

Networking Technologies and Applications

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Why DSL?

- DSL – Digital Subscriber Line
- Dial-up speed – 56 Kbps
 - Other technologies – much higher speeds
 - Obligated 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 or you should move closer
 - Lower the speed, higher the service range – more potential subscribers
 - Lower the speed, fewer interested subscribers

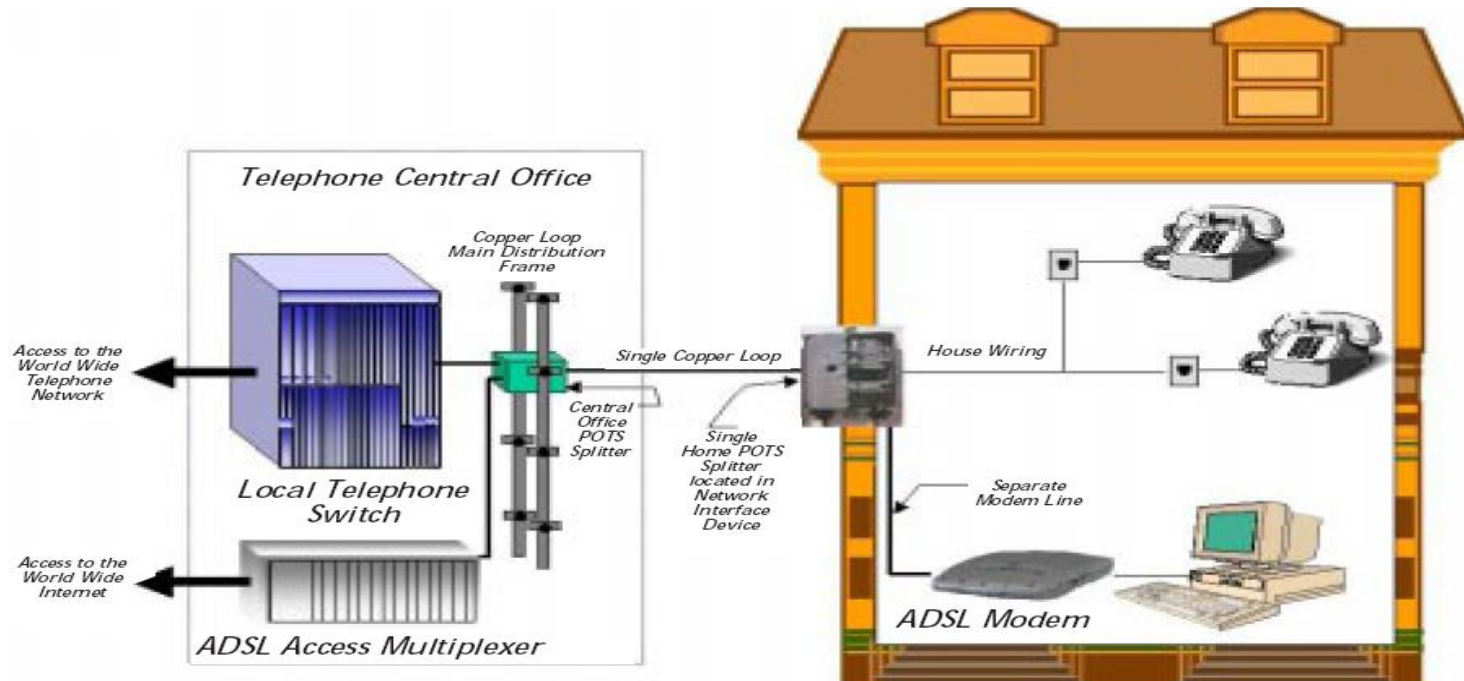
ADSL - Asymmetric Digital Subscriber Line

- DMT – Discrete Multitone Modulation
 - 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

ADSL architecture



ADSL G.dmt

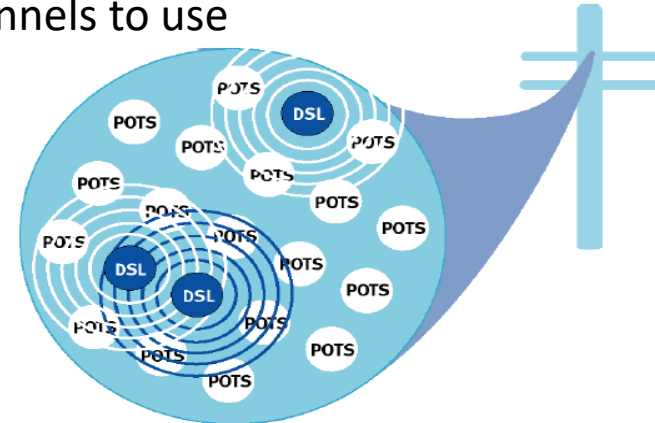
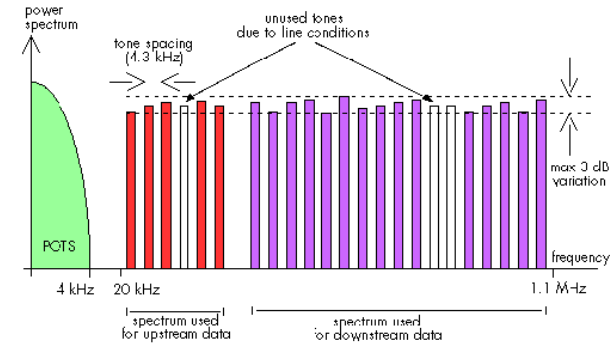
- ITU-T G.992.1 standard (1999)
 - <http://www.itu.int/rec/recommendation.asp?type=folders&lang=e&parent=T-REC-G.992.1>
- Much larger bandwidth for downstream traffic than for upstream
 - Designed for the needs of web browsing
 - Maximal downlink speed 8 Mbit/s
 - usually 512 Kbit/s – 1 Mbit/s
 - Maximal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

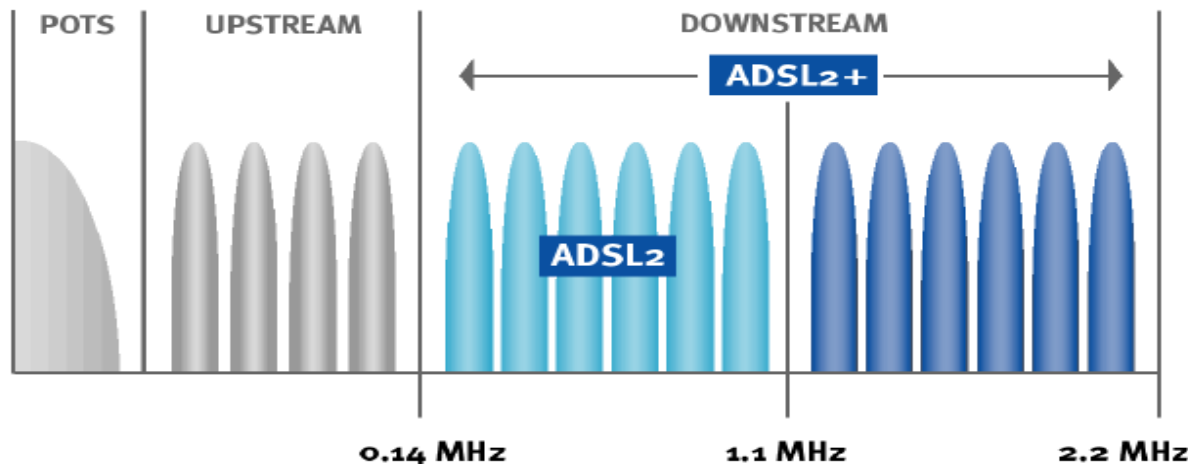
ADSL G.dmt 2

- 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

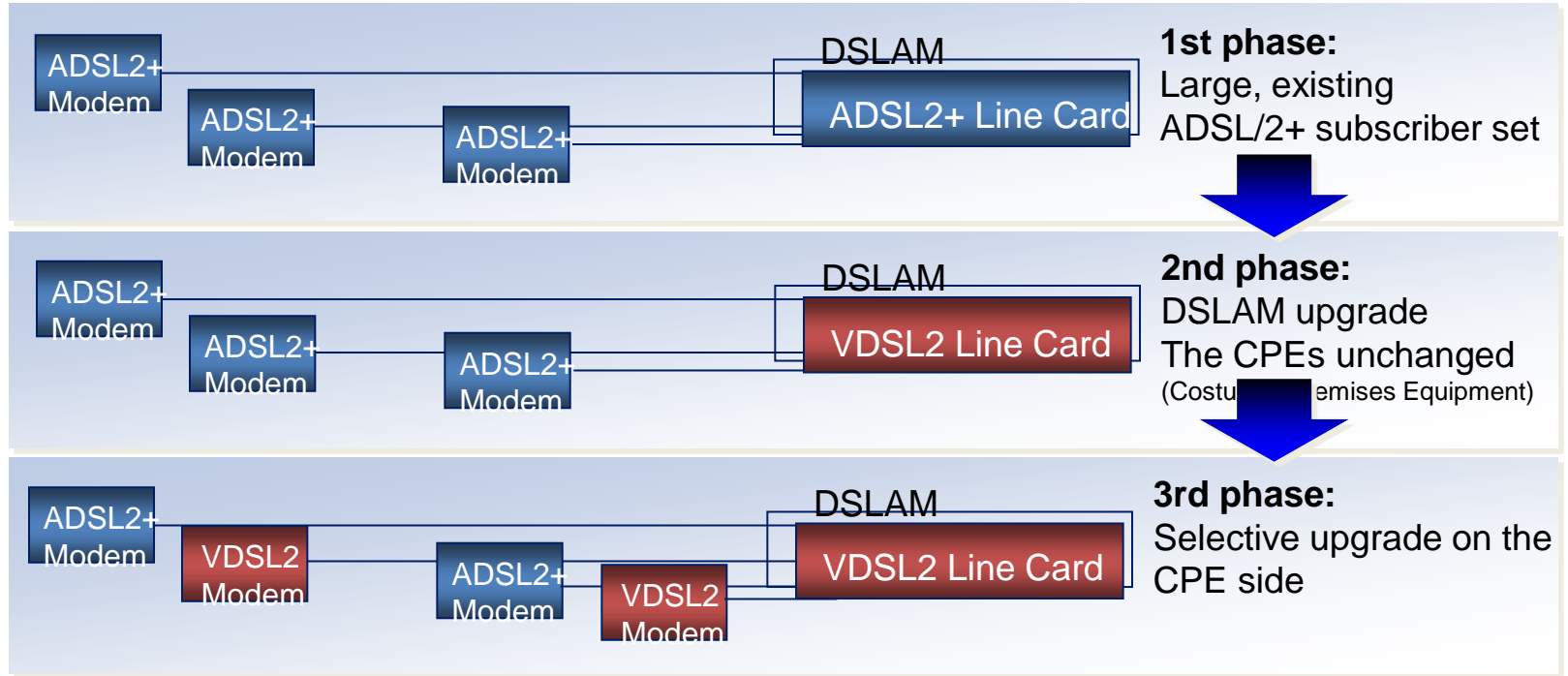


ADSL 2+

- 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



ADSL compatibility



Triple Play

- Triple Play
 - marketing term for 3 parallel IP services:
 - internet
 - television
 - Video on Demand (VoD) or Live Streaming
 - 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

Networking basics

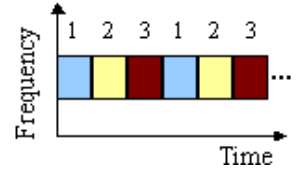
- The different access networks often are using a *shared transmission medium*
 - Many others can hear me, I can hear many others
 - Providing a dedicated channel to every subscriber might be either impossible, or too expensive
- The problem is to solve the *access control* to the transmission medium
 - Users do not know about each other who wants to send and when
 - Access to the medium has to be coordinated

Multiple Access

- **Solutions based on fixed allocations**

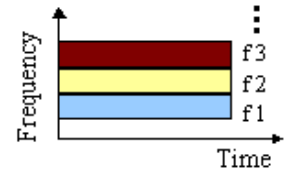
- **TDMA – Time Division Multiple Access**

- Each user has its own timeslot to send
 - Can use the entire frequency band



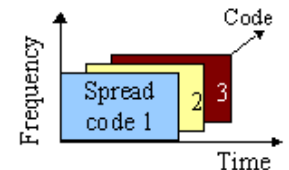
- **FDMA – Frequency Division Multiple Access**

- The spectrum is split into channels
 - Each user has its own channel



- **CDMA – Code Division Multiple Access**

- Each user communicates over the entire frequency domain, all the time
 - Traffic is separated based on code theory
 - The sender multiplies the signal with a spreading code, and sends over the result
 - The receiver multiplies again the received signal with the same spreading code, to reproduce the original signal
 - Codes are orthogonal
 - » Multiplying two different codes returns a series of 0s



Multiple Access vs. Multiplexing vs. Duplexing

- **Multiple Access (TDMA, FDMA, CDMA)**
 - Regulating channel access in case of many parallel sources
 - Normally in the uplink direction
- **Multiplexing (TDM, FDM, CDM, ...)**
 - Combining multiple signals, from one or many sources, onto the same shared medium
 - Uplink or downlink direction
- **Duplexing (TDD, FDD)**
 - Regulating the resources for downlink and uplink traffic
 - FDD – Frequency Division Duplexing
 - „Paired” frequencies, separate uplink and downlink channels
 - TDD – Time Division Duplexing
 - „Unpaired” frequencies, divided adaptively between uplink and downlink traffic

Multiple Access

- Fixed allocation is not efficient if traffic is sparse, and bursty
- **Contention-based Channel Access**
 - **Polling**
 - **Reserving and scheduling resources** based on current demand
 - **Random access**
 - A node starts sending when it wants, no previous reservation
 - If several nodes start speaking in the same time, collision occurs, the packet should be retransmitted later
 - ALOHA, Slotted ALOHA, CSMA/CD