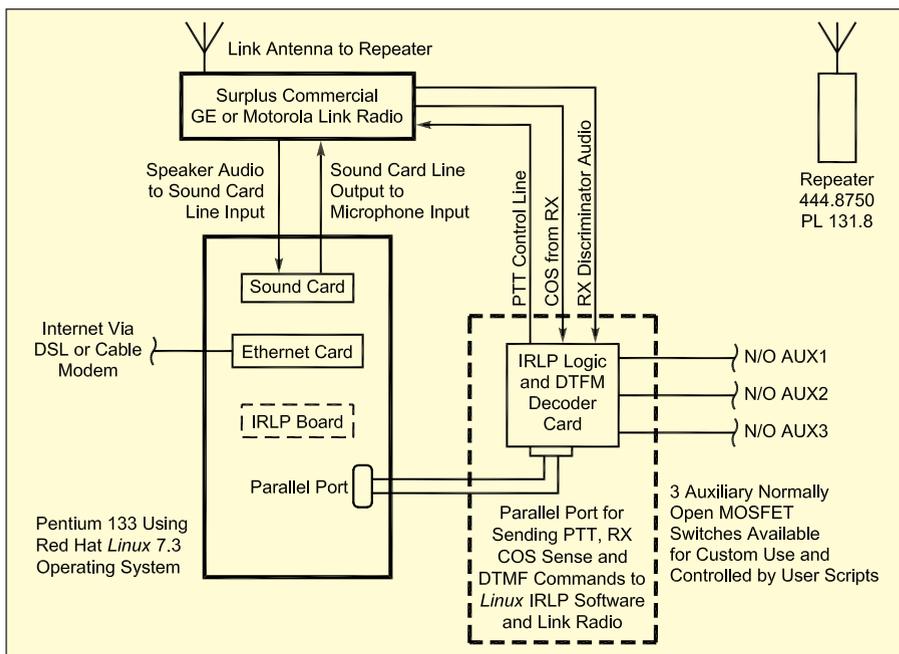


Figure 1—A block diagram of an IRLP system, showing the PC controller, link radio IRLP interface card and repeater.

IRLP reflectors spread around the world. (See sidebar, “What is a Reflector?”)

Audio Delays

As with any digitally voice-encoded system, some audio delays are encountered. PTT key-up delays are mainly caused by the delay it takes radios to decode the tone squelch information. The first thing users need remember is to wait about ½ second after pressing the PTT switch before talking. (To dispel Internet delay myths, once a call has been set up, the audio delay over the Internet is about the same as one experiences when using a digital cell phone.)

Using IRLP is similar to using your local repeater, except for the aforementioned PTT ½ second hold for each access. One should also pause about 5 seconds between transmissions, to allow for break-ins from other operators. Other than your local repeater’s courtesy tone and ID, you will hear no courtesy beeps or CW IDs from the other station. This makes IRLP-linked calls very transparent and it’s difficult to know if the other station is across town or across the world. The audio quality is just that good. A basic block diagram of the IRLP system can be seen in Figure 1.

Audio Path to the Internet

Now that a connection has been established, the IRLP software takes audio from the receiver, which is then fed into the LINE IN connector of a PC sound card. As soon as a valid COS signal (carrier detect) is sensed (from the originating link radio), the received audio is con-

verted into ADPCM (Adaptive Differential Pulse Code Modulation, a predictive audio compression encoding system) digital data. The software then converts this data into digital packets; each assigned an IP address for a destination node. These packets now flow through the Internet to the destination PC where the packets are decoded and then sent to the sound card LINE OUT jack. This audio is then fed to the link radio’s transmitter audio input. The destination link transmitter is keyed the instant that valid TCP/IP packets start to arrive. As soon as the data stops flowing, the link radio automatically un-keys, and when the destination node replies, the process reverses.

The Digital Audio Process

The underlying audio processing technology in IRLP is based upon a modified freeware application called *Speak Freely*.¹ The modified version of *Speak Freely* used by IRLP actually produces the VoIP data and decodes the audio. While some may be familiar with the *Windows*-based *Speak Freely* application, IRLP runs the *Linux* version. Since our VHF and UHF repeaters do not require anything even close to MP3 audio quality, IRLP is using VoIP at a low data bit-rate to communicate. With the vast majority of nodes using cable or DSL modems, the 32 kb/s data rate for ADPCM is a non-issue. Some nodes using dial-up with limited bandwidth use a CODEC to utilize

¹Notes appear on page 32.

GSM encoding. This encoding format requires a data rate of only 17 kb/s, albeit at the cost of some audio quality. It is also not as robust as ADPCM with respect to the handling of packet loss.

The interface between the radio and the PC is performed using a small custom logic board connected to the computer’s parallel printer port. This board samples the received audio for DTMF signals, detects the link receiver COS (carrier operated squelch) for positive and instant remote keying, and generates the transmit PTT line for the link radio. All of the command I/O between the PC and the IRLP board is handled by a connection to the PC’s parallel port.

The entire system is DTMF (tone) controllable. The control codes lay imbedded in a separate program that reads DTMF tones from a DTMF decoder located on the interface controller board. These codes activate various parts of the software. DTMF codes are used to enable/disable linking, to open/close links and set identifiers. Every site has the ability to connect directly to any other site, either by using direct connections or reflector sites.

The version 3.0 board also features three auxiliary outputs allowing simple scripting to command these switches ON or OFF. Several node owners have actually used the IRLP board and some basic bash scripts to write a simple repeater controller on the IRLP platform.

These outputs can sink 2 A of current, which is more than adequate for most solid-state applications. They can additionally drive a high current relay to control anything from tower lights to an air conditioner.

Behind the Scenes

IRLP operates on a very robust distributed network infrastructure, which is rarely seen or heard from by users.

Even though the IRLP system is currently mature and reliable, the true spirit of Amateur Radio implies experimentation, including possible improvements and enhancement to the IRLP software. Unlike *Windows*-based systems, IRLP updates are automatically downloaded to each node *without* the need for a reboot.

All updates to IRLP software are distributed daily during the wee hours of the morning without the need for operator interaction. When updates are ready for distribution, they are simply uploaded to the root home IRLP server. The home server then notifies the five distributed machines around the world that new code is ready for download. This is performed via rsync, a program providing a very fast method for bringing remote files into

sync. It is accomplished by sending just the differences in files across the IRLP network, resulting in a very bandwidth-efficient updating process.

All network nodes can then be brought up to the latest software release during an early morning file update check. In addition, there is no need to re-boot after every update, a requirement so familiar to *Windows* users.

IRLP_BIND for DNS Service

Most readers who are on the Internet will be familiar with the term DNS (Domain Name System). IRLP makes use of a custom application modeled after the Berkley Internet Name Domain (BIND) called IRLP-BIND. Written by VE7LTD, IRLP_BIND is similar to *Microsoft* DNS and handles all connect requests by instantly converting the 4-digit IRLP node request into an IP address (see sidebar, "What is an IP?") used to find the destination node. Before VE7LTD developed the IRLP-bind system, an ever-growing host file had to be constantly downloaded by each node every time the IP changed on any node in the system. This resulted in a tremendous waste of bandwidth on the IRLP server.

When any connection is attempted between IRLP nodes, the originating node does a routing lookup from one of five servers co-located with major reflectors distributed around the world. These five machines—besides serving as reflectors and providing the IRLP-bind service—also mirror all of the latest IRLP code updates and PGP (*Pretty Good Privacy*—an encryption code) key rings. Each local repeater node is assigned one of these five servers as a primary server based on its node number and geographic location in the world. If one server should go down, the node just looks at the next server down the list. This change shortened the time for new nodes to be recognized by the rest of the IRLP network and reduced the amount of traffic on the [irlp.net](http://www.irlp.net) server by many orders of magnitude. Additionally, no single server failure could then take down the routing.

Even if a route to all five servers were to fail, a host file is also stored locally with the current IP address of all nodes and can be accessed. To keep this local host file current, a new host file is downloaded whenever the node sees the IP lookup returning a newer address. Even if the node makes no calls, a new host file is downloaded by each node at 3 AM. To prevent a major bandwidth rush on the name servers, IRLP takes the difference of the *Node Number/Modulus 600* and uses that as a sleep time to avoid a backlog of the daily updates.

One of the IRLP install team, Pete, VK2YX, points out that the IRLP software designers have gone out of their way to accomplish a single goal...that is, to make nodes as "maintenance free" as possible. From the basic software design that handles changing IP addresses, to a server back-end that handles completely automated software upgrades, updates and installation (all during normal system operation), the nodes are designed to keep owners from worrying. In spite of this good design, Pete volunteers that, "Good ideas and new software are always welcomed by the software team."

Many of today's IRLP "standard" features were once just "good ideas" on the part of various system owners. Many software designers have "migrated" their ideas to the rest of the IRLP fraternity via software review and then release, through the back-end systems.

IRLP allows the node owner to customize the node in any way they see fit. One can add scripts to do almost anything, such as:

- Play ARRL or equivalent news broadcasts
- Play severe weather alerts with text to voice freeware
- Enable a local voicemail system
- Enable clock/time/date features with atomic clock accuracy
- Build your own features with simple scripting

Authentication Security from Hackers

Unlike systems with minimal, if any, security, that allow users access from a PC, IRLP uses a system to ensure that each call setup is authenticated 100% and authorized to transmit on the amateur bands. The PGP encryption process is used so that when a connect request is made, the connecting node and the destination node exchange key challenges. These must authenticate or the connection is refused.

Some details of the IRLP connect request authentication are:

- IRLP uses public/private PGP key authentication to encrypt a random message with a 512 bit key.
- The calling node must authenticate with the node called.
- Once this is done, the called node has to prove to the calling node that it is in fact who it claims to be.
- The authentication is bi-directional insuring against falsification.
- The PGP key is created *only* by the IRLP installer and uploaded to the master IRLP key ring.
- If there is ever a compromised node, the ability to remove it from the key ring is only a keystroke away.

What is an IP?

An IP is like a telephone number and is used to address and route packets around the Internet. An IP address can be recognized by four pairs of digits separated by periods such as 209.140.206.201. This sample IP is the actual numeric address for WWW.ARRL.NET and can actually be used in place of the label "www.arrl.net."

There are static and dynamic IPs; dynamic is the type consumers are provided with. Internet Service Providers (ISPs) never have sufficient IPs for every client, so they dynamically assign IPs when one connects to the Internet. Some ISPs set very short "lease" times so they can provide service to all subscribers with a fraction of the IPs actually required for continuous service. This means that, if a machine is idle for more than a set time, even though connected to the Internet, its IP is reassigned. As soon as access is attempted again, the ISP assigns a new IP. The IP leases can be as short as 10 minutes. This was a major challenge to be overcome with IRLP.

Hosting your Own Node

The actual PC hardware requirements associated with this technology are usually found in most basements, left over from several previous computer upgrades. Almost anyone with Internet access can host an IRLP node; however, a 24/7 DSL or cable modem is recommended, in order to keep the node quickly abreast of updates.

IRLP can operate quite nicely on a P100 or faster machine equipped with 32 MB of RAM, a 1 GB hard drive, a *Linux* friendly network card and an ISA true *SoundBlaster16* sound card. Unless the node is co-located with the repeater, a link radio is also required.

Anyone thinking of hosting a node should visit the official IRLP Web site at www.irlp.net and review the FAQ sections.²

It is strongly recommended that, because of the duty cycles encountered in IRLP, you not use an amateur-class mobile transceiver for the link radio. When connected to a reflector, the link radio is in a key down state, as is the repeater. A robust surplus commercial transceiver is recommended. The GE *Phoenix* or the Motorola *M* or *GM* series radios with the 16-pin option connector make perfect link radios. All of these transceivers have CTCSS coding capability and they can be interfaced without internal access. All the required signals at the proper levels are available through the option plugs.

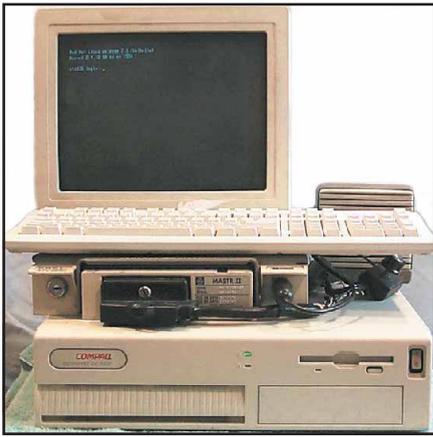


Figure 2—A typical node with a commercial link radio controlled by a PC. This is node 3350, Denver, Colorado. The link radio shown is a surplus GE Mastr II.

The most difficult task reported by new node owners using non-commercial radios is locating a place to take off a COS signal. A COS signal that follows the squelch activity is necessary in order to tell the IRLP node you have audio to send to another node. Since most nodes utilize CTCSS, this point must only change state with a valid CTCSS tone. The commercial equipment usually has a proper COS signal available from the system plug.

For receive audio it is necessary to pick a point unaffected by the local volume. This is usually a connection to the high side of the volume control or the discriminator output. Figure 2 shows a typical node with a commercial link radio controlled by a PC.

Without debating the virtues of flat or pre-emphasized audio, the transmit audio can be fed directly into the microphone input. The PTT switching connections should be obvious on most equipment.

All of these signals are accessible through the system plugs on most commercial radios as well as the packet ports on some of the newer amateur transceivers. However, the COS or CTS signal on a number of ham transceivers is usually taken off before the CTCSS decoder making the signal unsuitable for link radio purposes. With the relatively low cost of available surplus commercial equipment, that equipment would present a far better choice for fixed link radio service.

Most nodes are tested and de-bugged on a simplex frequency before being used to bring IRLP service to a local repeater. Before connecting with a local repeater, it is important that you devise a method to make sure that your repeater's hang timer, courtesy tones and CW/Voice IDs do not get sent to the IRLP network.

This can easily be accomplished by either modifying the way your repeater's CTCSS encoder follows receive activity or, if it uses a standard squelch circuit, by adding a basic CTCSS encoder. In either case, the encoder needs to be configured so that it generates tone only when the repeater's receiver is actually receiving a signal. This is easily accomplished by using the COR (carrier operated relay) or COS signal to also control the CTCSS encoder, in addition to controlling the repeater controller.

Then, with the repeater only sending CTCSS tones when a signal is being received at the repeater, the IRLP link radio will only generate a COS signal when a valid CTCSS tone is present. It is this level change that drives the COS input on the IRLP board.

With this simple change, the link radio will no longer pass the hang timer, the periodic station IDs or any courtesy tone when users drop their PTT. With these minor changes, those at the other end of the IRLP connection will have their repeater drop and generate a local courtesy tone at the same time the originating station drops PTT. There are then no superfluous beeps or waiting for the other repeater to drop before responding.

This muting of all such tones and hang timers is a hard and fast rule enforced on most reflectors. Imagine having 20 or more repeaters connected to a reflector and having to listen to various local IDs every 30 seconds...not a pretty picture.

Now that we've figured out the RF control interface, it's time to order the IRLP kit. This includes all of the main hardware and software. Transceiver interface cables are easily fabricated by the node operator.

Full ordering information can be found on the IRLP web site at www.irlp.net.

The Installation

Once you have received your IRLP board and the *Red Hat 7.3* CD you'll be ready to sacrifice an older *Pentium I* or *II* machine to operate under *Linux*. Don't be intimidated by *Linux*. The author had never used *Linux* before installing our group's first node back in the spring of 2001. At that time, IRLP was operating under *Red Hat 6.2* and the install went very smoothly. Now, with *Red Hat 7.3*, there is even better support for sound and network cards. With the detailed systematic instructions furnished, the installation of *Linux* is quite straightforward and is usually accomplished within 30 minutes.

Once you are able to telnet out of the *Linux* box to the IRLP server, you are all

set to download the latest IRLP software from the IRLP FTP server. Again, the installation is quite straightforward. Part of the installation process is the generation of the PGP encryption keys used for authentication. These keys are emailed to IRLP along with the answers to questions only the person ordering the IRLP node would know. This is used for authentication before the PGP keys are added to the IRLP key ring. Without the keys being installed in the key ring, the new node will be unable to place or receive calls. This feature is one of the major-selling security features with licensing bodies worldwide.

As soon as the PGP keys are added, the node is operational.

Great Web Tools

There are some very powerful Web based tools provided to assist the users determine real-time status of nodes. Point your browser to status.irlp.net and you'll see all current network activity showing node activity by country.

You can also see the reflector status at a glance. All reflectors and their sub-channels are listed, showing the number of connected stations on each sub-channel. There is also a complete list of all nodes worldwide, showing their status. The page is dynamically created each time it is loaded. By clicking the hyperlink header on each column, you can sort the ever-growing list on any header. The sample listing seen in Figures 3 and 4 is sorted by country showing the status and the length of time each node has been in that status. It can be seen from the sample that node 8880 in McMurdo, Antarctica has only been idle for 12 minutes and node 6030 in New South Wales, Australia has been connected to node 1230 in Canada for 3 minutes. From this status page, one can click on the node city and view a detailed map showing the location of the node. By clicking the node number link, one can also view other details, such as a detailed description of the node owner, frequency and CTCSS tone used.

These user tools were originally designed by Richard Whitaker, VY1RW, and expanded to the current system by Kent, NØPSR, with input from Marcus, WA2DCI, and other IRLP users.

Reflector Cops?

There are some basic rules that must be followed when connecting to a reflector in order to insure minimal disruption to users. For the user, these rules are basic, such as a 5-second delay between transmissions to allow other stations a break-in period. Technical problems on a node can cause difficulties for all con-

IRLP Node codes and locations Sorted by: Country

Node ID	Callsign	City	Prov./St.	Country	NodeFreq	Status	Length
8880	KC4USV	McMurdo Station	--	Antarctica	146.5200	IDLE	12 mins
6010	VK2RMP	Wollongong	NSW	Australia	146.8500	IDLE	79 mins
6020	VK2RMB	Terry Hills	NSW	Australia	146.8750	down	3 days
6030	VK2RMR	Mt Rivernew	NSW	Australia	439.5750	Linked 1230	3 mins
6040	VK2RTZ	Newcastle	NSW	Australia	146.7750	IDLE	626 mins
6050	VK2RCZ	Sydney	NSW	Australia	439.4250	IDLE	552 mins
6060	VK2RAG	Gosford	NSW	Australia	438.0750	IDLE	1013 mins
6110	VK1RBM	Canberra	ACT	Australia	438.0250	Linked 3110	3 mins
6200	VK6RFM	Fremantle	W.A.	Australia	146.9500	Linked 9070	793 mins
6210	VK2ZTA	Wahroonga	NSW	Australia	439.2500	IDLE	1145

Figure 3—An example of IRLP Node ID codes and locations, sorted by country.

Network Summary

737 - Total Nodes		573 - Online/Active		499 - Idle		18 - Offline/Down			
Country	Nodes	Online	Idle	Offline	Country	Nodes	Online	Idle	Offline
Antarctica	1		1		Australia	42	1	32	9
Barbados	1		1		Belgium	1		1	
Canada	154	16	129	9	Dominica	1		1	
England	23	4	15	4	Germany	1		1	
Grenada	1		1		India	1			1
Japan	3		3		Netherlands	2		2	
Netherlands Antilles	2	1		1	New Zealand	4		3	1
Norway	1		1		Scotland	2		2	
South Africa	2		2		Sweden	9		8	1
Trinidad & Tobago	3	1	1	1	USA	357	33	295	29

Figure 4—A network summary display tool.

nected stations. Each reflector typically has a small number of reflector “cops” ready to drop a node should anything interfere with normal system operation. Blocking a node takes but a few seconds and once blocked, the packets from that node are ignored. When a node is blocked, the system automatically e-mails the node owner, explaining the issues surrounding the block and the time of the block. When the node owner has rectified the problem, a reinstatement is requested and the firewall block is removed.³

Is VoIP Legal?

Legality depends upon your location. US readers should refer to the article by Steve Ford, WB8IMY, “VoIP and Amateur Radio,” *QST*, Feb 2003, pp 44-47. A sidebar in that article explains the possible implications of US Part 97 regulations when linking and using VoIP in an unattended mode.

The abbreviated response is that, for two repeaters linked via IRLP in unattended mode, no issue exists as long as control of the node is at 222.15 MHz or above (with the exception of the CW, SSB and amateur satellite portions of the 70-cm band).

In Canada, unattended VHF simplex or in-band linking is allowed. However, in Germany, linking of any kind, on any frequency, has been a regulation issue. Until recently, the only DL stations heard were those within range of the Belgium and Dutch nodes. DARC (the German national Amateur Radio society) is working to bring regulations in line with current enabling technologies. Recently, a node in Nuremberg, DB0VOX, became active, so progress is being made.

Groups and Nets

The IRLP 4 Kids Net was formed in November 2001 to provide a common meeting place for young hams to com-

municate worldwide via Amateur Radio using the IRLP network.

The Kids Net meets each Saturday at 0100 UTC (Friday evening in North America). That net has been using the Las Vegas reflector (9508) that supports both dial-up and broadband users. A *Yahoo!* group has been set up at groups.yahoo.com/group/irlp4kids/.

A Canadian YL Net has been started using IRLP. This net was described by Diane, K2DO, in her *QST* “YL News” column in the January 2003 issue of *QST*, p 92. IRLP allows many groups to meet worldwide with no concern about propagation or antenna restrictions that would normally preclude HF operation. The YL Net meets on the 9000 Vancouver reflector.

Listen to IRLP

Those outside the range of an IRLP node can listen-in via a streaming audio feed that this author maintains. The easiest way to access this is to go to the www.irlp.net Web site and click on the *Listen Live* link.⁴ The audio stream is a duplicate of the main reflector 9200 channel in Indianapolis, Indiana. It allows anyone to monitor the reflector audio from anywhere an Internet connection is available.

Synergy!

With the rapidly growing adoption of IRLP and other VoIP applications, a new world is opening up for both beginners and old-timers in Amateur Radio. The merging of hand-held radio operation with the adaptability and reliability of computers brings synergy. Marrying wired networks to radio empowers a system whose boundaries are limitless, for both emergency and routine communications. We’ve come full circle—merging wire with wireless to join our knowledge of radio and communications with the

wired capabilities of the Internet. May that marriage prosper, bring many newcomers to Amateur Radio and enhance operation for all!

Thanks to the IRLP designer, Dave Cameron, VE7LTD, for his assistance in preparing this article and for his dedication to this project.

Are You Interested?

If this article has piqued your interest, please browse the official IRLP Web site at www.irlp.net and feel free to contact the IRLP designer Dave, VE7LTD, at dcameron@irlp.net or the author at ve3sy@arrl.net.

Notes

- ¹www.speakfreely.org/ The VoIP SpeakFreely Web site.
- ²www.irlp.net/ Internet Radio Linking Project Web site.
- ³www.kwarc.org/irlp/ IRLP user guidelines
- ⁴www.kwarc.org/listen/ Streaming audio feed of IRLP.

*Paul Cassel, first licensed in 1961 as VE3AVY, spent most of his working career in the two-way radio, cellular and messaging industry. He is now retired and, between consulting projects, enjoys operating HF as well as mobile IRLP. Paul is married to Marg, VE3RE, licensed since 1973. He can be contacted at 1083 Notre Dame Dr, Petersburg, ON N0B 2H0, Canada, or at ve3sy@arrl.net. His Web site is www.ve3sy.com. **QST***

