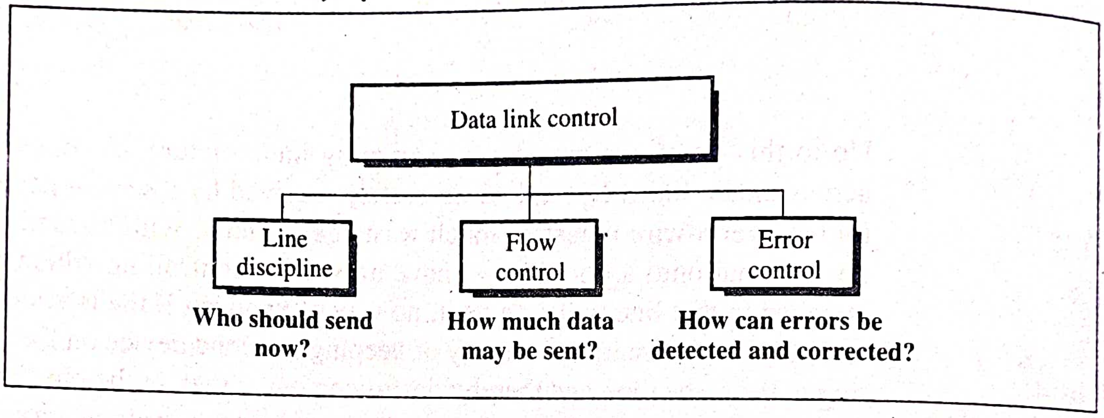
- Line discipline coordinates the link systems. It determines which device can send and when it can send.
- Flow control coordinates the amount of data that can be sent before receiving acknowledgment. It also provides the receiver's acknowledgment of frames received intact, and so is linked to error control.
- Error control means error detection and correction. It allows the receiver to inform the sender of any frames lost or damaged in transmission and coordinates the retransmission of those frames by the sender (see Figure 10.2).

Figure 10.2 *Data link layer functions*



10.1 LINE DISCIPLINE

Whatever the system, no device in it should be allowed to transmit until that device has evidence that the intended receiver is able to receive and is prepared to accept the transmission. What if the receiving device does not expect a transmission, is busy, or is out of commission? With no way to determine the status of the intended receiver, the transmitting device may waste its time sending data to a nonfunctioning receiver or may interfere with signals already on the link. The line discipline functions of the data link layer oversee the establishment of links and the right of a particular device to transmit at a given time.

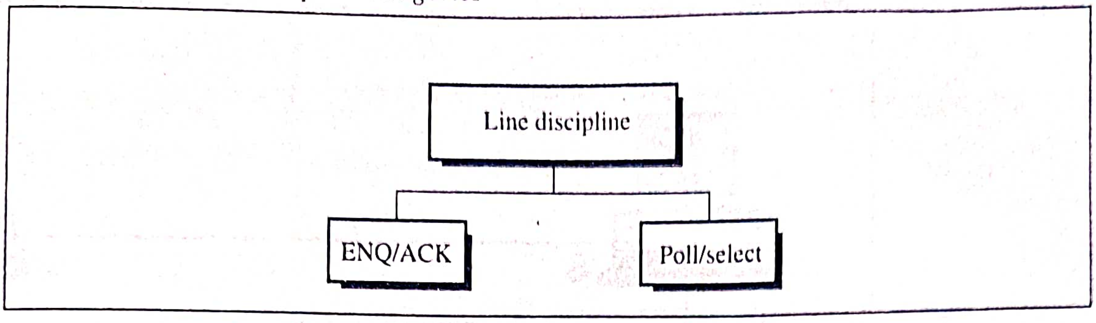
Line discipline answers the question, Who should send now?

Line discipline can be done in two ways: enquiry/acknowledgment (ENQ/ACK) and poll/select. The first method is used in peer-to-peer communication; the second method is used in primary–secondary communication (see Figure 10.3).

ENQ/ACK

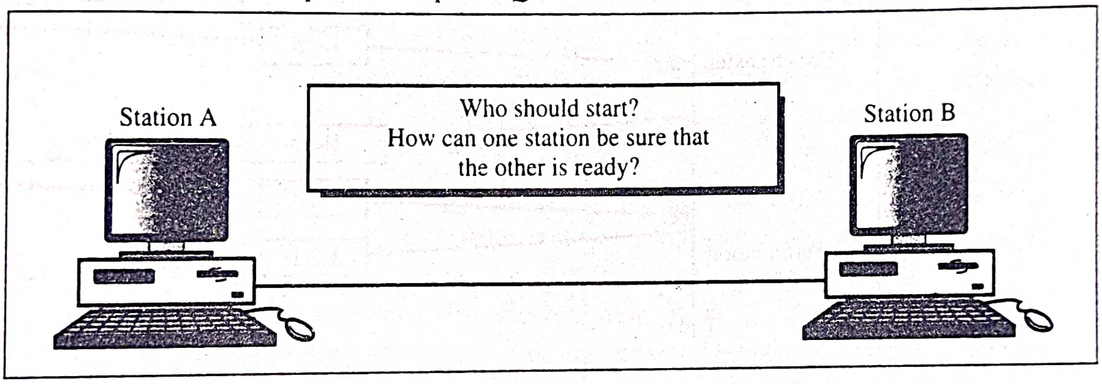
Enquiry/acknowledgment (ENQ/ACK) is used primarily in systems where there is no question of the wrong receiver getting the transmission, that is, when there is a dedicated link between two devices so that the only device capable of receiving the transmission is the intended one.

Figure 10.3 *Line discipline categories*



ENQ/ACK coordinates which device may start a transmission and whether or not the intended recipient is ready and enabled (see Figure 10.4). Using ENQ/ACK, a session can be initiated by either station on a link as long as both are of equal rank—a printer, for example, cannot initiate communication with a CPU.

Figure 10.4 *Line discipline concept: ENQ/ACK*

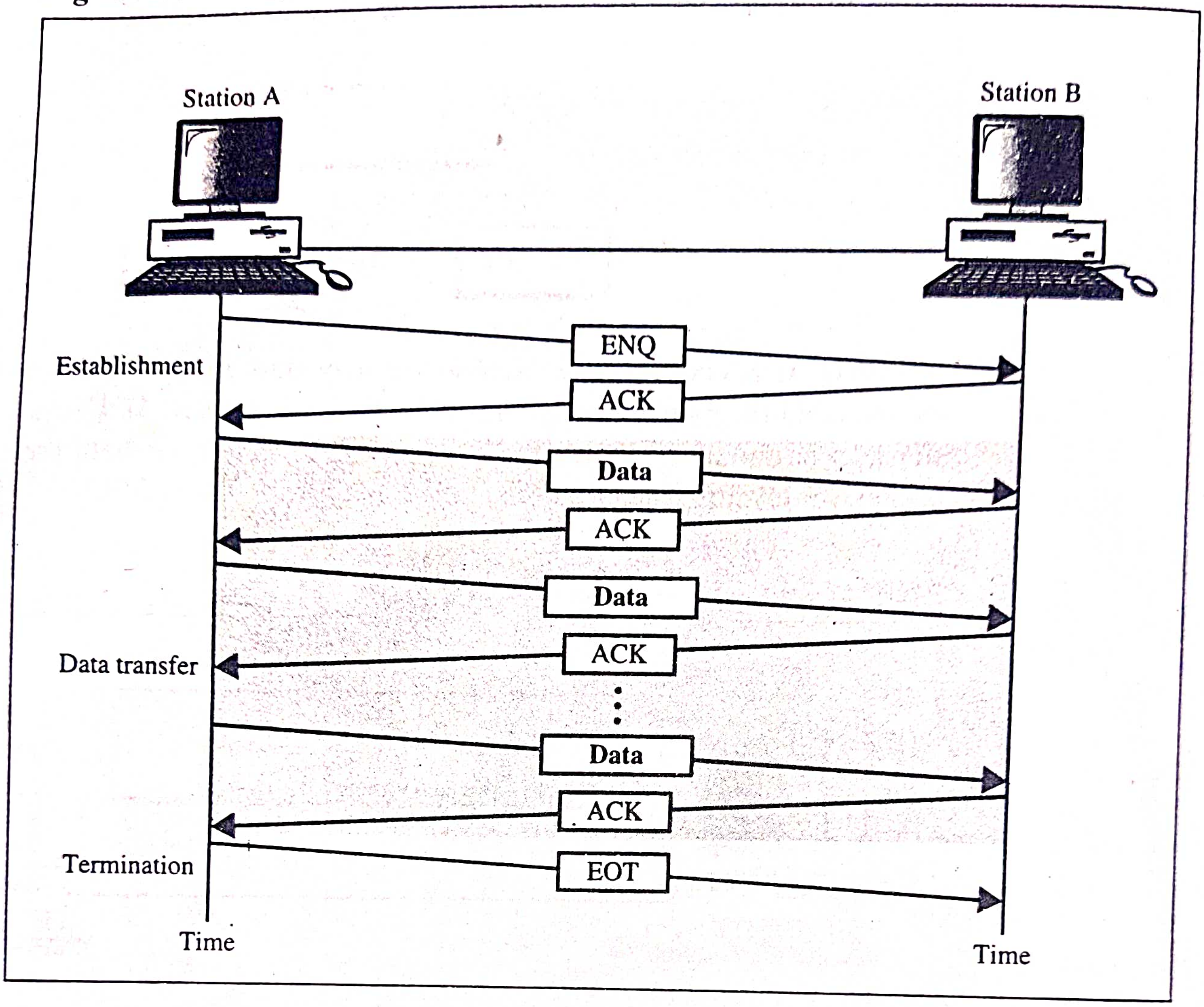


In both half-duplex and full-duplex transmission, the initiating device establishes the session. In half-duplex, the initiator then sends its data while the responder waits. The responder may take over the link when the initiator is finished or has requested a response. In full-duplex, both devices can transmit simultaneously once the session has been established.

How It Works The initiator first transmits a frame called an enquiry (ENQ) asking if the receiver is available to receive data. The receiver must answer either with an **acknowledgement (ACK)** frame if it is ready to receive or with a **negative acknowledgement (NAK)** frame if it is not. By requiring a response even if the answer is negative, the initiator knows that its enquiry was in fact received even if the receiver is currently unable to accept a transmission. If neither an ACK nor a NAK is received within a specified time limit, the initiator assumes that the ENQ frame was lost in transit, disconnects, and sends a replacement. An initiating system ordinarily makes three such attempts to establish a link before giving up.

If the response to the ENQ is negative for three attempts, the initiator disconnects and begins the process again at another time. If the response is positive, the initiator is free to send its data. Once all of its data have been transmitted, the sending system finishes with an **end of transmission (EOT)** frame. This process is illustrated in Figure 10.5.

Figure 10.5 *ENQ/ACK line discipline*

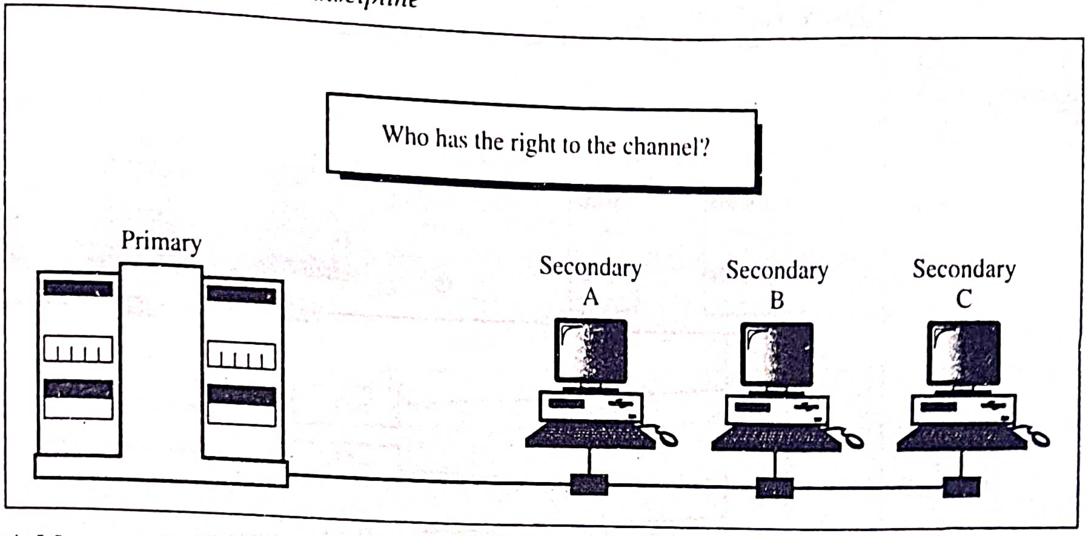


Poll/Select

The **poll/select** method of line discipline works with topologies where one device is designated as a **primary station** and the other devices are **secondary stations.** Multipoint systems must coordinate several nodes, not just two. The question to be determined in these cases, therefore, is more than just, Are you ready? It is also, Which of the several nodes has the right to use the channel?

How It Works Whenever a multipoint link consists of a primary device and multiple secondary devices using a single transmission line, all exchanges must be made through the primary device even when the ultimate destination is a secondary device. (Although the illustrations that follow show a bus topology, the concepts are the same for any multipoint configuration.) The primary device controls the link; the secondary devices follow its instructions. It is up to the primary to determine which device is allowed to use the channel at a given time (see Figure 10.6). The primary, therefore, is always the initiator of a session. If the primary wants to receive data, it asks the secondaries if they have anything to send; this function is called *polling*. If the primary wants to send data, it tells the target secondary to get ready to receive; this function is called *selecting*.

Figure 10.6 *Poll/select discipline*



Addresses For point-to-point configurations, there is no need for addressing; any transmission put onto the link by one device can be intended only for the other. For the primary device in a multipoint topology to be able to identify and communicate with a specific secondary device, however, there must be an addressing convention. For this reason, every device on a link has an address that can be used for identification.

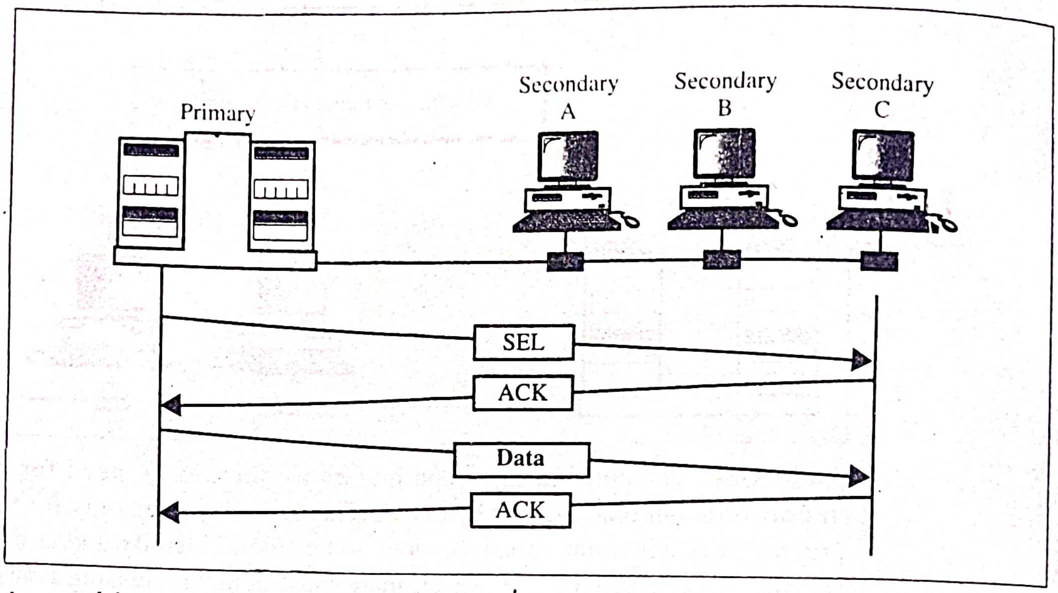
Poll/select protocols identify each frame as being either to or from a specific device on the link. Each secondary device has an address that differentiates it from the others. In any transmission, that address will appear in a specified portion of each frame, called an address field or header depending on the protocol. If the transmission comes from the primary device, the address indicates the recipient of the data. If the transmission comes from a secondary device, the address indicates the originator of the data. We will discuss addressing further when we discuss specific protocols in Chapter 12.

Select The **select** mode is used whenever the primary device has something to send. Remember that the primary controls the link. If the primary is not either sending or receiving data, it knows the link is available. If it has something to send, it sends it. What it does not know, however, is whether the target device is prepared to receive (usually, *prepared to receive* means *on*). So the primary must alert the secondary to the upcoming transmission and wait for an acknowledgment of the secondary's ready status. Before sending data, the primary creates and transmits a select (SEL) frame, one field of which includes the address of the intended secondary. Multipoint topologies use a single link for several devices, which means that any frame on the link is available to every device. As a frame makes its way down the link, each of the secondary devices checks the address field. Only when a device recognizes its own address does it open the frame and read the data. In the case of a SEL frame, the enclosed data consist of an alert that data are forthcoming.

If the secondary is awake and running, it returns an ACK frame to the primary. The primary then sends one or more data frames, each addressed to the intended secondary. Figure 10.7 illustrates this procedure.

Poll The polling function is used by the primary device to solicit transmissions from the secondary devices. As noted above, the secondaries are not allowed to transmit data unless asked (don't call us—we'll call you). By keeping all control with the primary,

Figure 10.7 *Select*



the multipoint system guarantees that only one transmission can occur at a time, thereby ensuring against signal collisions without requiring elaborate precedence protocols. When the primary is ready to receive data, it must ask **(poll)** each device in turn if it has anything to send. When the first secondary is approached, it responds either with a NAK frame if it has nothing to send or with data (in the form of a data frame) if it does.

If the response is negative (a NAK frame), the primary then polls the next secondary in the same way until it finds one with data to send. When the response is positive (a data frame), the primary reads the frame and returns an acknowledgment (ACK frame) verifying its receipt. The secondary may send several data frames one after the other, or it may be required to wait for an ACK before sending each one, depending on the protocol being used.

There are two possibilities for terminating the exchange: either the secondary sends all its data, finishing with an end of transmission (EOT) frame, or the primary says, "Time's up." Which of these occurs depends on the protocol and the length of the message. Once a secondary has finished transmitting, the primary can poll the remaining devices (see Figure 10.8).

10.2 FLOW CONTROL

The second aspect of data link control is flow control. In most protocols, flow control is a set of procedures that tells the sender how much data it can transmit before it must wait for an acknowledgment from the receiver. The flow of data must not be allowed to overwhelm the receiver. Any receiving device has a limited speed at which it can process incoming data and a limited amount of memory in which to store incoming data. The receiving device must be able to inform the sending device before those limits are reached and to request that the transmitting device send fewer frames or stop temporarily. Incoming data must be checked and processed before they can be used. The rate