Reproduced from the Digital Communications chapter of the 10th edition of the Radio Communication Handbook

PACKET RADIO

(contributed by Chris Lorek, G4HCL)

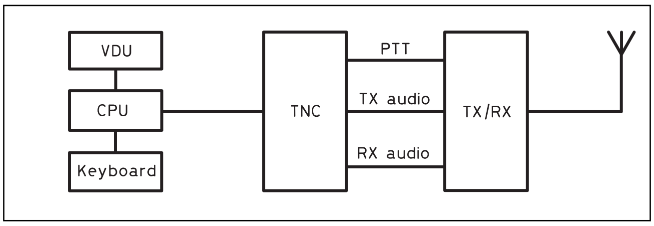

Fig 1: Block diagram of a typical packet radio station

Packet radio was the first true amateur digital, as opposed to analogue, transmission system. This makes the relaying of signals much more efficient since the data is reconstituted at each stage of the link and any end-to-end noise and distortion is simply that of the digitising process and not the transmission of the digital information.

One of the other main benefits of this mode of operation was always assumed to be that the channel could be shared by many users. Unfortunately the radio-based systems are different to computer networks in that not all stations can receive each other, thus making it more difficult for channel sharing.

As with other methods of data communications, packet radio commonly makes use of a terminal unit (Terminal Node Controller, or TNC), either a stand-alone unit or as part of a PC-based system using the sound card as an interface.

Very simply, the function of the TNC is to take the arriving data and assemble it into packets which are then passed to the on-board modem (or PC sound card under PC control) for conversion into audio tones. The receive side of the TNC performs the reverse of the tasks outlined.

On VHF the transmission speed for most end-user access is 1200 baud with tone frequencies of 1200Hz (mark) and 2200Hz (space), with 300 baud and 200Hz shift being employed for HF applications. These standards coincide with Bell 202 and 103 modems for VHF and HF respectively. A data speed of 9600 baud is commonly used for inter-site linking and for satellite communications by ground-based users on VHF and UHF. A block diagram of a typical packet station is shown in **Fig 1**.

Channel Access

The basis of a packet radio contact is that each station transmits some information and receives an acknowledgement. If no acknowledgement is received then the information is retransmitted. One of the main causes of non-receipt of acknowledgement is collision with another transmission of either the main transmission or the acknowledgement.

Early packet radio experiments made use of a channel access system in which a station transmitted without checking whether the channel was free. If the transmission was not acknowledged within the correct time slot, the TNC waited a random length of time before retrying. Current packet systems make use of data carrier detect (DCD) - they listen for an empty channel before transmitting. This is not a guarantee against collisions, because two stations may 'decide' to transmit at the same time, but it is an improvement.

AX.25 Level 2 Link Layer Protocol

Version 2 of the AX.25 Level 2 protocol was adopted by the ARRL back in October 1984. This protocol follows that of CCITT Recommendation X.25 except that the address field has been extended to accommodate amateur callsigns, and an Unnumbered Information (UI) frame has been added. This protocol formally specifies the format of a packet radio frame and the action a station must take when it transmits or receives such a frame.

At this link layer, data is sent in blocks called frames. As well as carrying data, each frame carries addressing, error checking and control information. The addressing information carries details of the station which sent the frame, who it is intended for and which station should relay it.

This forms the basis of many stations sharing the channel since any station can be set up to monitor all frames on the channel, through various stages to monitor only those intended for it and ignore any others. The error-checking information allows the intended recipient to determine if the frame has been received free of errors. If this is the case and the two stations have previously established a connection, an acknowledgement is generated by the receiving station. If errors are detected the frame is ignored and some time later the sending station resends the frame.

AX.25 Format

Packet radio transmissions are sent in frames with each frame divided into fields. Each frame consists of a start flag, address field, control field, network protocol identifier, information field, frame check sum (FCS), and an end flag. **Fig 2** shows the format of a frame and **Fig 3** shows a typical address field.

Flag field

Each frame starts and ends with a flag which has a particular bit pattern: 01111110. This pattern appears only at the beginning and end of frames. If five 1 bits show up elsewhere in the frame, a procedure called zero insertion (more commonly called bit stuffing) takes place and a 0 is inserted by the sending station and deleted by the receiving station. The receiver will therefore delete any 0 bit which follows five consecutive 1 bits that occur between the flag fields.

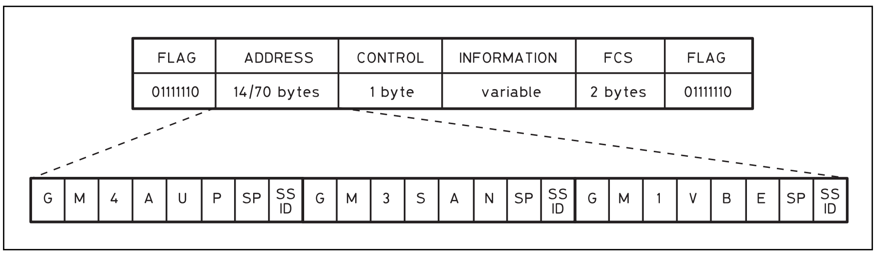

Fig 2: Format of a frame

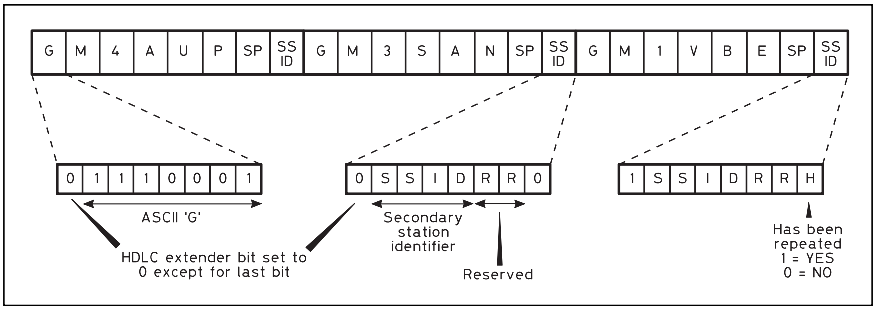

Fig 3: A typical address field

Address field

The address field consists of the destination field, source field and up to eight optional relay or digipeat stations. These fields usually contain callsigns and space is available for up to six characters per callsign with a seventh available as a secondary station identifier (SSID). This allows up to 16 different packet radio stations to operate with one callsign. The default is an SSID of 0.

For example, GM4AUP-0 could be the real-time station, GM4AUP-2 could be a personal message system (PMS) and GM4AUP-4 could be a node station. The SSID byte in the digipeater address also contains information as to whether it is repeating a frame or not.

Control field

The control field is used to identify the type of frame being transmitted and the frame number.

Protocol identifier field

This field is contained within the information field and identifies what, if any, network layer protocol is being used.

Information field

The information field contains the data to be transmitted and can contain any number of bytes, up to a maximum of 256, of information.

Frame checksum field

The FCS is a 16-bit number calculated by the sender. On receipt of a frame the receiving station calculates a FCS and compares it with that received in the FCS field. If the two match, the receiving station acknowledges the frame.

AX.25 operation

As previously described, the TNC is the device which assembles the data into frames as above. When first powered up, the TNC is in a disconnected state and is monitoring traffic on the appropriate radio channel.

In order to communicate with another station it is necessary to enter the connected state. This is done by issuing a connect frame which contains the callsign it is requesting connect status with as the addressee. If the other station is on the air it will automatically respond with an acknowledgement frame and the stations become connected.

If no acknowledge frame is received the requesting station re-issues the command a pre-determined time later and continues to do so until a preset number of tries has taken place. If no connection is established the requesting TNC issues a failure notification.

Once a link is established the TNCs enter the connected or information transfer state and exchange information and supervisory frames. The control field contains information about the number of the frame being sent and the number of the last one received (0 to 7). This allows both TNCs to know the current link status and which to repeat if necessary.

When in the connected state either station may request a disconnection which occurs after an acknowledgement is received or if no response is received after several attempts.

Packet Operation

Packet operation currently makes use of the HF, VHF, UHF and SHF parts of the spectrum with both terrestrial and satellite links being utilised. In the early days, much packet operation was real-time person-to-person operation, either direct or through a digipeater.

Most TNCs are capable of digipeat operation and this enables stations who cannot contact each other direct to do so by the on-frequency retransmission of the digipeater. Most TNCs are capable of digipeat operation and this enables stations who cannot contact each other direct to do so by the onfrequency retransmission of the digipeater. As packet became more popular the real-time operation tended to be replaced terrestrially by store-and-forward systems such as nodes, although there are Earth-orbiting digipeaters placed into operation periodically from amateur-radio equipped space stations.

Digipeaters

Most TNCs can be used as digipeaters as this function is usually contained within the AX.25 Level 2 firmware.

Fig 4 shows how two stations A and D can connect to each other using digipeaters B and C. In order for information to be passed from station A to station D via the digipeaters B and C, the information frame must be received by station D and the acknowledgement frame received by station A before a frame can be said to be successfully sent. Digipeaters B and C play no part in the acknowledgement process; they merely retransmit any frames that contain their callsigns in the digipeat portion of the address field. If the acknowledgement is not received by station A then the frame is retried over the whole path. The use of digipeaters has reduced dramatically in recent years with the advent of the network nodes.

Network Nodes

The network node significantly improved the packet radio system as a means of communicating between packet-equipped stations in both real time and by the use of mailboxes. The major advantage of a network node over a digipeater is that any frame sent is separately acknowledged between each individual element rather than along the whole chain.

Fig 5 shows a system with station A trying to communicate with station D via the nodes B and C. In trying to communicate

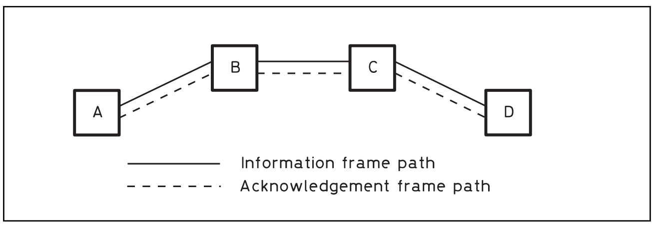

Fig 20.4: How two stations can connect to each other using digipeaters

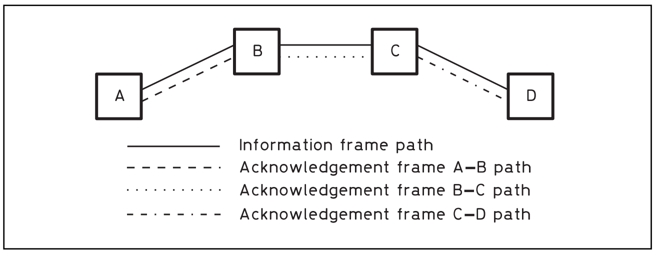

Fig 5: How two stations can connect to each other using network nodes

with each other the information is sent from station A to node B and acknowledged back to station A. Node B then passes the frame on to node C and receives an acknowledgement back. Node C then passes the frame to station D who acknowledges it back to Node C.

If anywhere in the path no acknowledgement is received, the frame is retried only over the part of the path for which no acknowledgement has been received.

There are two types of network protocol in use - virtual-circuit and datagram. In the virtual-circuit protocol the appearance of a direct connection between the two stations is provided. In order to establish communications a 'call set-up' packet is sent through the network to make a path to the other station. Once this path is established, information is sent through the circuit. Any packets sent do not have the full address of the required path because the network attempts to maintain this path for the duration of the contact. After the contact is completed the virtual circuit is cleared by removing the information on the path along the network.

An example of a virtual-circuit protocol is the RATS Open System Environment (ROSE) developed by the Radio Amateur Telecommunications Society (RATS) of New Jersey. ROSE is a firmware replacement for TNC2 clones. The virtual-circuit protocol is not very common in the UK and most networking is done using the datagram protocol.

In the datagram protocol each packet contains full network addressing and routing information. This enables a packet to reach its destination via any route still open, regardless of how reliable the network may be.

The network overhead is greater in this protocol but it has much greater flexibility and the end user does not need to know the route, only the node nearest him and the node nearest the station with which he desires to connect. Datagram protocols used in the UK are NET/ROM (and clones such as TheNET), TheNODE and Internet.

TCP/IP

The Internet protocol software was written by Phil Karn, KA9Q, and is more commonly known as TCP/IP which is an acronym for two protocols, the Internet Protocol (IP) and the Transmission Control Protocol (TCP).

In reality KA9Q's TCP/IP consists of a suite of individual protocols, Address Resolution Protocol (ARP), File Transfer Protocol (FTP), Serial Line Transfer Protocol (SLIP), Simple Mail Transfer Protocol (SMTP), Telnet Protocol, User Datagram Protocol (UDP) as well as TCP and IP.

Each station using TCP/IP is a network node with a unique IP address that has been assigned by the local IP address co-ordinator. The amateur TCP/IP network has been assigned the network name AMPRNET and all amateur addresses commence with the two digits 44, followed by three digits indicating the country code (as an example of a full address '44.131.5.2' is assigned to G3NRW). TCP/IP is becoming very popular in the UK and is said to offer many advantages over 'ordinary' AX.25.

DX Clusters

A DX Cluster provides DX operators with information on stations being worked/heard on all modes, along with information on QSL managers, WWV propagation and prefixes for example. The operation is not dissimilar to mailbox operation but it allows users to stay connected to their local DX Cluster for so long as they wish to receive announcements. The type of announcement the user receives is customised to suit his own needs and can be used to select prefix information, band information, mode information or a combination of all those.

Each cluster is generally referred to as a cluster node and these nodes can be connected together to each other via the packet network. This enables an item of DX information (commonly referred to as a spot) to be propagated to all other cluster nodes in the network, thereby in theory enabling all connected users to see this spot in a short timeframe.

DX Cluster spots are quite common on virtually all contesting software, in lots of major SSB and CW contests, as well as being in use by all major DXpeditions. Some stations remain connected to the Cluster all the time and have an audio warning from their PC to tell them about any DX that might be available. Internet-based DX Clusters are commonly used as an alternative to radio-based DX Cluster connections where the station can be connected in this way. Using appropriate software on a PC, received DX cluster spots can be used to automatically tune a transceiver to the DX station's transmitting frequency and mode if a 'wanted' country is identified, as well as making the appropriate log entry automatically once contact has been made.

Packet Radio Bibilography

Further information can found from the following books and periodicals:

- *Your First Packet Station*, Steve Jelly, G0WSJ, RSGB, 1996.
- *Packet Radio Primer*, Dave Coomber, G8UYZ, and Martyn Croft, G8NZU, RSGB, 2nd edition 1995.
- *NOSIntro*, Ian Wade, G3NRW.
- *AX.25 Link Layer Protocol*, ARRL.
- *ARRL Handbook*, ARRL.
- *RadCom*, the RSGB members' magazine.

Information on licensing and policy matters with regard to data communications is available from the datacomms section of the RSGB's Emerging Technology Coordination Committee.