for a multidrop data link is a *network*. Networks can be constructed in a variety of topologies: buses, rings, stars, and meshes, as shown in Fig. 5.11.

A bus structure is the most basic network topology in which all nodes share the same physical medium. When one node wishes to transmit data, it must wait for another node to finish and release the bus before it can begin. The ring topology implements a daisy-chained set of connections where each node connects to its two nearest neighbors, and information usually flows in one direction (although bidirectional rings are a variation on this theme). A benefit of the ring is that a single long wire does not have to travel between all nodes. One disadvantage is that each node is burdened with the requirement of passing on information that is not destined for it to keep the message from being lost.

Mesh networks provide ultimate connectivity by connecting each node to several of its neighbors. A mesh can provide increased bandwidth as well as fault tolerance as a result of its multiple connections. Properly designed, a mesh can route traffic around a failed link, because multiple paths exist between each node in the network. The downside to these benefits is increased wiring and communications protocol complexity.

Star networks connect each node to a common central hub. The benefits of a physical star topology include ease of management, because adding or removing nodes does not affect the wiring of other nodes. A downside is that more wiring is necessary to provide a unique physical connection between each node and the central hub. A starred network may send data only to the node for which it is destined. Unlike a ring, the node does not have to pass through information that is not meant for it. And unlike a bus, the node does not have to ignore messages that are not meant for it. The requirement for a central hub increases the complexity of a star network. As more nodes are added to the network, the hub must add ports at the same rate.

A network may be wired using a physical star topology, but it may actually be a bus or ring from a logical, or electrical, perspective. Implementing differing physical and logical topologies is illustrated in Fig. 5.12. Some types of networks inherently favor bus or ring topologies, but the flexible management of star wiring is an attractive alternative to a strictly wired bus or ring. Star wiring enables nodes to be quickly added or disconnected from the central hub without disrupting other nodes. Bus and ring topologies may require the complete or partial disruption of the network medium to add or remove nodes. A star's hub typically contains electronics to include or bypass individual segments as they are added or removed from the network without disrupting other nodes.

5.8 NETWORK DATA FORMATS

Common data formats and protocols are necessary to regulate the flow of data across a network to ensure proper addressing, delivery, and access to that common resource. Several general terms for

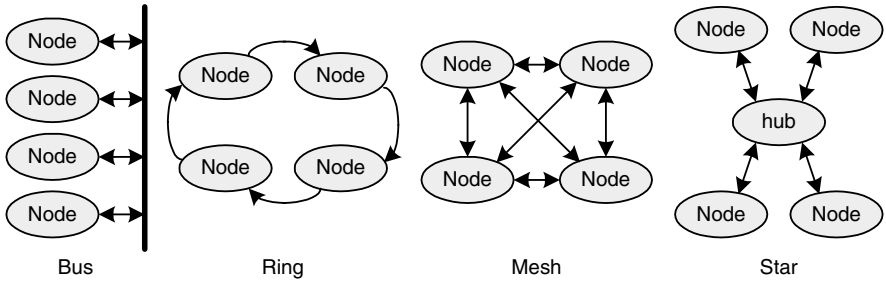

FIGURE 5.11 Basic network topologies.

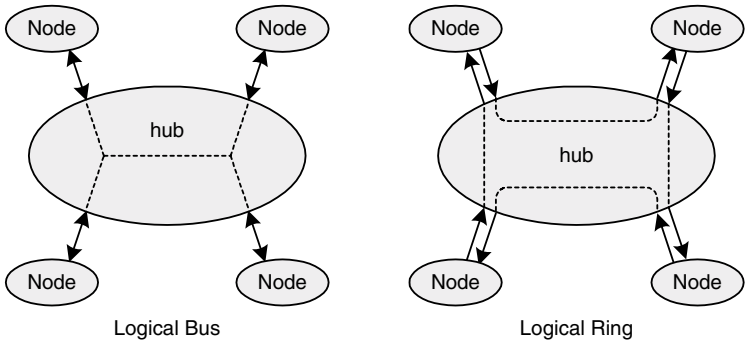

FIGURE 5.12 Physical vs. logical network topologies.

message elements on a network are *frame*, *packet*, and *cell*. Frames are sets of data that are framed at the beginning and end by special delimiters. Packets are sets of data that are not fully framed but that have some other means of determining their size, such as an embedded length field. Cells are fixed-length frames or packets. Frames and packets usually imply variable length data sets, but this is not a strict rule. As with many terms and classifications in digital systems, specific definitions are context specific and are often blurred: one system's cells may be another's frames. Frames, packets, and cells are composed of *headers*, *payloads*, and *trailers,* as shown in Fig. 5.13. The header is a collection of data fields that handle network overhead functions such as addressing and delineation. The actual data to be transmitted is placed into the payload. If present, a trailer is commonly used to implement some form of error checking and/or delineation. Not all packet formats specify the inclusion of trailers. When present, a trailer is usually substantially smaller in length than the header.

Networking is an aspect of digital systems design that directly involves hardware–software interaction at a basic level. One cannot really design networking hardware without keeping in mind the protocol, or software, support requirements. One key example is packet format. Hardware must have knowledge of the packet format so that it can properly detect a packet that is sent to it. At the same time, software must have this same knowledge so that it can properly parse received packets and generate new ones to be transmitted.

As soon as more than two nodes are connected to form a network, issues such as addressing and shared access arise. When there is only one transmitter and one receiver, it is obvious that data is intended for the only possible recipient. Likewise, the lone transmitter can begin sending data at any time it chooses, because there are no other transmitters competing for network access.

Network addressing is the mechanism by which a transmitting node indicates the destination for its packet. Each node on the network must therefore have a unique address to prevent confusion over where the packet should be delivered. In a bus topology, each node watches all the data traffic that is placed onto the network and picks out those packets that are tagged with its unique address. In a ring topology, each node passes packets on to the next node if the destination address is not matched with that node's address. If the address is matched, the node absorbs the packet and does not forward it on to the next node in the ring. Logical star and mesh topologies function a bit differently. Nodes on

FIGURE 5.13 Generic packet structure.