DIGITAL SUBSCRIBER LINE (DSL)

ECE 424 – DIGITAL COMMUNICATION

Monday, 13 April 2026

COURSE OUTLINE (5)

Course Purpose:
To enable students understand the fundamental principles of digital transmission systems as used in fixed and mobile telephony, wired and wireless computer networks, data storage and digital broadcasting.

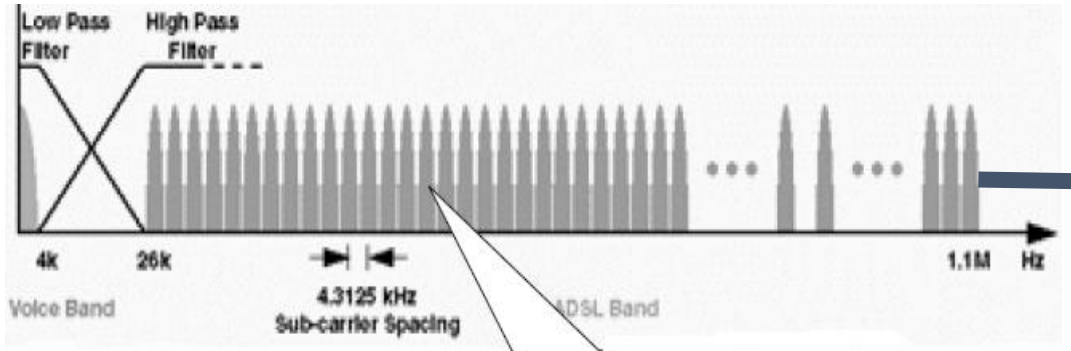
Expected Learning Outcomes:
At the end of the course, students will be able to:

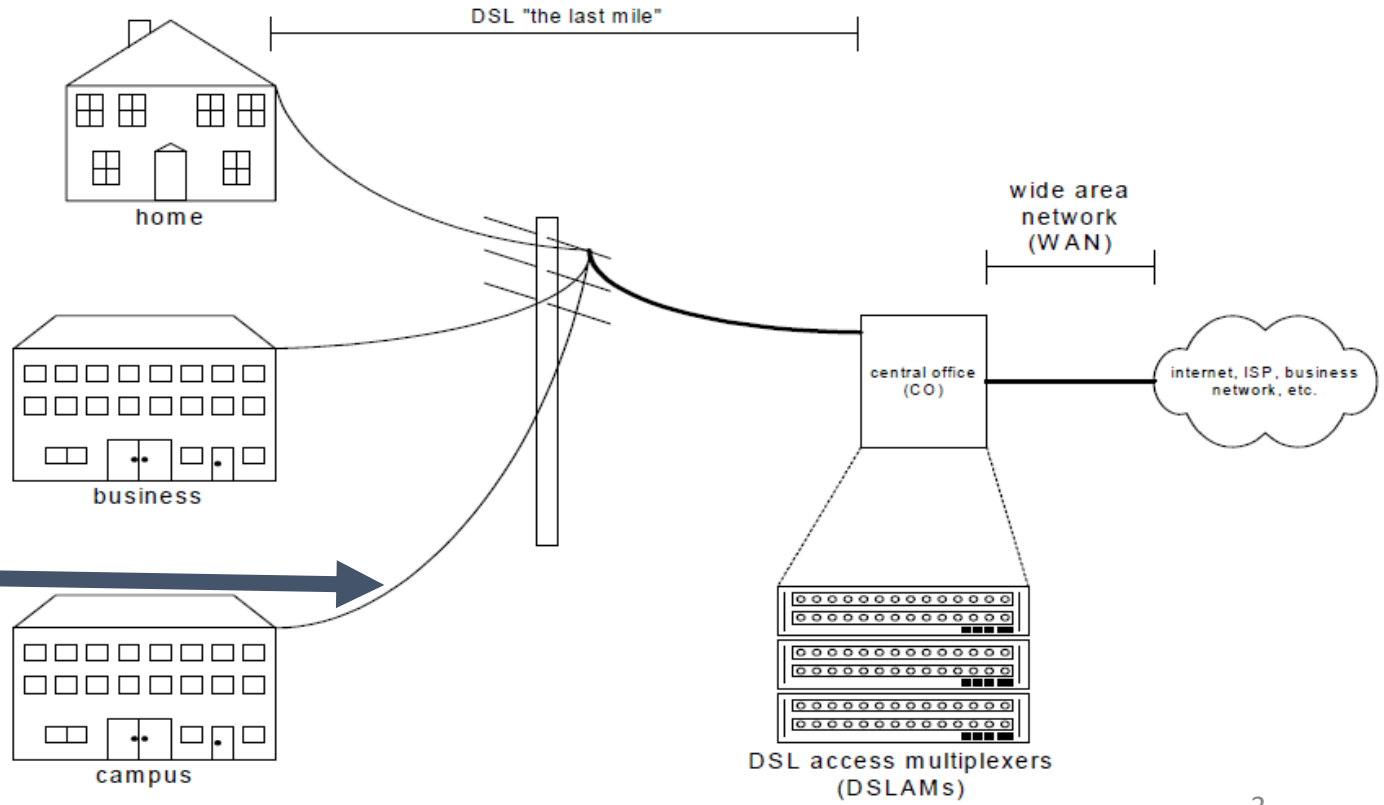
(i) describe binary and duo binary pulse Amplitude Modulation (PAM);
(ii) design digital coding schemes;
(iii) derive error performance equations for digital modulation schemes(ASK,FSK,PSK,DPSK);
(iv) state strengths and weaknesses of M-ary PSK with QAM signaling schemes;
(v) design a basic digital communication systems.

Course Content:
Signal digitization: Pulse Amplitude Modulation (PAM), sampling theorems and sampling circuits, Pulse code modulation (PCM). Quantization and signal conditioning: Uniform and non-uniform quantization; companding methods; vocoders; signal-to- quantization noise ratio. Waveform coding: Pulse transmission, PCM, Pulse-shaping; Delta modulation; adaptive delta modulation; Differential Pulse Code Modulation (DPCM), M-ary encoding. Digital Modulation: Amplitude shift keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), Quadrature Amplitude Modulation (QAM) and Differential Phase Shift Keying (DPSK). Signal recovery in ASK, FSK and PSK; Gaussian Minimum Shift Keying (GMSK); Performance comparison. Information theory: information sources, entropy, channel capacity; Source Coding; entropy coding. Error control: Error control coding techniques; Transmission errors; Error detection methods; intersymbol interference and the eye pattern; Linear block codes; Cyclic codes; convolution codes. Multiplexing: Frequency division multiplex (FDM), Time Division Multiplexing (TDM), plesiochronous digital hierarchy (PDH). Spread spectrum communication: Direct sequence and frequency hopping methods; synchronization, spreading codes and their generation. Data transmission: Local data transmission protocals (Ethernet, token ring); Modems; high Asymmetric Digital subscriber line (ADSL); Very–high Speed Digital subscriber line (VDSL), integrated services digital network (ISDN).

DIGITAL SUBSCRIBER LINE (DSL) DEFINED

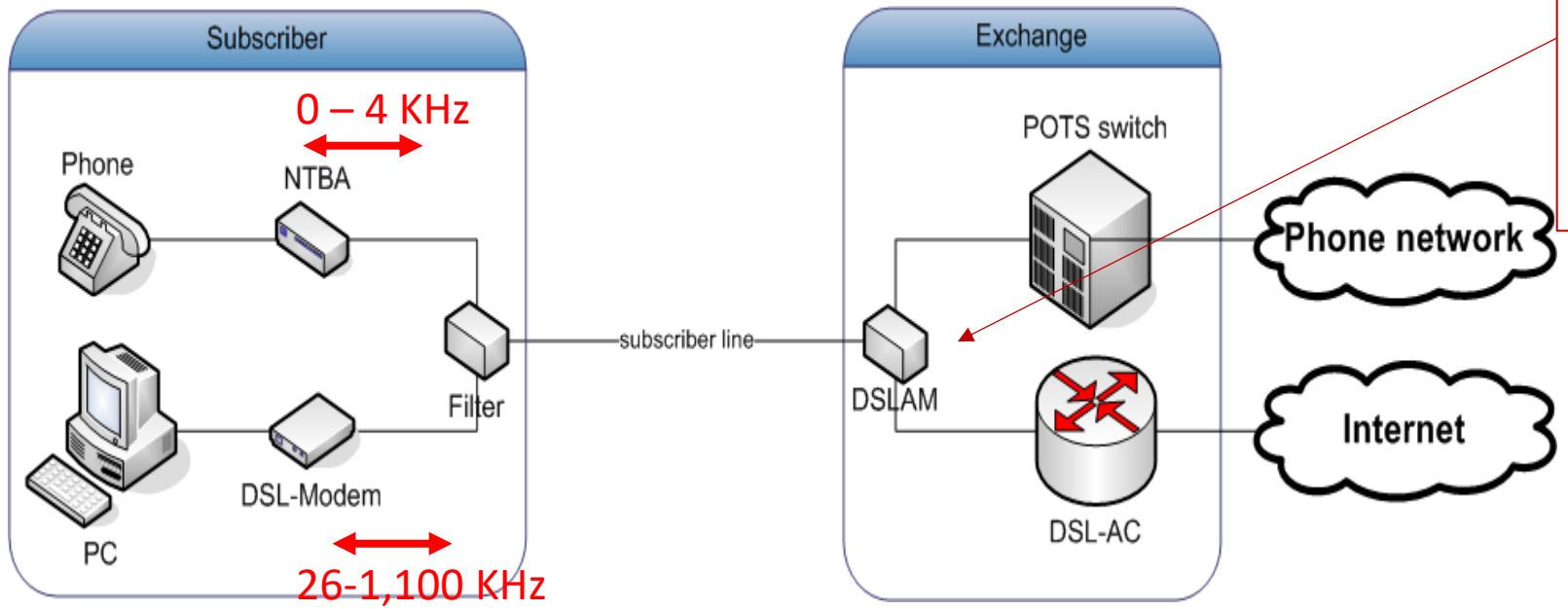
1. **Digital Subscriber Line (DSL)** refers to a group of technologies that utilize the unused bandwidth in the existing copper access network to deliver high-speed data services from the distribution centre, or central office, to the end user.
2. **DSL technology is attractive because it requires little or no upgrading of the existing copper infrastructure.**





DIGITAL SUBSRIBER LINE PRINCIPLE(1)

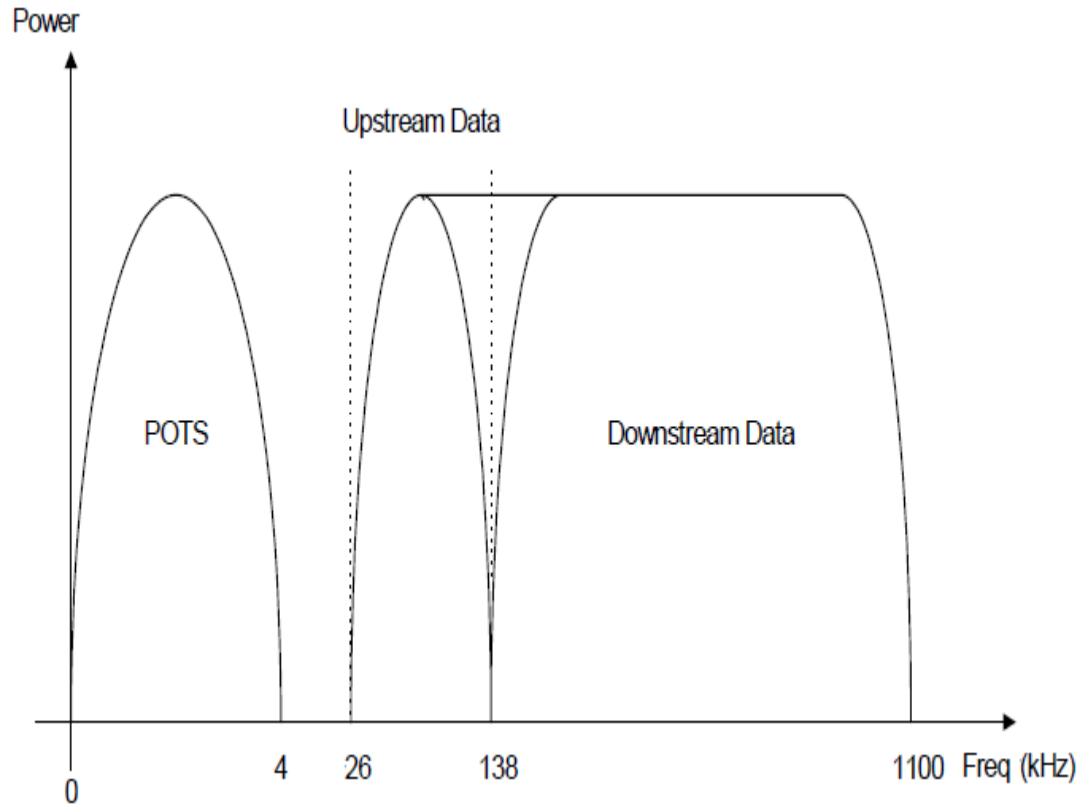
1. The local loop connecting the telephone exchange to most subscribers has the capability of carrying frequencies well beyond the 3.4 kHz upper limit of POTS.
2. Depending on the length and quality of the loop, the upper limit can be tens of megahertz.
3. DSL takes advantage of this unused bandwidth of the local loop by creating 4,312.5 Hz wide, over and above 4KHz.
4. Allocation of channels continues at higher and higher frequencies (up to 1.1 MHz for ADSL) until new channels are deemed unusable.
5. Each channel is evaluated for usability in much the same way an analog modem would on a **Plain Old Telephone System (POTS)** connection.
6. More usable channels equates to more available bandwidth, which is why distance and line quality are a factor (the higher frequencies used by DSL travel only short distances).



A DSLAM (Digital Subscriber Line Access Multiplexer) is a network device that aggregates multiple DSL (Digital Subscriber Line) connections into a single high-speed uplink

DIGITAL SUBSRIBER LINE PRINCIPLE(2)

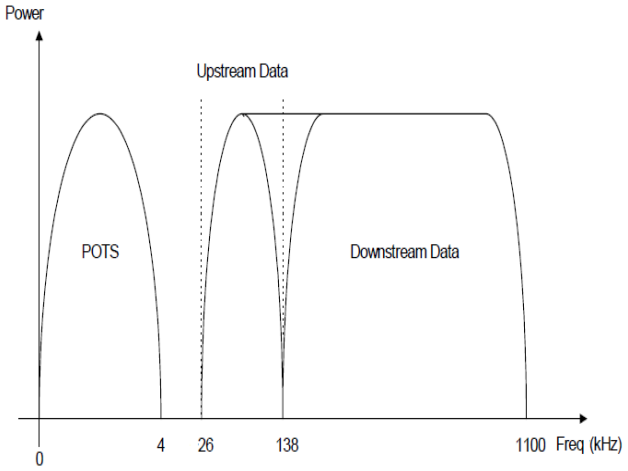
- The pool of usable channels is then split into two different frequency bands for upstream and downstream traffic, based on a preconfigured ratio.
- This segregation reduces interference.
- Once the channel groups have been established, the individual channels are bonded into a pair of virtual circuits, one in each direction.
- Like analog modems, DSL transceivers constantly monitor the quality of each channel and will add or remove them from service depending on whether their quality.



ASYMMETRIC DIGITAL SUBSCRIBER LINE (ADSL)

The most commonly used DSL system is the **Asymmetric Digital Subscriber Line** which comes in the following standards:

1. ANSI T1.413-1998 – First ADSL standard
2. G.992.1 = 8.1/0.8 Mbps (down/up) using 256 bins
3. G.992.2 = 1.5/0.5 Mbps using 128 bins
4. G.992.5 = ADSL2plus = 24 Mbps at 5,000 feet (Jan 2003)
5. ADSL4 = 52 Mbps proposed quad spectrum (ADSL2++)



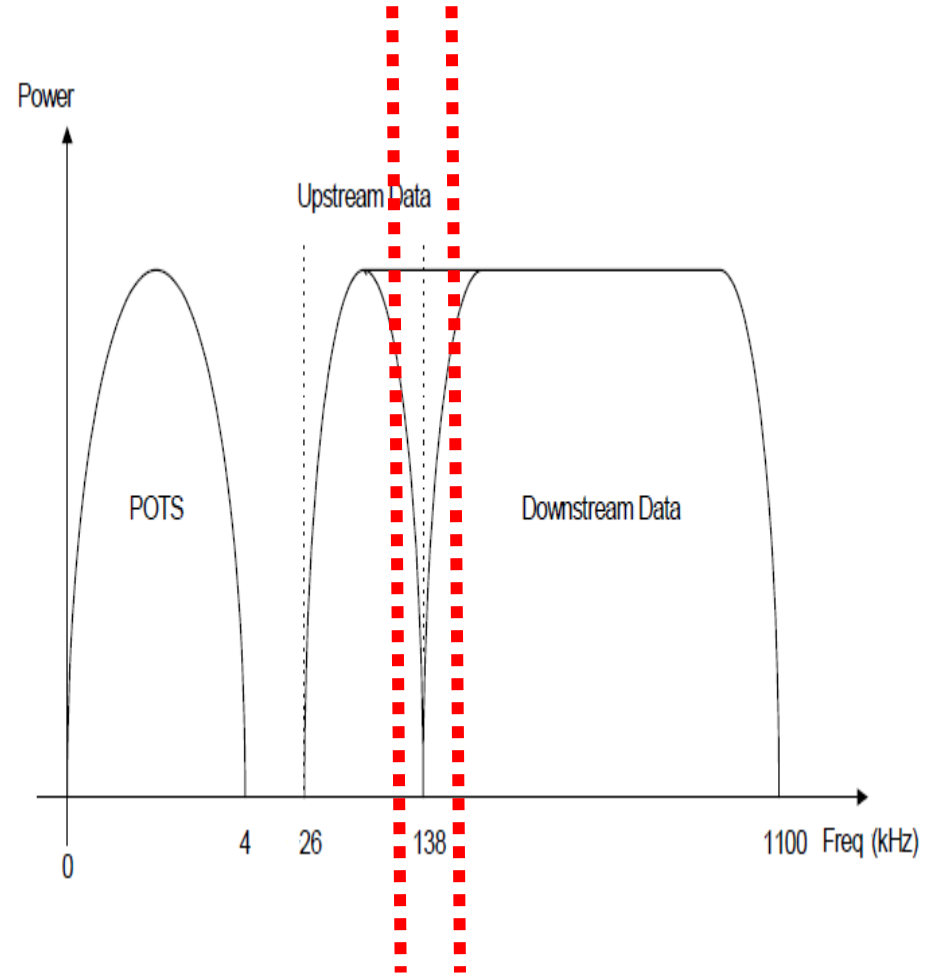
ANSI T1.413-1998 (DOWN STREAM)

1. **ANSI T1.413-1998 standard** divides the useful bandwidth of the standard two-wire copper medium used in the PSTN, which is 0 to 1,104kHz, into 256 separate 4.3125kHz wide bins called sub-carriers (**224 down-stream and 32 up stream**) .

2. A sub-carrier is associated with a discrete frequency, or tone, indicated by 4.3125kHz x n, where n = 1 to 256, and is essentially a single distinct data channel.

ALLOCATION OF FREQUENCY BAND

1. The frequency layout can be summarised as:
   - 300 Hz - 4 kHz, voice.
   - 4–25 kHz, unused guard band.
   - 25–138 kHz, 25 upstream bins (7-31).
   - 138–1104 kHz, 224 downstream bins (32-255)
2. Typically, a few bins around 31-32 are not used in order to prevent interference between upstream and downstream bins either side of 138 kHz.
3. These unused bins constitute a guard band to be chosen by each Digital Subscriber Line Access Multiplexer (DSLAM) manufacturer. Hence, it is not defined by the standard.

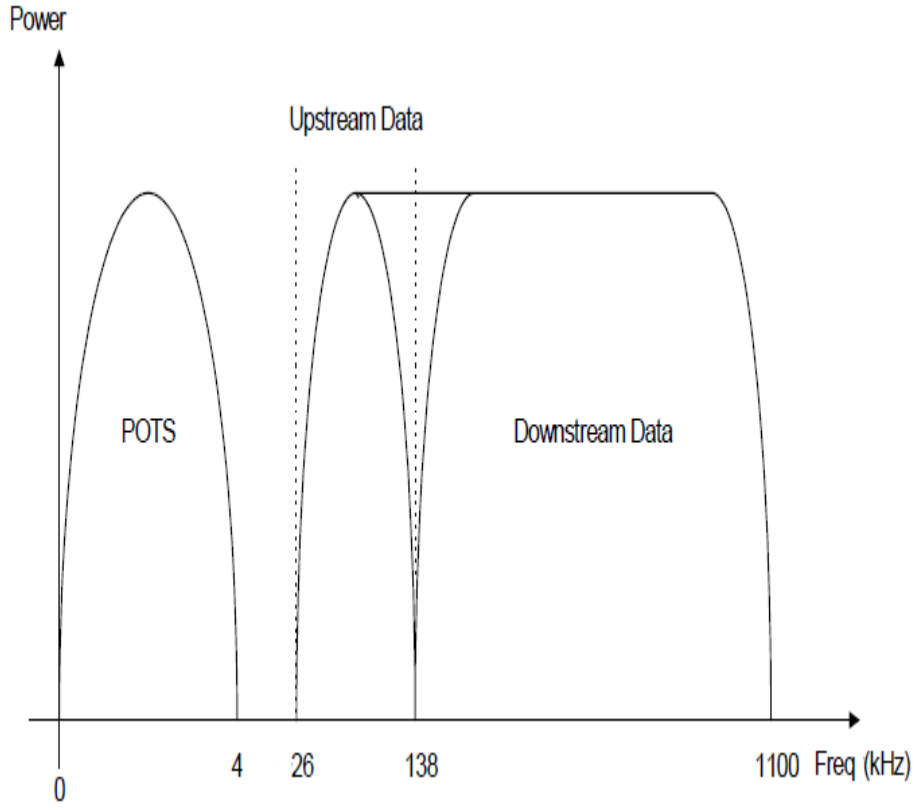


ANSI T1.413-1998 DOWN STREAM

1. Sub-carrier 256 and sub-carrier 64 are not available for user data, thus limiting the total number of available downstream sub-carriers to 254.

2. Each carrier supports 15-bit frame size which are transmitted at 4,000 frames/second or a bit stream of 15x4000 = 60kb/s

3. The maximum down-link data rate is therefore 60,000 X (224-2) = 13.32 Mb/s.



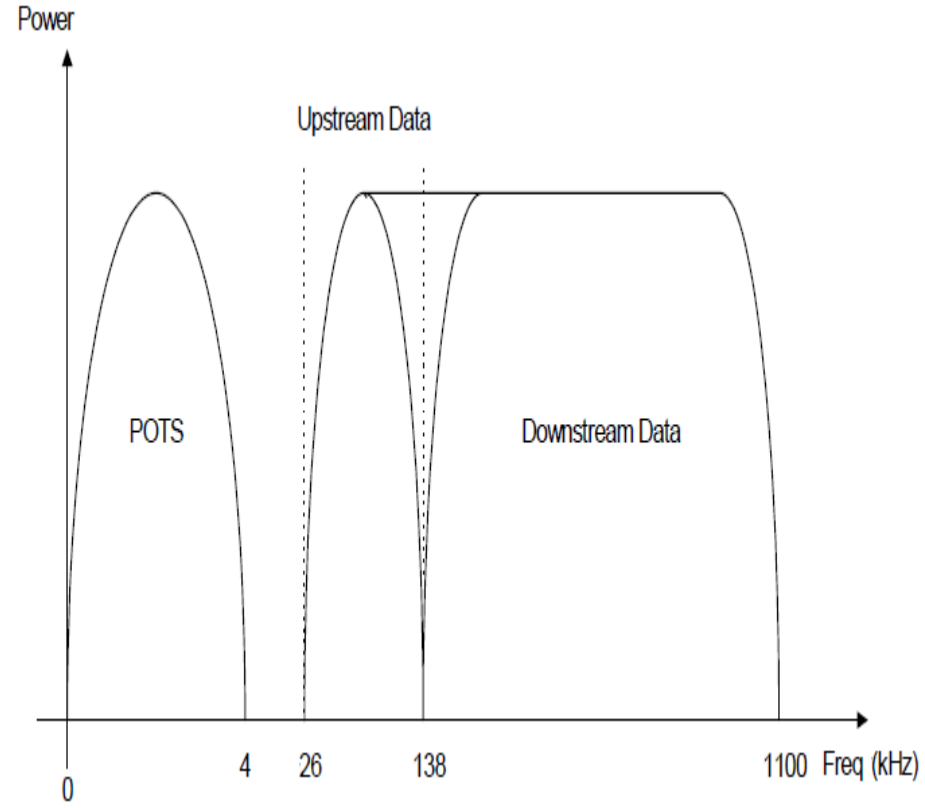
ANSI T1.413-1998 (UP STREAM)

1. In the upstream direction, a maximum of 32 carriers are used to modulate data.

2. Sub-carrier 32 and sub-carrier 16 are not used to carry user data.

3. Each carrier supports 15-bit frame size which are transmitted at 4,000 frames/second or a bit stream of 15x4000 = 60kb/s

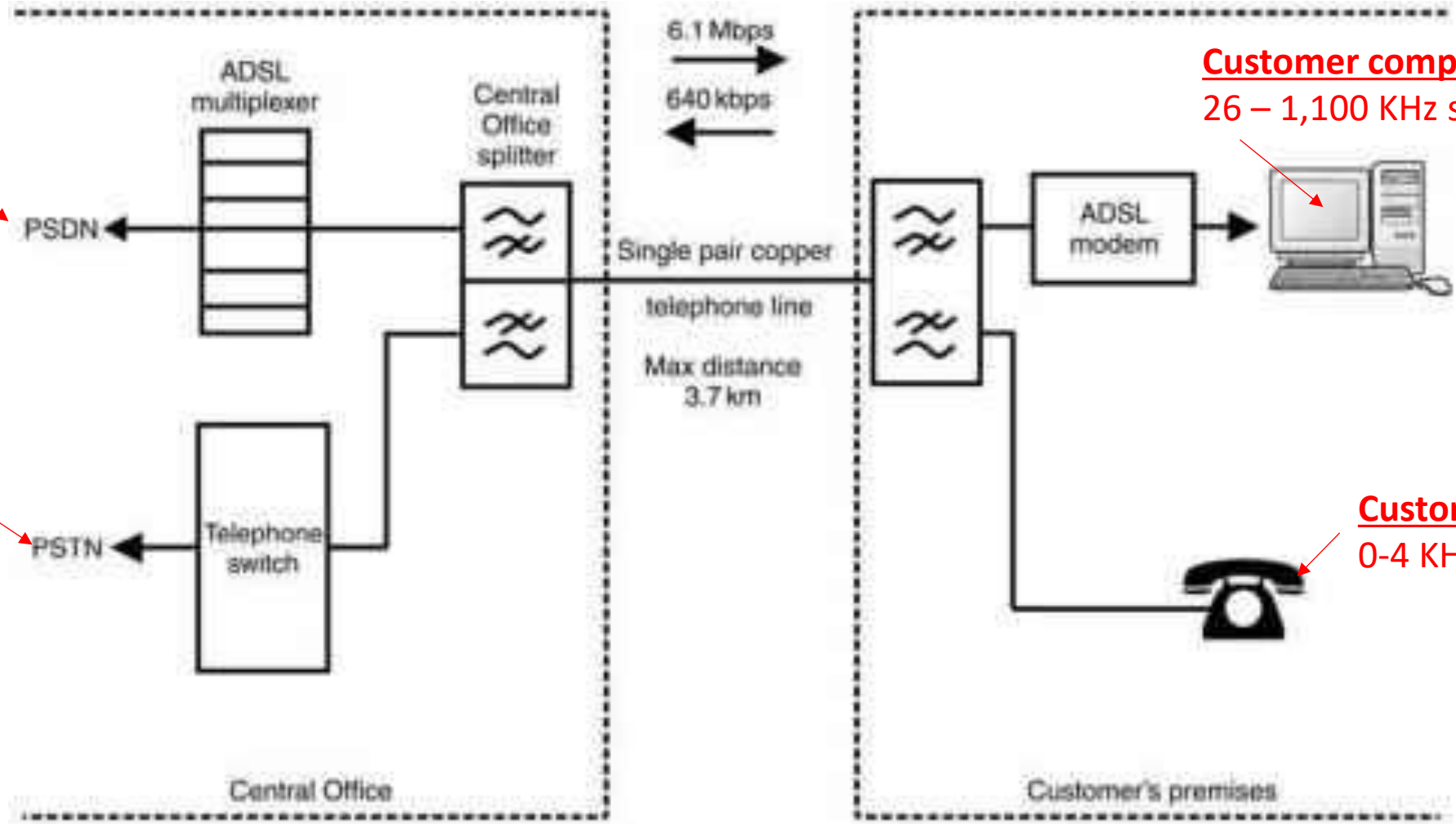
4. The maximum up-stream data rate is therefore 30 X 60,000 = 1.8 Mb/s.



TYPICAL ADSL SET-UP (1)

Public Switched Data Network(PSDN)
Corporate network or Internet service provider

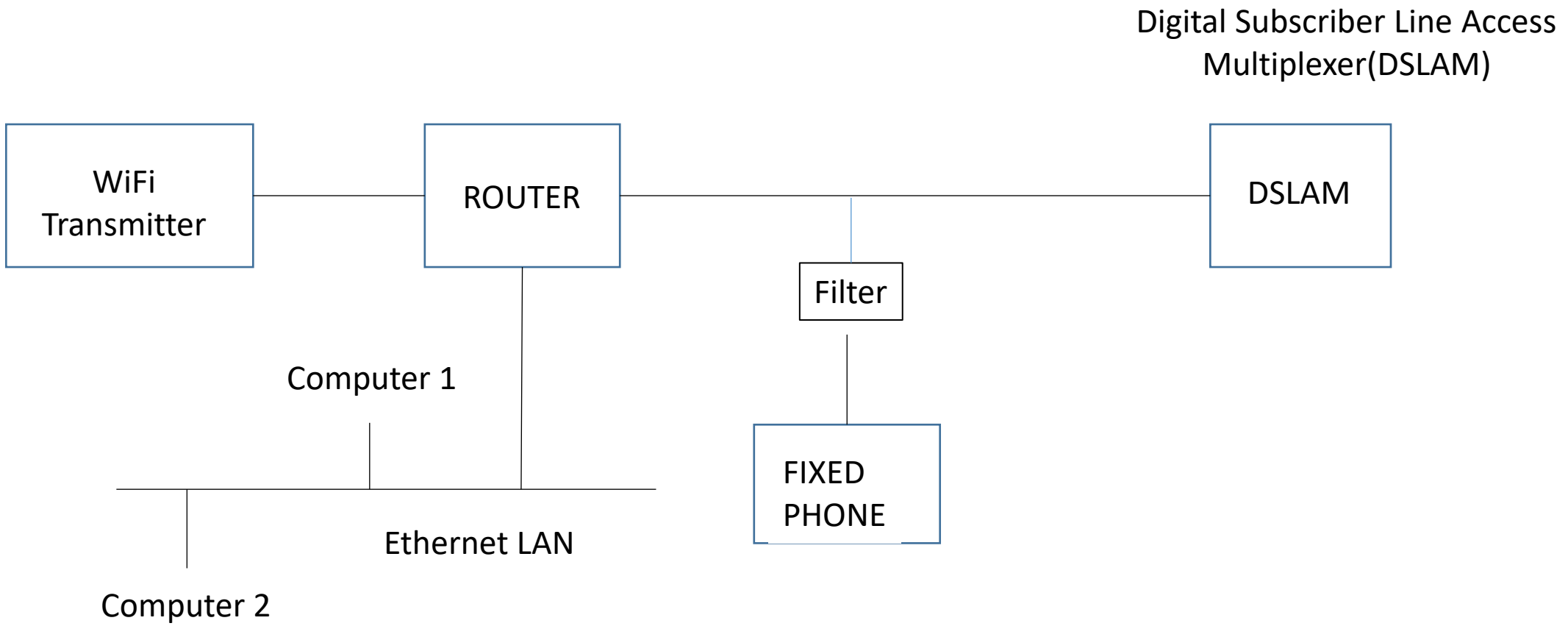
Public Switched Telephone Network(PSTN)
Fixed or cellular telephone system



Customer computer
26 – 1,100 KHz signal

Customer Telephone
0-4 KHz signal

TYPICAL ADSL SET-UP (2)



VHDSL - DEFINITION

- **Very-high-bit-rate digital subscriber line (VDSL or VHDSL)** is a digital subscriber line (DSL) technology providing data transmission faster than ADSL over a single flat untwisted or twisted pair of copper wires **(up to 52 Mbit/s downstream and 16 Mbit/s upstream**).
- **VHDSL on coaxial cable** can achieve speeds of up to 85 Mbit/s down- and upstream) using the frequency band from 25 kHz to 12 MHz.
- These rates mean that VHDSL is capable of supporting applications such **as high-definition television, as well as telephone services (voice over IP) and general Internet access, over a single connection.**
- **VHDSL is deployed over existing copper wiring** used for analogue telephone service and lower-speed DSL connections.

VDSL STANDARDS

- **VDSL standard was approved by ITU in November 2001.**
- Second-generation systems (VDSL2; ITU-T G.993.2 approved in February 2006) use frequencies of up to 30 MHz to provide data rates exceeding 100 Mbit/s simultaneously in both the upstream and downstream directions.
- **The maximum available bit rate is achieved at a range of about 300 meters; performance degrades as the copper cable attenuation increases.**

VERSION	STANDARD NAME	COMMON NAME	DOWNSTREAM RATE	UPSTREAM RATE	APPROVED IN
VDSL	ITU G.993.1	VDSL	55 Mbit/s	3Mbit/s	2004-06-13
VDSL2	ITU G.993.2	VDSL2	100 Mbit/s	100 Mbit/s	2006-02-17