An Introduction to APRS

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1 What is APRS

The Automatic Packet Reporting System (APRS)[1] developed by Bob Bruninga, WB4APR, is a lightweight AX.25[2] system that allows users to transmit location and other data in single data packets. Normally stations being tracked use GNSS receivers to provide real time tracking data.

APRS uses existing packet TNCs (terminal node controllers), Soundmodems and small, low cost micro-controller driven units to transmit standard AX.25 packets on a frequency of 144.800 at 1200 baud. APRS can also be used over HF, satellite links and smartphones.

APRS is intended as a short-range tactical system; however, APRS systems can be viewed over broad areas using internet gateways. The gateways can be run on low-cost computers, and can mediate the transmission of packets to and from the international APRS-IS system.

APRS is supposed to augment your voice system and should help reduce voice traffic - but is not a replacement for it!

Some applications of APRS have been the following:

- Post Disaster Management
  - Damage assessment
  - Liason tracking
  - Logistics management
  - Site talk in
- Search and Rescue
- Public Service Events
  - Bike Rallies
  - Parades

    - Hillwalking

- Repeater Advertising

2 How does APRS work?

An APRS station broadcasts (beacons) a single packet of information to all stations in range. This packet usually contains Global Navigation Satellite System (GNSS) co-ordinates and other information. The packet may be received and decoded by any station that can hear it and has suitable software or hardware. Digipeater (Digital Repeater) stations can also hear a packet and rebroadcast it based on rules in the digipeater software and commands that are integral to the packet. Packets that need to travel long distances can also be routed across the public internet.

The fundamental principles of APRS as described by Bob Bruninga are:

- The system should provide reliable real time, short rangee, tactical digital communications.
- Use a 1200 baud network system operating as an Aloha random access channel.
- You should hear everything nearby or within 1 digipeater within 10 minutes.
- You should hear everything within your Aloha circle within 30 minutes.

3 Whats this Aloha Circle?

In an Aloha network, stations contend for access by waiting to transmit for a random period of time and have not heard any other stations in that period. At 1200 baud, the 144.800 frequency can support 50 or so user stations at reasonable packet sizes and beacon rates. An Aloha Circle is the radius around you that contains enough stations to fully fill up the channel. This will be unique at any location (review `http://www.aprs.org/aloha.html` for more information).

There are some problems with this however. The Aloha circle definition is based on the premise that APRS packets take a finite amount of time to transmit and so only a limited number of users may operate in a given area. Poor station configuration can cause packets to travel too far over RF, causing traffic congestion in distant APRS networks, and thus making the channel unusable for those users. Also, mis-configured stations can cause digipeaters to bounce a packet back and forth, effectively blocking out all other users in the area. In addition, stations that beacon too often *steal* transmit time away from other users without getting any benefit because the change in location is too small to be seen on a map (or non-existent if the station is fixed).

This means that the rate at which an APRS station transmits beacons is an important consideration. The more often a station beacons, the fewer users can use the system. Your beacon rate should take into consideration what you are intending to accomplish and how fast you expect to be

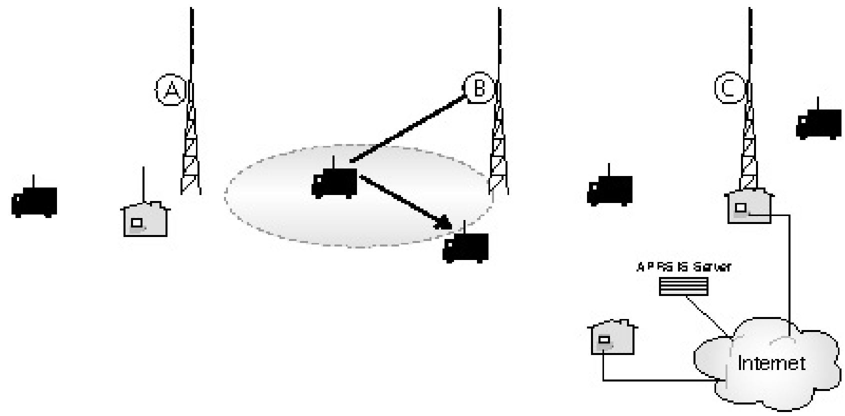

Figure 1: An APRS station beacons and is heard by every other APRS Station in direct range.

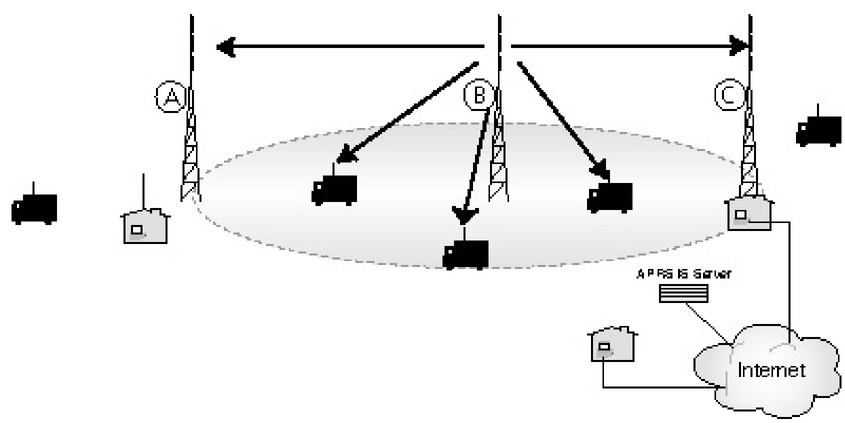

Figure 2: The packet is re-broadcast by every digi than can hear it. The packet is heard by every other APRS station in direct range, including other digi.

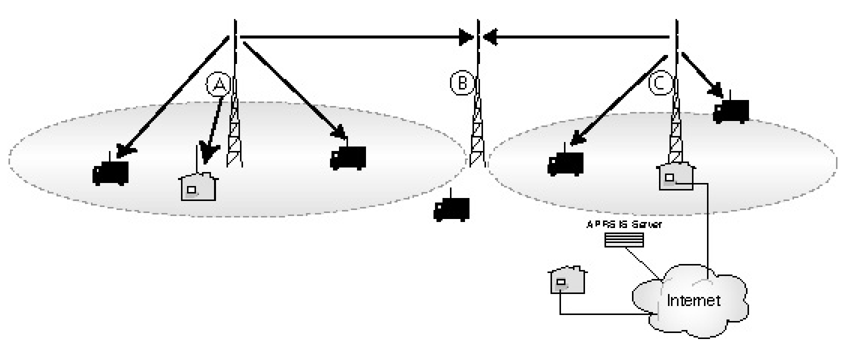

Figure 3: The packet is rebroadcast by every digi that heard the first digi. The packet is heard by every APRS station in direct range of this second set of digis, including the first one.

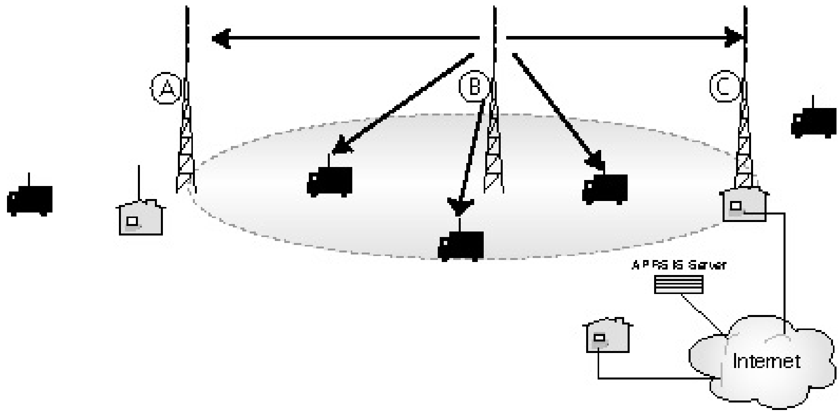

Figure 4: The packet is again rebroadcast by every digipeater in direct range of the second set of digis, including the original digipeater. The new WIDEn-n paradigm (i.e. the use of WIDE2-2 etc) is intended to control this process.

moving. Stations that expect to be moving very slowly over a large area should beacon occasionally (walking/offroading). Stations that are moving rapidly over a small area should beacon more often (or use smartbeaconing®). If you expect be tracked on a high-resolution map and the person(s) tracking you needs to know exactly where you are, then it makes sense to beacon faster.

Fixed or stationary stations (digipeaters, home stations etc.) should only beacon once every 10-30 minutes.

Mobile stations should generally beacon no faster than once every 3 minutes. With a three minute beacon rate, a station will move the following distances at a given speed:

Speed	Distance
100kph	5000m
80Kph	4000m
50kph	2500m
25kph	1250m
5kph	250m

Table 1: Speed vs Distance Travelled in 180 seconds

4 Station Types

Digipeaters A digipeater is a station that retransmits the packets that it hears. There should only be a few digipeaters in a given area i.e. they should have relatively little overlapping coverage. The Southern Ireland Repeater Group has the EI2MLD-2 Digipeater up on Mt. Leinster on the primary APRS frequency of 144.800Mhz. It is running APRS specific firmware.

Internet Gateways An internet gateway relays packets from radio to the Internet and vice versa. It can be combined with a digipeater and / or a fixed station and would require a computer

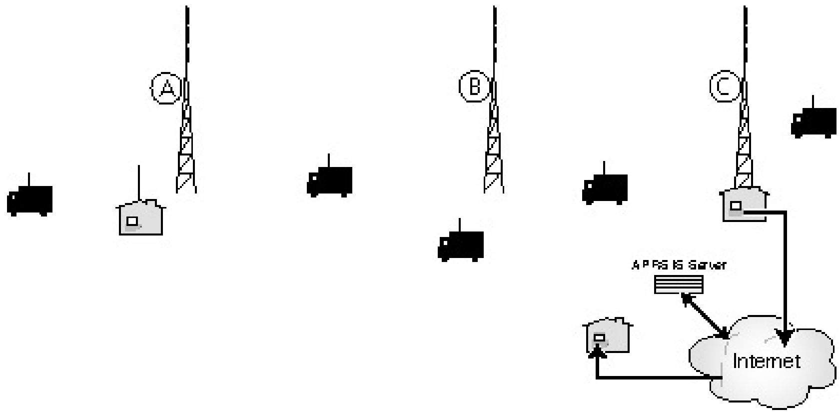

Figure 5: Any packet heard by an internet gateway is transmitted over the Internet to an APRS-IS server. This data is relayed out to any APRS software that is connected to an APRS-IS server.

and internet connection. EI3RCW-2 and EI5HBB-10 are active I-Gates in the South East.

Fixed Station A fixed station transmits APRS packets, but remains in one place. It can be used to monitor an area or to transmit local information objects.

Trackers A tracker is an APRS station that is capable of transmitting a packet containing location information. They are usually small and portable for moving between vehicles. Examples I have used are the Byonics TinyTrack/PocketTracker[3], the opentracker[4], the Kenwood TH-D72.

Mobile Station Usually a tracker semi-permanently fixed in a vehicle. This can include a computer or a suitable GPS for display purposes (e.g. Kenwood TM-D700/TM-D710)

Passive Stations A passive station only listens to APRS packets, but does not transmit anything. Generally used with a computer just to see other stations.

EI3RCW-2 and EI5HBB-10 are both currently acting as a digipeaters and I-Gates into the APRS-IS. For a number of years now the autor has been running the T2IRELAND APRS-IS aggregation server `http://ireland.aprs2.net:14501/`. This server has, on average, about 300 clients connected and generally has between 5000 and 10000 bytes-per-second going through it 24x7, 365 days per year.

5 Configuration Information

You will need to know the following information to configure your APRS station be it software or hardware:

- SSID (Secondary Station IDentification)
- Latitude and Longitude

- Via Path (Unproto Address)
- Beacon Comment
- Beacon Rate
- Status Text
- Status Rate (dealt with above)

Lets briefly examine each one in turn.

5.1 SSID

In Packet Radio you can have up to 15 Secondary Station IDentifiers (SSID's), an example is EI7IG-1 through EI7IG-15. EI7IG without an SSID extension, is considered the 0 (zero) SSID, thus it is possible to have sixteen different stations/calls on the air at the same time using our single call sign. That's where the numbers in the call sign come into play. The added dash numbers (-1 ... -15) are used to distinguish the various station(s) or node(s).

So, your SSID uniquely identifies your station. It consists of your callsign at a minimum and is transmitted every time you beacon. It is very useful when you have more than one station operating simultaneously (mobile/home/portable).

In the early days of APRS, the SSID was used to identify the 'type' of the station for display purposes (its symbol). Nowadays as almost all APRS devices are capable of having a symbol configured and included as part of the beacon this is no longer required, though this convention is still supported and mostly followed (i.e. -4 a bicycle, -9 signifies a car, -10 a motorcycle, -12 a jeep).

5.2 Latitude and Longitude

Latitude and longitude coordinates describe your location uniquely on the face of the earth. Latitude runs north and south, with values from 0 degrees at the equator to 90 degrees at the poles. Latitudes also need a N/S identifier. This may be done by setting the value negative for southern latitudes or including the letters 'N' or 'S'. Longitude runs from 0 to +180 degrees starting at a line running through Greenwich, England and going east. It runs from 0 to -180 going west towards US. This may be alternatively noted by including the letters 'E' or 'W'. APRS co-ordinates are expressed in degrees, decimal minutes format (+DD MM.mm). That is, the decimal places of the coordinate value are removed from the degrees and multiplied by 60 (i.e. the latitude +32.5000 would be expressed as +32 degrees 30.00 minutes). If you have a GNSS receiver connected to your equipment you will not have to enter this manually. The standard settings to use with a GNSS device (GPS) are NMEA[5] Out or NMEA In/Out at 4800 baud.

5.3 Via Path

15 years ago there was huge debate on the **aprssig** mailing list[1] what address should be used and in what way. consensus was reached as to what the paths should be and how digipeaters should be configured. For the really curious have a read of [6]. For the South East EI8JA and I recommend that the following paths be used.

Fixed Station WIDE2-1, this should get a packet one hop through the nearest Digipeater and onto the nearest Internet Gateway.

Mobile Station WIDE1-1, WIDE2-2, as the network expands this should get a packet three hops from (for example) a fringe coverage area into an area with an Internet Gateway. WIDE1-1 also lets lower level 'fill-in' [7] digipeaters be used where available (Cork Area mostly)

Special Event Stations WIDE1-1, this should keep the traffic fairly local

Digipeaters None, keeps traffic local

Other (less frequently used) addresses that can be used are:

GATE means 'gate packet to HF'

NOGATE, RFONLY means 'don't gate to Internet'

TCPIP, TCPXX, qXX APRS-IS only, not used on RF

As per [6] there is no support for RELAY, WIDE or TRACE in any of the digipeaters or Internet Gateways that we have configured.

5.4 Beacon Comment

The beacon comment is a piece of text that goes out with each beacon Can be anything you want, as long as it is short i.e.

Monitoring 145.525

Your web page

I would advise against using your email address as it will be picked up by spambots.

An interesting idea that could be used here comes from Bob Bruninga, which he calls APRS Voice Alert [8]. Basically this means that you do not turn the volume on the radio down, but leave it up

[1] http://lists.tapr.org/mailman/listinfo/aprssig_liststapr.org

and then set a 136.5Hz CTCSS tone to mute the speaker. This way you will not hear any packets, but anyone can call you with voice by setting a matching CTCSS Transmit Tone, then you can both QSY for your chat, and when finished you can return to your APRS configuration. This really only applies to mobile stations as a fixed station transmitting a 136.5Hz tone would cause serious annoyance to every mobile station within range. If you so desired, you could announce in your comment the CTCSS tone frequency you were using, thus anyone within range could call you, and then you could QSY.

5.5 Status Message

The status message is a text message that is transmitted with your beacon, but not necessarily every time you beacon. Generally you can set your station to transmit your status once every n beacons (where $n > 1$).

Can be used to transmit the status of your station (i.e.):

- On duty
- On station
- En Route
- Committed
- Emergency

If you are using a Tracker of some sort, or a Kenwood APRS capable radio, please, please, be careful about the "Emergency" setting. Every time an "Emergency" status message gets to the APRS Internet System (APRS-IS), all connected terminals worldwide will be alerted to your 'emergency' and, if you are very unlucky, may start calling police stations. This could be your local station or theirs in order to get assistance to you.

6 APRS Hardware

6.1 TNC

A TNC (Terminal Node Controller) is a basically a packet modem. One port interfaces to a radio, the other to a computer (or GNSS receiver).

Software package called AGWPE[9], Direwolf[10] or UZ7HO[11] can replicate the functions of a TNC, thus reducing the cost of a system.

There are some dedicated low cost devices that take the place of TNCs. These include the TinyTrak/PocketTrack and the OpenTracker, in the €50-100 range. These devices are attached to a GNSS receiver and are only for transmitting location data, they cannot receive (though the TinyTrak & OpenTracker can detect an open squelch).

6.2 GNSS Receiver

There are many GNSS receivers to choose from, in many shapes and sizes. The USA's NAVSTAR Global Positioning System (GPS) is no longer the only kid on the block, Russia's GLONASS, China's BeiDou and Europes Galileo all now operate in a similar fashion. Some are more practical than others for specific applications. Garmin and Magellan are still common handheld brands in the western world. Prices range from €100 and up. Bargains can be had(search on Ebay). With improvements in technology, receivers have gotten smaller, examples of some USB devices include `https://www.sparkfun.com/products/15733` and `https://www.sparkfun.com/products/15136` with astonishing accurancy which would not have been possible for the price (€200) only several years ago.

6.3 Radios

Whether you use a Mobile or Handheld (lower power) depends mostly on personal preference. Also, as the there is relatively little traffic in Ireland, handhelds are still ok for the foreseeable future, however as the amount of traffic increases (bold assumption!), experience in other countries has shown that attempts to use Handhelds have generally been unsatisfactory since the handhelds are having to fight mobile stations putting out 20 to 50 watts. Also worth bearing in mind is that cabling standards can be quite different for each radio / TNC combination. That said, some radios have *data* DIN plugs that allow for simple, common connections (e.g. FT817/FT7100/FT1500/FT857/FT847/Icom IC-7100 are all identical). There are some radios such as the Kenwood TM-D710 and the TH-D72/TH-D74 that have everything built in, just switch on.

6.4 Computers

You only need a computer if you want to see other stations or you want to run an internet gateway or smart digipeater. This could be a laptop, desktop or Raspberry Pi. The only thing to consider is that you can communicate with the radio modem interface. These days that could be USB, SPI (Raspberry Pi) or maybe RS-232 if you have an old TNC.

7 Getting Set Up

Older GNSS receivers, TNC's and computers generally use RS-232 connections. These tend to use either 9 pin or 25 pin 'DB' connectors. RS-232 connections were intended to connect a computer (DTE) to a piece of communications gear (DCE). If you are not sure which pin is the transmit pin and which is the receive, check the voltages between pins 2 and ground and also pin 3 and ground. Generally the pin with a negative voltage is the transmit pin. This should be connected to the receive pin on the GPS and vice versa.

If you do need a USB to RS-232 adaptor, stick to those with genuine FTDI chipsets. Life is too short for dodgy clones.

TNC to radio connections are custom depending on both the TNC and Radio. Though the *Big Three*, Yaesu, Icom, Kenwood did standardise on the 6 pin Mini-Din a number of years ago. It is becoming more difficult to find on newer radios.

7.1 GPS Accuracy

If accuracy is how correct a position is, with precision being how finely resolved a position is, then older Garmin & Magellan GPS receiver positions are often very precise, but not that accurate (switch on your GPS with a clear sky, sit still and watch the numbers slowly change). Accuracy is influenced by environmental factors including ionospheric distortion and satellite geometry.

Nowadays consumer grade GNSS receivers are accurate to 5 meters or better. Now with multiple constellations of systems, GPS, Galileo, BeiDou and GLONASS. Some are even accurate to centimers.

8 Software

If you want to see APRS stations, you will need some software. There are software packages for most operating systems:

- Windows: YACC, APRSISCE/32, SARTrack, Xasitr, PinpointAPRS
- Mac: YACC, Xastir
- Unix: YACC, Xastir
- Raspberry Pi: YACC, Xastir

And some internet based services such as findu (i.e. `http://www.findu.com/cgi-bin/find.cgi?EI7IG-9`) and aprs.fi (`https://aprs.fi/#!mt=roadmap\&z=11\&call=EI7IG-9`)

If you wish to connect to an Internet Server, I would suggest connecting to Ireland.aprs2.net port 14580. Look at `http://ireland.aprs2.net:14501` for more information on the ports available.

8.1 Discussion

In summary, APRS is a real-time tactical digital communications protocol for exchanging information between a large number of stations covering a large (local) area. As a multi-user data network, it is quite different from conventional packet radio.

APRS turns packet radio into a real-time tactical communications and display system for emergencies and public service applications (and global communications).

Although the more recent interfaces to the Internet make APRS a global communications system for live real-time traffic, this is not the primary objective. How APRS is used in an emergency or special event is what drives the design of the APRS protocol. Although APRS is used almost all of the time over great distances, and benign conditions, the protocol is designed to be optimised for short distance real-time crisis operations.

APRS provides universal connectivity to all stations by avoiding the complexity and limitations of a connected network. It permits any number of stations to exchange data just like voice users would on a voice net. Any station that has information to contribute simply sends it, and all stations receive it and log it. Secondly, APRS recognises that one of the greatest real-time needs at any special event or emergency is the tracking of key assets. Where is the On Scene Co-ordinator? Where are the emergency vehicles?[2] In order to provide for these scenarios, APRS is a full featured automatic vehicle location and status reporting system too.

Although most APRS software can automatically track mobile GNSS equipped stations, it also tracks perfectly well with manual reports. Additionally, any station can place an object on his map including oneself and within seconds that object appears on all other station displays. In the example of a parade, as each checkpoint with packet/APRS comes on line, its position is instantly displayed to all in the net. Whenever a station moves, (s)he just updates his position on his map and that movement is transmitted to all other stations. To track other event assets, only one operator needs to monitor voice traffic to hear where things are. As (s)he maintains the positions and movements of all assets on his screen, all other displays running APRS software are automatically updated.

Some Radios such as the Kenwood TM-D710/TM-D74 have APRS built in, this allows it to be used completely independently of a computer. If it is used as a home station, and the position is programmed into the radio, a distance and bearing to all received stations is available on the display, and short messages can be exchanged with other stations on frequency. With the addition of GNSS to this radio, the mobile station can be tracked in real-time on the console of any other APRS capable radio or on the screen of any APRS equipped computer.

Things change slightly with the addition of an Internet Gateway (or Igate). An Igate takes the

[2] `https://tapr.org/?attachment_id=7045`

packets heard on RF and pushes it into the APRS internet backbone. Briefly, there are several core[12] servers that exchange all packets between them, there are also second tier[13] servers which connect to these core servers. The purpose of these is to reduce the load on the core servers. The author runs a *tier two* server `http://ireland.aprs2.net:14501` hosted in the TSSG Research Group[14] in Waterford IT. The Igate which is running in Waterford IT (EI3RCW-2) is connected into this aprs-is server as are others. These send all (received from RF) position reports and messages up to `http://ireland.aprs2.net`, and also receive (and transmit to RF) all messages destined for a local APRS station. This allows someone removed from the situation i.e. in a different country, to see what is happening in an area around an Igate. This allows me, for example, to monitor APRS activity while I'm in work with no radio. I connect my APRS application, Xastir[15] to T2IRELAND, as the Igates receive packets on their RF ports they forward them to the tier 2 server, which sends them back down to me (and other clients) and also forwards those packets onto one of the core servers.

Users are encouraged to use the tier two servers, as it helps reduce the load on the core servers. If you are looking for an internet server to connect to I would recommend `ireland.aprs2.net` port 14580 (or `euro.aprs2.net` port 14580). And lastly, as a reminder the primary frequency for APRS in Ireland is 144.800, have a listen out, you might just be surprised at how many stations are within radio range.

9 Acknowledgements

This article is largely based on a presentation given by John Beadles N5OOM[16]. Many thanks to the Southern Ireland Repeater Group for the work on the network in the South of Ireland. APRS is a registered trademark of Bob Bruninga, WB4APR

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