Networking Technologies and Applications

Rolland Vida
BME TMIT

September 8, 2021

Lecturers

Rolland Vida
IE 348, vida@tmit.bme.hu

Miklós Máté
IE345, mate@tmit.bme.hu

István Moldován
IB 229, moldovan@tmit.bme.hu

Administrative details

Slides on the webpage:

http://www.tmit.bme.hu/vitmac05

No book, but (quite) detailed slides

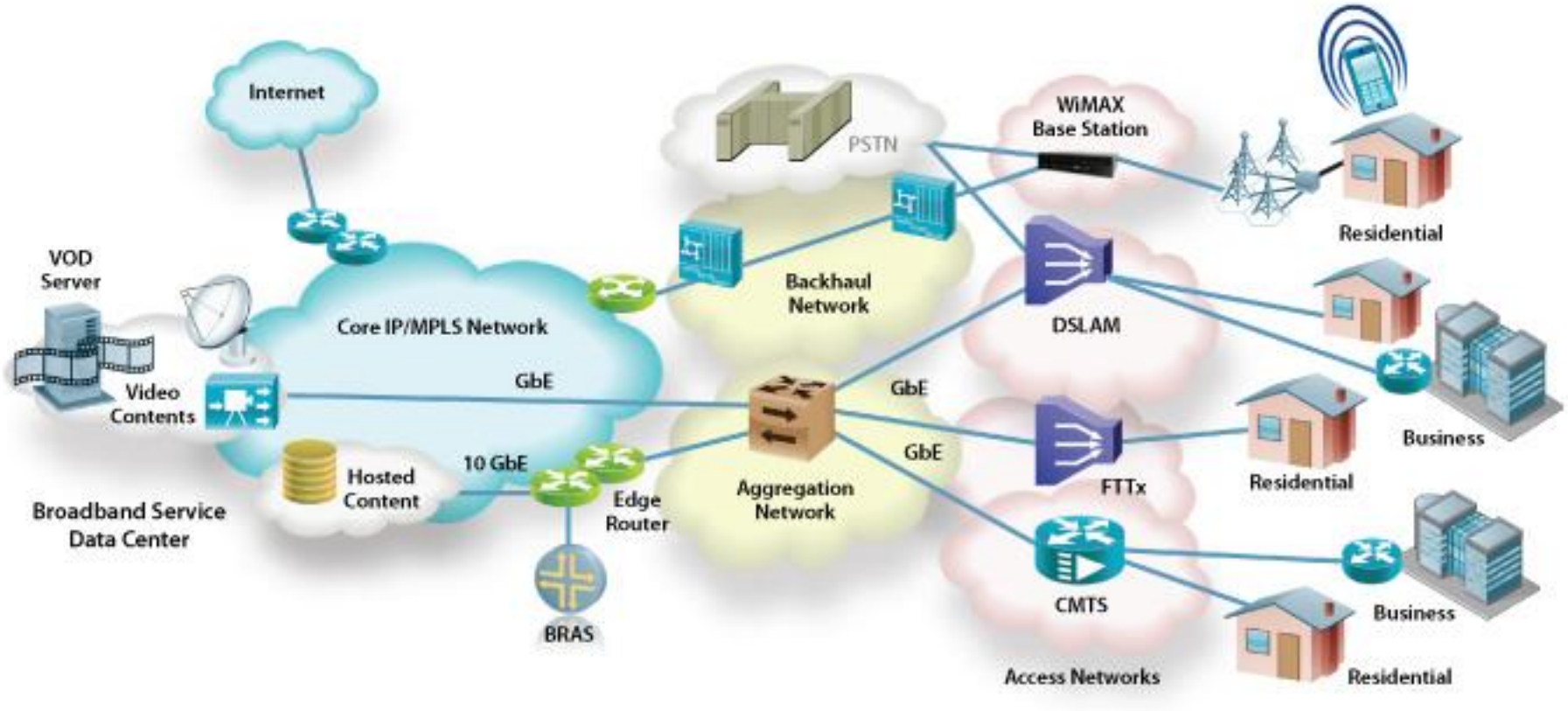
Presence at the lectures not mandatory **(but advised)**

Exams

- 1 mid-term exam, around end of October
- 1 re-take for the mid-term, during the last week
  - The grade of the mid-term exam will not be part of the final grade, you just have to pass it for the signature
  - Material for the mid-term and the re-take are the same

- Written exam

Big picture


Internet
PSTN
WiMAX
Base Station
Residential
VOD
Server
Core IP/MPLS Network
Backhaul
Network
DSLAM
GbE
GbE
Video
Contents
GbE
Business
Hosted
Content
10 GbE
Edge
Router
Aggregation
Network
FTTx
Residential
Broadband Service
Data Center
CMTS
Business
BRAS
Access Networks
Residential

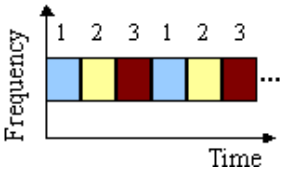
Networking basics

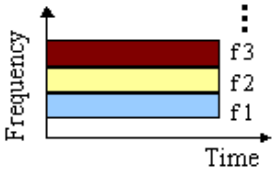
- The different access networks often are using a ***shared transmission medium***
  - Many others can hear me, I can hear many others
  - Providing a dedicated channel to every subscriber might be either impossible, or too expensive

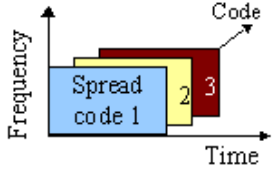
- The problem is to solve the ***access control*** to the transmission medium
  - Users do not know about each other who wants to send and when
  - Access to the medium has to be coordinated

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 eceiver 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

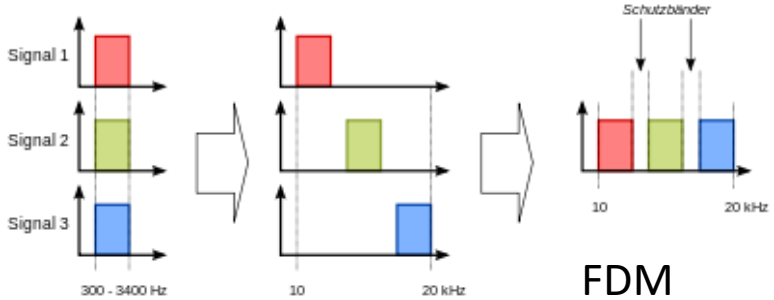




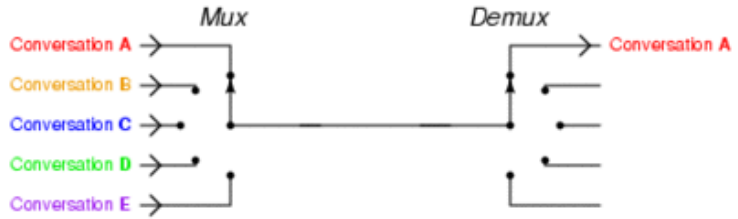


Multiple Access vs. Multiplexing

- **Multiple Access (TDMA, FDMA, CDMA)**
  - Regulating channel access in case of many parallel users
  - 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



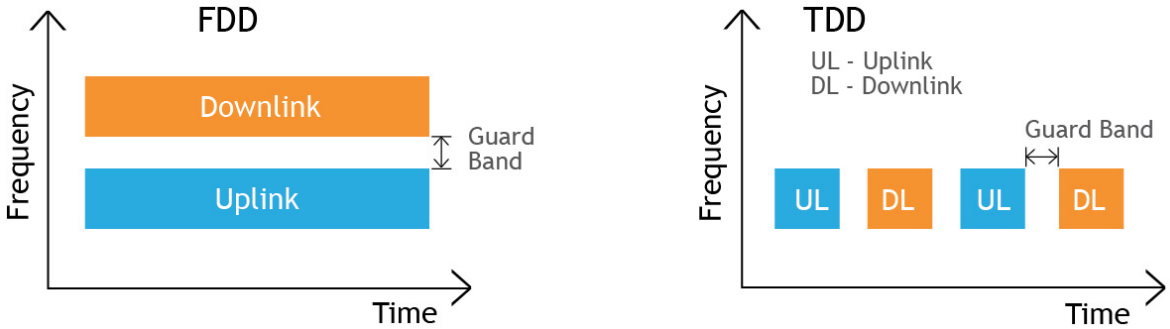
FDM



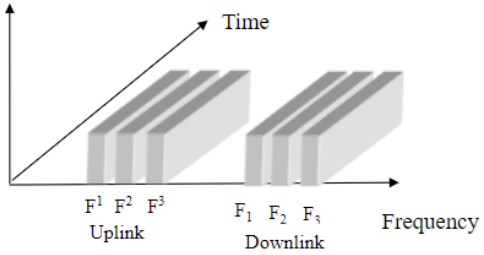
TDM

Duplexing

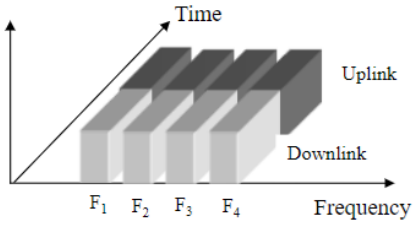
- **Duplexing (TDD, FDD)**
  - Regulating the resources for downlink and uplink traffic
  - FDD – Frequency Division Duplexing
    - „Paired” frequencies, separate uplink and downlink channels
  - TDD – Time Division Duplexing
    - „Unpaired” frequencies, divided adaptively between uplink and downlink traffic



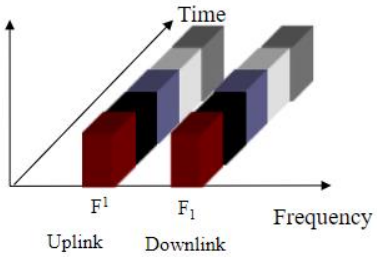
Multiple Access + Duplexing



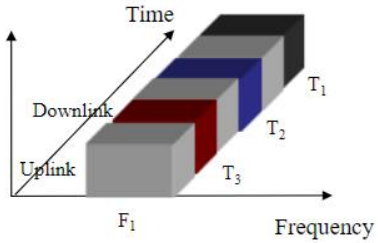
FDMA/FDD



FDMA/TDD



TDMA/FDD



TDMA/TDD

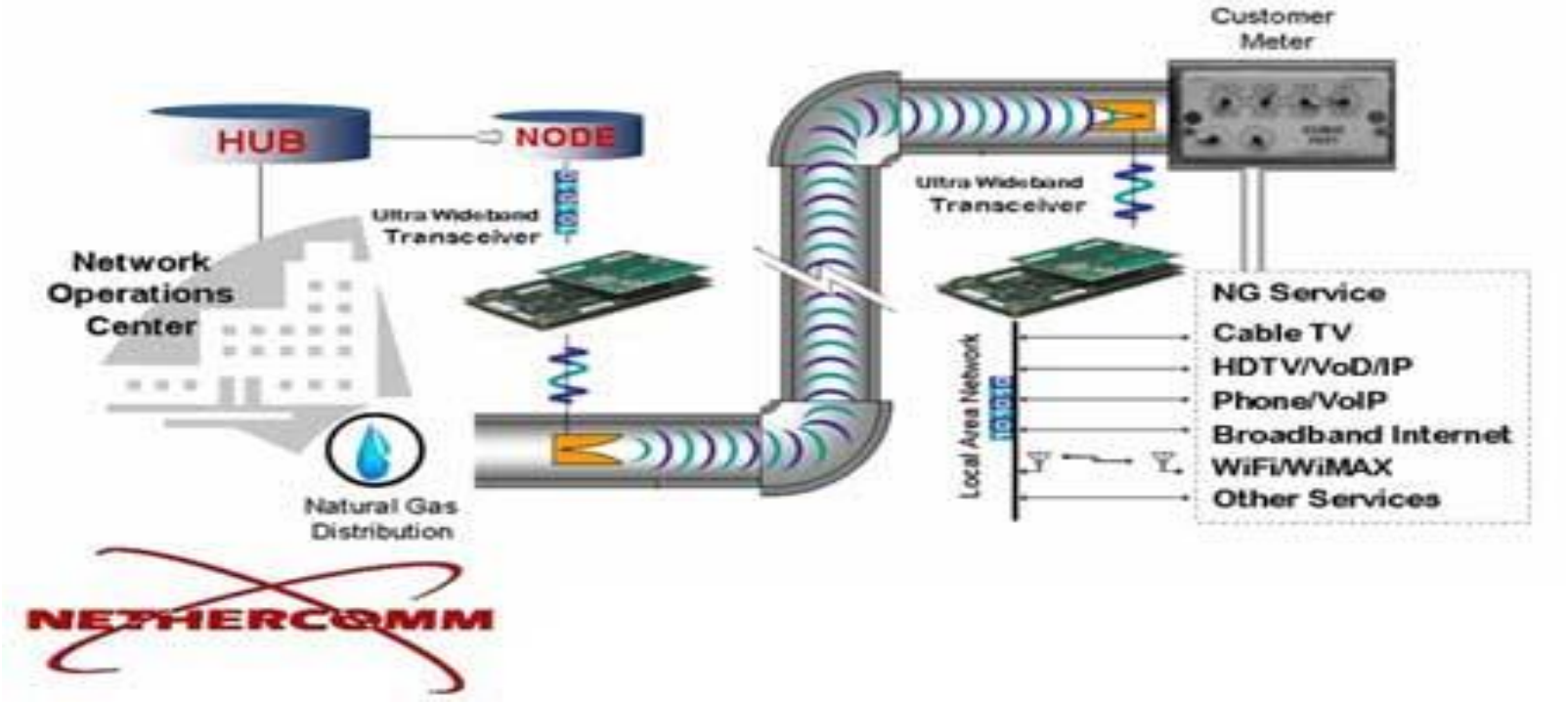
Multiple Access

- 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

Access Networks

- Building wired networks might be 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?

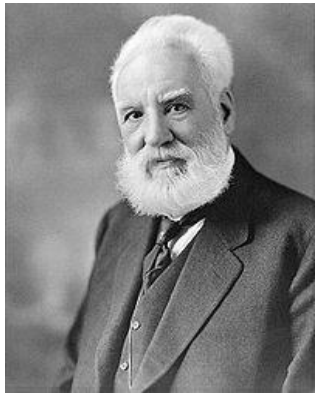


Internet through the gas pipe?

- Idea from NetherComm in 2005
- Ultra Wideband
  - Large frequency band (>500 MHz), large transfer speeds (100 Mbps)
  - In case of high power transmitters too much interference with other wireless technologies. Therefore, its operation only allowed for short ranges
  - In underground gas pipes this is not a problem, we can use higher transmit powers
- The UWB technology seemed promising, but …
  - Strict regulations, slow standardization, lower speeds than promised
  - In 2008-2009 the industry support melts away
  - NetherComm disappears

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

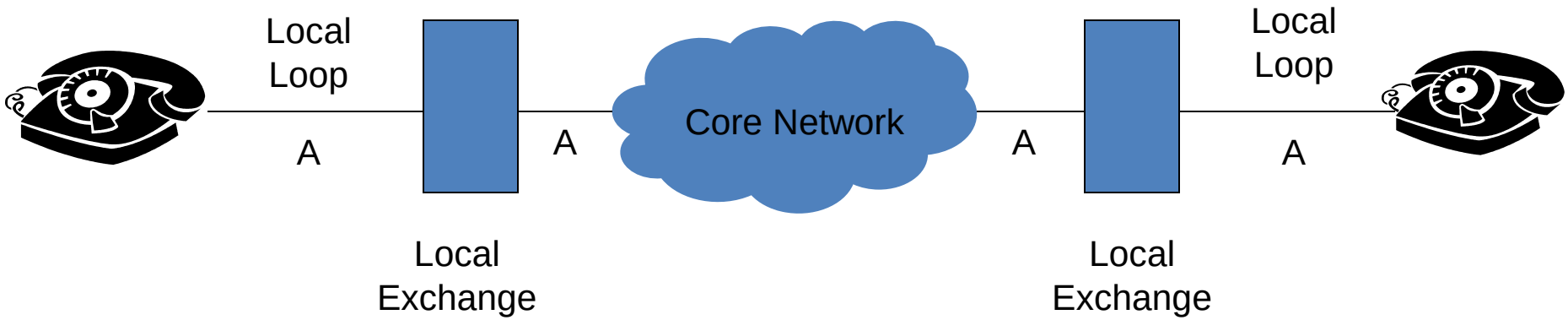
- 1878 – Bell Telephone Company
  - The first switching center – New Haven, Connecticut
  - A human operator switching manually between the users
- Inter-city calls
  - Linking the telephone switching centers
  - Secondary centers, hierarchical architecture
- Only in the US more than 22.000 centers today,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

From Computer Desktop Encyclopedia
Reproduced with permission.
© 1999 Nortel Networks

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

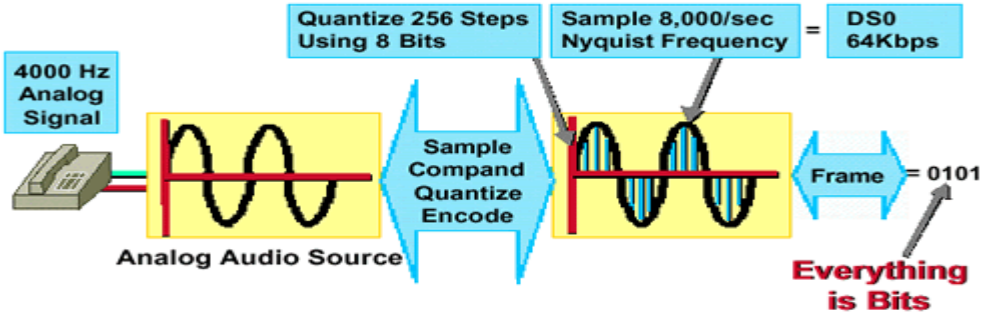

Local
Loop
A
A
Core Network
A
Local
Loop
A
Local
Exchange
Local
Exchange

Voice channel

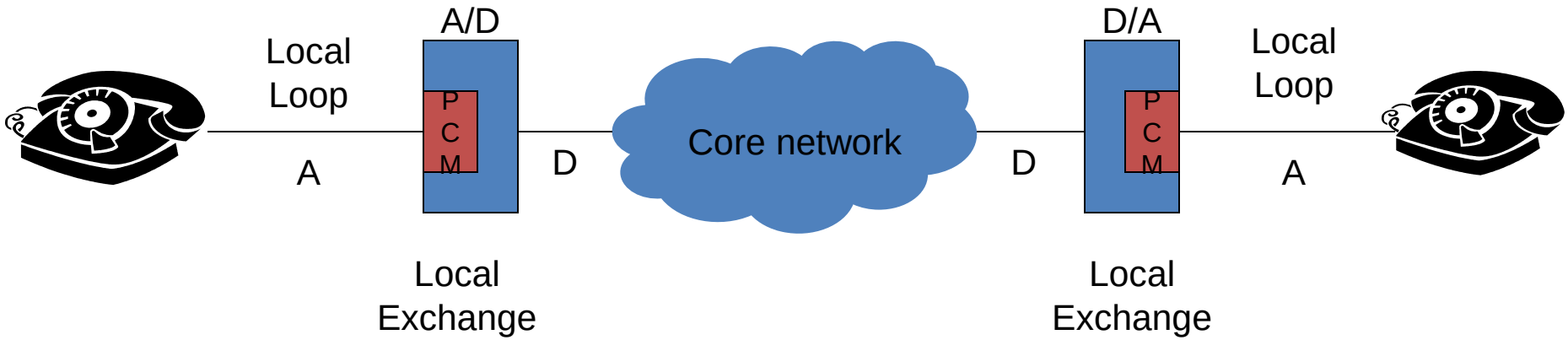
- 4kHz bandwidth for the voice channel
  - The transmission domain of the voice signal between 0.3 and 3.4 kHz
  - Some added guard bands
- The frequency range sensed by the human ear: 20Hz – 15-20 kHz
  - The goal was to transmit the voice signals
  - Not all the sounds should be transmitted
    - Economic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

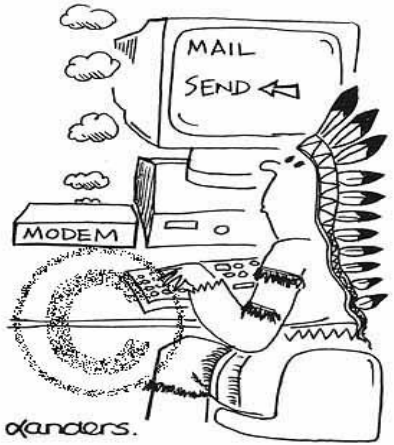


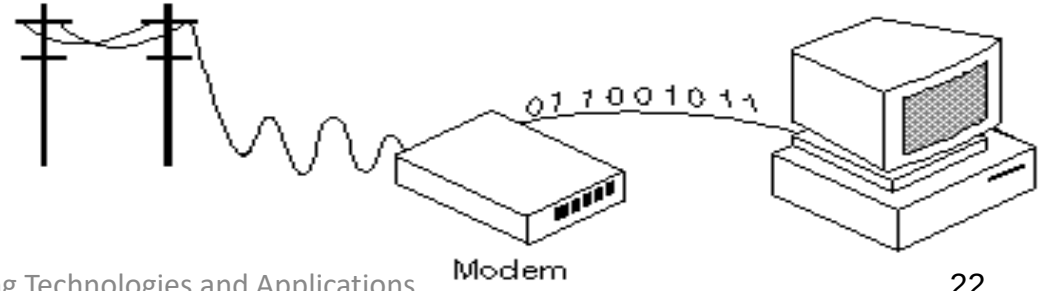
Digital speech transmission



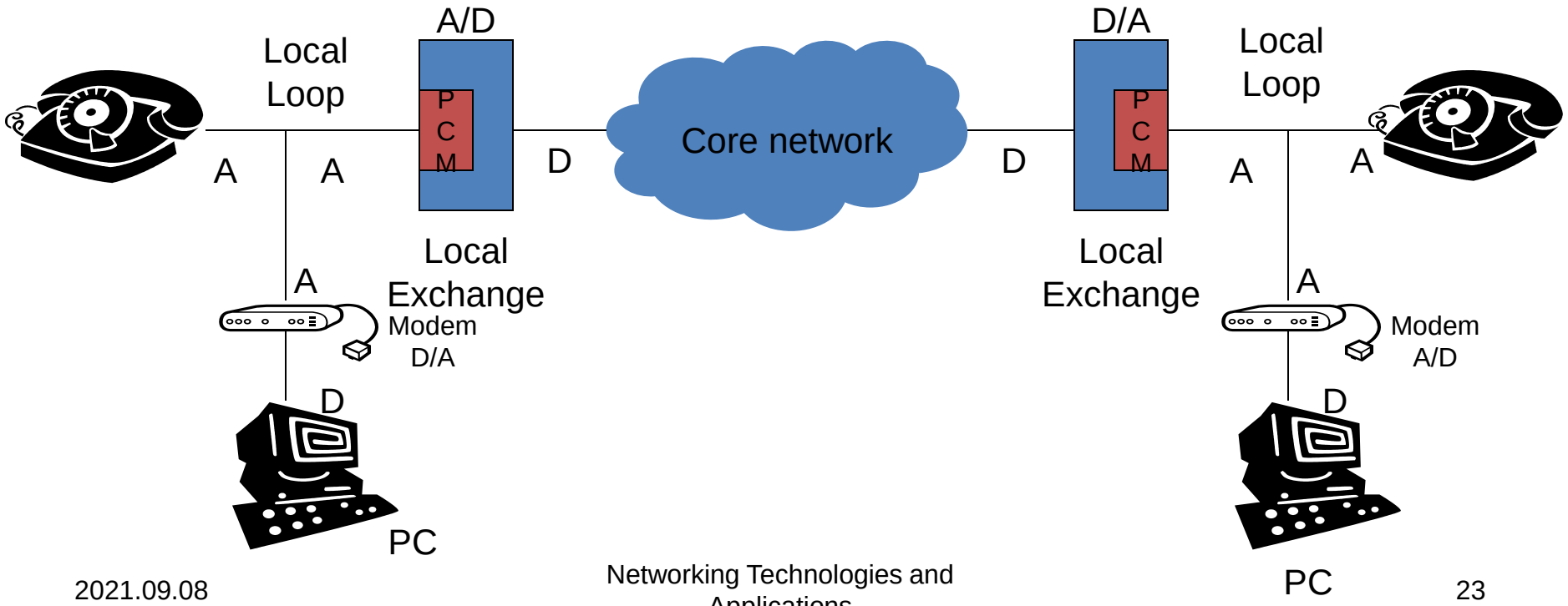
Dial-up Access

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





Dial-up access



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

Dial-up is dying out…?