Chapter III:
Modems and Interfaces

III.1 PRINCIPLE OF A DATA LINK

A transmission line is a link between two machines. We generally use the term **transmitter** to designate the machine that sends data and **receiver** for the machine that receives it.

Machines can sometimes alternate between being a receiver and a transmitter (this is generally the case for computers connected via a network).

Communication between computer systems occurs via links whose main components are defined by the recommendations of the **ITU-T** (International Telecommunication Union-Telecommunication Standardization Sector). The following figure highlights these different components.

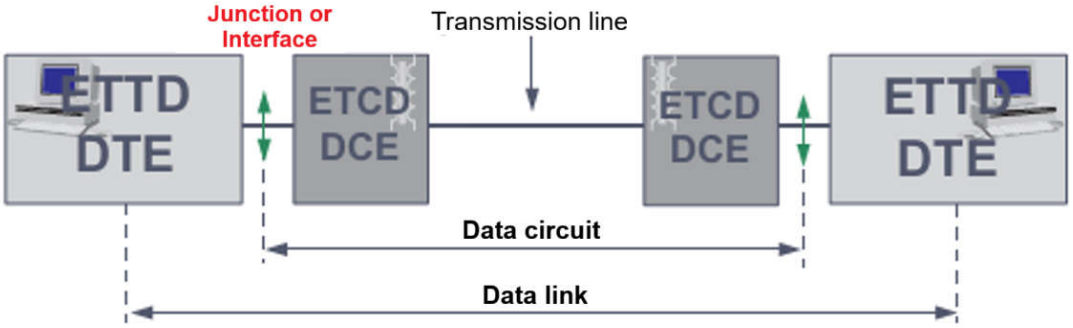


Figure III.1: *Components of a data link.*

III.1.1 DTE (Data Terminal Equipment)

Located at the end-point of the link, the DTE performs data processing and integrates a communication controller. It can be a computer, a terminal, a printer, or more generally, any equipment that does not connect directly to the transmission line.

III.1.2 DCE (Data Communication Equipment)

The transmission of data over the line is handled by the DCE, which can be a modem, a multiplexer, a concentrator, or simply an adapter (pseudo-modem).

The DCE has two essential functions:

- **Adapting the binary signal** between the DTE and the transmission line, which generally corresponds to encoding and modulation (or demodulation and decoding, depending on whether it is sending or receiving).
- **Managing the link**, which includes the establishment, maintenance, and termination of the line connection at each end.

Author: Dr. H. Zerroiki

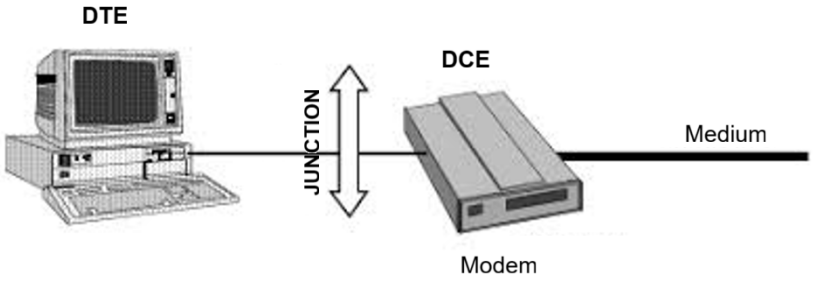
The DCE is characterized by its:

- Bit rate (bits/s),
- Modulation type (for modems),
- Synchronization mode (synchronous/asynchronous),
- Transmission line type (PSTN, 2-wire Leased Line, 4-wire Leased Line, etc.),
- Circuit operating mode (simplex, half-duplex, full-duplex),
- Encoding method (baseband converter or modem),
- Modulation rate (baud),
- Physical interface type with the DTE.

III.1.3 The Junction as the Interface between DCE and DTE

The junction allows the DTE to control the data circuit (connection establishment and termination, transmission initialization, etc.).

A DTE/DCE interface specifies:



- A **mechanical interface** that defines the physical connector.
- An **electrical interface** that determines the voltage levels of the signals that pass through the junction.
- A **functional interface** that specifies the functions performed by each pin: data transfer, control signals, synchronization signals, and grounds.
- Finally, a **procedural interface** that defines the command and exchange procedures.

III.2 MODEMS

The name Modem is a portmanteau of the terms **Mo**dulator/**Dem**odulator. It is a device capable of transforming digital signals into analog signals, a process known as **modulation**. It is also capable of converting analog signals back into digital signals, which is the inverse process, identified as **demodulation**.

We use the term modem to describe devices designed to allow digital machines (e.g., computers) to communicate with each other, to access the Internet, to send or receive faxes, and to engage in digital telephony, all across an analog network (e.g., Public Switched Telephone Network, power lines, radio networks).

The modem also integrates other functions, namely:

- Voltage level adaptation with the DTE,
- Encoding,
- Filtering,
- Amplification and line matching.

A modem is characterized by:

- The modulation rate,
- The modulation type (phase, amplitude, frequency),
- The synchronization mode (synchronous/asynchronous),
- The operating mode (half/full duplex),
- The connection method (junction with a coupler, 2- or 4-wire line, or switched telephone network),
- The interface with the DTE.

III.2.1 Standardization

The **ITU-T** (International Telecommunication Union - Telecommunication Standardization Sector; until 1992, this body was known as the ITTCC, International Telegraph and Telephone Consultative Committee) has issued a number of recommendations concerning the operation of modems. These recommendations specify the operating conditions for the devices: authorized transmission speeds, modulation types, compression systems, and/or optional error detection systems. They effectively constitute standards that are respected by numerous manufacturers. Below are some important standards:

- **V.21 Standard:**
  - Rate: 300 bps
  - Transmission type: Asynchronous
  - Medium: PSTN or 2-wire Leased Line (LL)
  - Modulation: Frequency Shift Keying (FSK)
  - Mode: Full-duplex via band splitting
- **V.22 Standard:**
  - Rate: 600 or 1200 bps
  - Transmission type: Synchronous
  - Medium: PSTN or 2-wire LL
  - Mode: Full-duplex via band splitting
  - Modulation: 4-state phase modulation (QPSK)
- **V.23 Standard:**
  - Rate: 600 or 1200 bps
  - Transmission type: Synchronous and asynchronous

- Medium: PSTN or 2- or 4-wire LL
- Mode: Half-duplex on 2-wire, full-duplex on 4-wire
- Modulation: Frequency Shift Keying (FSK)
- Optional 75 bps reverse channel

- **V.29 Standard:**
  - Rate: 4800 or 9600 bps
  - Transmission type: Synchronous
  - Medium: 4-wire LL
  - Modulation: 8 phases and 2 amplitudes (QAM)
  - Mode: Full-duplex

- **V.32 Standard:**
  - Rate: 9600 bps
  - Mode: Full-duplex
  - Modulation at 2400 baud with a 32-point constellation

- **V.34 Standard:**
  - Rate: 28.8 kbps
  - Operation in full-duplex and simplex modes
  - Modulation: Quadrature Amplitude Modulation (QAM)
  - Synchronous transmission over the line at various modulation rates

- **V.90 Standard:**
  - Rate: 56 kbps for the downstream link (to the user), but 33.6 kbps for the upstream link (to the network); an asymmetric link, similar to ADSL.
- **V.92 Standard:**
  - Downstream rate up to 56 kbps, and upstream rate up to 48 kbps.

III.3 ADSL MODEMS

ADSL stands for **Asymmetric Digital Subscriber Line**.

III.3.1 Characteristics

The most important characteristic of ADSL is its ability to offer high-speed digital services over the existing copper network, overlaid on top of—and without interfering with—the traditional analog telephone service.

ADSL can achieve data rates of several Mbps over distances of less than 5 km. It provides a high-speed Internet connection and supports applications such as IP telephony and TV over IP.

III.3.2 Principles of ADSL Operation

ADSL is a Frequency-Division Multiplexing (FDM) technique that allows the line's bandwidth to be shared among three main functions: the telephone service, the **Upload** stream (from client to server), and the **Download** stream (from server to client).

The telephone service uses frequencies from 300 Hz to 4 kHz, so this band is reserved for it. The Upload stream is generally less demanding than the Download stream, so it is allocated a relatively narrow band (from 64 kHz – 200 kHz). Since the Download stream is typically more significant, it is assigned a wide band at the highest frequencies (from 200 kHz – 1104 kHz). Figure III.2 shows the frequency allocation for each use case.

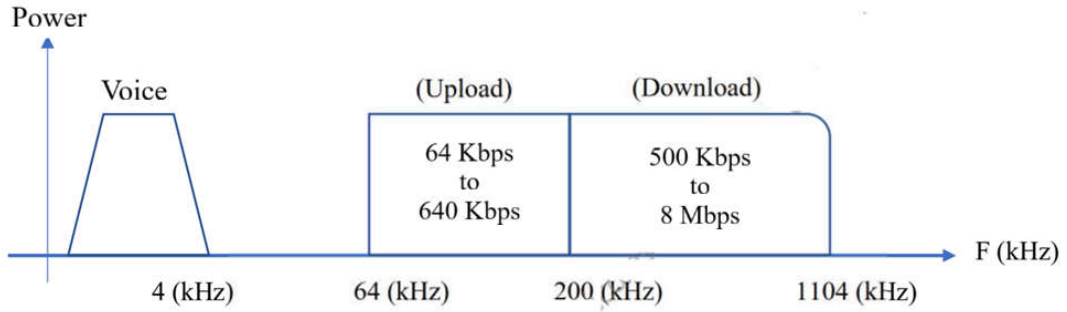


Figure III.2: *ADSL Frequency Band Allocation.*

The 64 kHz to 1104 kHz band is divided into 256 sub-channels (carriers or tones) of 4 kHz each, plus 4 control sub-channels (Figure III.3).

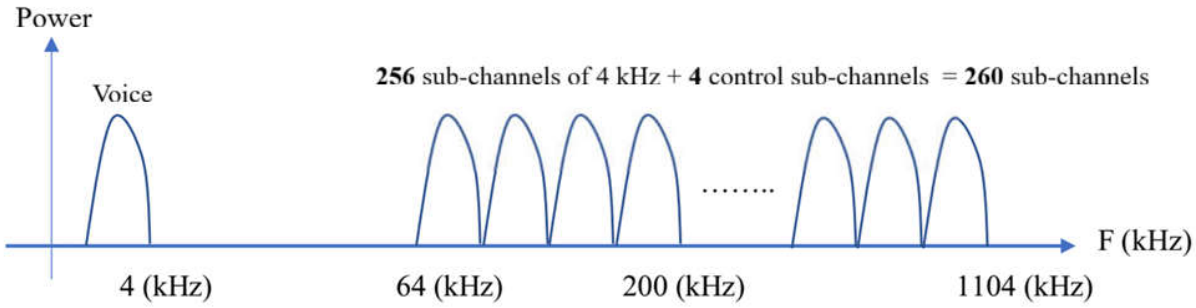


Figure III.3: *Division of the data band into multiple 4 kHz sub-bands.*

Each sub-channel uses **QAM (Quadrature Amplitude Modulation)** followed by a frequency transposition according to a specific encoding scheme called **DMT (Discrete Multi-Tone)**, with a data rate of 32 kbps per channel. This allows for achieving up to 640 kbps for uploading and up to 8 Mbps for downloading.

Accessing an operator's internet network via the telephone line requires the use of a filter (splitter) at the user's premises, which separates the traditional telephone service from the ADSL modem (Figure III.4).

Figure III.4: *ADSL link between an end-user and the voice and data networks.*

Author: Dr. H. Zerroiki

In addition to connecting the modem to the filter via a telephone cable (RJ11 connector), the modem offers access via Ethernet (Twisted Pair with RJ45 connector), USB, or Wi-Fi (wireless). On the telecommunications operator's side, a **DSLAM (Digital Subscriber Line Access Multiplexer)** handles the multiplexing and serves as the interface between the ADSL customers and the operator's high-speed network.

III.3.3 ADSL2+ and its Evolutions

The first version of ADSL was limited to a downstream rate of 8 Mbps for maximum distances of 5 km. ADSL2+ can reach 25 Mbps for maximum distances of 2 km. This gain is primarily achieved by using a frequency band up to 2.2 MHz with the same modulation techniques.

By using an even wider and higher frequency band, **VDSL (Very High bit-rate DSL)** can achieve a receive rate of 52 Mbps and a transmit rate of 12 Mbps. VDSL2 will theoretically allow these rates to be doubled.

ADSL, initially designed for Video on Demand (VoD) services, provided high-speed access for Internet connections and is now facing competition from fiber optic access.