Digital Subscriber Line

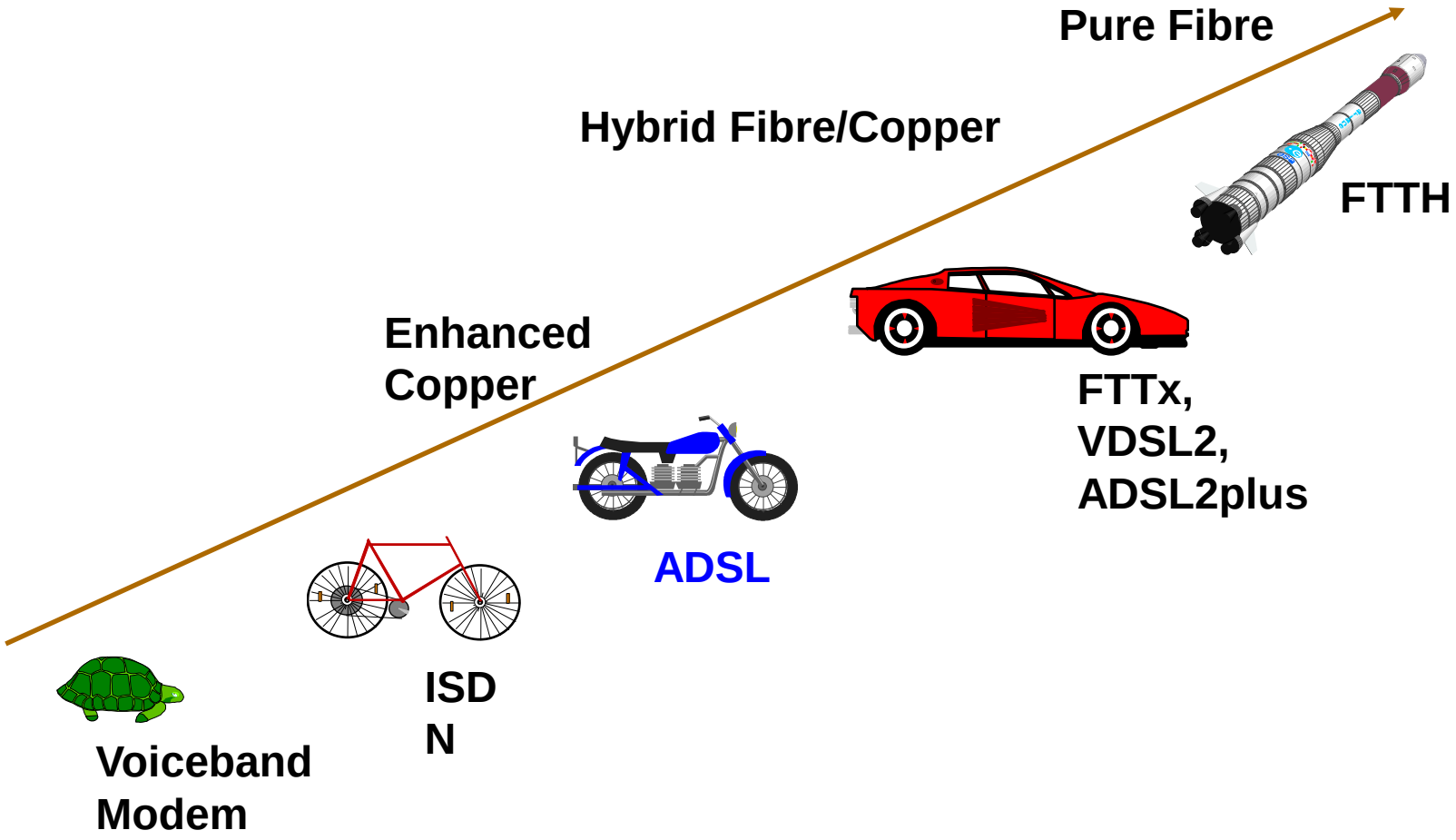
Market Status of ADSL

- ADSL is the #1 Broadband Choice in the World with over 60% market-share
- ADSL is now available in every region of the world
- ADSL is capable of providing up to 50 Mbps, and supports voice, video and data.
- There is broad equipment interoperability and there are currently established test specifications for ADSL, ADSL2plus, SHDSL, and VDSL

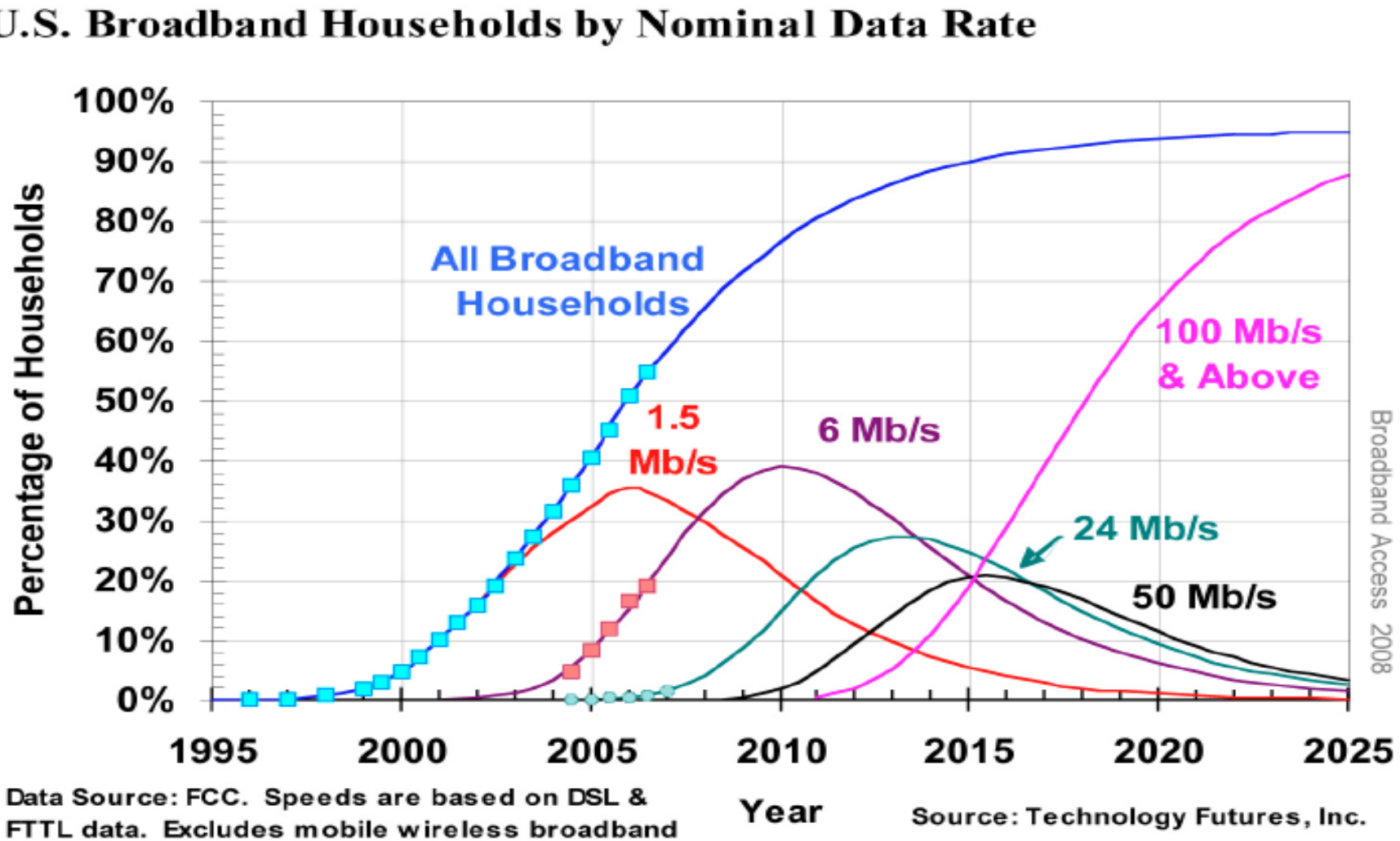
Market Status of ADSL

- DSL lines rose from 173 Million in September 2006 to 500 Million in 2010
- Broadband growth is 1.25 Million each week with 66% DSL (+800,000 DSL installs per week)
- Broadband subscribers 66% DSL, 23% CATV, 10% FTTx, 1% Satellite

Evolution of Digital Access



Broadband outlook



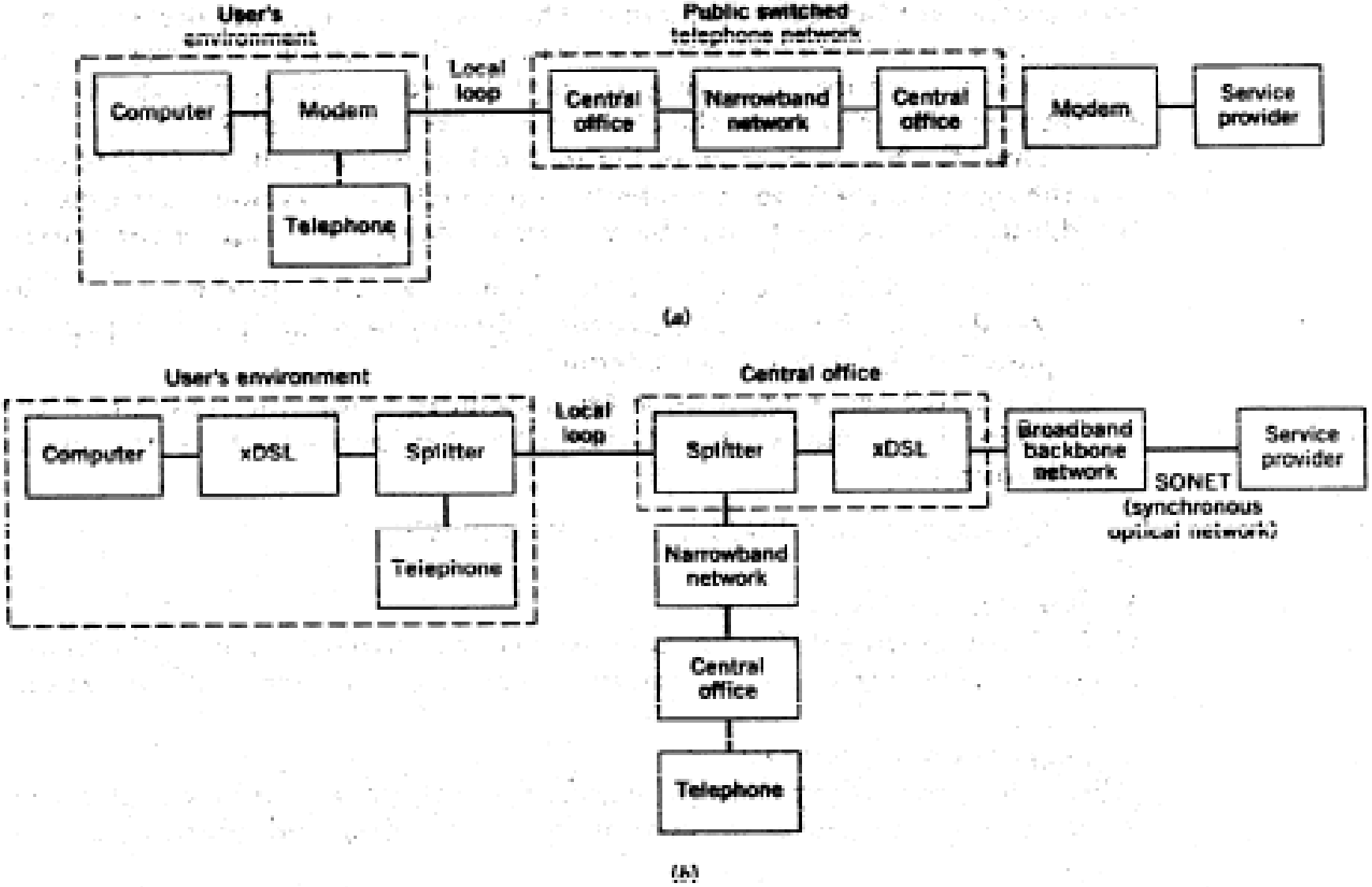
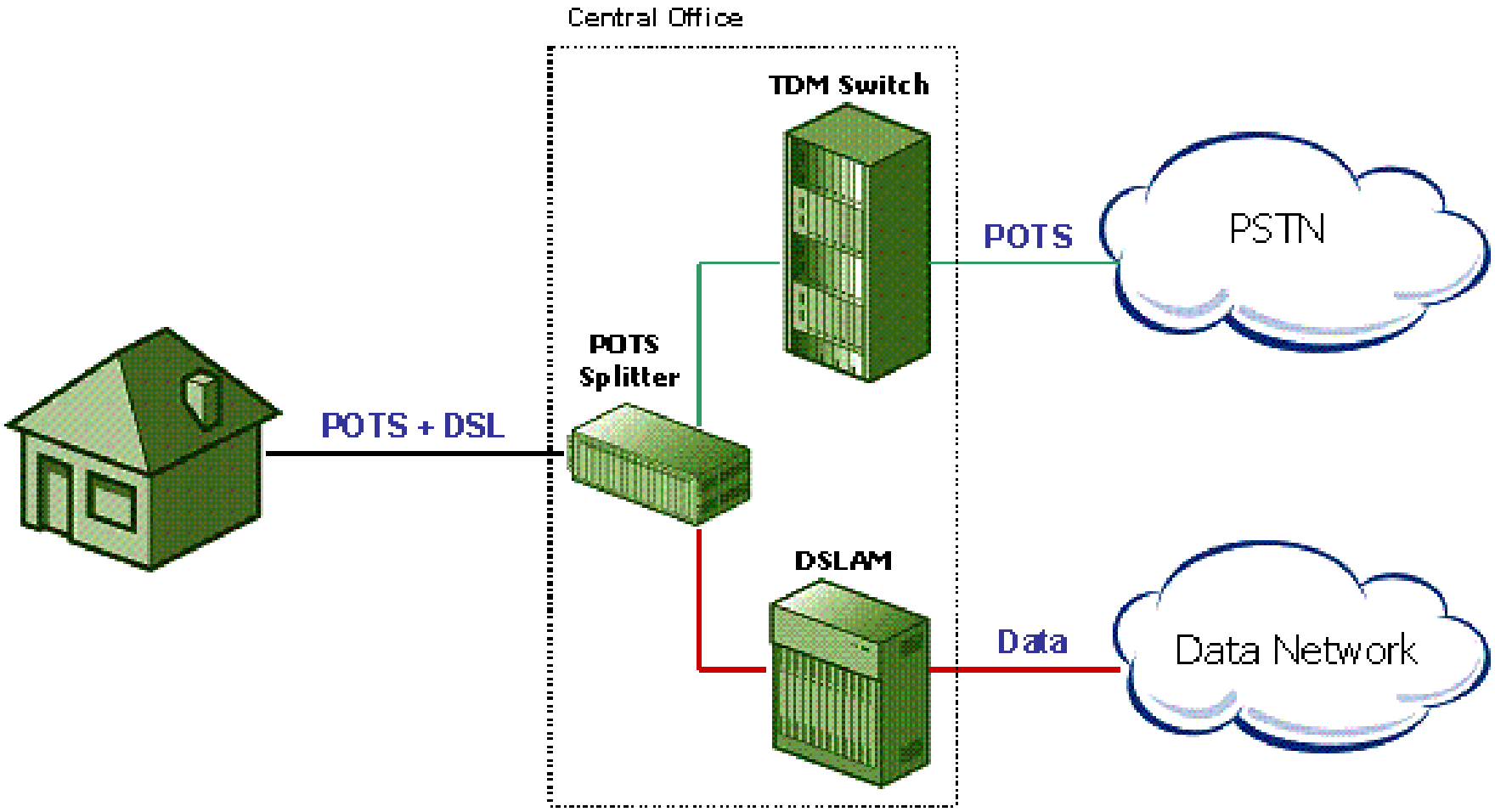
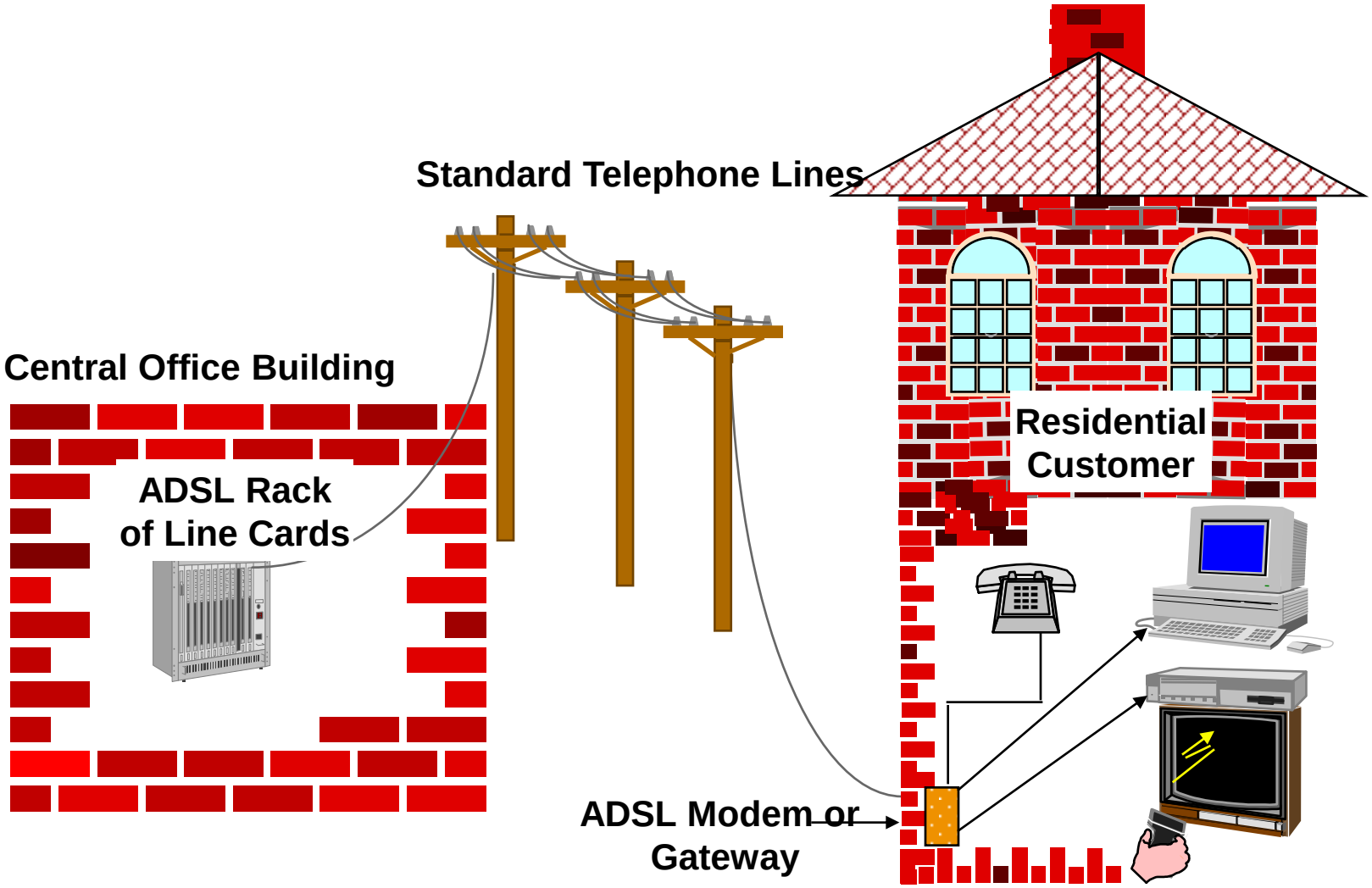


FIGURE 6.61 (*a*) Voiceband modem environment. (*b*) xDSL (digital subscriber line) environment, where x stands for "asymmetric" or "very high-rate."

DSL connection



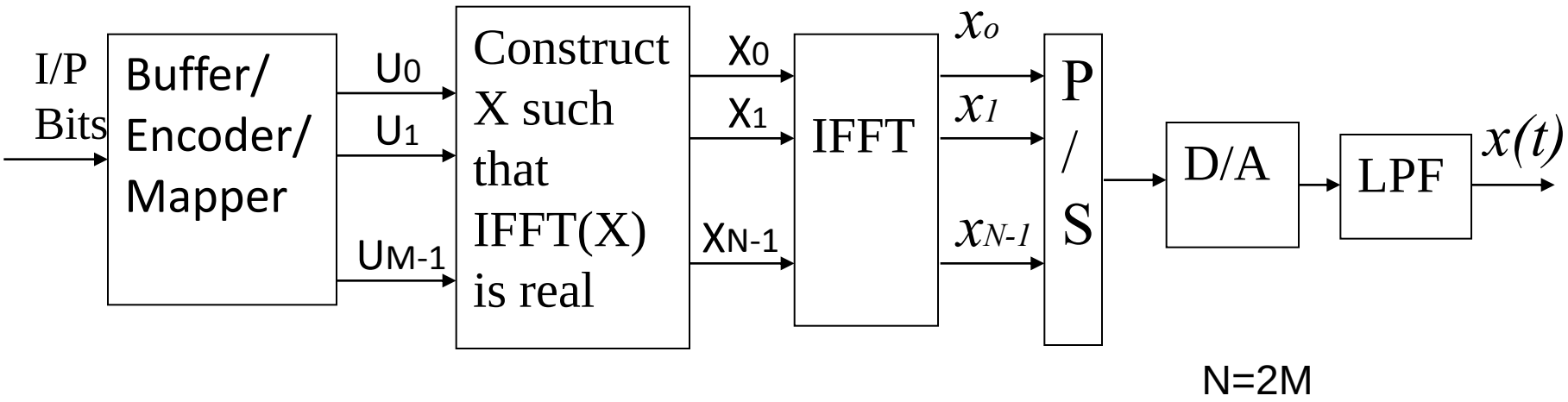
DSL equipment



DSL Technology Options

Fmily	ITU	Name	Ratified	Maximum Speed capabilities
ADSL	G.992.1	G.dmt	1999	7 Mbps down, 800 kbps up
ADSL2	G.992.3	G.dmt.bis	2002	8 Mb/s down, 1 Mbps up
ADSL2plus	G.992.5	ADSL2plus	2003	24 Mbps down, 1 Mbps up
ADSL2-RE	G.992.3	Reach Extended	2003	8 Mbps down 1 Mbps up
SHDSL	G.991.2	G.SHDSL	2001	5.6 Mbps up/down
VDSL	G.993.1	Very-high-data-rate DSL	2004	55 Mbps down, 15 Mbps up
VDSL2	G.993.2	Very-high-data-rate DSL 2	2005	100 Mbps up/down

Discrete Multitone (DMT)



- An I/P bit stream is buffered into blocks of *b* bits
- Of these *b* bits, b_k (k=0,1, …,$M-1$) are intended for use in the k^{th} subchannel.
- The b_k bits are translated in the DMT encoder into a complex subsymbol, X_k.

DMT Symbol construction

- The IFFT combines the *M* subsymbols into a set of *N* real-valued time domain samples x_n, *n*=0,1,...,*N*-1 as follows
- where

$$x_n = \frac{1}{N}\sum_{k=0}^{N-1} X_k e^{j2\pi kn/N}$$

$$X_k = \begin{cases} U_k & K = 1,2,...,N/2-1 \\ \mathrm{Re}(U_0) & K = 0 \\ \mathrm{Im}(U_0) & K = N/2 \\ U^*_{N-k} & K = N/2+1,...,N-1 \end{cases}$$

- The conjugate symmetry conditions on $\mathrm{X_k}$ are imposed to force x_n to be real

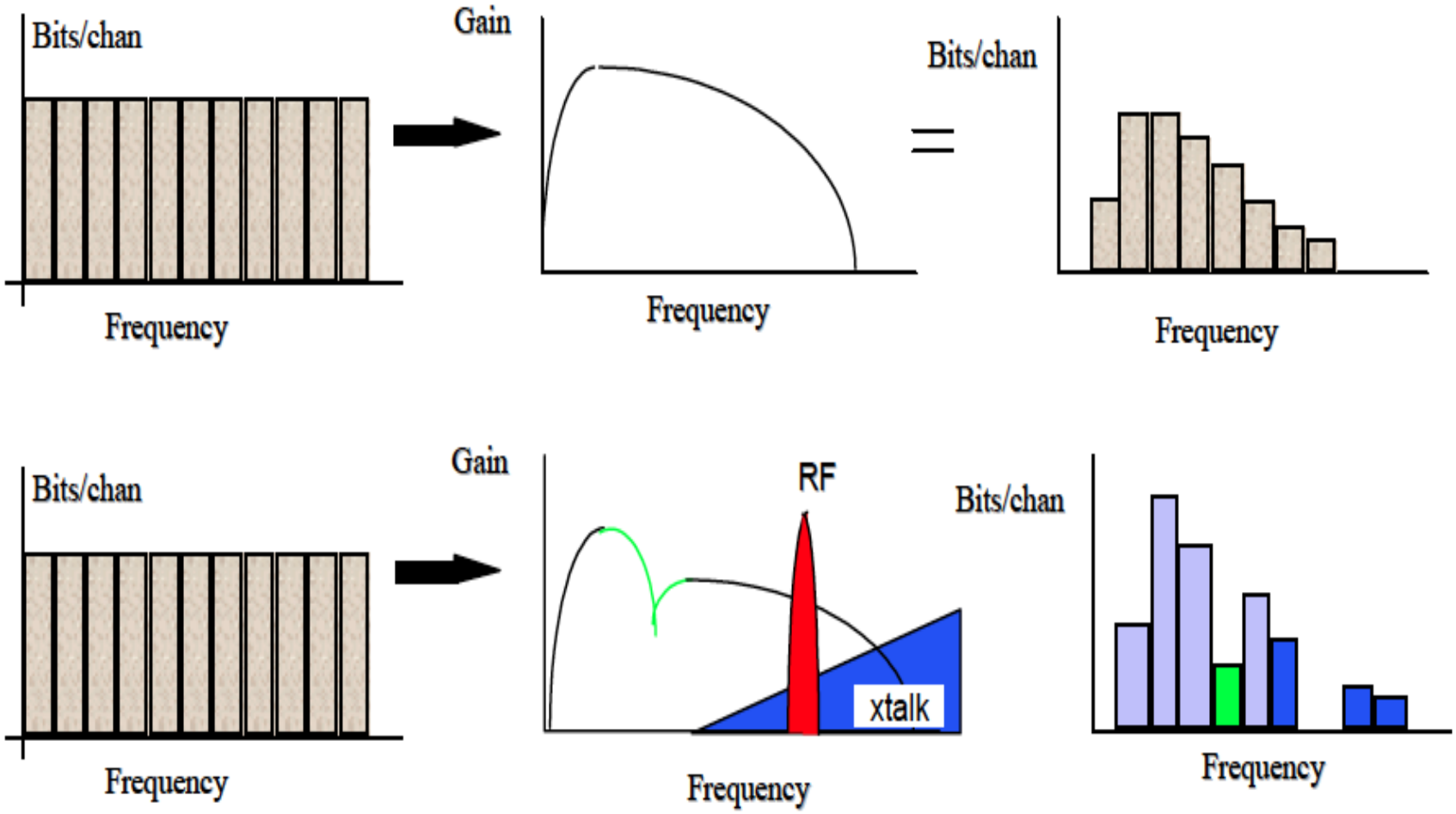
Digital Subscriber Line (DSL)

- ADSL (asymmetric DSL) and VDSL (very-high – rate DSL) uses DMT
- For ADSL, downstream bit rate may reach 9Mbps, while upstream bit rate may reach 1Mbps.
- For VDSL, downstream bit rate may reach 26 Mbps, while upstream bit rate may reach 3Mbps.

Advantages of DMT

- The ability to maximize the transmitted bit rate which is provided by tailoring the distribution of information bearing signals across the channel according to channel attenuation and noise conditions.
- DMT is adaptive to changing line conditions by changing the number of bits per channel

Bit loading


Bits/chan
Frequency
Gain
Frequency
Bits/chan
=
Frequency
Bits/chan
Frequency
Gain
RF
xtalk
Frequency
Bits/chan
Frequency

ITU G.992.1 (G.DMT)

- Delivering high-speed data communications at rates up to 12 Mbit/s downstream and 1.3 Mbit/s upstream.
- 255 carriers (bins) centred on multiples of 4.3125 kHz. DMT has 224 downstream frequency bins and up to 31 upstream bins. Bin 0 is at DC and is not used.
- When voice is used on the same line, then bin 7 is the lowest bin used for ADSL.
- The centre frequency of bin N is (N x 4.3125) kHz. The spectrum of each bin overlaps that of its neighbors: it is not confined to a 4.3125 kHz wide channel. The orthogonality of OFDM makes this possible without interference.
- Up to 15 bits per symbol can be encoded on each bin on a good quality line.

ITU G.992.1 (G.DMT)

- The frequency layout can be summarized as:
- 0-4 kHz, voice.
- 4-25 kHz, unused guard band.
- 25-138 kHz, 25 upstream bins (7-31).
- 138-1107 kHz, 224 downstream bins (32-255).
- 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.
- Each bin caries between 2 and 15 bits

Bin quality and bit rate

- The quality of the line (how well it performs) at the frequency of the bin in question determines how many bits can be encoded within that bin.
- SNR may differ for each bin and this plays an important factor for deciding how many bits can be encoded reliably on it.
- Generally speaking, 1 bit can be encoded reliably for each 3 dB of available dynamic range above the noise floor within a transmission medium so, for example, a bin with an SNR of 18 dB would be able to accommodate 6 bits.

DMT Bits-per-bin Examples