PRINCIPLES OF RADIO NETWORKING

The primary focus of this chapter is the basic concept of radio networking. The ideas are not difficult. Unfortunately, however, the language which is often used can be difficult to understand because of the intense academic study around networking. Those terms which really do apply to ham networks will be explained and so will the concepts. Chapters 9 & 10 describe several types of networks which are in wide use by hams.

8.A WHAT IS A NETWORK?

The "Webster's New Collegiate Dictionary" (1974) provides the following definition of a network:

> **net-work** n 1: a fabric or structure of cords or wires that cross at regular intervals and are knotted or secured at the crossings 2: a system of lines or channels resembling a network 3: an interconnected or interrelated chain, group, system <a network of hotels> 4a: a group of radio or television stations linked by wire or radio relay 4b: a radio or television company which produces programs for broadcast over such a network.

In a very general sense, personal packet stations can thus be considered a network. This general sense of networking is inherent in the very construction of packet radio. At this level, nodes are not an issue. Software (such as LanLink) in personal stations can make this happen pretty easily at individual stations. These stations can also be used as digipeaters for wide-area service but such a network requires a very high knowledge of every detail.

In the narrow sense, a network is a system of stations (called, in our case, nodes or packet switches) that are linked by radio or other methods. Nodes provide connection services. But if the node is isolated from other nodes, the connection service is local, only; if the node has no user access, the connection service is wide-area, only.

8.B WHY HAVE NETWORKS?

There are a number of reasons why networks are so attractive.

8.B.1 WIDE-AREA CONNECTION SERVICES: Users (usually) do not need to know the details of network operation or structure to reach moderately distant network points. The degree to which network details are hidden depends on the network protocol being used. There are several protocols in general ham use (NET/ROM, TexNet, FlexNet, ROSE, TCP/IP) and each hides network details to varying degrees and in varying ways.

8.B.2 ERROR CORRECTION: All of the protocols we use provide additional error correction beyond that of basic packet stations or digipeaters.

8.B.3 FAULT TOLERANCE: When reasonably well designed, networks provide some degree of equipment failure tolerance. When one part of the network fails, the network provides alternate ways of providing its wide-area connection service. Usually, the wide-area connection service continues in the presence of the failure without any special action on the part of the user (unless the failure involves either the network destination or the one-and-only way to reach the destination). The degree to which intervention is required by node operators depends on the protocol.

8.B.4 GOOD OPERATION: Lest this list of good reasons for having a packet network leave you with a "warm-fuzzy" feeling, be aware of this: the mere existence of a network does not guarantee good operation! There are quite a few technical reasons why a given network might not work well. See, particularly, section 8.D.

8.C NETWORKING NODES & SWITCHES

The terms node and switch are generally synonymous. But, generally, ROSE networks call their nodes packet switches and NET/ROM networks call their's nodes. Here, the term node will be used with the understanding that the term is intended to apply equally to those devices frequently called packet switch.

A node manages networking details. What the details are and how they

are managed depend greatly on the protocol in use.

Nodes often, but not always, provide network access to users. Sometimes, nodes are set up only for the purpose of joining two sections of a network; if there is little or no reason for user access at that point, the node operator may economize and leave out the radio for user access. In some cases, such as TCP/IP and certain other personal-use mailboxes, personal stations may also be nodes.

Nodes sometimes offer other services beyond the basic connection services. This often include bulletin boards, weather servers, etc.

Occasionally, nodes are isolated (that is, not part of a network). This may be true because of geography or it may be true because the node operator does not want it to be part of a wide-area network. In either case, such nodes can only provide local services (mailbox, etc).

8.D NETWORK ARCHITECTURE

There is a variety of network architectures in use throughout the country. Lets look at several examples which are independent of the networking software. They apply equally well to Net/Rom, ROSE, TexNet, FlexNet, or TCP/IP. There are also a significant number of networks which contain "worm-holes". These are links which are not traditional ham-radio links. They may be commercial satellite links. They may be internet links (see Chapter 15). They may be leased or "borrowed" links on commercial common carries such as AT&T, or SPRINT using cable, microwave, or optical fiber. The presence of these links does not really alter the schemes shown below. Just imagine that one of the links shown as an RF link is some other medium which has the same end-end Physical Link characteristics (see section 11.C).

8.D.1 SINGLE FREQUENCY NETWORK: One of the first networking schemes used the same frequency for users and node-to-node linking. This system is still widely used in parts of British Columbia, Alberta, Montana, Wyoming, Southeastern Idaho, parts of Utah, and Nevada (all on 145.01MHz). Northern California and Southern Oregon also have single frequency systems.

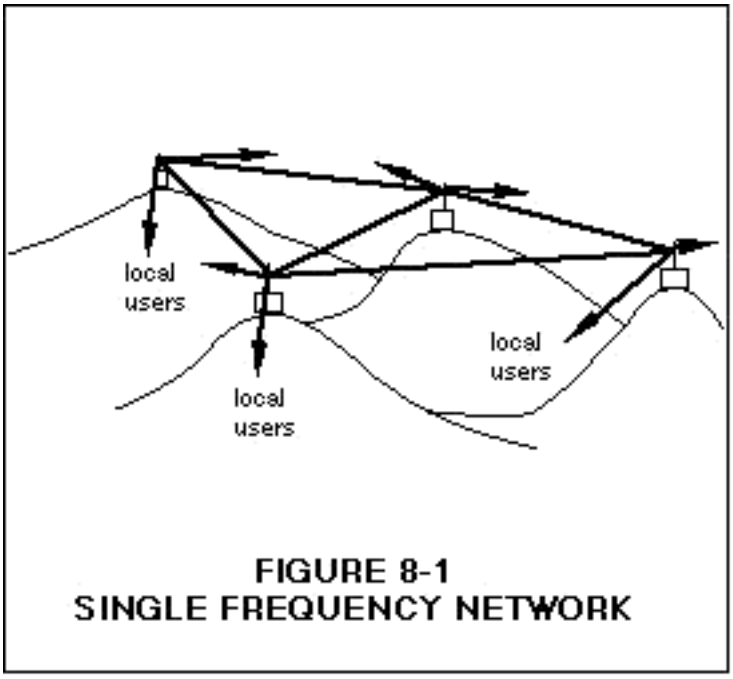

FIGURE 8-1
SINGLE FREQUENCY NETWORK

These work fine so long as the user level is low. This kind of network can, however, become easily overloaded as one node's users are hidden to the next node. Similarly, with a network which covers a very wide area as these often do, many nodes are hidden to others in the same system. Under the right circumstances (not very many users), the system does work.

8.D.2.WIDE AREA BACKBONE: The next evolutionary step and a substantial improvement over the single frequency network is the addition of a "backbone". Here, every node contains two transmitters operating on different frequencies. One is for users and one (same frequency for all nodes) is for node-to-node linking. This is shown in Figure 8-2.

Since each user frequency of each node is different, one node's users are of no importance to the next node. Congestion drops significantly. Users see a great decrease in retry rate and the time required for packets to move between nodes drops significantly.

The change to this network style usually occurs because of user pressure. And the change is usually accompanied by a rapid growth in new users (or "old" ones returning because it now works much better). In fact, there is a common belief that the single frequency systems continue to operate only because its poor performance discourages growth in user numbers! In many metropolitan areas, the growth has

been so great that even this style is no longer adequate.

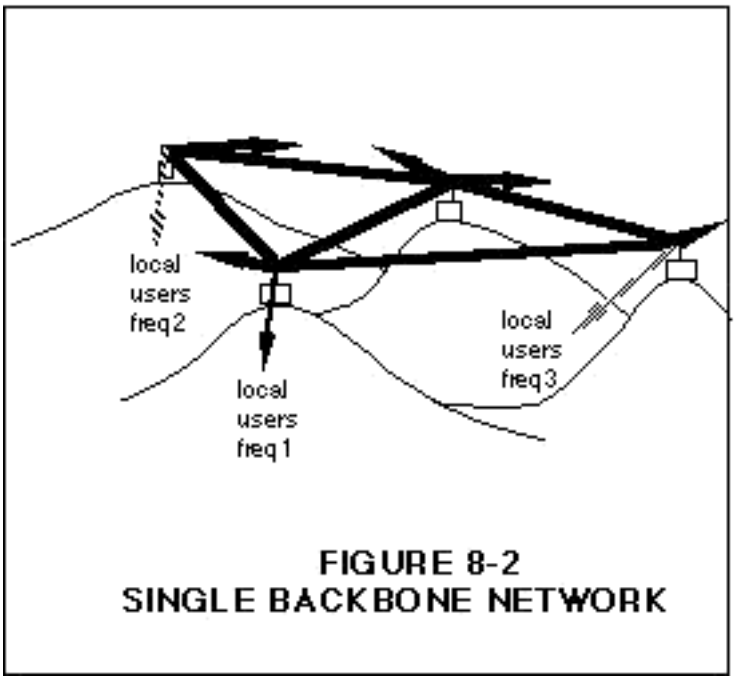

FIGURE 8-2
SINGLE BACKBONE NETWORK

What's wrong with this network? The problem is that it covers a large area on a single backbone frequency. Some parts of the network are hidden to other parts. Studies by W0RLI and others in the Portland, Oregon area have shown that the maximum number of nodes on a single frequency when BBS forwarding is involved should not exceed about 4!

8.D.3 BACKBONE "CLUSTERS": The cluster system places a few neighboring nodes on a single backbone frequency (which is a different frequency than the one used for the same purpose by other near-by nodes). The nodes on a single frequency form a "cluster". Then, another frequency (often on a different band) is used to join clusters. Figure 8-3 illustrates this arrangement.

In the Northwest, frequencies near 223 MHz (1.25 Meter band) are often used for cluster frequencies and frequencies in the 70cm band (near 430 MHz or 440 MHz) are often used for cluster-cluster linking. There is, however, no firm rule about frequencies used. In Southern California and Nevada, 50MHz band (6 Meter band) has been used. Frequencies above the 70cm band have also been used.

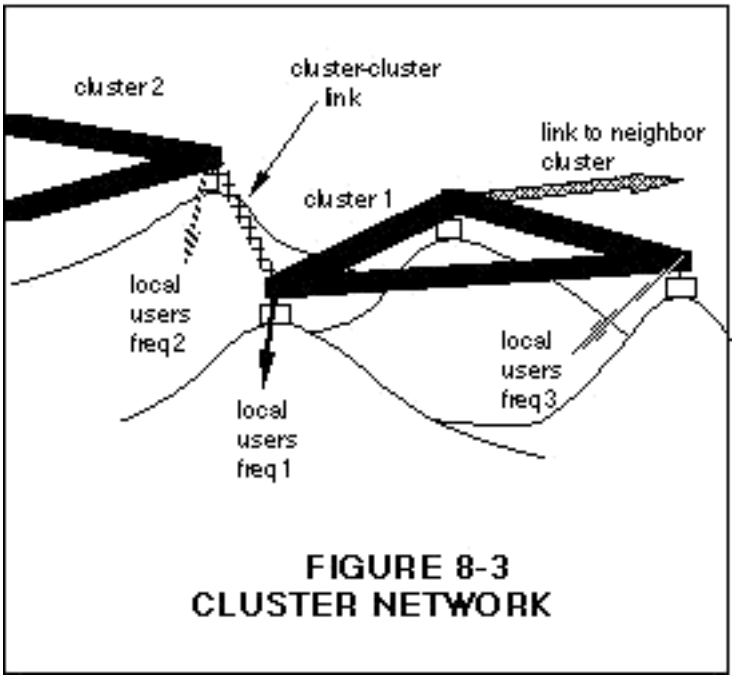

FIGURE 8-3
CLUSTER NETWORK

This arrangement requires at least some of the nodes in a cluster to contain 3 (or more) ports. Of course, this raises the cost of a node. And not all sites can provide antenna space or power for such installations.

8.D.4 POINT-POINT LINKS: As clusters shrink in number of members, the extreme case is that each frequency has only 2 nodes. The links are then called "point-point" because they go from one single point to another. This style of network is shown in Figure 8-4.

If the link is reasonably good, the retry rate drops to a very low value because there is no competition for the frequency. Directional antennas can now be used between nodes and this improves both the received and transmitted signal from both partners. Every packet which enters a node leaves on a different frequency. Of course, the cost goes up.

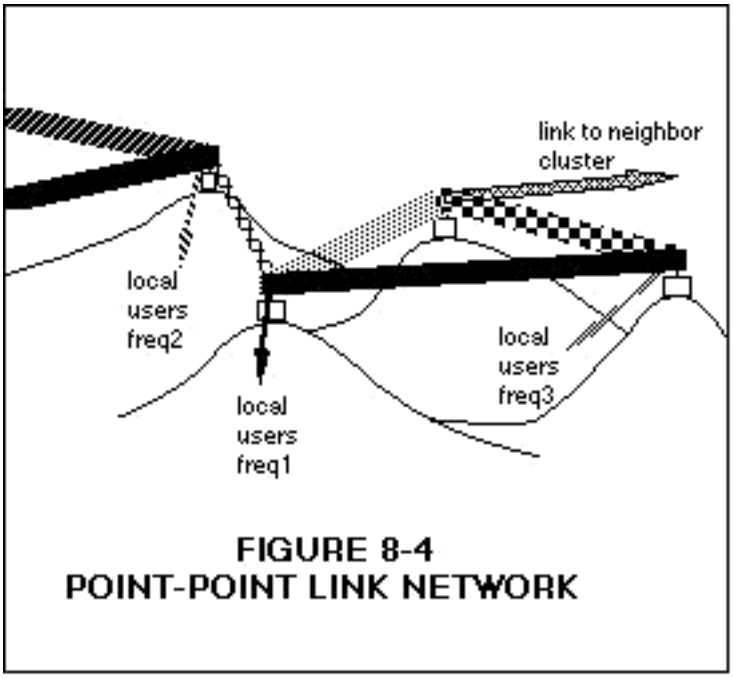

FIGURE 8-4
POINT-POINT LINK NETWORK

8.E WHAT'S IN A NODE?

Nodes are the work-horses of packet networks. It may be intuitively obvious that a node needs a radio for each frequency that it operates on. It may also then seem reasonable that an antenna is also needed (usually) for each frequency. But is is less obvious what else is required to make a node work.

8.E.1 Single-frequency TNC nodes: The simplest node is probably the single-frequency node built from a TNC. The usually preferred TNC type is the TNC2-clone. This is because the special ROM which makes the TNC operate as a node is designed only to operate in this kind of TNC. This type of node may also be called single-port.

8.E.2 Multi-frequency TNC nodes: This node arrangement consists of several single-frequency nodes joined together.

The basic arrangement is shown in Figure 8-5. It is frequently called a node-stack. This name is derived from the common arrangement for the TNCs and radios... that is, they are frequently placed on top of each other in a "stack". It is also referred to as a multi-port node.

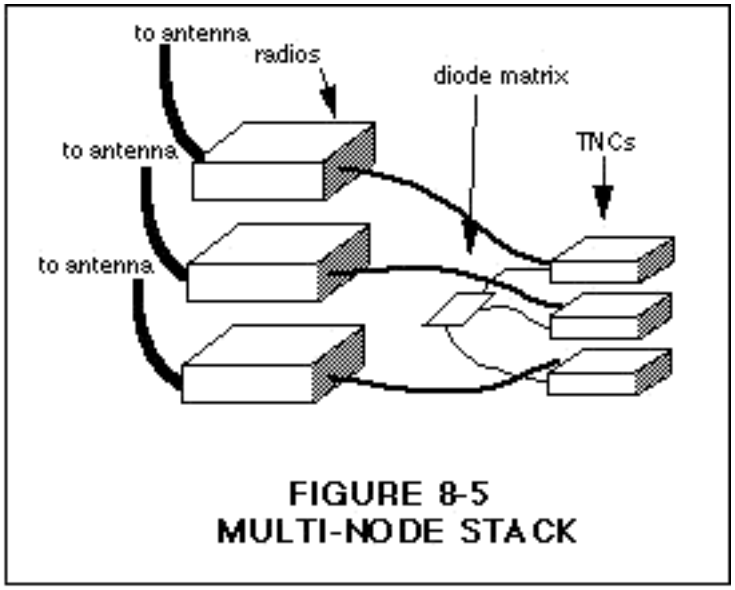

FIGURE 8-5
MULTI-NODE STACK

The connection between them is through the connector where a terminal normally is attached to the TNC. The common connection point is in a device called a diode matrix. This device keeps TNCs from attempting to all send signals to other TNCs at the same time.

The program ROMs in the TNCs are the same as in the single-frequency version.

8.E.3 Multi-frequency Computer-based nodes: This node arrangement relies on a computer to carry out the packet management and network operation. TNCs are still used but they function much more like a conventional modem. Figure 8-6 shows how such a node is constructed.

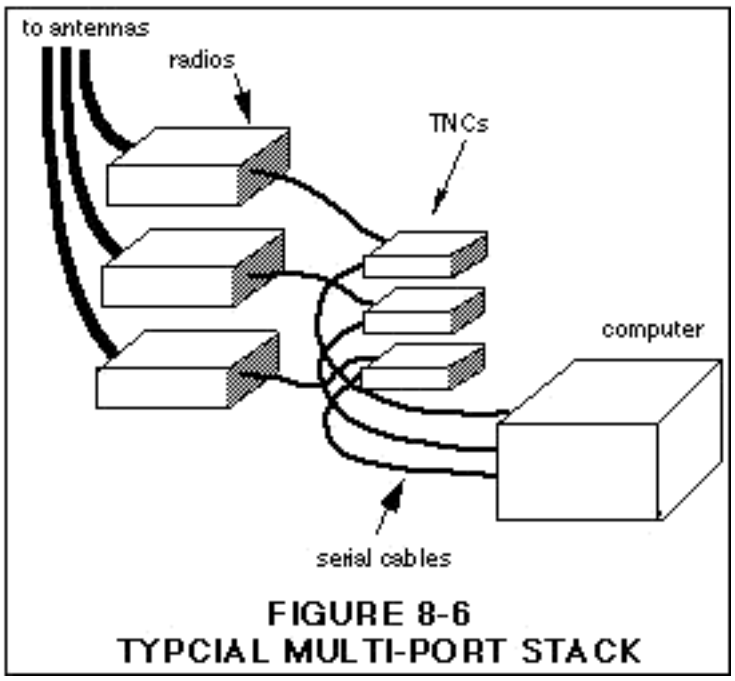

FIGURE 8-6
TYPCIAL MULTI-PORT STACK

This node setup is most commonly found with bulletin boards. The TNCs, themselves, operate in a mode called KISS (which stands for Keep It Super Simple); this mode is available in most TNCs and causes them to operate very nearly as a conventional modem.

8.E.4 Multi-frequency DataEngine nodes: This node uses a new device called DataEngine (manufactured by Kantronics). The device comes with two modems and is capable of operating to 9600 baud. Thus, by connecting two radios (of the appropriate kind) to it, a two-port node can be very easily constructed. A conventional TNC may be attached to the computer port to make a 3-frequency node and two DataEngines may be connected together to make a 4-frequency node.

8.E.5 TexNet nodes: These nodes are (minimum) two-port devices readily supporting both 1200 baud and 9600 baud. The low baud-rate port operates using standard AX.25 and the other ports use a protocol known as TEXNET-IP. Thus, on the backbone side, they are not compatible with the nodes previously discussed.

8.E.6 FlexNet nodes: FlexNet nodes are not based on TNC2s. They are referred to as RNMCs (Rein Main Network Controllers). These nodes are becoming widely used in Germany, Belgium, France, Switzerland, Austria, Italy, and Hungary. This spread is thought to be (at least partly) due to the low cost of the nodes.

RNMCs can support up to 6 ports. A 1200 baud user port is common. Like TexNet, node-to-node linking does not use Net/Rom protocol. Interestingly, this protocol is designed carry almost any other protocol wrapped inside its own. Node-node links are commonly operated at 9600 baud.

8.F SUMMARY

In this chapter, we have attempted to look at networks in a rather broad sense. We found that networks can provide wide-area connection services, additional error correction, network-level fault tolerance; but we also found that just because a network exists, there is no guarantee that it will work well!

Networking nodes manage the details of the network. Nodes can also provide access to the network for users and may also provide other services such as bulletin boards.

Networks may be arranged in a number of ways. The most rudimentary is the single-frequency system where nodes link with each other on the same frequency that users occupy. The next level of improvement is the single-frequency backbone system. Here, nodes are joined on a common frequency called a backbone while each has a different user frequency; the ability to support large numbers of users is quite a bit better for this system than for single-frequency systems. Cluster systems divide the network into smaller backbones which are joined by links on different frequencies. Point-point link systems use a unique frequency between each node and has the best ability to support many users of all of the network styles discussed.

Nodes, the key elements of networks, come in several basic varieties. The simplest is probably the single-frequency node built from a TNC with a special program ROM. Multi-frequency nodes may be constructed several ways. One way is to connect together a number of TNC-based nodes (one TNC per frequency). Another is to use a multiport controller such as a Data Engine. Yet another is to use a computer as the core of one or more nodes. Finally, special nodes may be constructed (as in the case of TexNet).

The network characteristics discussed in this chapter are independent of the protocol used. For more information about NET/ROM networks, see Chapter 9. For more information about TexNet, ROSE, TCP/IP and FlexNet networks, see Chapter 10. For the most detailed information about every node type available to the author, see Chapter 24 in Volume 2.