AX25

Analyzing Packet Radio Networks

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ABSTRACT

This paper describes AX.25 packet radio networks using XNET, a software program specifically designed for this unique type of network analysis. Networks are complex entities most easily explained visually. Through the graphical displays, one can more easily gain an appreciation and understanding of network behavior. *XNET* runs on UNIX/LINUX systems supporting the Tcl/Tk language. XNET is the result of a Master's degree project requirement completed in May, 1995 at North Central College, Naperville, Illinois. All source code is released under the terms of the GNU General Public License and is available at the author's home page.

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INTRODUCTION

Wireless communication systems are changing at an unprecedented rate. The explosion in cellular phone communication is just one of many examples. 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 and placed additional burdens on 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 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 of 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 is also popular. The AX.25 protocol is a variant of the international X.25 protocol with modifications to meet the unique requirements of wireless communication and packet radio in particular.

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 phenomenon 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, not all hosts on the network can hear each other for numerous reasons, buildings and the local terrain being 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 and it drastically changes after sunset. The medium is also affected by the 11 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.

This paper will concentrate on the analysis of AX.25 packet radio networks operating in the 144-148 MHz band.

XNET: 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 who have no intention of using a network analyzer program such as XNET, the diagrams in this paper and the XNET Home Page on the World Wide Web should prove to be of interest as they clearly show how a packet network functions.

Before examining the diagrams created by XNET, a firm grasp of *connection oriented* protocols such as AX.25 is necessary. Figure 1 shows several stations (also called nodes) with lines used to 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. Fortunately, the AX.25 data link layer protocol supports source routing which allows a station to specify the path of the packet. This 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.

It is not hard to imagine that 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 ascertain that the design requirements will be met. However, even when modeling is performed, the network should be analyzed during operation to confirm design goals and to understand how the network may be improved. XNET is the network analyzer tool that performs this important function.

XNET is an X-Windows based network analyzer that will collect and display network data allowing the user to understand network traffic and channel utilization. The program is written in Tcl/Tk (Tool Command Language / Toolkit) and 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 statistics
¥Graphical representation of network utilization
¥Display of raw network traffic
¥Playback of network traffic
¥Visual display of network connections
¥Extensive use of color and GUI for navigating

MAIN CONSOLE

When XNET first begins, a single window, called the “console”, is displayed as shown in Figure 2. This console provides the primary user interface for the operation and control of XNET. 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, and 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 XNET 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 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, 82 nodes were active on the network, only 10 nodes are currently active, and 9 of the nodes have sent and received packets.

MAP WINDOW

The "map" window gives the "big picture" of the network. It is intended as a graphical representation of a heard node on the network sending packets to a destination node. Before examining an example map, a few network concepts and definitions are important to understand.

Referring to Figure 3 (A), 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). If Node2 sends a packet to Node1, a line is drawn from Node2 on the left (source) to the Node1 on the right (destination). Similarly, if Node1 sends a packet to Node4, a line is drawn from Node1 on the left (source) to Node4 on the right (destination). In Figure 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*. A further explanation of connected Nodes is in order.

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* and 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 resulting in a connection. 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, meaning 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 11 packets to N5AUX and 70 seconds has passed since that packet was transmitted. Similarly, KC5COF-1 has sent 2 packets, and 85 seconds has elapsed since the last packet. Keeping tracking 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 Figure 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, that allows 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. Through the use of graphical displays, color, and an easy to use interface, the program provides an excellent tool for the analysis of amateur radio AX.25 networks. The reader is encouraged to browse the XNET web page for further examples and colorful map displays which greatly enhances 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://www.qualcomm.com/~rparry/xnet.html`.

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   `http://www.sunlabs.com:80/~rjohnson/tcl/`
   `http://wwwtios.cs.utwente.nl/~binkhors/tcl.html`

6. Amateur Radio Specific Linux Web page URL
   `http://www.rahul.net/perens/LinuxForHams/`

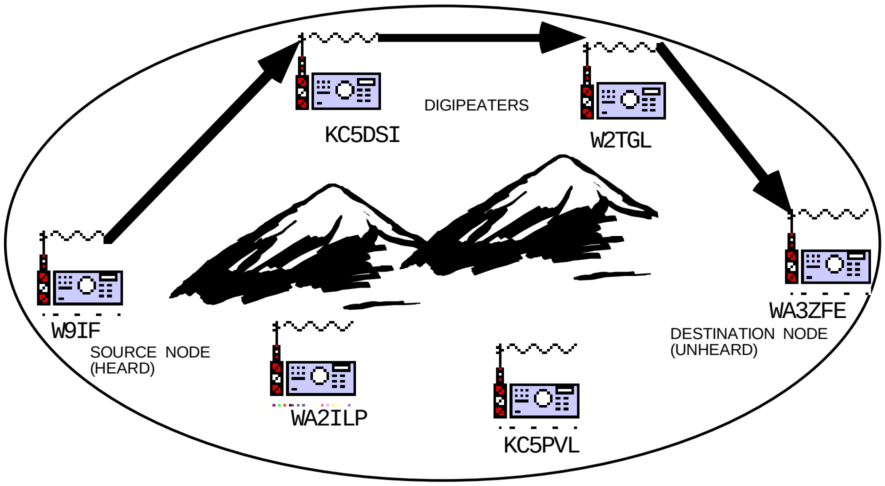

FIGURE 1

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. Using this method causes delays, but allows a station to connect to a station that would normally be unreachable. This illustrates one of the many differences between wire and wireless networks.

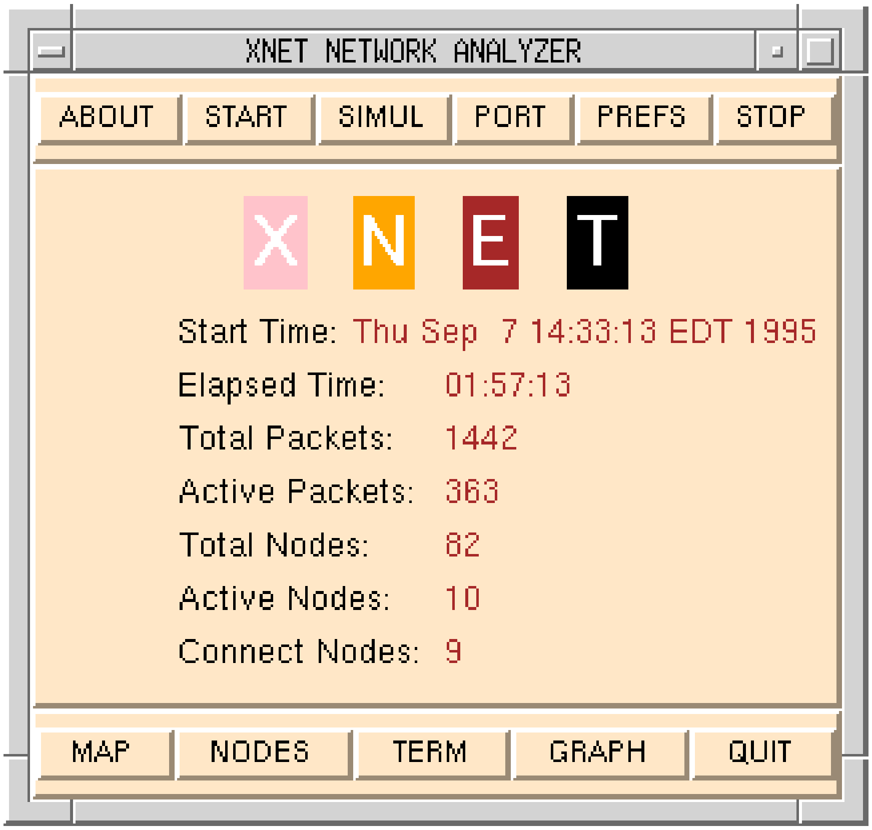

FIGURE 2

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 which shows stations in a graphic format.

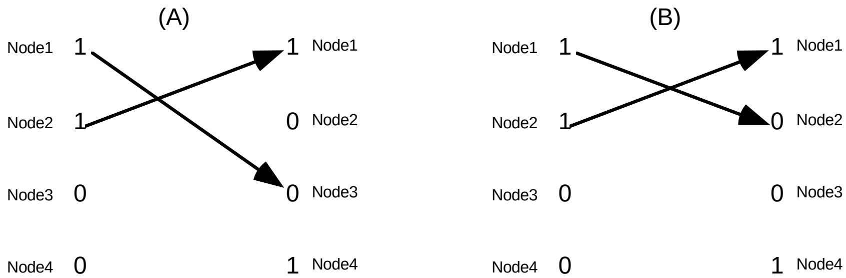

FIGURE 3

These figures illustrate the basic design for an XNET map. AX.25 supports connectionless transmission of packets as shown in (A). Node 1 sends a packet to node 3 and node 2 sends a packet to node 1, but neither acknowledges receipt of the packet. AX.25 is also a connection oriented protocol as shown in (B). Nodes 1 and 2 send packets to each other which is interpreted by XNET as a connection.

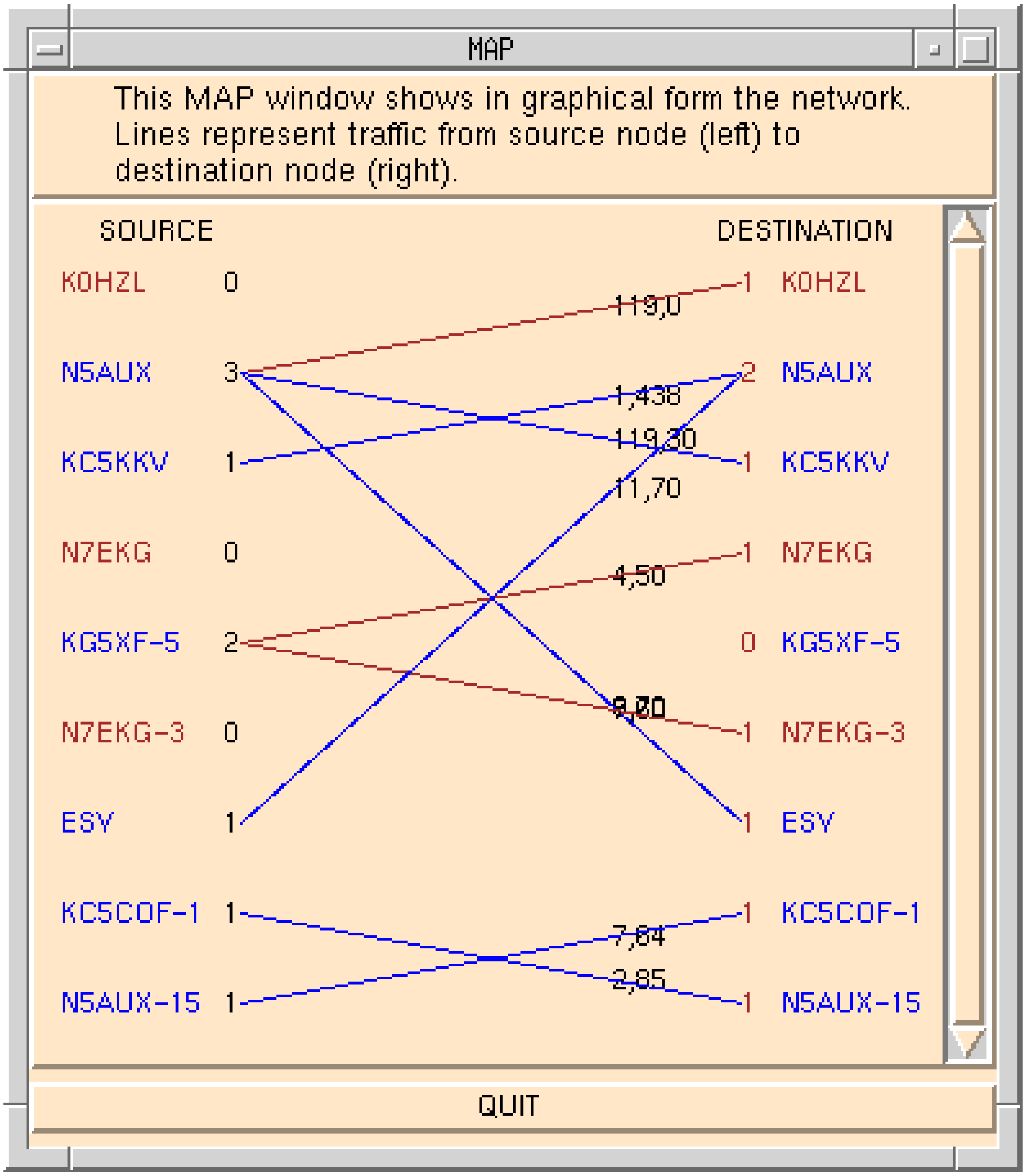

FIGURE 4

Each line from a source to a destination represents the flow of one or more packets. Each station is shown as both a source on the left and again as a destination station on the right. When viewed on a color, monitor connection packet traffic is blue and connectionless traffic is brown.

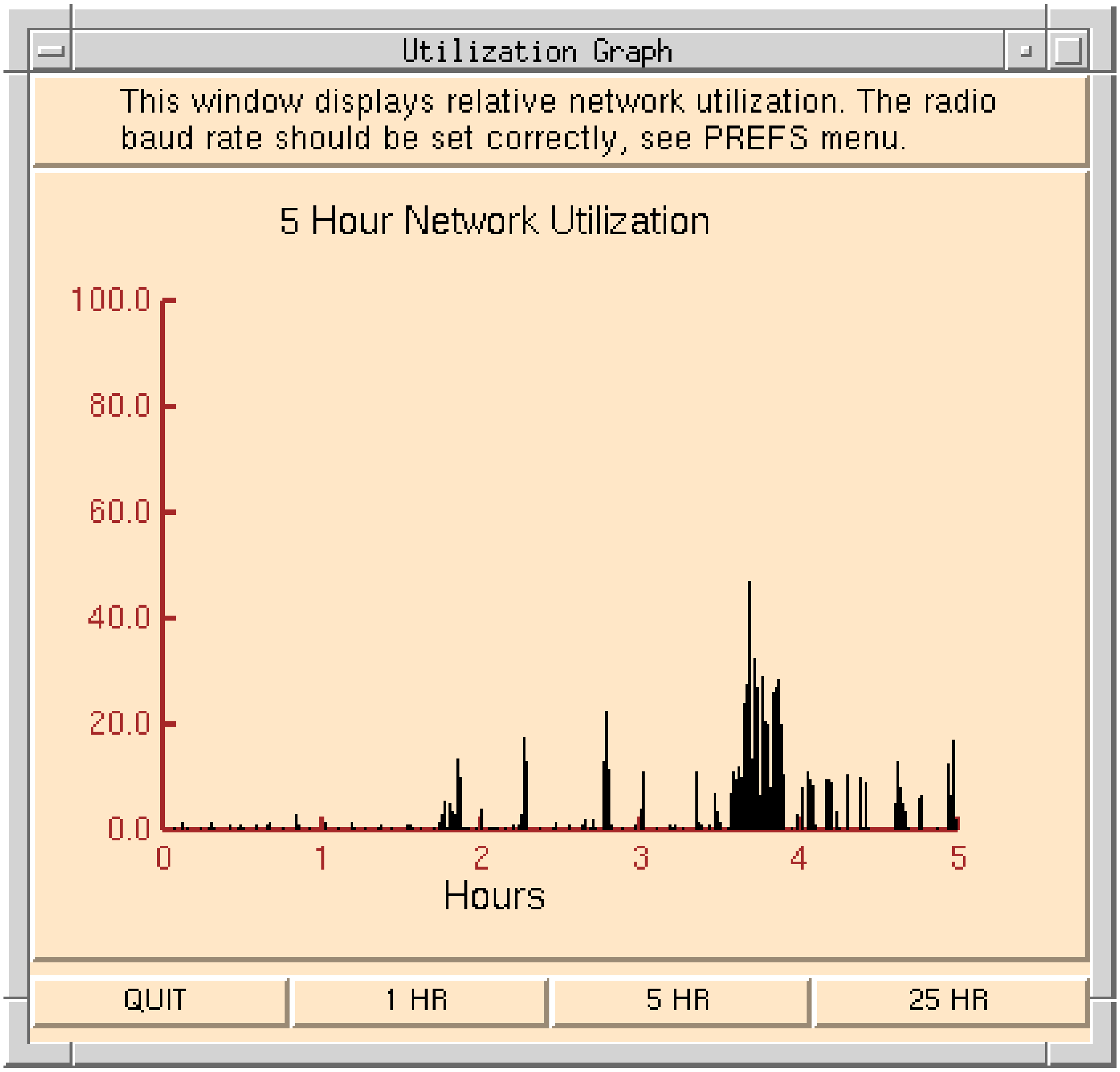

FIGURE 5

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.