Networking Technologies and Applications

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Introduction

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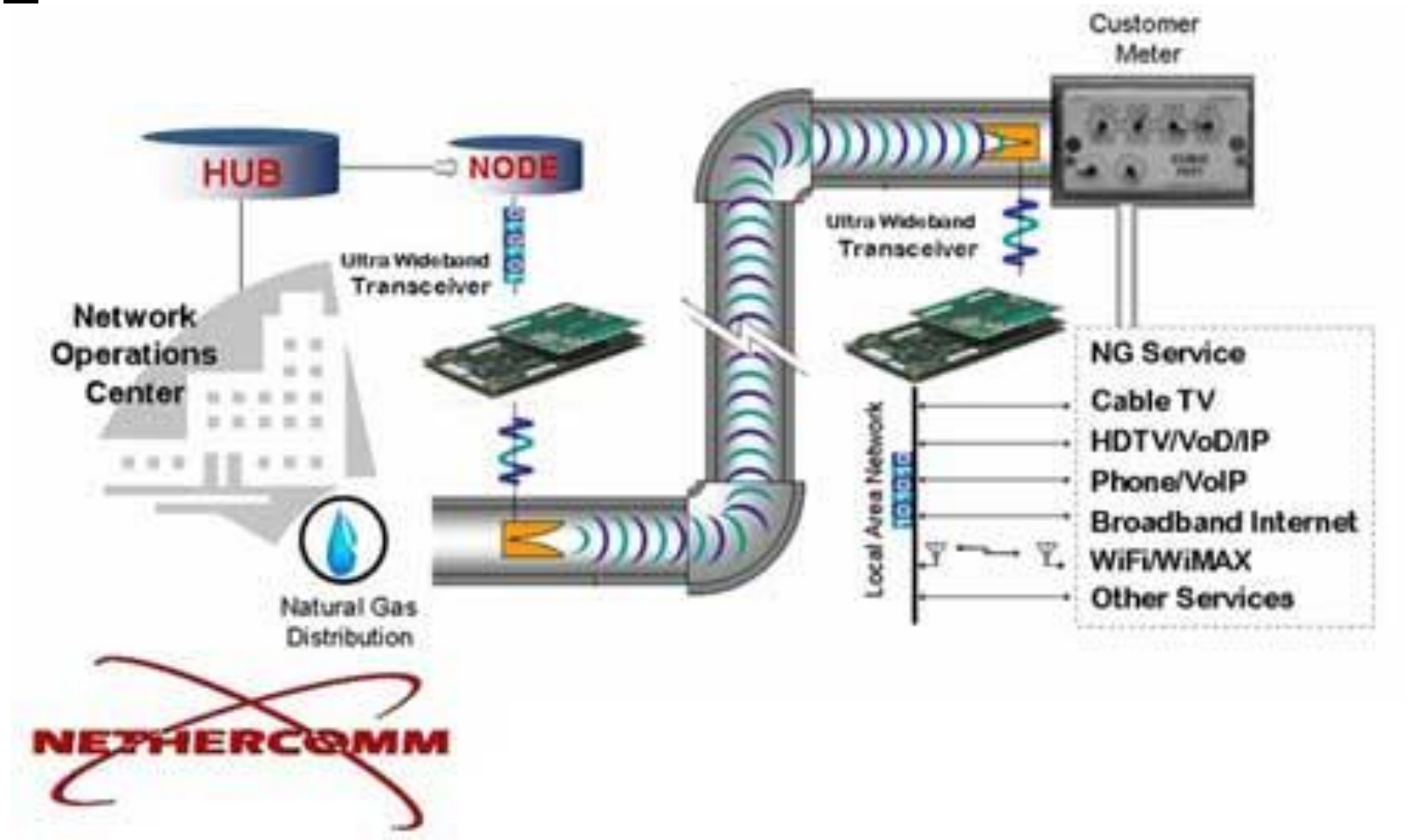
Slides

- http://www.tmit.bme.hu/vitma341_2015_en

Introduction

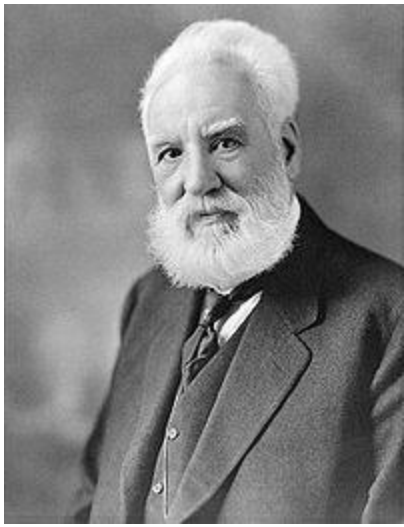
- Easiest way for two computers to communicate – direct connection
- If long distances and many computers – too expensive
  - It's not the cost of the wires…
    - But the digging, and the work inside the buildings
- Solution: use some existing infrastructures/networks
  - Public Switched Telephone Network (PSTN)
  - Cable TV network
  - Electric network
  - Gas pipes (?)
    - Ultra Wideband radio communication
  - Drainpipes (?)
    - Optical fiber cables
- But sometimes you can build new ones as well…

Internet through the gas pipe?



PSTN

- The telephony network was designed only for speech transmission
- 1876 – Graham Bell patents the first telephone
  - A few hours before Elisha Gray
- You could buy the phone, but the wire was installed by the users
  - A separate wire for each pair of users
  - In a year the cities became completely „wired”



PSTN

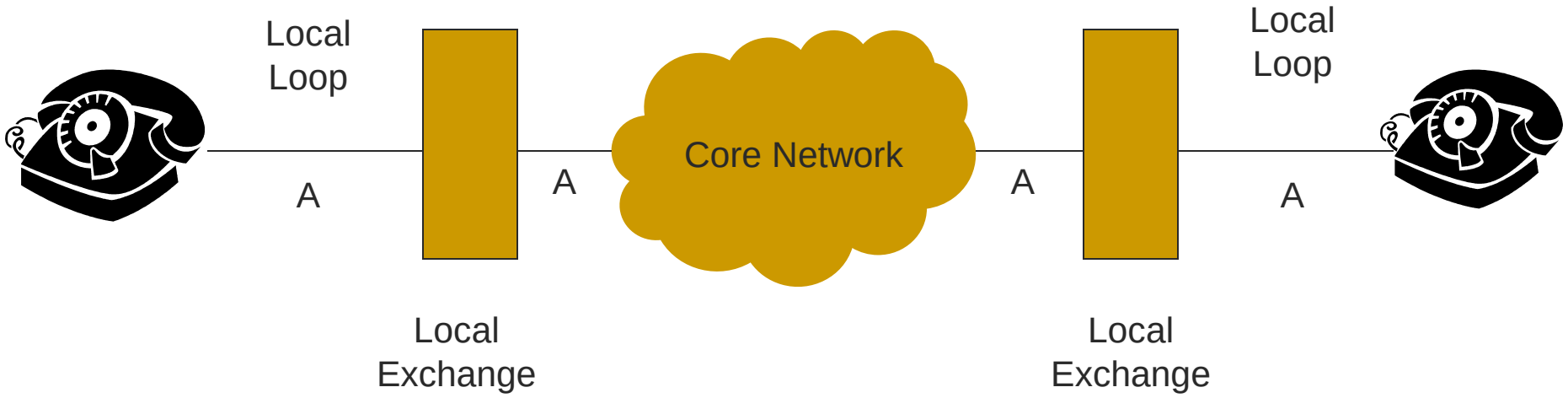
- 1878 – Bell Telephone Company
  - The first switching center – New Haven, Connecticut
  - A human operator switching manually between the users
- Inter-city calls
  - Linking the telephone switching centers
  - Secondary centers, hierarchical architecture
- Only in the US more than 22.000 centers today, 5-level hierarchy

PSTN

- Elements of the PSTN network:
  - Local loop
    - From the user's home to the local exchange point
      - „last mile"
      - Optical local loop, wireless local loop
    - Twisted pair of copper wires
  - Switching centers / telephone exchanges
  - Optical trunks
    - Linking the a switching centers
    - Core network

- The first network was completely analog
  - Step by step transition to digital transmission, mainly in the core

PSTN

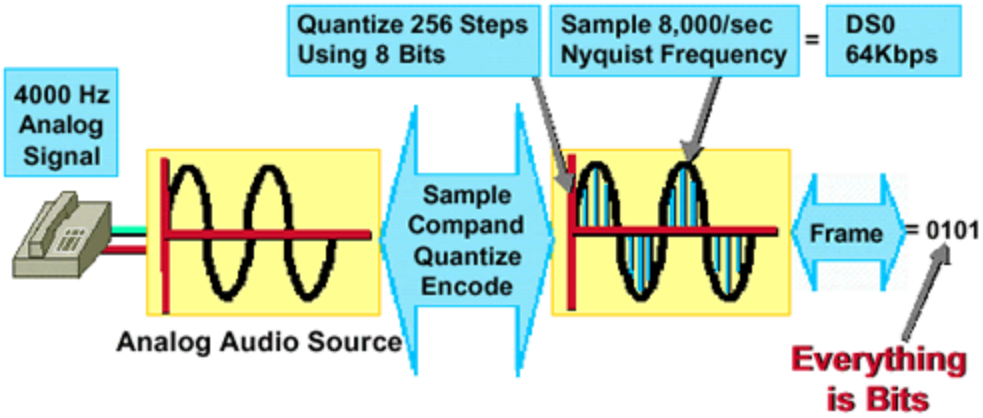

Local
Loop
A
A
Core Network
A
Local
Loop
A
Local
Exchange
Local
Exchange

Voice channel

- 4kHz bandwidth for the voice channel
  - The transmission domain of the voice signal between 0.3 and 3.4 kHz
  - Some added guard bands
- The frequency range sensed by the human ear: 20Hz – 15-20 kHz
  - The goal was to transmit the voice signals
  - Not all the sounds should be transmitted
    - Economic aspects

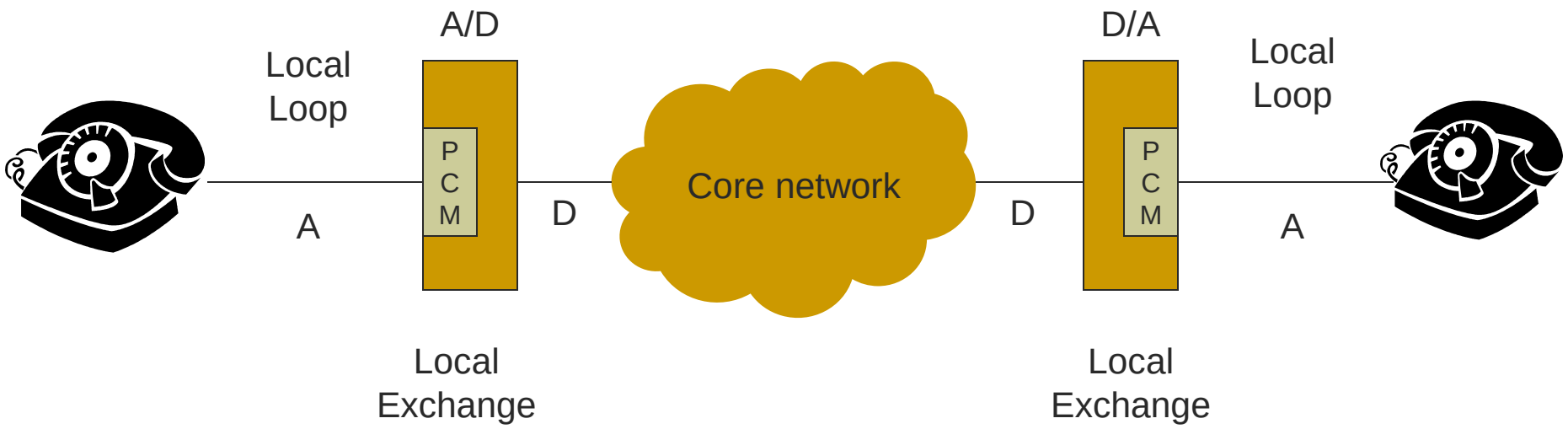
PCM

- Pulse Code Modulation
  - Transforming analog signals to digital
- Based on the Nyquist rule, for a 4kHz signal we need an 8kHz sampling
  - Quantized to 256 signal levels
    - Represented on 8 bits
  - Transmission speed: 8bit x 8kHz = 64 kbit/s



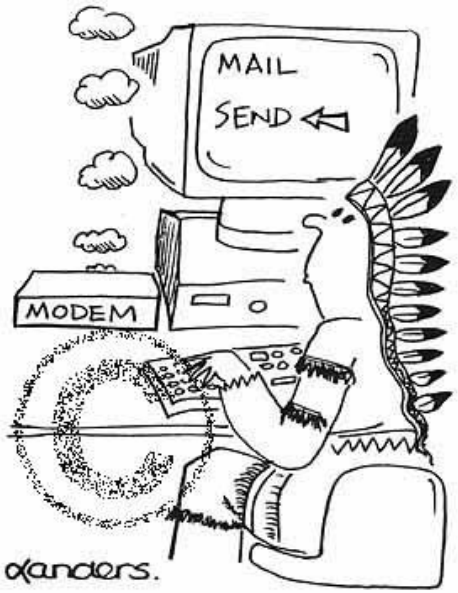
Pulse Code Modulation (PCM)
DS0

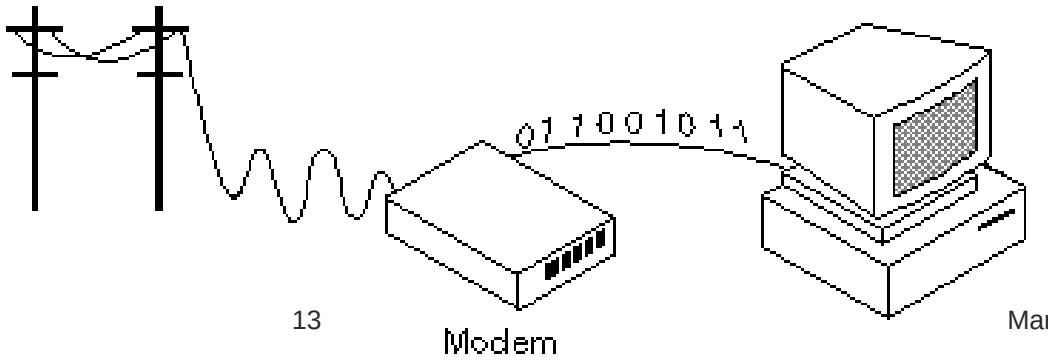
Digital speech transmission



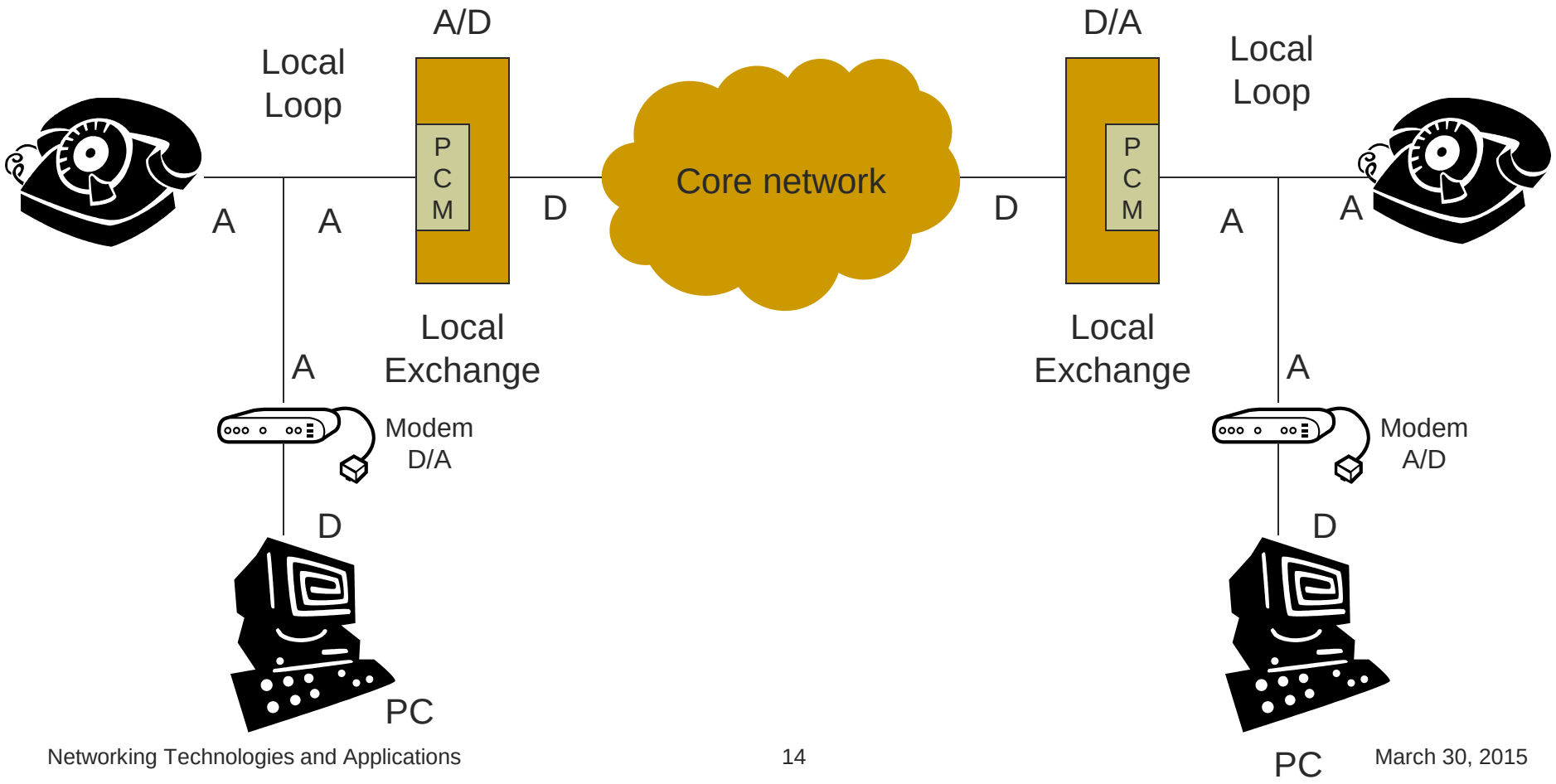
Dial-up Access

- The digital information of a computer transformed into analog signals, and transmitted over a PSTN network
  - „Modem” – modulator-demodulator
    - Amplitude modulation
    - Frequency modulation
    - Phase modulation





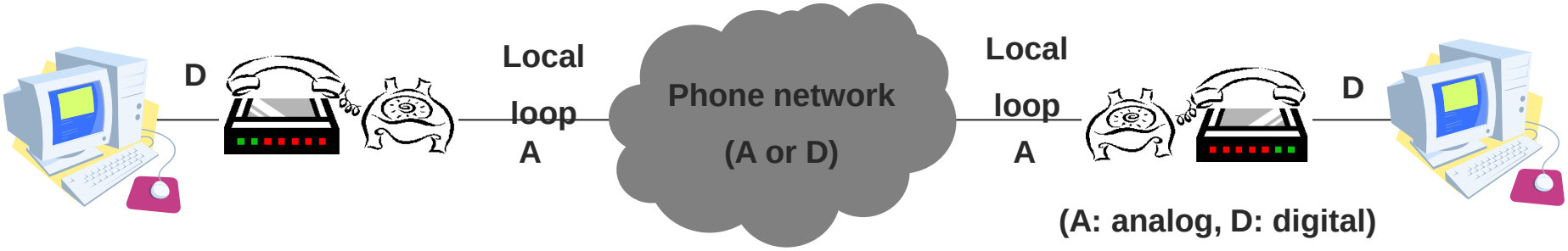
Dial-up modem



Modem history

- The first modem in the 50's
  - Used by the American Air Force to transmit military data over the telephone network
    - Dedicated lines
    - Half-duplex system
      - While one side transmits, the other side is silent
- Acoustic modems
  - The first commercialized modem – Bell 103 (1962)
    - 300 bps full duplex transmission
    - ITU-T V.21
  - The connection is built and interrupted manually
  - Interesting fact: compatible with many of the current dial-up modems

Acoustic modems



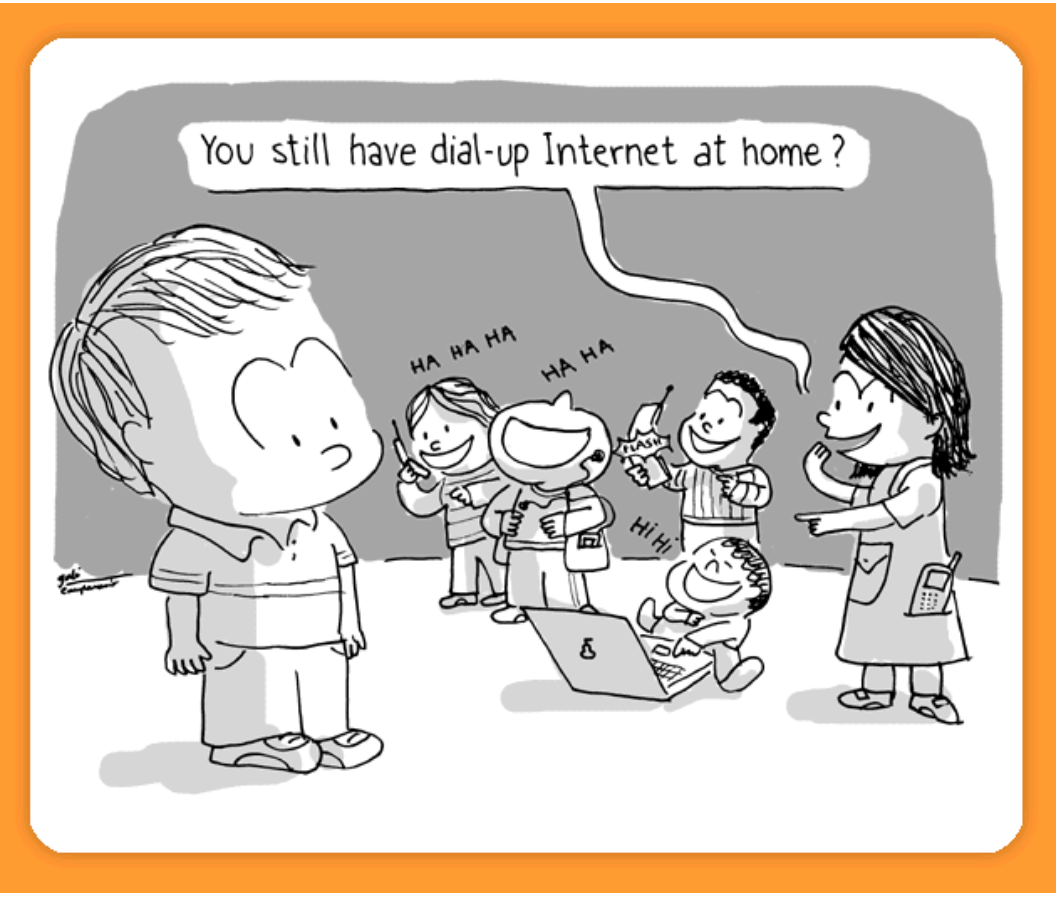
Modem standards

- Evolution of the standards
  - ITU-T V.22 – 1200 bps
  - ITU-T V.22bis – 2400 bps
  - ITU-T V.32 – 9600 bps (1984)
  - ITU-T V.32bis – 14.4 Kbps (1991)
  - ITU-T V.34 – 28.8 Kbps
  - ITU-T V.34bis – 33.6 Kbps (1994)
  - ITU-T V.90 – 56.6 Kbps downstream, 33.6 Kbps upstream (1996)
  - ITU-T V.92 – 56.6 Kbps downstream, 48 Kbps upstream

What's the limit?

- The core network is digital
  - After the PCM coding, the signal is restricted to a 64 Kbps channel, this is the upper limit
    - In most of the systems 1 bit/byte for signaling
    - Max. 56Kbps
  - Quantization noise due to the A/D and D/A conversions
    - The actual limit is 33.6 Kbps
  - For the V.90 modems, only the downstream speed is 56 Kbps
    - If talking to a content provider that reaches the network on a digital connection
    - Fewer D/A conversions
      - Significantly lower noise

Dial-up is dying out…?



Why DSL?

- DSL – Digital Subscriber Line
- Dial-up speed – 56 Kbps
  - Cable modem – 10Mbps on shared cables
  - Wireless technologies – up to 50 Mbps
  - Obliged to move, if you want to keep the subscribers
- Emerges the broadband connectivity
  - Mostly a marketing term
  - Not clear what broadband means
- xDSL – different DSL versions

Why is DSL fast?

- Why is dial-up slow?
  - The PSTN network optimized for voice transmission
    - A band-pass filter in the local exchange
    - Only the 4 KHz large voice channel remains
  - Data is also restricted to this channel
- The line of the xDSL subscriber has no filter
  - You can use the entire capacity of the local loop
    - It depends on the length of the loop, the thickness and the quality of the cable
    - Optimal case: new cables, thin bundles, short loop
- If you want higher speed, you need many local exchanges
  - If someone lives far away, he should move closer
    - Lower the speed, higher the service range – more potential subscribers
    - Lower the speed, fewer interested subscribers
- Solution?
  - Mini exchanges close to the users (expensive, but no better way)

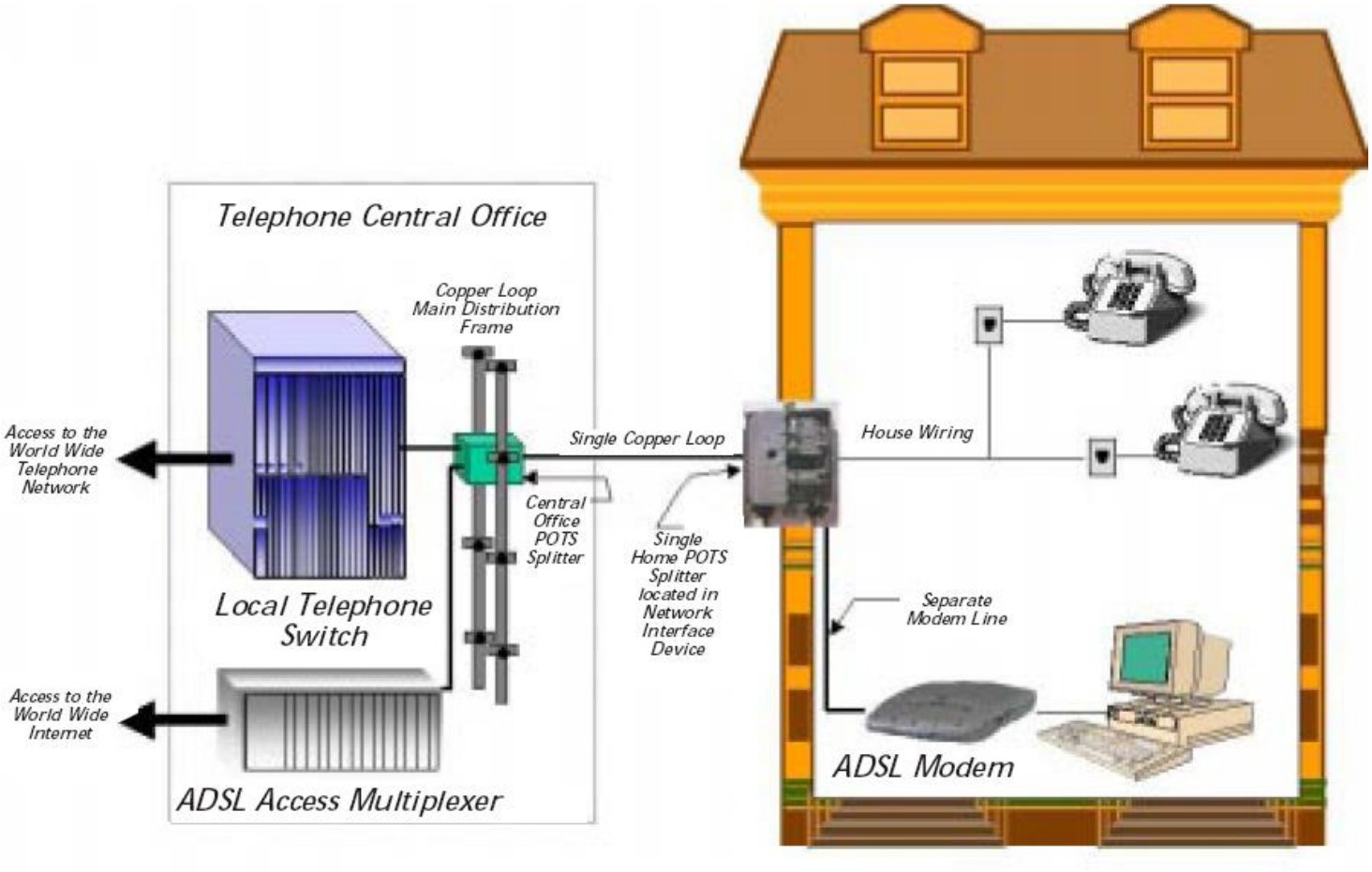
ADSL - Asymmetric Digital Subscriber Line

- Two competing and incompatible modulation schemes
  - DMT – Discrete Multitone Modulation - deployed today
  - CAP – Carrierless Amplitude Phase Modulation - not used since 1996
- DMT
  - 1.1 MHz frequency domain
  - 256 channels, 4.3125kHz each
    - Channel 0 – POTS (voice)
    - Channels 1-5 – guard band (empty)
      - To avoid interferences between voice and data channels
    - 1 upstream and 1 downstream channel for signaling
    - The remaining channels split between upstream and downstream user data
- Frequency allocation in ADSL
  - 0-4 kHz – voice
  - 4-25 kHz – guard band
  - 25-160 kHz – upstream band
  - 200 kHz - 1.1 MHz – downstream band

ADSL architecture

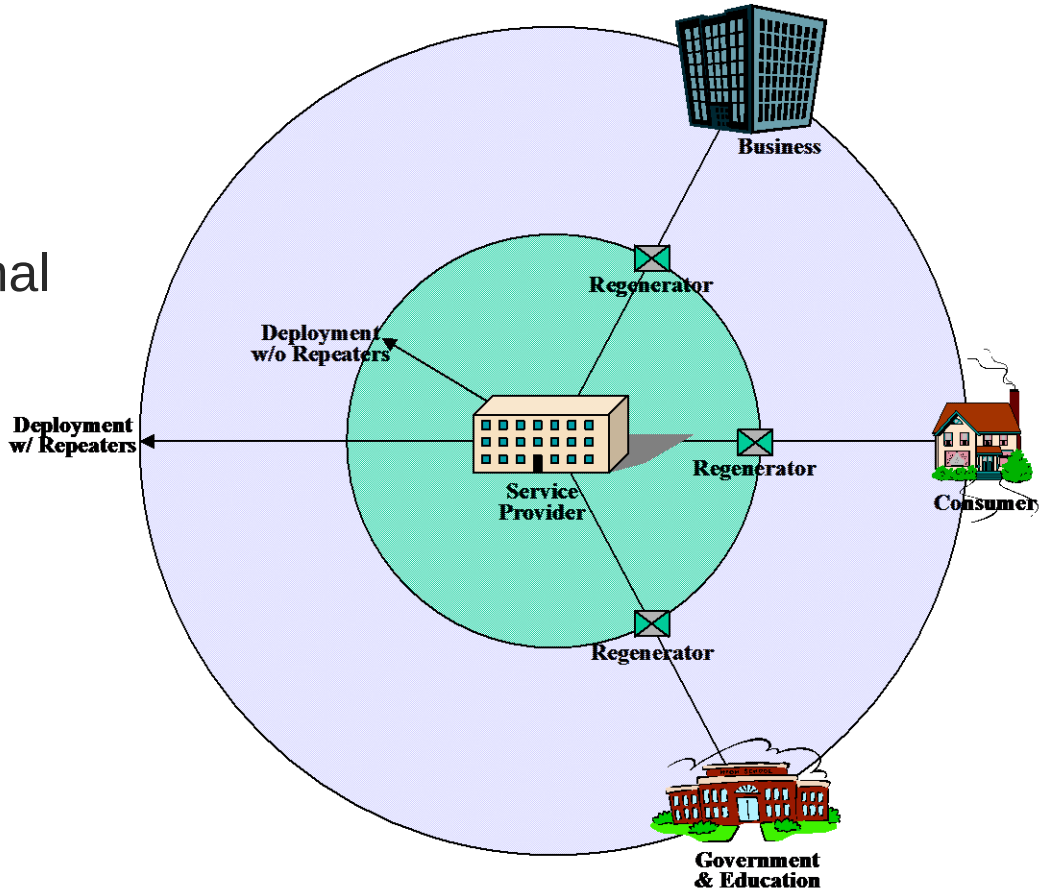
- At the operator
  - POTS Splitter
    - Frequency splitter to separate voice and data traffic
      - Voice is directed to the local exchange
      - Everything above 26 KHz is directed to the DSLAM
  - DSLAM – DSL Access Multiplexer
    - Splits the bit stream into packets and sends them to the ISPs network
- At the subscriber
  - POTS Splitter
  - ADSL modem
    - Digital signal processing
  - High speed connection to the PC
    - Ethernet cable and card
    - Sometimes USB connection
    - Internal ADSL modems

ADSL architecture



The service range

- Repeaters
  - Regenerator
    - Regenerates the signal
  - Amplifiers
    - Amplify the signal
  - ADSL service on a range of up to 16 km



ADSL G.dmt

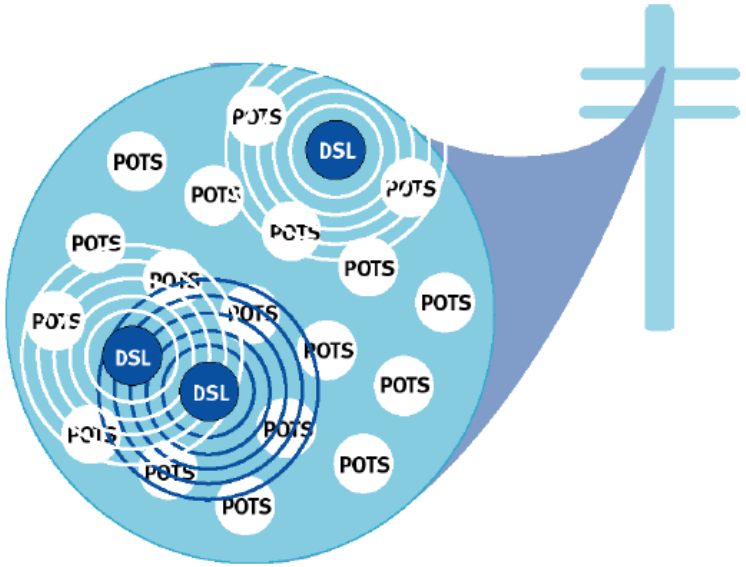
- ITU-T G.992.1 standard (1999)
  - http://www.itu.int/rec/recommendation.asp?type=folders&lang=e&parent=T-REC-G.992.1
- Much larger bandwidth for downstream traffic than for upstream
  - Designed for the needs of web browsing
  - Maximal downlink speed 8 Mbit/s
    - usually 512 Kbit/s – 1 Mbit/s
  - Maximal uplink speed 1 Mbit/s
    - usually 64 Kbit/s – 256 Kbit/s
- Service range of max. 3 km from the local exchange

ADSL G.dmt 2

- ITU-T G.992.3 standard (2002)
- Extends the traditional ADSL technology
  - Maximum downlink speed increased to 12 Mbit/s
  - Service range extended with ~ 500 meters
    - The improvements mainly due to the limitation of the interferences on long loops
- ADSL2 is energy efficient
  - As opposed to ADSL, it differentiates between periods with or without traffic
- ADSL2 can temporarily switch to „complete digital” mode
  - The voice and guard channels used for data traffic

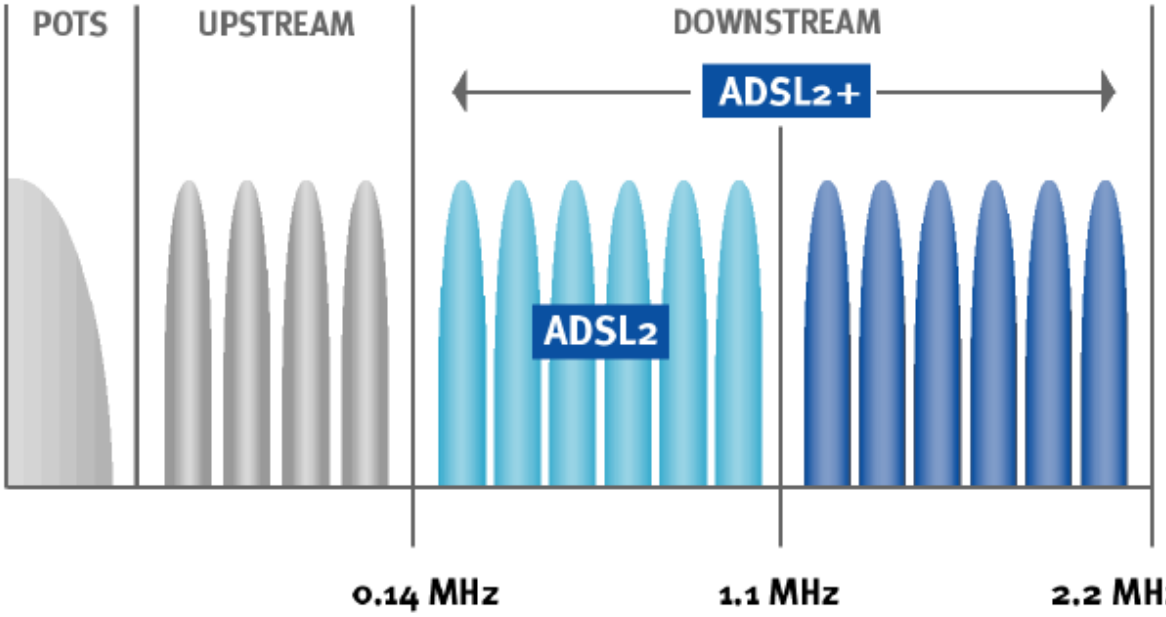
ADSL G.dmt 2

- Seamless rate adaptation (SRA)
  - 20-25 twisted pairs in a bundler
  - „Crosstalk” from the neighboring pairs
    - Might lead to the ADSL connection being dropped
  - ADSL2 can adapt the speed
    - If too much noise on a channel, it can be blocked
    - The modem and the DSLAM agree on which channels to use



ADSL 2+

- ITU-T G.992.5 (2003)
- Bandwidth is increased by enlarging the frequency domain
  - The frequencies used for voice and upstream traffic do not change
  - The upper frequency of the downlink channel is increased from 1.1 to 2.2 MHz.
    - The maximum downlink speed increases from 8Mbit/s to 16 Mbit/s
      - The service range is lowered to 1.5 km



G.SHDSL

- Symmetric High-speed DSL
  - ITU-T G.991.2 (2001)
- 2.3 Mbit/s maximum speed in both directions
  - If a second twisted pair is added, it can be extended to 4.6 Mbit/s
  - service range of 3 km
    - As distance increases, the transmission quality is gradually decreasing

SHDSL applications for business

- **Web hosting**
  - If a web server is operated over a DSL connection
  - High upstream bandwidth needed
- **Videoconferencing**
  - Text, voice and video data to be transmitted
  - Symmetric traffic
- **VPN (Virtual Private Network) services**
  - Private network over a public telecommunication infrastructure
  - The privacy of the data transfer ensured through tunneling and encryption
  - VPN connections over SHDSL, linking the remote offices of a company, if there is no FTTx solution, or it is too expensive
- **Remote LAN Access**
  - Teleworking or SOHO (Small Office Home Office)
  - High speeds needed to ensure the same user experience as in the real office

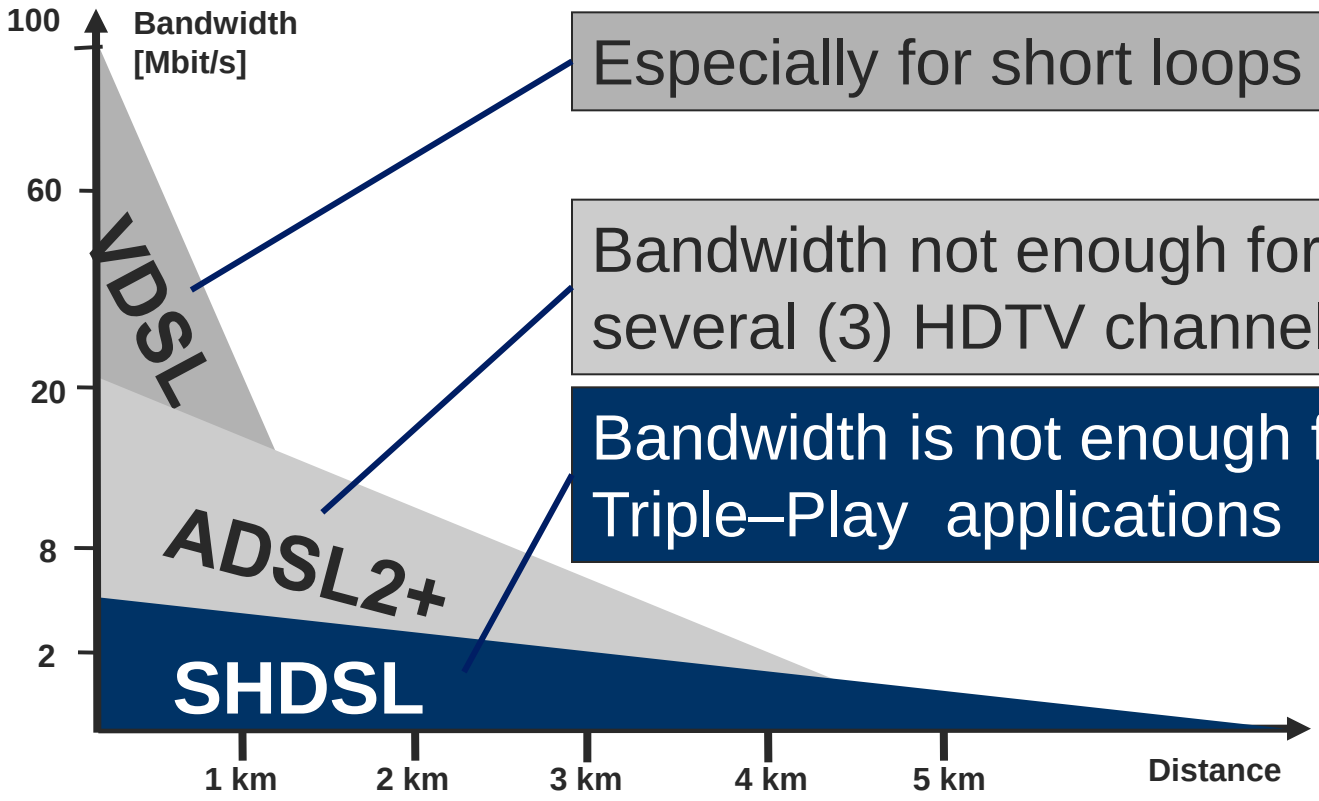
SHDSL applications at home

- **Internet Gaming**
  - The home user operates a game server, or plays against other home users
  - A good upstream connections is essential
- **Residential Gateway Access**
  - A CPE (Customer Premises Equipment) that provides access to several services such as home video monitoring or intelligent home applications
- **Peer-to-peer applications**
  - File sharing, application layer multicast
  - Symmetric connection is needed

VDSL

- Very-high-data-rate digital subscriber line
  - ITU-T G.993.1 (2004)
- Significantly higher speeds on lower distances
  - 52 Mbit/s downstream,16 Mbit/s upstream
    - Might be symmetric as well (26-26 Mbit/s)
  - 12 MHz bandwidth
  - Max. 1 km service range
    - Usually rather 300 m
- Mainly used to extend the optical access inside buildings
  - Optical cables are not recommended inside buildings, because of the many necessary inflections
  - The twisted copper pair (VDSL) is a good replacement

VDSL2



Especially for short loops

Bandwidth not enough for several (3) HDTV channels

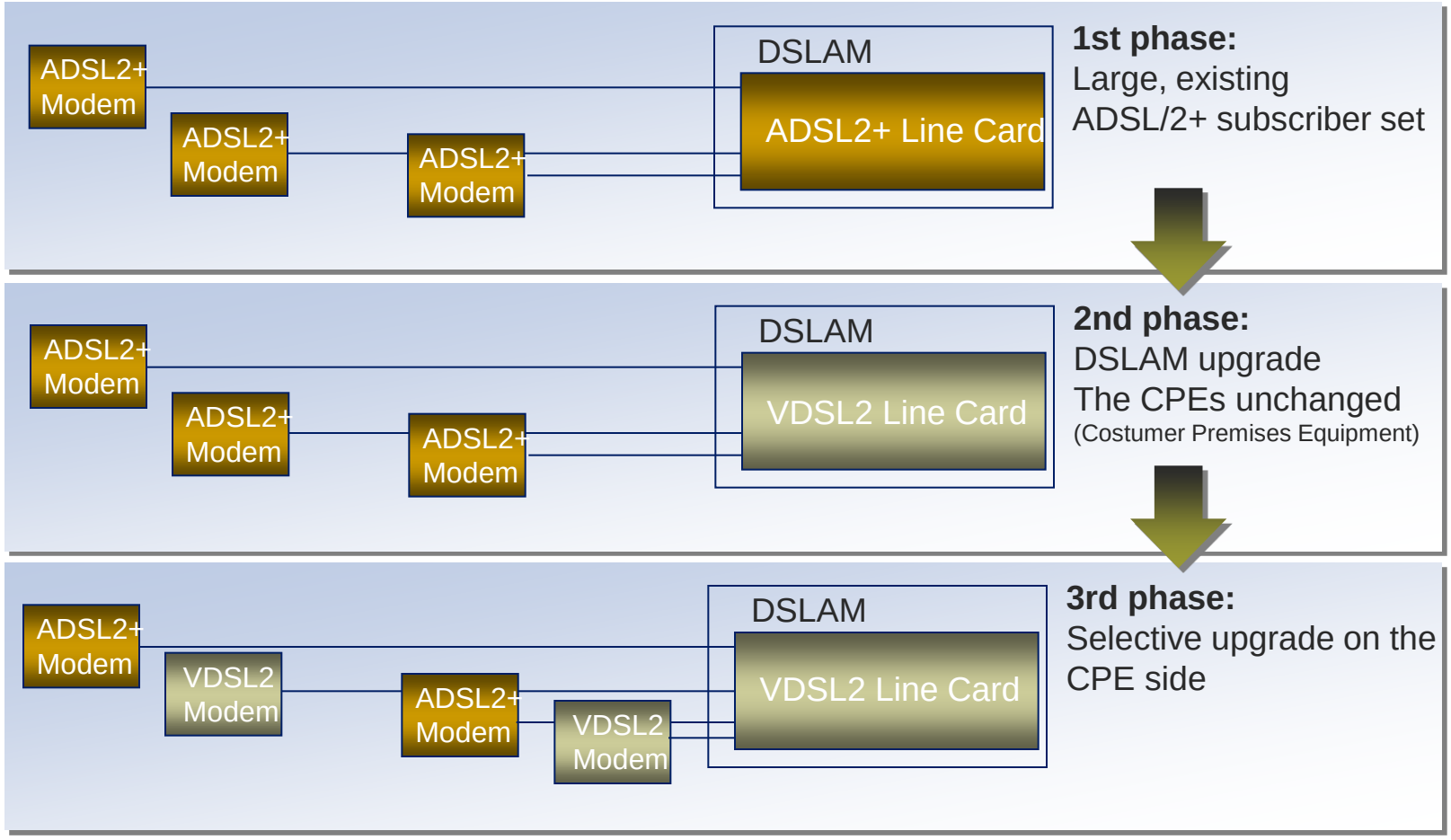
Bandwidth is not enough for Triple–Play applications

VDSL2 = VDSL speeds with ADSL/2+ service range

VDSL2

- ITU-T G.993.2 (2005)
  - 100 Mbit/s downstream and upstream
  - 30 MHz frequency domain
  - 3 km service range
    - High speed and large range are not compatible
- 8 specified profiles, different service levels
  - Different user expectations in different geographical areas
- ADSL-compatible (VDSL is not)
  - Easy to deploy, attractive technology for the service providers

ADSL compatibility



Triple Play

- Triple Play
  - marketing term for 3 parallel IP services:
    - internet
    - television
      - Video on Demand (VoD) or Live Streaming
      - MPEG 2, Set Top Box (STB)
    - telephony
      - Voice over IP (VoIP)
  - Rather a business model more than a technology standard
- Quad(ruple) Play
  - The same 3 services, over a wireless interface

VDSL2 QoS

- No Quality of Service support in VDSL
  - In VDSL2 yes
  - Necessary for triple-play services
- Applications have different requirements

Application	Sensible to delay	Sensible to packet loss
Data	/	Yes
Video	No	Yes
Voice	Yes	No
Gaming	Yes	Yes

- Voice
  - Delay – max. 150ms end-to-end
  - BER – between 10^{-5} and 10^{-2}, depending on the used codec
- Video
  - Delay – seconds! for VoD or streaming
    - Zapping delay
  - BER – from 10^{-7} (video telephony) to 10^{-13} for HDTV
    - High Definition Television

VDSL2 QoS

- Different traffic types
  - Voice
    - Small packets (100-400 byte/packet)
    - Generated with constant speed
  - Video
    - Large packets
    - Generated with changing speeds (bursty traffic)
- „dual path” - „dual latency” support in VDSL2
  - Specified bandwidth per traffic type
  - The bursty video does not affect the voice traffic

G.fast

- Proposed in 2014, to be deployed in 2016
- Speeds between 150 Mb/s and 1 Gb/s, for very short loops (100-200 m)
- **Time Division Duplexing (TDD)** instead of **Frequency Division Duplexing (FDD)** as in ADSL2 and VDSL2
  - FDD – separate frequencies for uplink and downlink
  - TDD – alternating time slots for uplink and downlink
  - Better usage of spectrum, possibility for energy saving
    - Discontinuous TDD, transmitter and receiver disabled for longer intervals than needed for the direction change.
    - Trade-of between throughput and power consumption

Other DSL solutions

- HDSL (*High bit-rate DSL*)
- IDSL (*ISDN DSL*)
- MSDSL (*Multirate Symmetric DSL*)
- RADSL (*Rate-Adaptive DSL*)

- No large-scale deployment