Communication Networks

VITMAB06

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BME TMIT
2024

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Introduction, numbering

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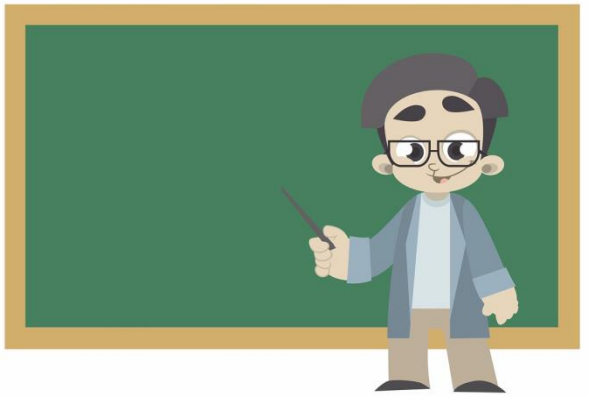
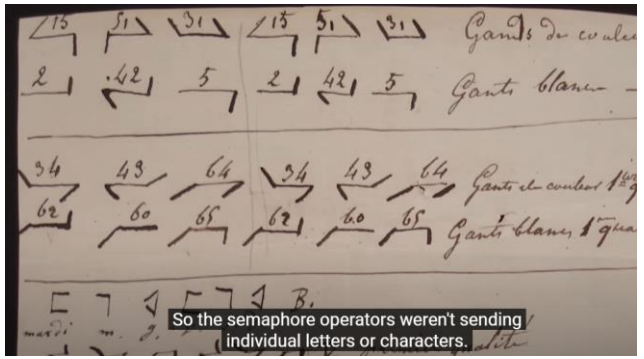
A bit of history



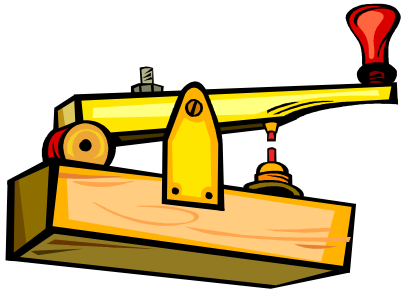
Early telecommunications networks

- Whistles, drums - even the ancient men (before speaking!)
- Messengers
  - 490 BC: Pheidippides, a messenger ran from the battlefield near Marathon to Athens to announce the Greek victory over Persia, "We won!„ and then collapsed and died.
  - 1860-61: USA, Pony Express: Changed horses, 3200 km/10 days
- Light / smoke / etc.
  - One of the oldest examples is the signal towers of the Great Wall of China. In 400 BC, signals could be sent by beacon fires or drum beats
  - Arabic Caliphate (Moors): Córdoba (Spain) - North Africa - Baghdad ("Torch Telegra
  - France: "telegraph" guardhouses, semaphores
    1852: 556 guardhouses, 4800 km network, between 29 large towns and Paris
    Encoded transmission!



There's a stunningly brilliant short video on the latter by Tom Scott here :
https://www.youtube.com/watch?v=cPeVsniB7b0

Later telecommunication systems



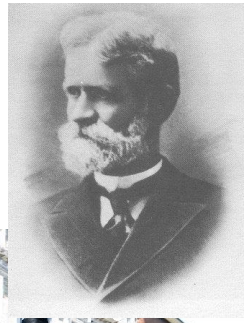
- The telegraph
  - Samuel Finley Breeze Morse (painter):
    Patent in 1837: telegraph + ABC
  - appr. 5-10 bit/s
    - words per minute, WPM
    - a "standard word" „PARIS”: * – – * * – * – * * * * * *
    - 20 – 30 WPM was common
  - parallel air cable
  - retransmission in nodes (telegraph station).

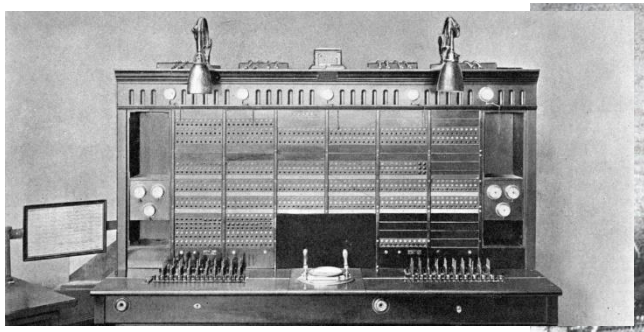
Later telecommunication systems

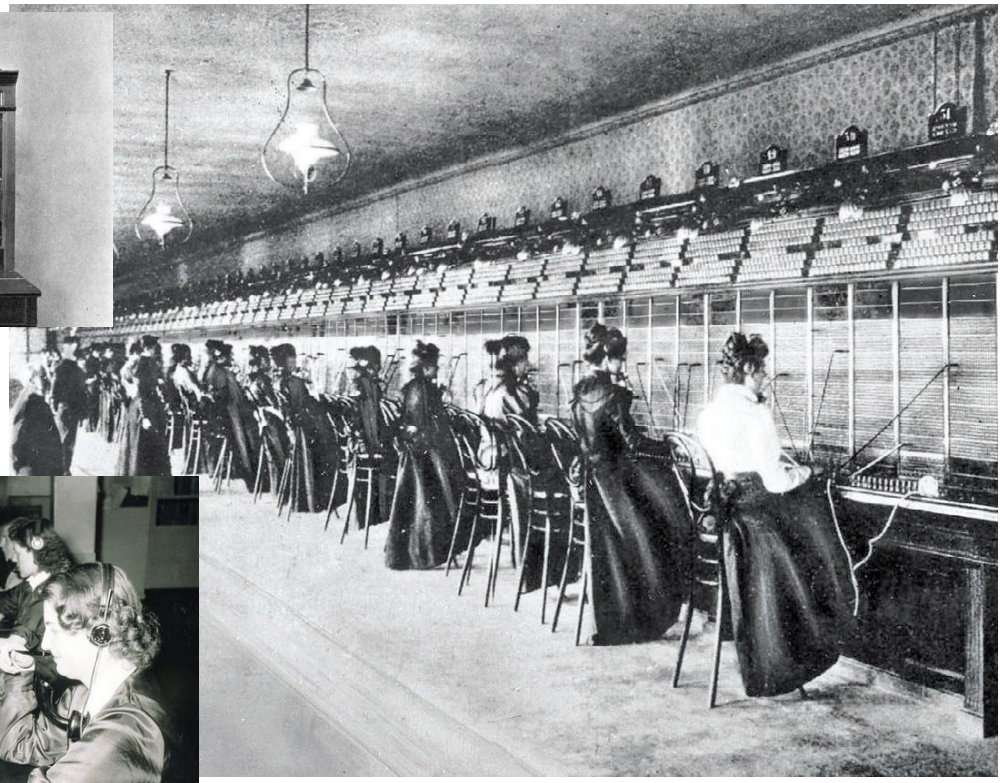
- Teletypewriter (telex)
  - Keyboard, Printing the letters
  - Davis Edvin Hughes (music teacher): 1854
    - Up to around 2000
  - Appr. 400 char/min
    - 5 bits/ char
    - Appr. 30-40 bit/s
  - Twisted pair
  - In early days: re-transmission
    - in more advanced cases: storage on punch tapes
  - Later: manual or mechanical circuit switching
    - automated switching: phone number, call.
      First : 1932

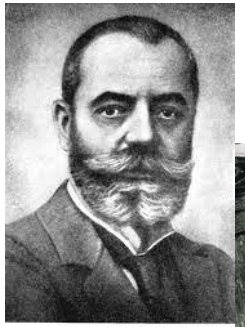
Later telecommunication systems

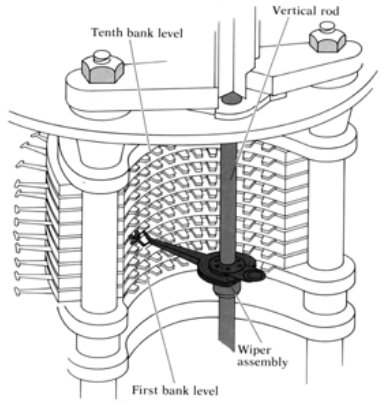
- Telephone
  - Alexander Graham Bell (teaches deaf mutes): ***1876.***
  - 1878. (manual) telephone exchange (in Edison's lab, idea of Puskás Tivadar)
  - 1889. Almon B. Strowger (funeral director!!!): automated telephone exchange

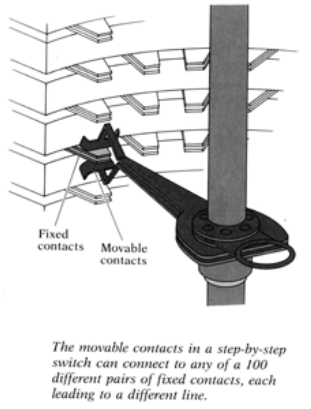












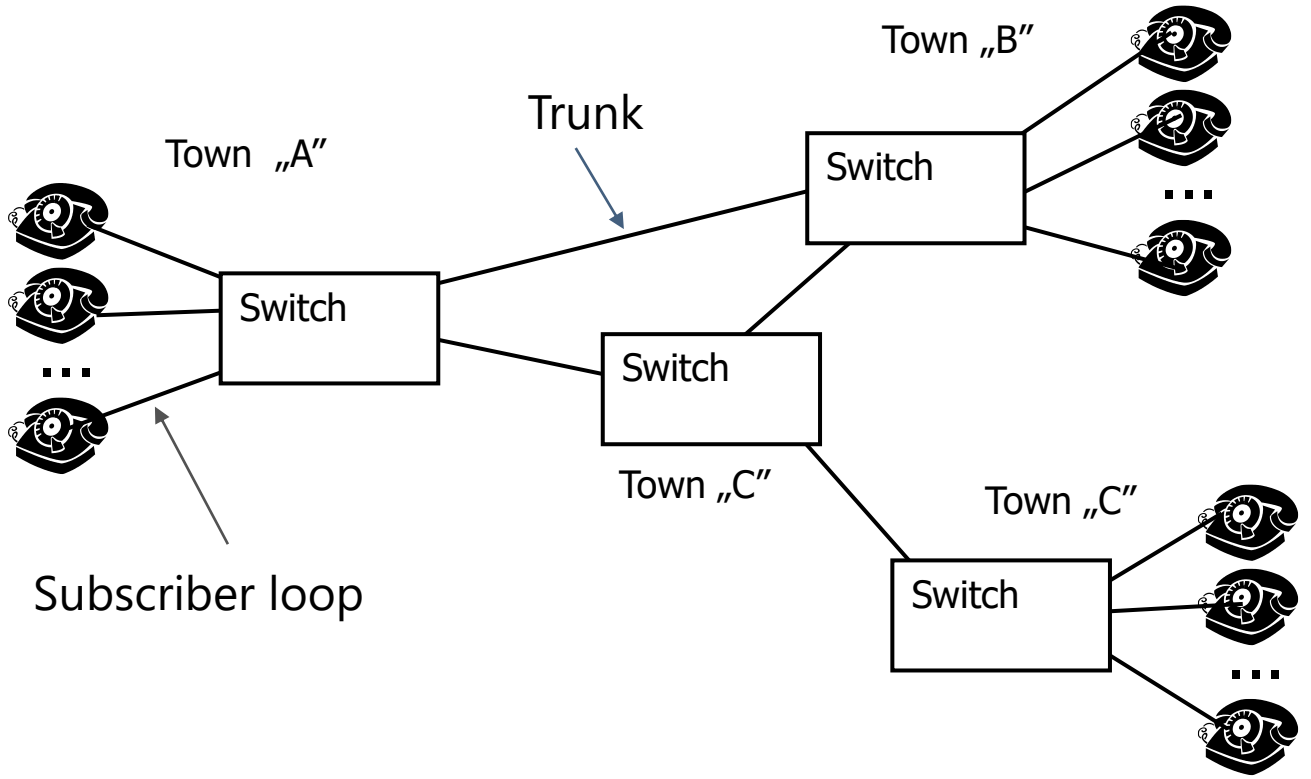
The movable contacts in a step-by-step switch can connect to any of a 100 different pairs of fixed contacts, each leading to a different line.

Voice transmission

1. Fixed telephone systems
2. Numbering in telephone networks
3. Analog and digital voice transmission

A classic fixed (landline) telephone network

- Terminals
- Switches or exchanges
- Transmission routes



- This is how hat a fixed telephone network once really looked like
- It's not like that anymore, but it will do as a first approximation

A few words about building blocks

- Terminals
  - classically: telephone (and fax, modem)
- Switches
  - hierarchically connected to each other
- Transmission routes
  - From the subscriber to the first switch: subscriber or local loop
    - typically a copper wire pair
  - Between switches: trunk
    - many voice channels multiplexed for one or several transmission channels (e.g. coax, microwave radio transmission, optical fiber)
- All of this can (could) be analog or digital
  - FDM (Frequency Division Multiplexing) – ANA
  - TDM (Time Division Multiplexing) - DIG

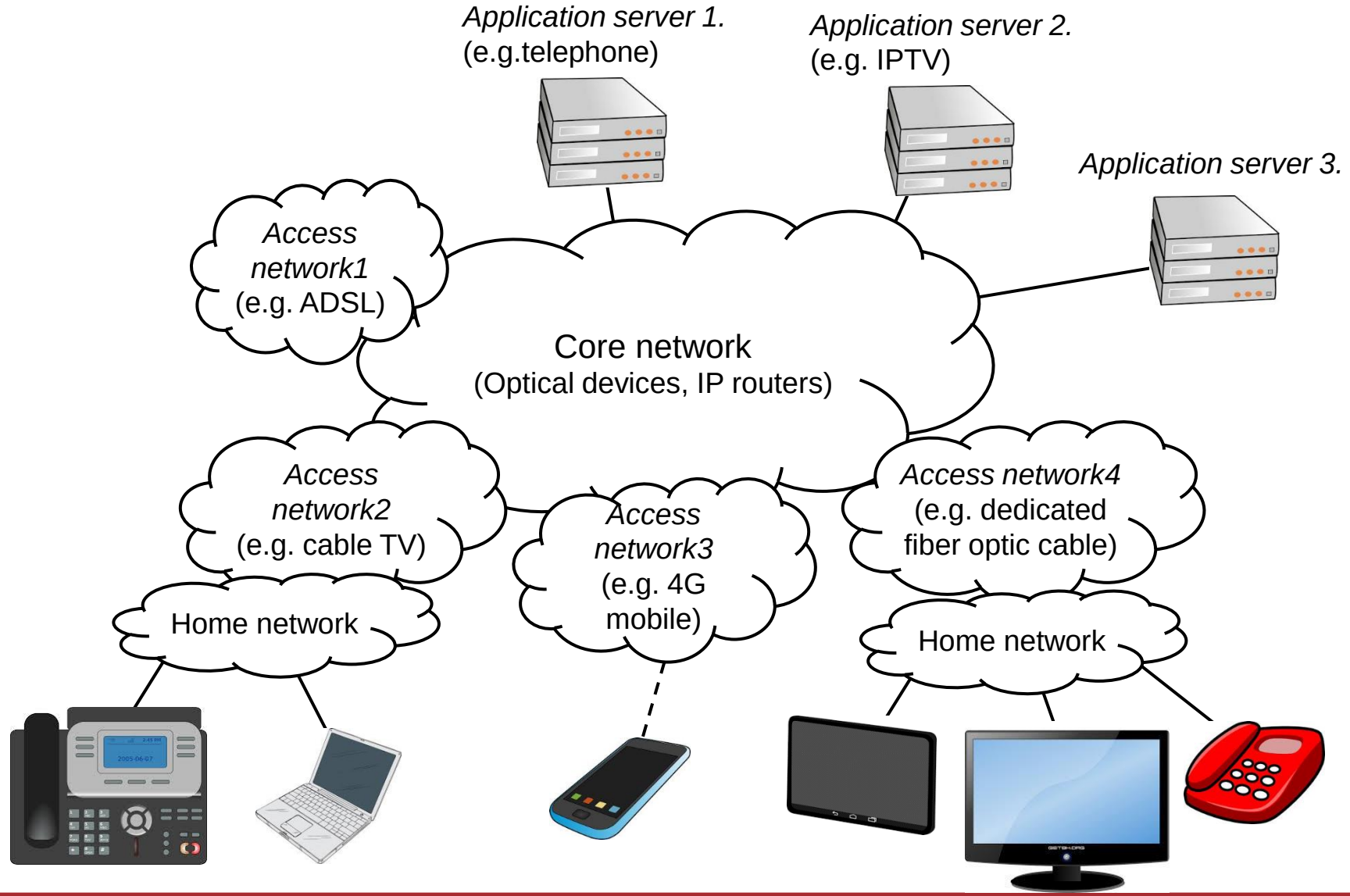
Today's Telecommunication Network

- Called: Next Generation Networks (NGN)
  - Concept from around 2004
  - It has now been gradually introduced worldwide

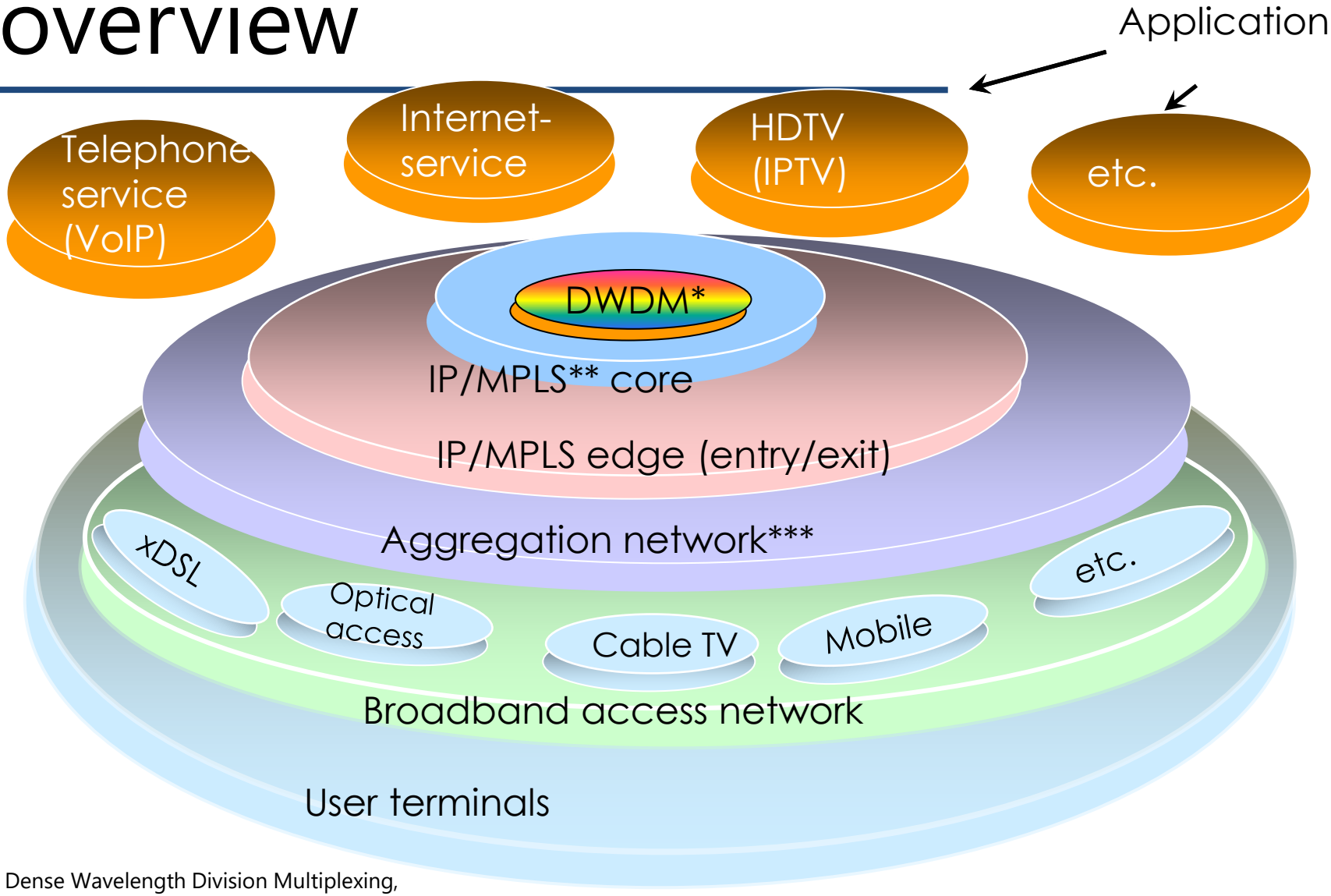
- All of these will gradually replace/merge the existing networks suitable for one(-two) purposes:
  - telephone network, cable TV network, data network (Internet), mobile network

- Basic idea:
  - all the above is information
  - single, packet switched (IP) core network
  - various access networks for this (e.g. ADSL, cableTV, fiber optic access, mobile phone, etc.)
  - various services implemented in the network with application servers (e.g. telephone service, TV service, etc.)
  - users can use these on different devices (e.g. watching TV on a tablet, receiving a landline call on a mobile phone, etc.)

NGN topological sketch



NGN overview



*DWDM = Dense Wavelength Division Multiplexing,
(It is a kind of high-capacity optical network, see later)

**MPLS = MultiProtocol Label Switching

***(OSI) Layer 2, i.e. not IP yet. More recently, e.g. often Ethernet (telecom. service provider)

Voice transmission

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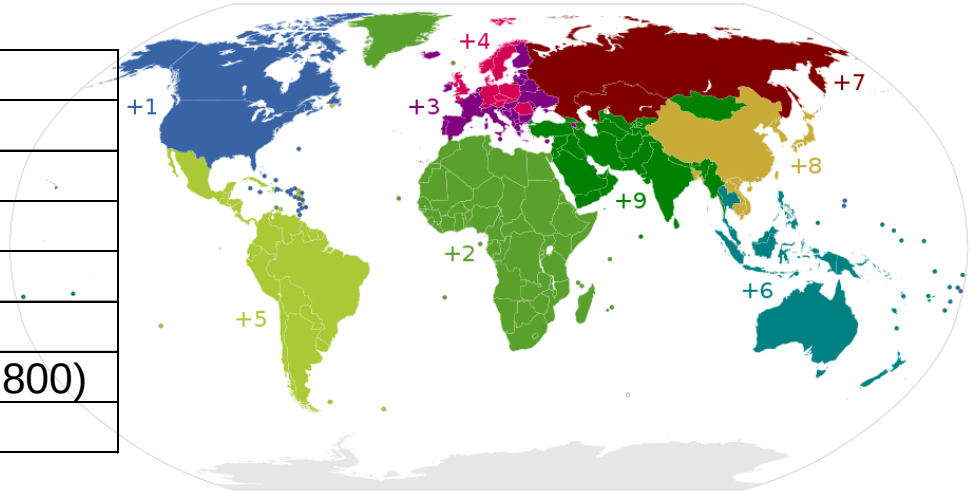
Numbering

You do not have to know the concrete numbers by heart for the exam

- In computer network it is called addressing (Numbering vs. addressing)
- Called party's number: identified originally the location (address function)
- Current trend : identifies the subscriber or service itself (name function)
  - mobile networks - obviously
  - examples in fixed networks:
    - number portability
    - premium rate, freephone (green), shared cost (blue) numbers
- E.164 Recommendation (ITU-T, http://www.itu.int/rec/T-REC-E.164/en)
- An international number: max. 15 digits
  - country code (1-3 digits) + national destination code (area code, service or network identifier) + subscriber number

1	North America
2	Africa (+Greenland)
3,4	Europe
5	Middle and South America
6	Australia and Pacific
7	Russia, Kazakhstan
8	Far East (+Inmarsat, Internat. Green Number: 800)
9	Middle and Near East



Numbering

You do not have to know the concrete numbers by heart for the exam

- Within the country: National Destination Number = National Destination Code + Subscriber Number
  - National Destination Number = NDC + SN
- National Destination Code:
  - Area code, e.g.: 33: Esztergom (geographical numbers)
  - Network Code, e.g.: 30: t-mobile
  - Service Code, e.g.: 80: green number
- Subscriber Number
- Important: public phone numbers are always prefix codes
  - i.e. one number cannot be a continuation of another
  - technologically, it can be easily solved in this way

Short codes (in Hungary)

- Prefixes (they cannot stand on their own, must be followed by a telephone number)

00	internat. prefix
06	nat. prefix
130	number presentation allowance prefix
131	number presentation disabling prefix
15cd	carrier selection prefix

You do not need to know the specific numbers and services by heart for the exam.

- Short Numbers

104, 105, 107, 112	emergency numbers
116c(d)	harmonized numbers of harmonized public services
118de	telephone inquiry
12cd	call centerof electronic service providers
140d-144d, 145de-149de	(premium rate) countrywide numbers
17c(d(e))	numbers allocated to electronic service providers
18c(d)	numbers of information and support services of public interest
190-194, 197-199	operator services

National Destination Codes in Hungary

- Area codes

You don't need to know these by heart for the exam either

A\B	2	3	4	5	6	7	8	9
2	Székesfehérvár	Biatorbágy	Szigetszentmiklós	Dunaújváros	Szentendre	Vác	Gödöllő	Monor
3	Salgótarján	Esztergom	Tatabánya	Balassagyarmat	Eger	Gyöngyös	-	-
4	Nyíregyháza	-	Mátészalka	Kisvárda	Miskolc	Szerencs	Ózd	Mezőkövesd
5	Debrecen	Cegléd	Berettyóújfalu	*Test*	Szolnok	Jászberény	-	Karcag
6	Szeged	Szentes	-	-	Békéscsaba	-	Orosháza	Mohács
7	Pécs	Szigetvár	Szekszárd	Paks	Kecskemét	Kiskunhalas	Kiskőrös	Baja
8	Kaposvár	Keszthely	Siófok	Marcali	-	Tapolca	Veszprém	Pápa
9	Zalaegerszeg	Nagykanizsa	Szombathely	Sárvár	Győr	-	-	Sopron

National Destination Codes in Hungary

You don't need to know these by heart for the exam either

- Service and Network Codes:

A\B	0	1
2	Mobile (yettel)	Nomadic service
3	Mobile (T-Mobile)	Mobile (Virtual operators)
4	Shared cost service („blue” number)	-
5	Mobile (digi)	Internet access
6	-	-
7	Mobile (Vodafone)	Machine-to-Machine communication
8	Freephone („green” number)	-
9	Premium rate service (unrestricted)	Premium rate service (restricted content and price)

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Numbering

- Open numbering scheme:
  - Two forms: local/national destination number
  - Local numbers shorter, only the Subscriber Number; you do not have to dial NDC from within the same geographic area
  - But it is different from elsewhere
  - =>Needs a national prefix (06 – in Hungary, 0 – in other European countries) to indicate if you dial the national destination (“full”) form

- Closed numbering scheme:
  - Always national destination number
  - Simple, unambigous
  - One form, independently where to start the call from
  - => no need for a national prefix
  - Tendency in Europe (Norway, France, Italy, UK….)
    - Especially in the 1990s

Closing the mobile numbers in Hungary

- 15 Jan 2010
- Mobile numbers can only be called with the NDC
- E.g.: 06-20-555-1234 vagy +36-20-555-1234
  - Since the geographical numbers are not closed, we united the drawbacks of the open and closed numbering schemes
  - Hungary is a funny country ☹
- Reasons:
  - so the first digit of the subscriber number can now also be 0 or 1, thus increasing the number of mobile subscriber numbers that can be issued by +25%
  - eliminating false calls
    - previously, many people only had the seven-digit subscriber number saved in the phone book for acquaintances who belonged to the same network
    - when porting the number, the subscriber number and phonebook remained, but the default network identifier changed, causing many wrong calls
    - closing the number field eliminated the possibility of this

Voice transmission

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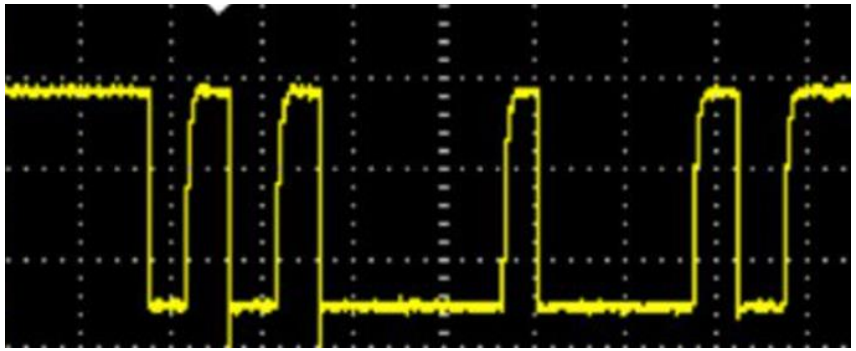
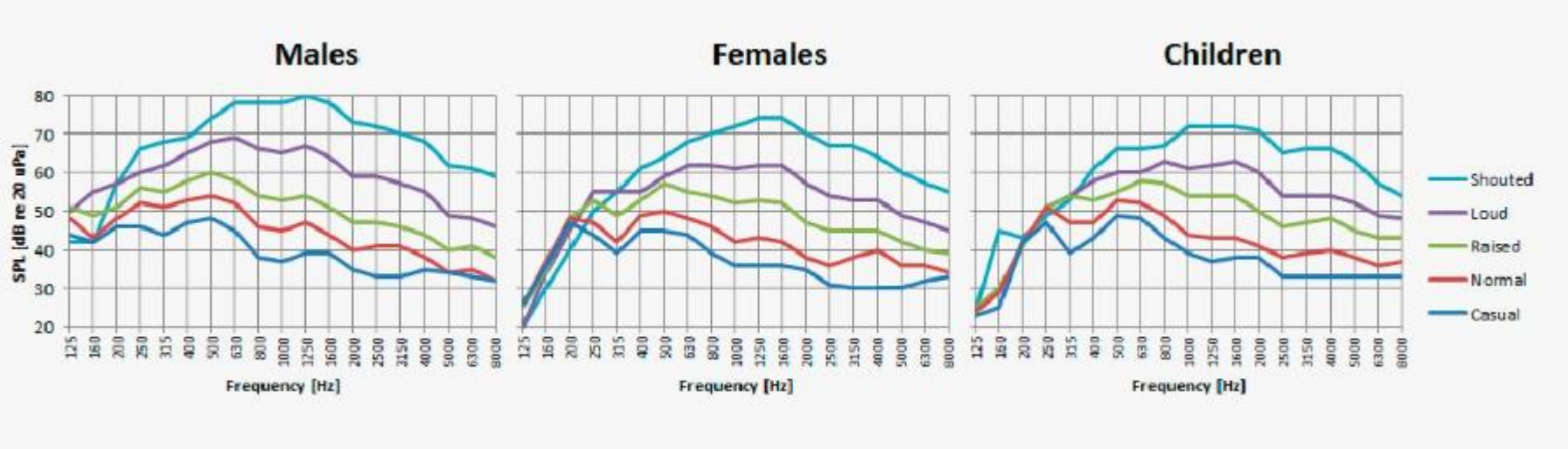


Analog voice transmission

- Terminal: sound wave ↔ analog electrical signal
- What do we know about the voice?
  - The human ear hears about 20 Hz - 20 kHz
    - Depends on age (you probably ~12 kHz)
  - The upper limit of the speech is 6-7 kHz



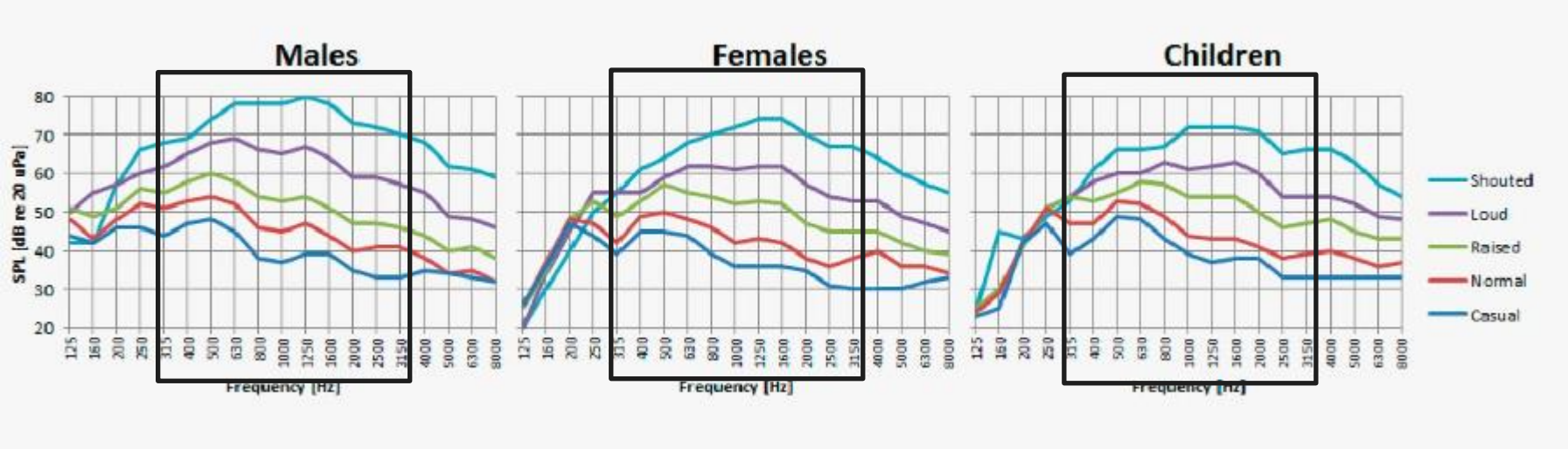
In telecommunication, voice means human's voice (speech)

Analog voice transmission

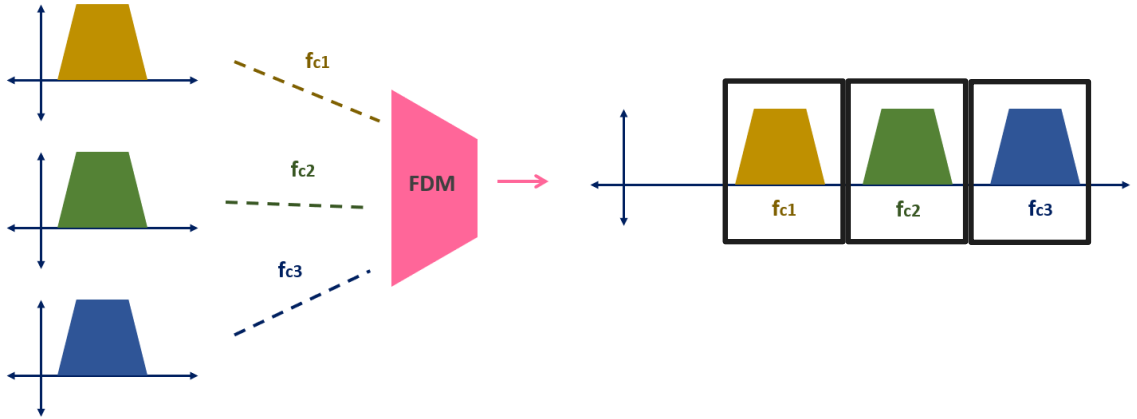
- How many Hz wide should a voice channel be?
  - the goal is simply to transmit intelligible, understandable speech
  - + economical aspects!
- Early multiplexed trunks used FDM (Frequency Division Multiplexing)
  - the narrower a voice channel is, the more can fit on a trunk line
- Nowadays: digital transmission – TDM (Time Division Multiplexing), IP
  - but bitrate matters here, too ...
  - and it is proportional to the transmitted bandwidth (see later: PCM)
- Understandability and voice quality as a function of transmitted frequency :
  - 500...1000 Hz: poor
  - 500...1500 Hz: tolerable
  - 400...2000 Hz: satisfactory
  - 300...2500 Hz: sufficient
  - 300...3400 Hz: good
  - 200...3500 Hz: very good
- Decision: **0,3 – 3,4 kHz band**
  - 3,1 kHz + guarding gaps = **A voice channel will be 4 kHz wide**

Analog voice transmission

- Voice 300-3400 Hz (0.3-3.4 kHz)

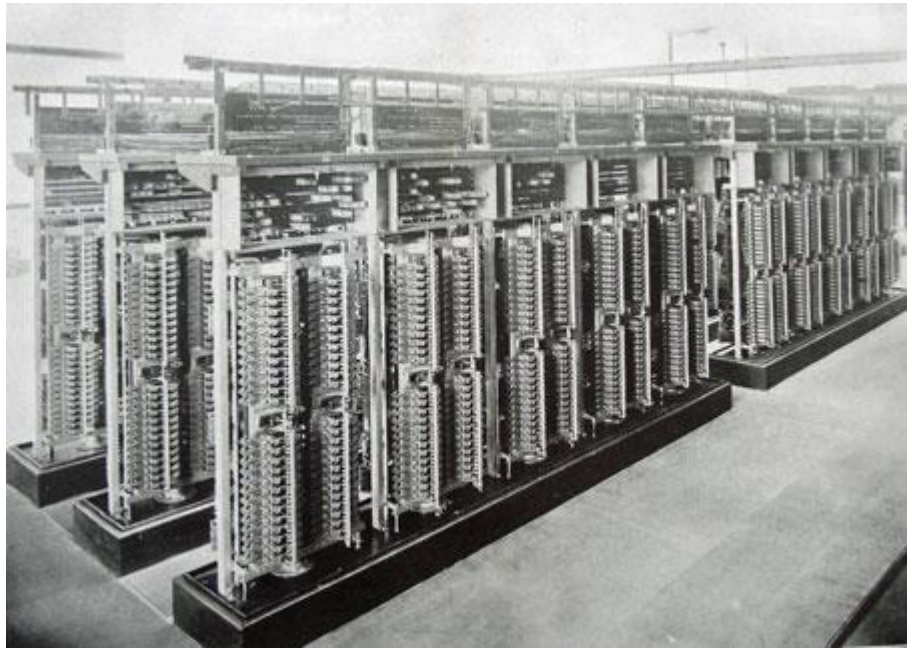


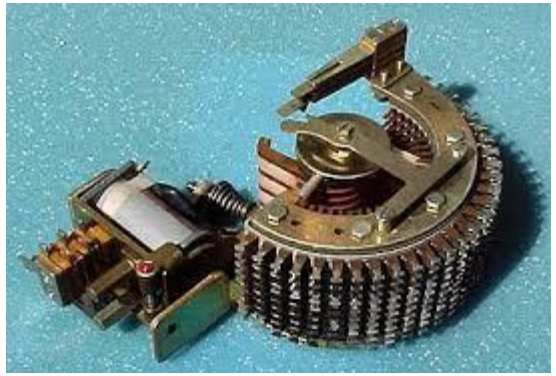
- FDM signal (schematic)
  - Non-ideal devices
  - To reduce the inter-channel influence
    => gap btw them
  - => 4 kHz



Analog telephone systems

- Initially end-to-end analog transmission
  - Analog terminals
  - Analog multiplexing on trunks (FDM, Frequency Division Multiplexing)
  - (Electro)mechanical switching, continuous galvanic connection inside the switch





The expansion of digital technology

- Digital technology appeared (during/after World War II)
- With many advantages compared to analog:
  - simpler, more reliable, cheaper
  - less space and power requirements
  - the signal/noise ratio is independent of the size of the network (though, the bit error rate may depend)
  - switching is possible without moving parts
  - a higher degree of network intelligence can be realized
  - much more sophisticated signaling is possible
  - data and voice signals can be handled in a uniform way
- It is worth digitizing the voice signal
  - and send over a digital telephone network this way
  - a huge transformation in the network!

Digital telecommunication networks

- Starting in the 1960s/1970s, network elements in developed countries were gradually replaced by digital ones
  - in Hungary it is finished around 2000
  - today, moreover, they are transferred in IP packets
  - Exception: the majority of *wired terminals* (telephones) remained analog
    - A/D-D/A conversion in the first network device
- How to digitize voice?
  - Next time

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