Chapter 4
Local Area Networks

4.1. PACKET RADIO NETWORKS

The ALOHANET of the University of Hawaii was one of the first local area networks [ABRA 70, BIND 75]. It pioneered packet switching in broadcast radio channels. The random access protocol of the original ALOHANET was of seminal importance in the development of the class of contention techniques for multiple access (including CSMA/CD).

The Hawaii work also inspired the development of a multi-hop packet radio network (PRNET) under the sponsorship of DARPA. PRNET employs packet repeaters to cover a wide geographic area. Its network-level protocols are designed to handle network users that are highly mobile [KAHN 78].

4.2. MULTIPOINT NETWORKS (BASEBAND)

Multipoint networks have either a bus or a tree topology. They can be implemented with coaxial cables or twisted pairs. Ethernet is probably the most successful and well known of the baseband multipoint cable networks [METC 76], although various other multipoint cable networks had been developed earlier (e.g., [WILL 73]). The basic configuration of Ethernet consists of a coaxial cable which serves as a passive broadcast medium (Figure 4-1). Each user connects to the cable with a tap and a transceiver. Removing power from the transceiver causes it to disconnect from the cable. Thus, it is easy to ensure that failures in a transceiver (or user) do not affect the operation of the network. This approach gives Ethernet good reliability, extensibility, and reconfigurability. The other prominent feature of Ethernet is the use of a CSMA/CD protocol for multiple access (see Chapter 3). The topology of Ethernet can be extended to that of an unrooted tree by the use of active packet repeaters joining together separate Ethernet segments as shown in Figure 4-2. Ethernet has a maximum data rate of 2.94 Mbps (with segment length limited to 1 Km) or a maximum data rate of 10 Mbps (with segment length limited to 500 meters) [SHOC 82]. The article by Shoch et al. [SHOC 82] gives a detailed technical description of the second-generation Ethernet, and it is reprinted below. A version of the detailed Ethernet specification can be found in [ETHE 81].

Another highly successful cable bus network is the Hyperchannel [THOR 79]. It also uses non-directional taps and baseband signalling. Hyperchannel has a maximum data rate of 50 Mbps. It is intended for the interconnection of mainframe computers and storage devices.

4.3. MULTIPOINT NETWORKS (BROADBAND)

In baseband local area networks, data signals being transmitted are not modulated onto a carrier signal. They are transmitted in their (unmodulated) digital form. Broadband networks employ RF modems that make possible the utilization of the entire cable bandwidth (about 300-400 MHz). In fact, there is so much bandwidth that it is probably desirable to divide it into different bands (using FDM) and to assign each band to a different application (data, voice, video, etc.). Broadband networks are typically built using readily available, low-cost CATV equipment, e.g., 75-ohm cables. (In contrast, Ethernets use 50-ohm cables.)

The transmission in most broadband networks is directional. This means that a signal going from a tap into the cable in Figure 4-1 is constrained to propagate away from the tap in

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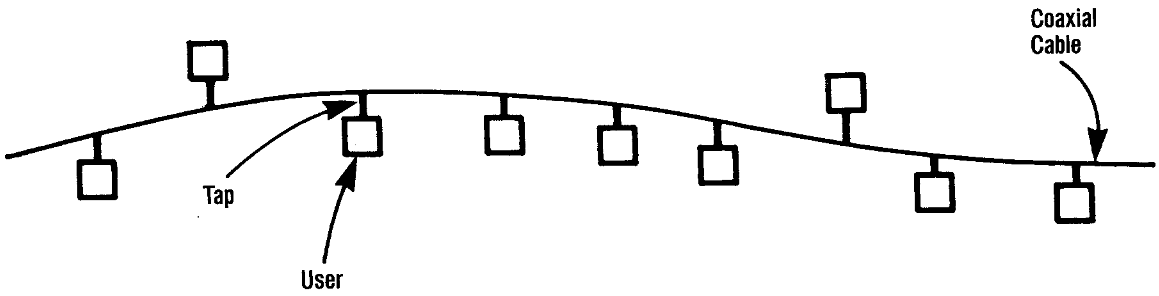

Figure 4-1. A multipoint bus network.

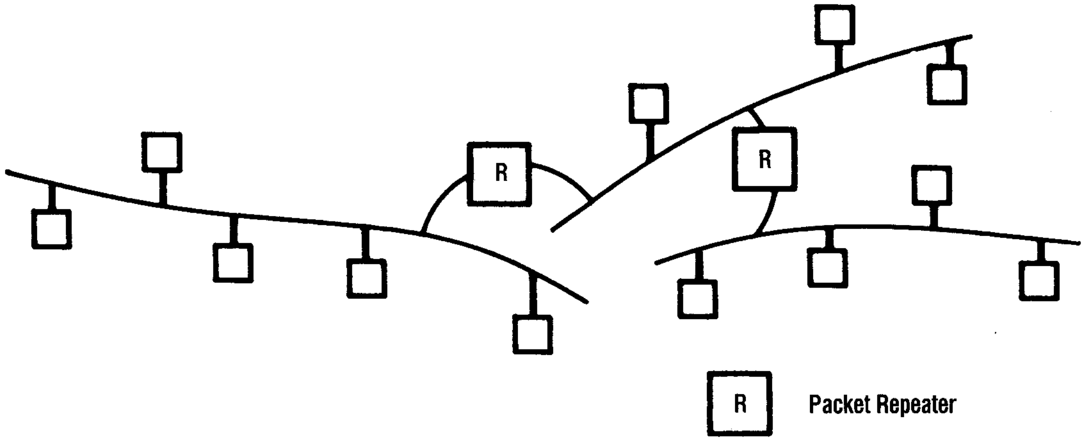

Figure 4-2. Multipoint cables joined by packet repeaters.

one direction only. (In a baseband bus network, a signal from a tap propagates in both directions away from the tap. Thus baseband networks are said to be bidirectional.)

Because of directional transmissions, the configuration of broadband networks are somewhat different from that shown in Figure 4-1. Three possible configurations are shown in Figure 4-3. In a single-cable system, the available frequency band is split into two, with one band for inbound transmission to the headend and the other band for the headend to retransmit anything that it has received outbound. A dual-cable system operates similarly but with two cables; thus the entire band is available in each transmission direction. In general, each cable, inbound or outbound, can be replaced by a tree configuration as shown in Figure 4-3(c). Appropriately spaced amplifiers powered from the center conductor of the cable (not shown in Figure 4-3(c)) can be used to maintain relatively constant receive signal strength for all users.

Each of the three configurations shown in Figure 4-3 is a broadcast channel as defined in Chapter 3. Previously described protocols, such as TDMA, CSMA/CD, and token passing, can be adapted for multiple access by users. For descriptions of some broadband networks, the reader is referred to [HOPK 79] and [BIBA 81].

4.4. RING NETWORKS

Ring networks constitute a major category of networks that are intrinsically different from packet radio and multipoint cable networks. For one thing, a ring is not a broadcast channel. Rather, it is a series of point-to-point channels. Each node on the ring is an active repeater joining two point-to-point segments.

There are three main protocols for sharing use of a ring network. An obvious one is token passing. This is the approach adopted in two recently developed ring networks [SALT 79, BUX 81] and in one of the IEEE Project 802 local area network standards. Farmer and Newhall probably wrote the first article describing a token ring [FARM 69]. An important consideration for token rings is how the network performs recovery when the control token is lost. A different approach, *slotted rings*, was proposed by several researchers in the early 1970s [PIER 72, FARB 72, WILK 79]. Think of a sequence of fixed-length slots traveling around the ring. Each slot is marked empty or busy. A node with a message to send will insert it into the first empty slot arriving from upstream

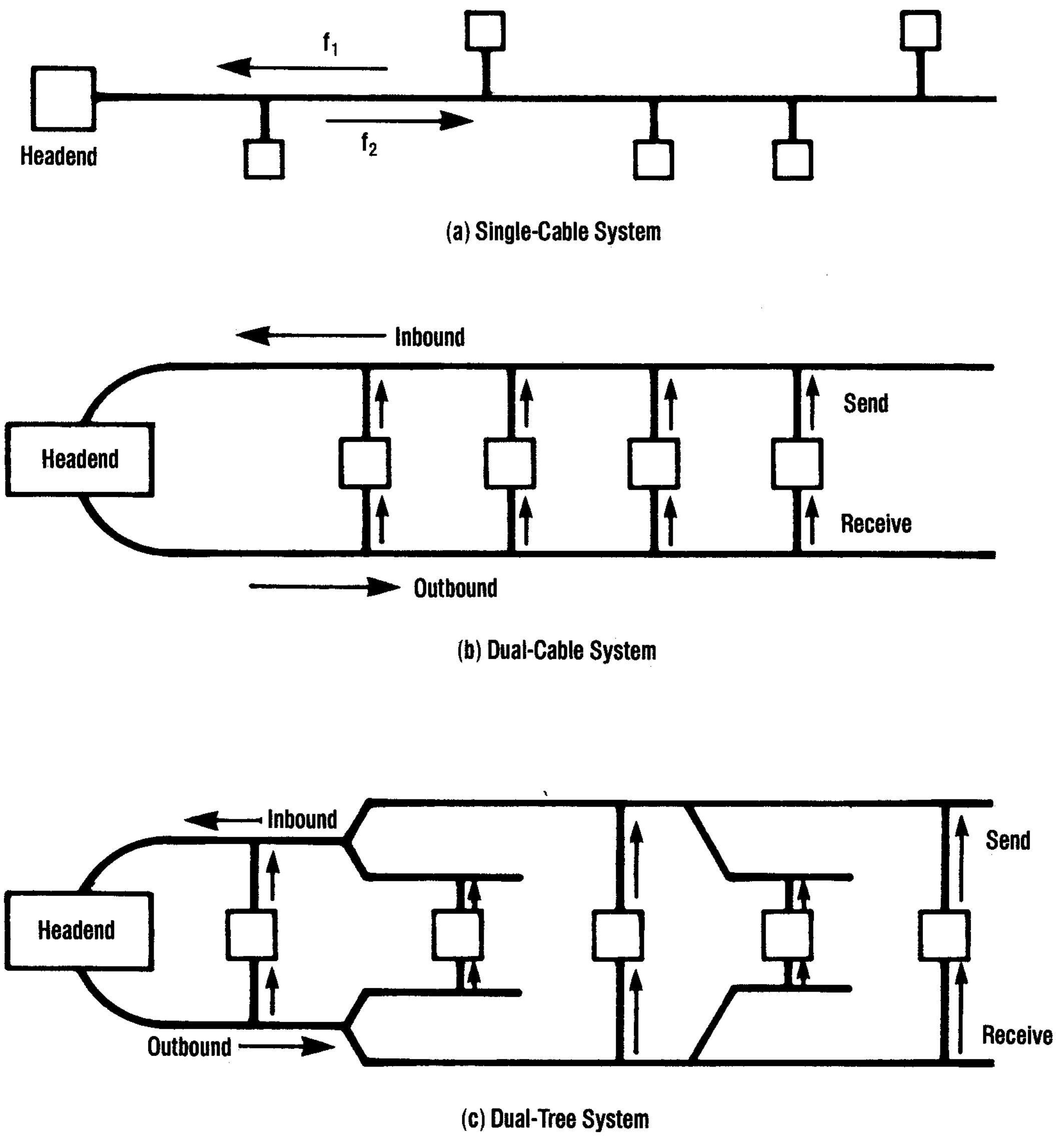

Figure 4-3. Broadband network configurations.

and will mark the slot busy as it is sent downstream. The subsequent removal of the message and the changing of the slot's status from busy to empty can be performed either by the receiver of the message or by the sender of the message (after the message has traveled all the way around the ring). The third approach, ***insertion rings***, was also proposed by several people [BOUD 73, REAM 75]. In this approach, a ring interface has hardware buffering that enables it to buffer incoming data from upstream at the same time when it is transmitting a locally generated message downstream. Insertion rings have more complex ring interfaces than do the other two approaches but they can accommodate variable-length messages as well as simultaneous transmissions by different users.

We discuss here a few points of comparison between rings and multipoint cables which we find interesting. A major advantage of rings is that they are made up of point-to-point channels. It is much easier to engineer transceivers for point-to-point unidirectional channels than for a multipoint broadcast cable. Furthermore, fiber optics can be used for point-to-point segments in a ring network. It is currently impractical to implement a multipoint broadcast network using fiber optics [RAWS 79]. A major weakness of Ethernet-type networks is that the CSMA/CD protocol becomes inefficient at high data rates (say, tens of Mbps). This is because at high data rates the end-to-end cable propagation delay becomes comparable in duration to packet transmission times. As a result, the advantage of carrier sensing is diminished and a CSMA/CD channel becomes effectively an ALOHA channel (see Chapter 3).

The obvious weakness of ring networks is their reliability. A failure in any node on a ring can disrupt the entire network. Various methods have been considered to improve the reliability of ring networks. An obvious approach is to introduce more connectivity into a ring; i.e., each node in the ring is connected to several other nodes [RAGH 82]. Such networks however have poor extensibility and reconfigurability. Adding new nodes or changing the network configuration entail significant disruptions to the network's operation. A different approach proposed by Lee [LEE 79] and Goyal and Lipovski [GOYA 80] is to implement ring protocols on non-ring topologies. A Hamiltonian graph is considered in [LEE 79] and trees are considered in [GOYA 80]. In each case, network reconfiguration to accommodate new nodes or to bypass failures can be done without too much difficulty. But they are only logical ring networks.

The most promising approach is probably the idea of star-shaped rings as proposed and investigated by researchers at MIT [SALT 79] and IBM Research at Zurich [BUX 81]. This approach provides relative ease in bypassing failed nodes for reliability and in extending and reconfiguring an existing network. For a description of this approach, the reader is referred to the article by Andrews and Schultz [ANDR 82], reprinted below. This article describes IBM's proposal to the IEEE project 802 on local area network standards. Saltzer and Clark gave a careful comparison of rings versus Ethernet-like cable networks in [SALT 81]. This article is also reprinted below.

4.5. ADDITIONAL REFERENCES

Draft versions of some IEEE project 802 local area network standards were published by the IEEE Computer Society [IEEE 82a, IEEE 82b, IEEE 82c].

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