AX.25

"Sniffing out" this protocol for packet radio networks

Richard R. Parry

Wireless communication systems are changing at an unprecedented rate. The explosion in cellular phone communication is just one example. There also appears to be no stopping it, as satellite based systems are already on the drawing board and should be operational by 1998. With these systems, no longer will a user be tied to sparsely spaced highway cell sites; the satellite constellation overhead will provide communication coverage virtually everywhere on earth.

The wide acceptance of portable laptop computers and the demand for "anywhere, anytime" Internet access has forced the development of new protocols such as Mobile-IP. This demand also has placed additional burdens on a limited frequency spectrum. It is imperative that the frequency spectrum be used wisely. For this reason advanced modulation techniques have been developed to allow multiple users access to the medium.

For example, data networks allow many users access to a Local Area Network (LAN). For voice networks, modulation such as Code Division Multiple Access (CDMA) allows users the ability to access the same frequency spectrum simultaneously in the wireless world.

Amateur radio operators have also developed wireless digital networks for communication. These networks allow operators to communicate with each other throughout the world. Communication can be as short as a few miles or as distant as global communication using satellite and terrestrial RF.

Popular modulation techniques range from simple radioteletype (RTTY), to more complex modulation schemes including Amateur Teleprinting Over Radio (AMTOR), packet radio (PACKET), and Packet Amateur Teleprinting Over Radio (PACTOR). All these communication techniques and protocols were developed specifically to meet the unique requirements of the wireless environment.

For packet radio networks, the AX.25 data link layer protocol is most often used. However, TCP/IP (Transport Control Protocol/Internet Protocol) is also popular. The AX.25 protocol is a variant of the international X.25 protocol applied to wireless communication and packet radio.

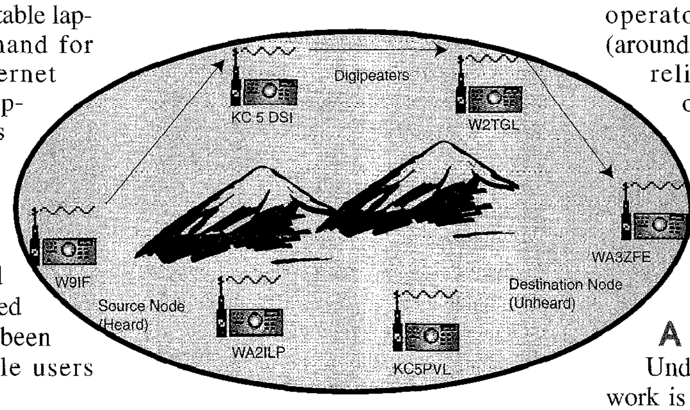

***Fig. 1** The AX.25 protocol supports source routing, which allows station W9IF to send a packet to WA3ZFE by specifying a path through KC5DSI and W2TGL. This method causes delays, but allows a station to connect to a station that would normally be unreachable.*

Most networks are composed of copper or fiber optic cable and provide reliable communication between hosts. The wireless medium is vastly different. It is less reliable and suffers from phenomena that are not present in conventional wired networks. For example, in a cable network all hosts on a network can hear each other. This makes "carrier sense" protocols such as Ethernet easy to implement. Before any host seizes the network, it first listens to help avoid collisions.

Wireless networks also support carrier sense. However, hosts on the network cannot always hear each other for numerous reasons. Buildings and the local terrain are two important factors that determine ability to receive information.

Other less obvious factors also affect the performance of a wireless network. For example, communication in the 3 to 30 MHz range varies over the course of the day. It drastically changes after sunset. The medium is also affected by the eleven-year sun-spot cycle and man-made interference. While amateur radio operators can make long distance (around the world) connections, most reliable operation and activity occurs above 50 MHz and is restricted to line-of-sight communication. We will concentrate on the analysis of AX.25 packet radio networks operating in the 144-148 MHz band.

A network analyzer

Understanding and studying a network is a complex matter. Fortunately, network analyzers, sometimes called "sniffers," are available to aid the packet user in understanding how a network operates. XNET is a network analyzer developed specifically to examine AX.25 networks. It is the result of the author's interest in networks, amateur radio, and graphical user interface applications. Even for those with no interest in using a network analyzer program, the diagrams here and on the XNET Home Page clearly show how a packet network functions.

Before examining the diagrams created by XNET, a grasp of *connection oriented* protocols such as AX.25 is necessary. Figure 1 shows several stations (also called nodes). The lines indicate packet traffic from a source to a destination. In a wireless LAN, all stations cannot be assured of hearing each other directly. Obstructions often prevent two stations from communicating, despite their proximity.

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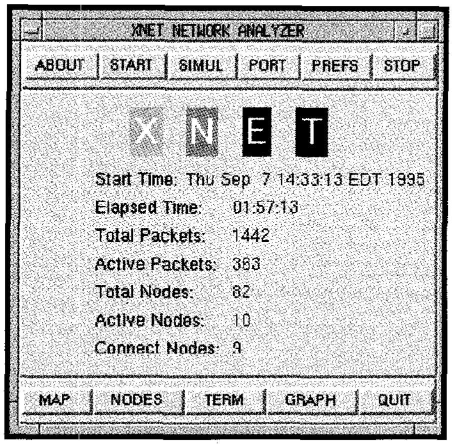

Fig. 2 The main XNET window is the control point for the network analyzer. The user may select several options including a simple terminal window that shows raw text packets, a node window that lists packet statistics in tabular form, a graph window to show network utilization and a map window that shows stations in a graphic format.

Fortunately, the AX.25 data link layer protocol supports source routing. This allows a station to specify the path of the packet. The process is called "digipeating" by amateur radio operators. The lines shown at the top of the figure show how the distance may be extended in a wireless network using digipeating. Specifically, station W9IF uses KC5DSI and W2TGL to repeat the packet and pass it along until it reaches the destination station WA3ZFE.

As traffic increases, networks can become overloaded causing delays that can make the network unusable or fail. Even in networks that appear to be functioning, there remains a need to monitor the network to assure that it is working properly.

Ideally, before a network is constructed, it should be modeled to ensure the design requirements will be met. However, even with modeling, the network should be analyzed during operation. Design goals should be confirmed and ways to improve the network should be sought. XNET is the network analyzer tool that performs this important function.

XNET is an X-Windows based network analyzer that collects and displays network data allowing the user to understand network traffic and channel utilization. The program is written in Tcl/Tk (Tool Command Language/ Toolkit). It can operate on any computer system supporting the language and the UNIX operating system. Additional hardware necessary to use XNET include a radio receiver and a Terminal Node Controller (TNC) which are common equipment used by all packet radio operators.

Functions performed by XNET include:

- Packet counting,
- Displaying network stations and stats,
- Graphical representation of network utilization,
- Display of raw network traffic,
- Playback of network traffic,
- Showing network connections,
- Using color and GUI for navigating.

Main console

When XNET first begins, a single window, called the "console," is displayed, as shown in Fig. 2. This console provides the primary user interface for operation and control. The main console's primary purpose is to allow the user to select desired features such as the MAP, TERM, NODES, and GRAPH windows, as well as setting preferences using the SIMUL, PORT, and PREFS windows to configure the program. The START and STOP buttons perform the function of beginning and ending the program. The ABOUT button provides a short description of the program, author, and version.

The *Start Time*, as shown in the console, is the time and date when XNET was started by the user. *Elapsed Time* represents the duration in hours, minutes, and seconds since it was started.

Total Packets indicates the total number of packets received from the starting time and date. *Active Packets* are packets from stations that are currently active on the network. In this example, during the nearly two-hour duration that the program operated, a total of 1,442 packets were received. Of these, 363 packets were received from nodes that are still on the network, the remaining packets are from nodes that are no longer active.

Total Nodes represents the total nodes that have been monitored from the initial *Start Time*. This value is similar to the *Total Packets* since it represents all nodes that are presently on the network as well as those that have disconnected from the network. *Active Nodes*, as its name implies, represents all nodes that are currently active on the network.

Connect Nodes represents the number of nodes displayed in the MAP window. All the nodes listed in the MAP window are nodes which have transmitted packets or have been sent packets. In the example, during the running period, eighty-two nodes were active on the network, only ten nodes are currently active, and nine of the nodes have sent and received packets.

Map window

The "map" window gives the "big picture" of the network. It is a graphical representation of a heard node sending packets to a destination node.

Referring to Fig. 3 (a) (pg. 16.), first note that each node is drawn twice, once as a source (left side) and once as a destination (right side). In addition, a line always represents packet traffic from source to destination (i.e., left to right). In Fig. 3 (b) we see Node1 sent a packet to Node2 resulting in a line. When Node2 returns a packet to Node1, another line is drawn, the result is a *connection.*

AX.25 is a *connection oriented protocol.* To a telecommunications engineer this has a very specific meaning. If a node sends a packet to another node, a line is drawn from the source to the destination node. If the destination node returns a packet to the source node, XNET assumes a connection between the nodes.

A few more terms are important to understand. *Heard Nodes* are stations that have transmitted a packet. Nodes that have been sent a packet are referred to as *Destination Nodes.* They may or may not be connected to the network.

When a node sends a packet, we have no way of knowing if that destination node is on the network until that destination node returns a packet. Then and only then is it promoted to *heard station* status. Other nodes which are on the network, but not heard directly, are referred to as *unheard stations* and are not displayed on the map.

We are now ready to examine the information provided by an XNET map. Figure 4 was developed from monitoring on-the-air packet networks in Dallas, Texas. It is important to emphasize that not all nodes are displayed; the map displays only heard stations and stations that have been sent a packet. In the figure, N5AUX sends a packet to node ESY and ESY returned a packet to N5AUX. This results in a connection.

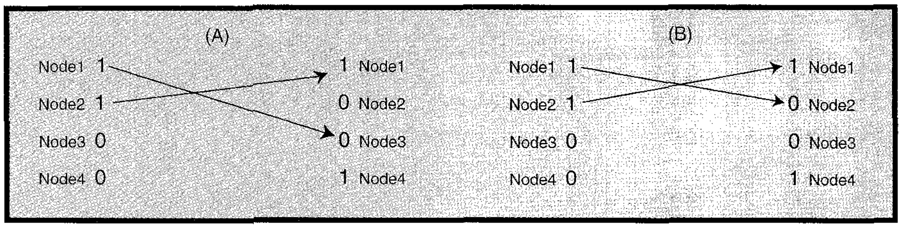

Fig. 3 ***These figures illustrate the basic design for an XNET map. AX.25 supports connectionless transmission of packets as shown in (A). AX.25 is also a connection oriented protocol as shown in (B).***

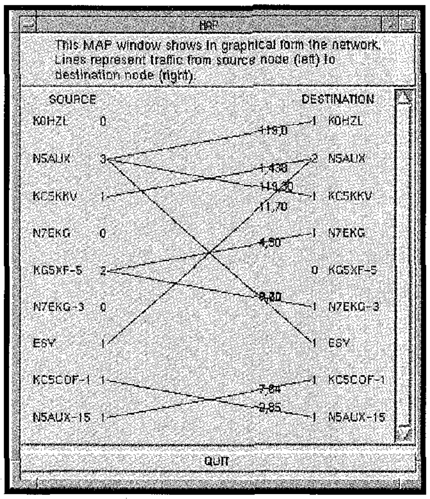

Fig. 4 ***Each station is shown as both a source on the left and as a destination station on the right. On a color monitor, connection packet traffic is blue and connectionless traffic is brown.***

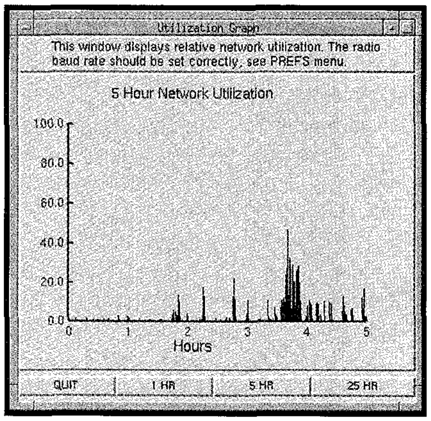

Fig. 5 ***This graph shows network utilization during a five hour period. XNET supports three sampling periods. The amplitude of the graph is a function of the number of packets received during a one-minute period.***

In a similar manner, N5AUX is also connected to KC5KKV. KC5COF and N5AUX-15 represent a third pair of connected nodes. The remaining nodes are not connected. This means that packets have been sent, but the destination nodes did not return a packet to the sender.

The XNET maps provide additional information. Near the destination node column on the right of the map are a pair of numbers. The first number is the number of packets sent to the destination node by the source node. The second value is the age in seconds of the most recent packet.

For example, ESY has sent eleven packets to N5AUX and 70 seconds has passed since that packet was transmitted. Similarly, KC5COF-1 has sent two packets, and 85 seconds has elapsed since the last packet. Keeping track of time is critical, since this is the method used by XNET to determine if the node has left the network.

Graph window

The "graph" window shown in Fig. 5 provides channel utilization information. This window can display utilization for 1-, 5-, and 25-hour intervals. The graph shows *relative* rather than the *absolute* value of network utilization. Specifically, XNET computes channel utilization based on the number of characters received during one minute sampling periods. The magnitude of the vertical line is based on the radio baud rate selected by the user in the PREFS menu.

Other windows

XNET provides the user with several additional windows. There are three preference windows: SIMUL, PORT, and PREFS. They allow the user to configure and select operating and configuration preferences which are saved and used each time XNET begins. The SIMUL window allows the user to select between the serial port of the computer or one of the pre-recorded simulations. If the serial port is selected, the PORT window needs to be configured for parameters such as the baud rate, number of stop bits, and parity type. Selecting a simulation is ideal for testing and educational purposes. The simulations are prerecorded network packet traffic.

Conclusion

XNET is intended to provide information about AX.25 packet radio networks that are difficult to ascertain by other means. The program displays network statistics in both tabular and graphical form. The reader is encouraged to browse the XNET web page for further examples which greatly enhance the ease of understanding a network.

Distribution

XNET is available under the GNU General Public License, Version 2, June 1991, Free Software Foundation, Inc., 625 Massachusetts Avenue, Cambridge, MA 02139. It may be downloaded from the author's home page at http://people.qualcomm.com/rparry/xnet

Read more about it

• Fox, Terry L., "AX.25 Amateur Packet-Radio Link-Layer Protocol, Version 2.0," October 1984, American Radio Relay League, Inc., Newington, Connecticut, October 1984.

• Ousterhout, John K., *Tcl and the Tk Toolkit*, Addition-Wesley, Reading, Massachusetts, 1994.

• Sproul, Mark, "Packet Tracker: A Graphical Packet Tracking Program," 12th ARRL Digital Communications Conference, Tampa, Florida, September 1993, pp. 76-82.

• Welch, Brent B., *Practical Programming in Tcl and Tk*, Prentice Hall, Upper Saddle River, NJ 1995.

• Key Tcl/Tk Web page URLs
http://www.sunlabs.com:80/research/tcl/
http://www.sunlabs.com:80/~rjohnson/tc/
http://wwwtios.cs.utwente.nl/~binkhors/tcl.html

• Amateur Radio Specific Linux Web page URL
http://www.Hams.com/perens/HamRadio.html

About the author

Richard Parry holds a BS in Electrical Engineering from the University of Illinois (Urbana, Illinois), an MBA from Northern Illinois University, (Dekalb, Illinois) and an MSCS from North Central College (Naperville, Illinois). He is attending the University of California-San Diego working on a Ph.D. in computer science and engineering.

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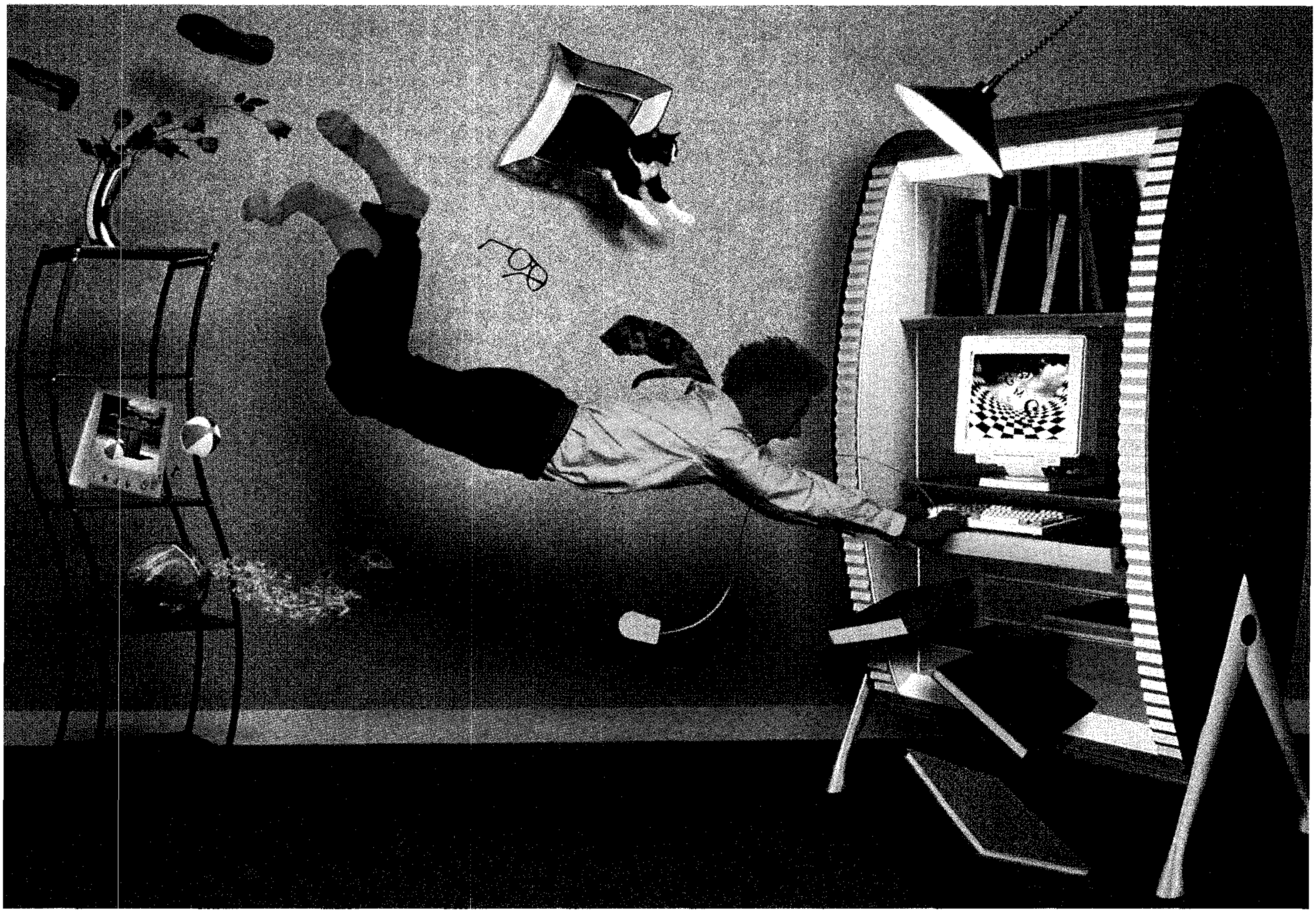

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