## Data Communications Interface

**Synchronization.** Operation of a sender and a receiver in unison.

**Asynchronous transmission.** Each character in data is treated independently

- Each character starts with a special start bit to alert the receiver
- Receiver continuously samples and looks for beginning of next character
- Not good for large data due to possible clock drift

**Synchronous transmission.** More efficient than asynchronous for large data blocks

- Data block formatted as a frame to include a starting and ending flag
- Synchronization can be achieved using a method like Manchester encoding

**Interface.** Point of interaction for independent systems or diverse groups

- Electrical characteristics
- Physical means of attachment
- Procedure for sending and receiving data

### Asynchronous and synchronous transmission

- Serial v. parallel transmission of data
- Serial transmission
  - Signaling element are sent one at a time over medium
  - Signaling element
    - Less than one bit; Manchester encoding
    - One bit; NRZ-L and FSK
    - More than one bit; QPSK
  - Receiver samples incoming signal once per bit time
    - Transmission problems may corrupt the signal
    - Arrival time and duration of bit may not be known to receiver
    - The clock in receiver may *drift* with respect to sender's clock
- Asynchronous transmission
  - Can be used to achieve synchronization
  - Avoid timing drift by not sending long, uninterrupted streams of bits
  - Data is transmitted one character at a time, with each character from five to eight bits
    - Synchronization must be maintained within each character
    - Receiver resynchronizes at the beginning of each character
    - Figure 6.1
      - Idle state on the line (medium)
      - Idle is indicated by binary 1 on line, indicated by presence of negative voltage on the line for NRZ-L
      - Beginning of character or start bit is binary 0
      - Characters are transmitted with least significant bit first

        - Data bits are followed by parity bit (most significant bit position), set by transmitter
        - Final element is stop bit, binary 1, as 1, 1.5, or 2 bit positions, same as idle state
        - Send the sequence ABC.
    - Timing requirements
        - Characters sent as 8 bits, including parity bit
        - Receiver has $\pm 5\%$ drift with respect to sender implies that eighth character is displaced by 45% and still correctly sampled
        - Figure 6.1c
        - Timing error significant to cause error in reception
        - Assume a data rate of 10kbps, giving a bit time of $100\mu s$
        - Receiver drift of 6% gives $6\mu s$ per bit
        - Receiver samples at $94\mu s$ with respect to transmitter clock, giving an erroneous last sample
    - Two errors
        1. Last bit may be incorrectly received
        2. Bit count may get out of alignment
    - Framing error
        - Character plus start bit plus stop bit constitute a frame
        - Bit 7 is a 1 and bit 8 is 0
        - Bit 8 could be mistaken for a start bit
        - Also possible due to noise causing false appearance of start bit during idle state
  - Simple and cheap
  - Overhead of 2-3 bits per character

- Synchronous transmission
  - Block of bits transmitted in a steady stream without start and stop codes
  - Clocks of bits must be synchronized to prevent timing drift
    - Separate clock line between transmitter and receiver
        - One side pulses the line regularly with one short pulse per bit time
        - Other side uses the pulse for clocking
        - Works well over short distances, but can have problems (noise or other) over long distances
    - Embed clocking information within data signal
        - Achieved using Manchester or Differential Manchester encoding for digital signal
        - Carrier frequency for analog signal, based on carrier phase
  - Receiver must determine beginning and end of data block
    - Each block begins with a *preamble* bit pattern and ends with a *postamble* bit pattern
    - Other bits added to the block to convey control information used in data link control procedures
  - Frame
    - Preamble + Data + Control Information + Postamble
  - More efficient than asynchronous
    - $> 20\%$ overhead in asynchronous transmission
    - Synchronous transmission has less than 100 bits overhead per frame
        - 1000 character block of data; 8000 bits
        - 48 bits of control, preamble, and postamble (using HDLC)
        - Percentage overhead $= \frac{48}{8048} \times 100 = 0.6\%$

**Line configurations (for data link)**

- Topology
  - Physical arrangement of stations on transmission medium
  - Point-to-point
    - Only two stations in the link
  - Multipoint link
    - Computer and terminals
    - LAN
  - Multipoint topology
    - Terminals only transmit a fraction of the time
    - Figure 6.3a
    - Point-to-point link requires one I/O port per terminal
    - Figure 6.3b
    - Multipoint configuration allows one I/O port to be shared between terminals, saving cost
- Full duplex and half duplex
  - Half duplex
    - Only one of the two stations in point-to-point link may transmit at a time
    - *Two-way alternate mode*
    - Terminal-to-computer interaction
  - Full duplex
    - Two stations can simultaneously send and receive data to/from each other
    - *Two-way simultaneous mode*
    - Computer-to-computer data exchange

**Interfacing**

- Devices generally do not directly attach to a network
  - Figure 6.4
  - *Data terminal equipment* (DTE)
    - Makes use of transmission network through the mediation of *data circuit-terminating equipment* (DCE)
    - DCE exemplified by a modem
- DCE
  - Interacts with both DTE and network
  - Responsible for transmitting/receiving bits, one at a time, over a network
  - Both data and control information may need to be exchanged
    - Information exchanged over a set of wires, or *interchange circuits*
  - Two DCEs across the network must understand each other
    - Receiver of each DCE must use the same encoding scheme and data rate as the transmitter of the other
- Standards to specify the nature of interface between DTE and DCE with four important characteristics
  1. Mechanical
     - Actual physical connection

- Matching male/female connectors

2. Electrical
   - Determine data rates and distances possible
   - Voltage level and timing of voltage change
   - Both DTE and DCE must use the same code (such as NRZ-L
   - Voltage levels must mean the same thing
3. Functional
   - Function performed by assigning meaning to interchange circuits
   - Data, control, timing, electrical ground
4. Procedural
   - Sequence of events for transmitting data
   - Based on functional characteristics of interface

- V.24/EIA-232-F
  - Most widely used interface, specified in ITU-T standard
  - EIA-232-F is the equivalent standard in the US
  - Originally called the RS-232 standard
  - Used to connect DTE to voice grade modems for use on public telecom network
  - Mechanical specification
    * Figure 6.5
    * 25-pin connector, defined in ISO 2110, with a specific arrangement of leads
    * Connector is terminating plug/socket on cable between DCE and DTE
    * All 25 wires are not used in the connection
  - Electrical specification
    * Defines signaling between DCE and DTE
    * Digital signaling on all interchange circuits
    * Electrical values interpreted as binary data or control based on function
      · Voltage negative than -3 volts is binary 1
      · Voltage positive than +3 volts is binary 0
    * Uses NRZ-L encoding
    * Interface rated at a signal rate of $<$ 20 kbps and distance of $<$ 15 meters
    * Same voltage level for control signals
      · Voltage negative than -3 volts is OFF
      · Voltage positive than +3 volts is ON
  - Functional specification
    * Figure 6.5 and Table 6.1
    * Circuits grouped into categories of data, control, timing, and ground
    * One data circuit in each direction to enable full duplex operation
    * Two secondary data circuits for half duplex operation
      · Link equipped with a reverse channel to enable halt or flow control message in half duplex mode
      · Reverse channel at a much lower data rate compared to primary channel
      · Reverse channel carried on a separate pair of data circuits at the DTE-DCE interface
    * 16 control circuits
      · First 10 control circuits relate to transmission of data over primary channel
      · Six out of these 10 circuits used for asynchronous transmission

    - Three other control circuits used for synchronous transmission
    - Signal quality detector turned ON by DCE to indicate the deterioration of signal quality beyond a defined threshold
    - Modems support more than one transmission rate to account for noisy transmission lines
    - Data signal rate detector used to change speeds, initiated by either of DCE or DTE
    - Circuit 133 enables a receiver to turn the flow of data on circuit 104 on or off
    - Next three control circuits (120, 121, 122) used to control the operation of secondary channel, possibly as reverse channel or some other purpose
  - Loopback testing
    - Allow DTE to cause the DCE to perform a loopback test
    - Useful fault isolation tool
    - Figure 6.6
    - In local loopback, transmitter output of modem connected to receiver input, disconnecting modem from transmission line
    - Stream of data generated by user device sent to modem and looped back to user device
    - For remote loopback, receiver output of remote modem is connected to modem's transmitter input
  - Timing signals
    - Provide clock pulses for synchronous transmission
  - Signal ground/common return
    - Return circuit for all data leads
- Procedural specification
  - Sequence in which various circuits are used for a given application
  - Example 1: Connecting two devices over short distance within a building
    - Asynchronous private line modem
    - Modem accepts digital signal from DTE, converts it to analog, transmits it for short distance over twisted pair
    - Data recovered by modem over other end, converted to digital to be presented to DTE
    - Two way exchange
    - Only following interchange circuits are required:

| | |
|---|---|
| 102 | Signal ground |
| 103 | Transmitted data |
| 104 | Received data |
| 105 | Request to send |
| 106 | Clear to send |
| 107 | DCE ready |
| 109 | Received line signal detector |

    - When modem is turned on and is ready to operate, it asserts the DCE Ready line by applying a constant negative voltage
    - When DTE is ready to send data (user hits key), it asserts Request to Send
    - Modem responds by asserting Clear to Send to say that data may be transmitted over Transmitted Data line
    - As data arrives, local modem asserts Received Line Signal Detector and delivers data on Received Data line
    - Asynchronous transmission obviates the need for timing circuits
  - Transmitting over phone network requires two additional leads

| | |
|---|---|
| 108.2 | DTE Ready |
| 125 | Ring indicator |

    - Figure 6.7
    - Modem responds to phone ring by asserting Ring Indicator

        - DTE answers the phone by asserting DTE Ready
        - DTE listens for Received Line Signal Detector, asserted by the modem when a signal is present; if circuit is not asserted, DTE drops DTE Ready

- ISDN physical interface
  - V.24/EIA-232 is expensive because of large number of circuits
  - Alternative uses fewer circuits but adds more logic to DTE and DCE interfaces
  - Uses a 15-pin connector in X.21 standard but 8-pin connector for ISDN (Integrated Services Digital Network)
  - Physical connection
    - Connection made between terminal equipment (TE) and network-terminating equipment (NT)
    - Figure 6.9
    - Two pins for data transmission in each direction
      - No specific functional circuits
      - Transmit/receive circuits carry both data and control signals
      - Control information transmitted as messages
  - Electrical specification
    - Unbalanced transmission (not used in ISDN)
      - Used on older interfaces (EIA-232)
      - Uses single conductor to carry the signal with return provided by ground
      - Used only on coaxial cable, or short distances on interchange circuits
    - Balanced transmission
      - Signals carried on a line (twisted pair) with two conductors
      - Signals transmitted as current to travel down one conductor and return on the other, forming a complete circuit
      - Also called *differential signaling* for digital circuits
      - Tolerates more and produces less noise than unbalanced
    - Basic data rate of 192 kbps, using pseudoternary coding