
Arquitecturas de Comunicações
MSc.Engenharia de Computadores e Telemática
1º ano, 1º semestre, 2024/2025

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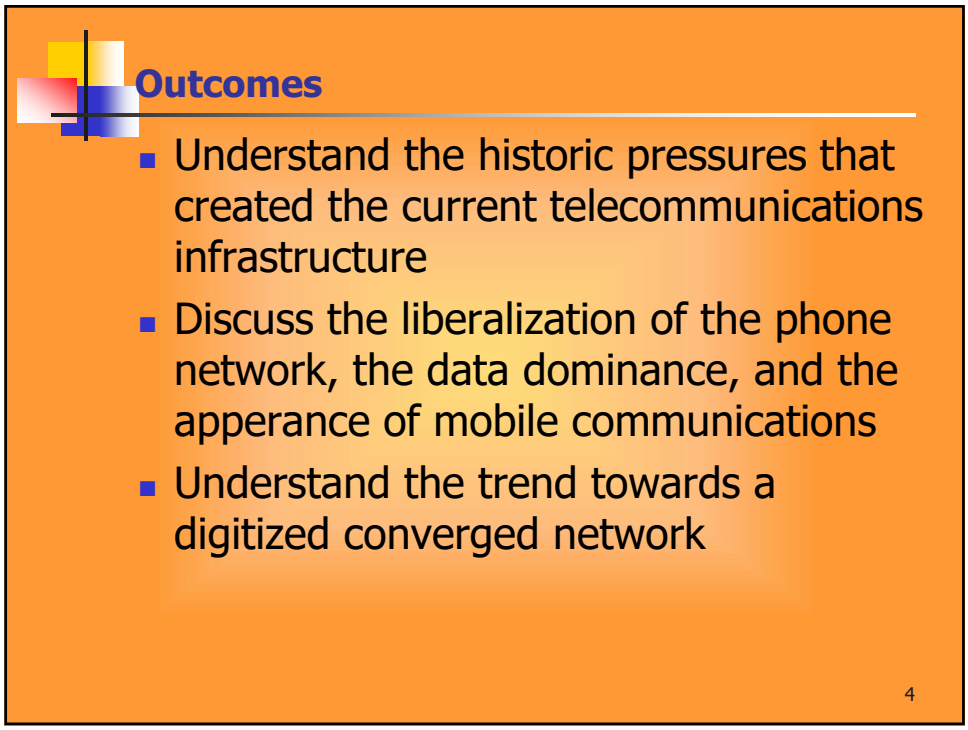
Outcomes
Understand the historic pressures that created the current telecommunications infrastructure
Discuss the liberalization of the phone network, the data dominance, and the apperance of mobile communications
Understand the trend towards a digitized converged network
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The communication network

What is then a network

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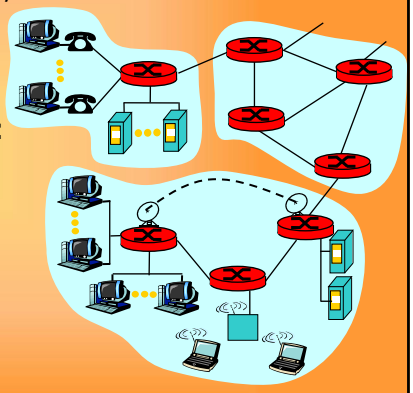
Networks: service vision

- Distributed communications infrastructure supporting applications, also potentially distributed
  - WWW, email, games, e-commerce, databases, voting
- Communications services supporting:
  - Connection-oriented
  - Connection-less
- Service platforms for millions of devices: *hosts, end-systems*
  - Pc's, workstations, servers
  - PDA's, phones, fridges...



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Network structure

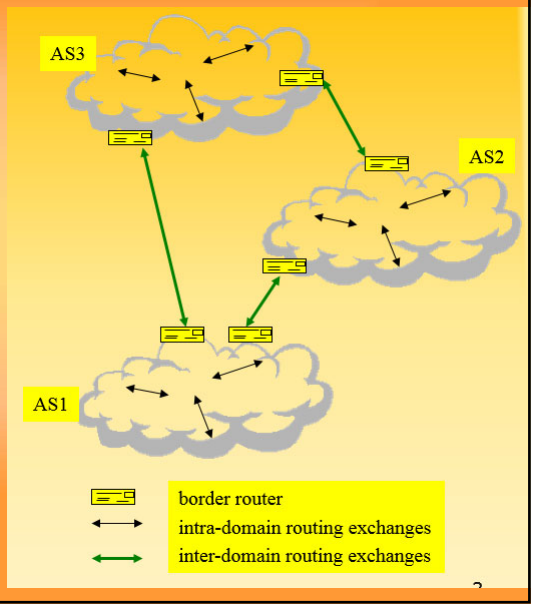
- Administrative borders define:
  - Autonomous systems(AS)
    - **Intradomain routing**
    - Internal policies
    - Different metrics can be used on different domains

    (connectivity protocols in Internet: RIPv2, OSPFv2)
  - Interconnection of ASs
    - **Interdomain routing**

    (Connectivity information protocols in Internet: BGP)

NOTE: this structure is for ALL NETWORKS

- But details presented are for ISPs.



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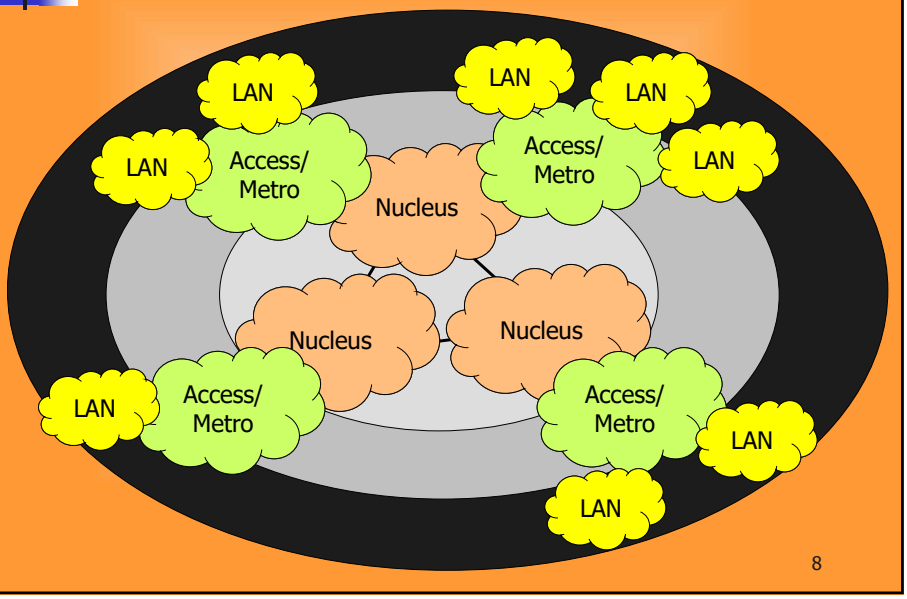
Network architecture



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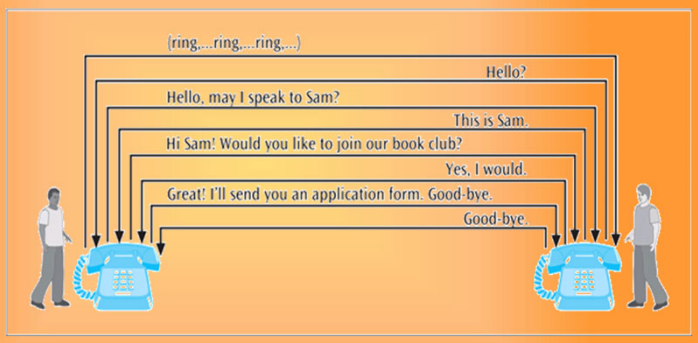
Connection-oriented versus Connectionless



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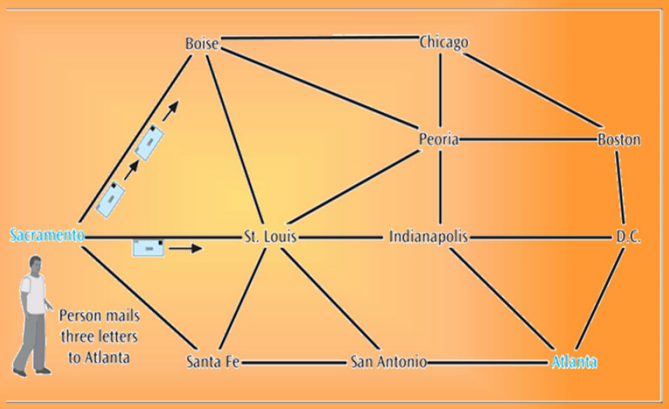
Connection-oriented versus Connectionless



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Connection-oriented versus Connectionless

- A connection-oriented application can operate over both a circuit switched network or a packet switched network.
- A connectionless application can also operate over both a circuit switched network or a packet switched network but a packet switched network may be more efficient.

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The communication network

Trends and history

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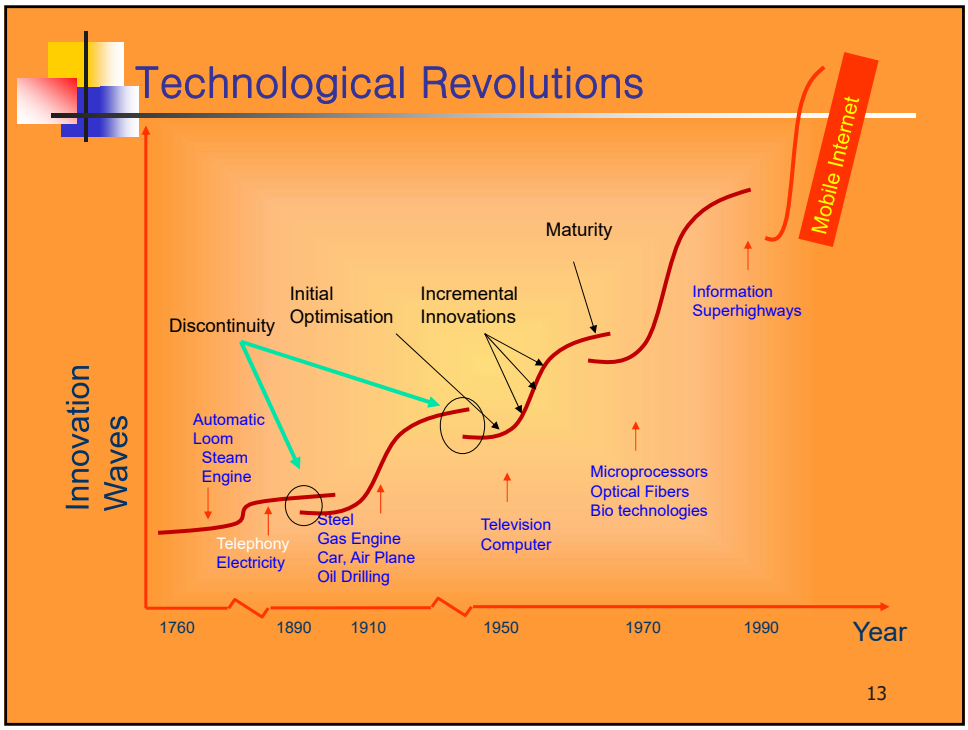

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Public Switched Telephone Network (PSTN)

Major Components of the Public Switched Telephone Network (PSTN):

- Switching Offices
- Transmission facilities
- Customer Premise Equipment (CPE)

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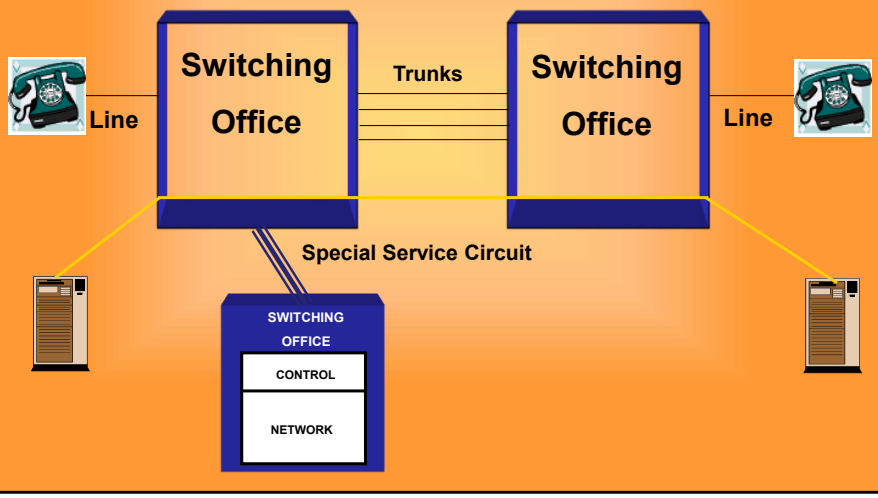
Transmission Facilities in Switching Offices



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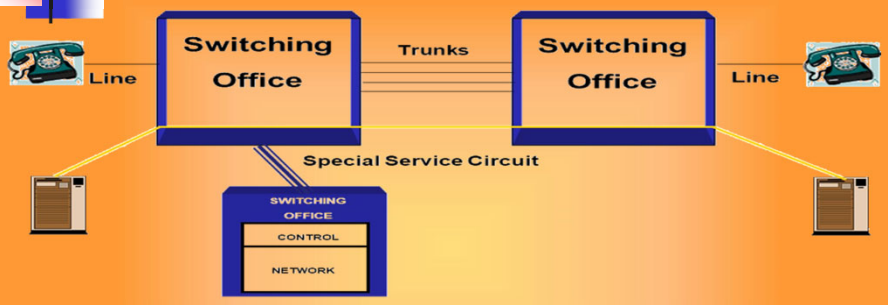
Telephone System



- Uses switched circuits (today: all virtual...)
  - Trunks are over optical fibers
- Access via low bandwidth circuits
- "out-of-band" call establishment using signalling system based in packets (SS7 – Signalling System 7)
- Channels between switching exchanges carry multiple calls
  - Multiplexing (analogue or digital)

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SS7?

Essential part in circuit-switching is the:

SIGNALING

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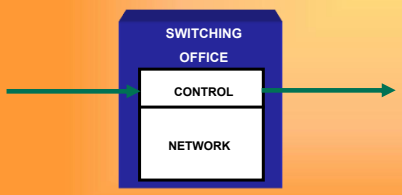
Signaling

Signaling is the generation, transmission, and reception of information needed to direct and control the setup and disconnect of a call.



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Signaling

- In-band signaling
  - The communication (setup and teardown phases) is performed by human operators and finished in the same circuit for both signaling and voice communication.
- Out-of-band signaling
  - Use the digital signals to create a connection between the caller and the called parties.
  - A portion of the voice channel bandwidth is used for signaling.

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Signaling Systems Today

- Signaling system's tasks nowadays
  - Providing dial tone, ring tone, and busy tone
  - Transferring telephone numbers between offices
  - Maintaining and monitoring the call
  - Keeping billing information
  - Maintaining and monitoring the status of the telephone network equipment
  - Providing other functions such as caller ID, voice mail, and so on

NOTE: this addresses phone network signalling.
You have signalling in all communication networks….

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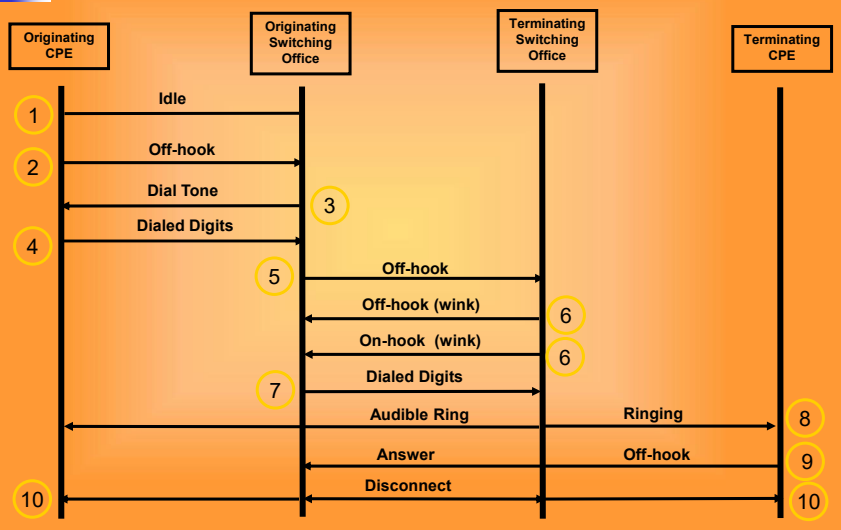
Signaling



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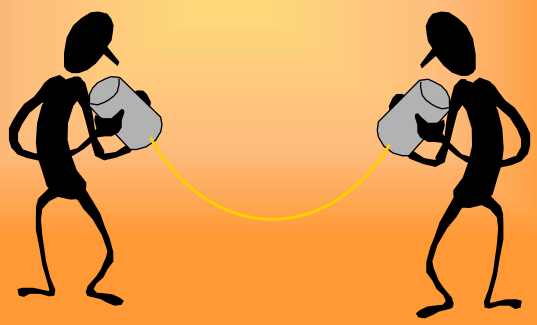
Common Channel Signaling (CCS)

Common Channel Signaling (CCS) is a signaling method that uses a separate dedicated channel to send and receive signaling information for a group of trunks or facilities by means of labeled messages.



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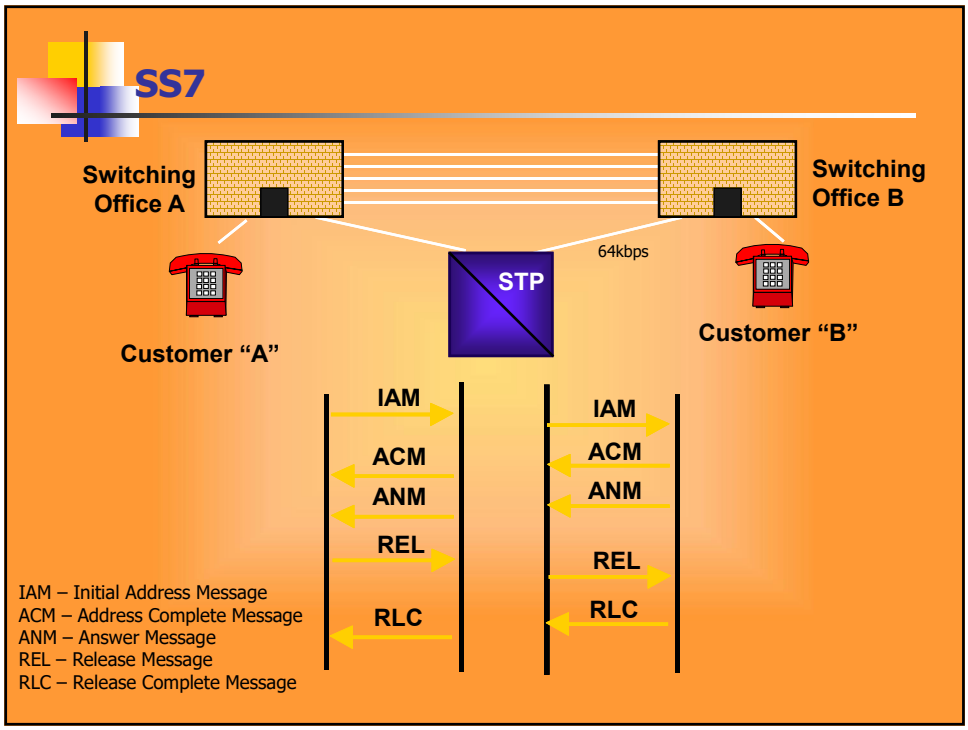
SS7
Switching Office A
Switching Office B
64kbps
STP
Customer "A"
Customer "B"
IAM
ACM
ANM
REL
RLC
IAM
ACM
ANM
REL
RLC
IAM – Initial Address Message
ACM – Address Complete Message
ANM – Answer Message
REL – Release Message
RLC – Release Complete Message

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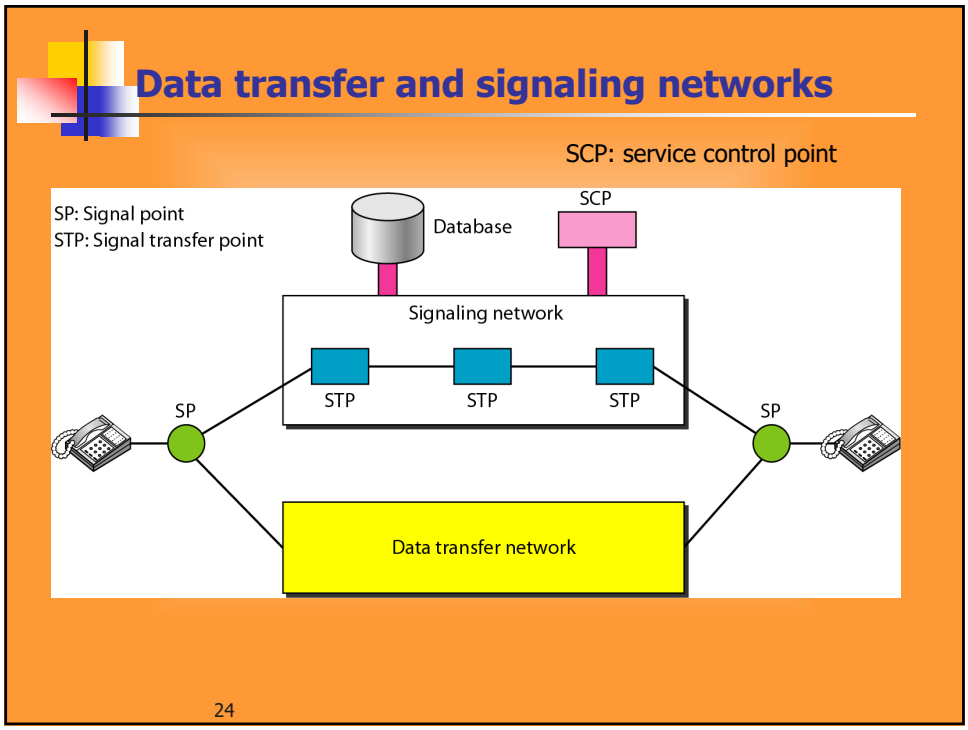
Data transfer and signaling networks
SCP: service control point
SP: Signal point
STP: Signal transfer point
Database
SCP
Signaling network
STP
STP
STP
SP
SP
Data transfer network
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SS7

The SS7 network and protocol are used for:

- Basic call setup, management, and tear down
- Wireless services
  - personal communications services (PCS), wireless roaming, and mobile subscriber authentication
- Local number portability (LNP)
- Toll-free and toll wireline services
- Enhanced call features
  - such as call forwarding, calling party name/number display, and three-way calling
- Efficient and secure worldwide telecommunications
- SMS (Short Message Service)

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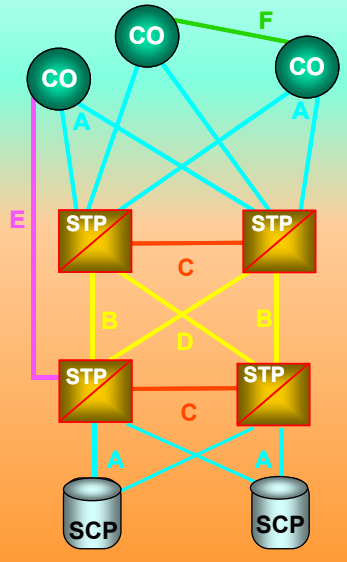
Signaling System 7 (SS7) LINKS



CO – central office

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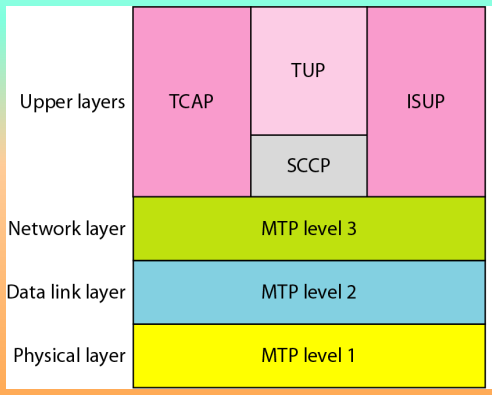
Layers in SS7



MTP: Message transfer part
SCCP: Signaling connection control point
TCAP: Transaction capabilities application port
TUP: Telephone user port
ISUP: ISDN user port

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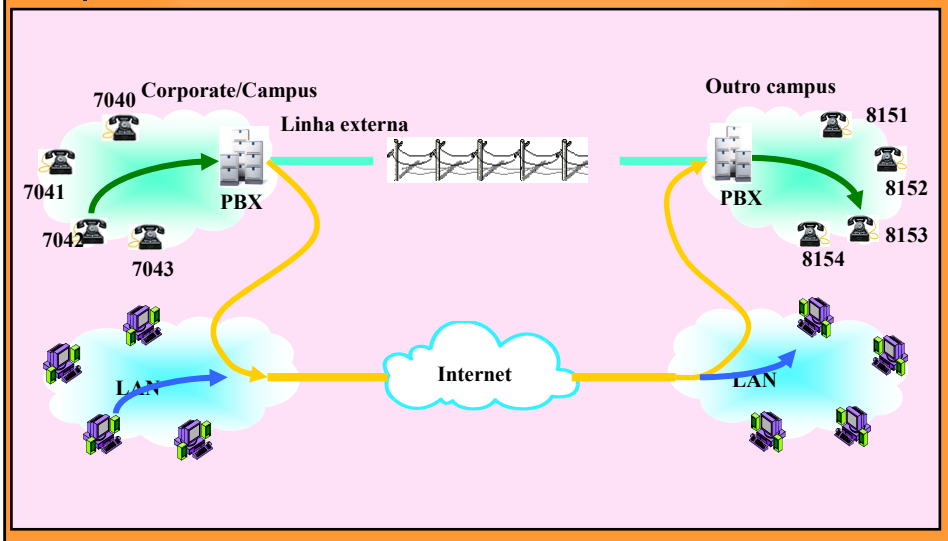
IP Telephony: when the PBX was replaced



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The communication network

The Internet

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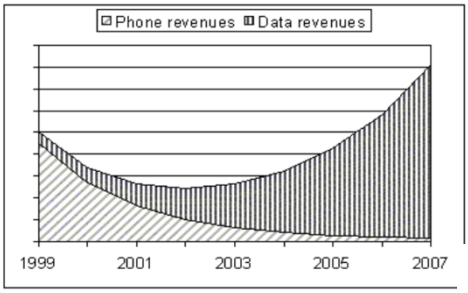
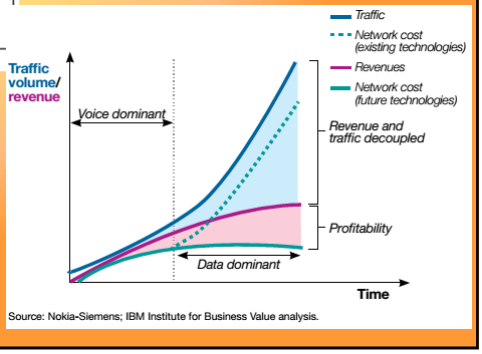
Evolution (@time): profits voice vs data





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Data Communications

- With increasing digitalization of all media, EVERYTHING is data communications
- We live in a Global Village
  - Supported by the Internet

Global computer network

  - A *comunity of communities*
  - The "*information highway*"
  - Also known as Cyberspace

Influence books:
- The third wave, Alvin Toffler
- Neuromancer, William Gibson

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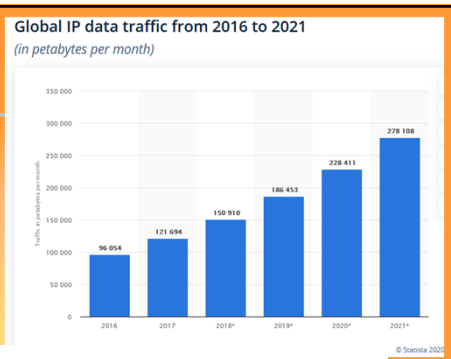
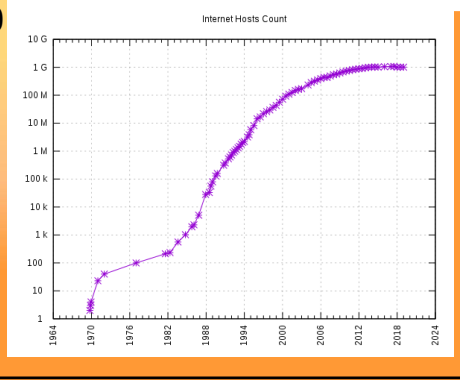
Global IP Traffic

- Total internet traffic has exploded
  - 1992, total traffic = 3TB month
  - 2014, total traffic = 450 EB month
  - 2022, total traffic = 396PB month, 4.75 ZB year

Giga, Tera, Peta, Exa





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Internet: history

- In the beginning:
  - Internet: R&D network
  - Homogeneous user community, with values and joint understanding
- Now:
  - Internet is comercial!
  - Internet used for
    - Both work and diversion
    - By people with very different values (if existing...)
- "Comercial" Internet
  - 1989 – First commercial ISPs (UUNet and PSI)
  - NSFNet blocked of commercial usage, but creating follow-up commercial service providers
  - In Europe, delay due to discussion on OSI acceptance
    - First ISP comercial (EUNet) only in 1991
  - In Pacific, problems also associated with OSI...
    - First ISP comercial (IIJ) in Japão in 1992

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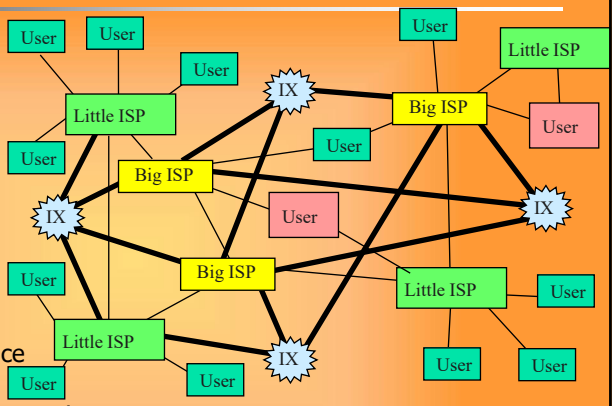
Real structure



- Apparently hierarchical (**bold** lines)
  - Backbone ISP provides service a ISPs increasingly smaller
  - Smaller ISPs eventually providing service end users.
- But hierarchy is not respected
  - Private connection agreements
  - Mechanisms for improvement of the network
  - All companies provie service to (some) users
  - Service providers connect to multiple connection provider
  - Users connect to multiple ISPs

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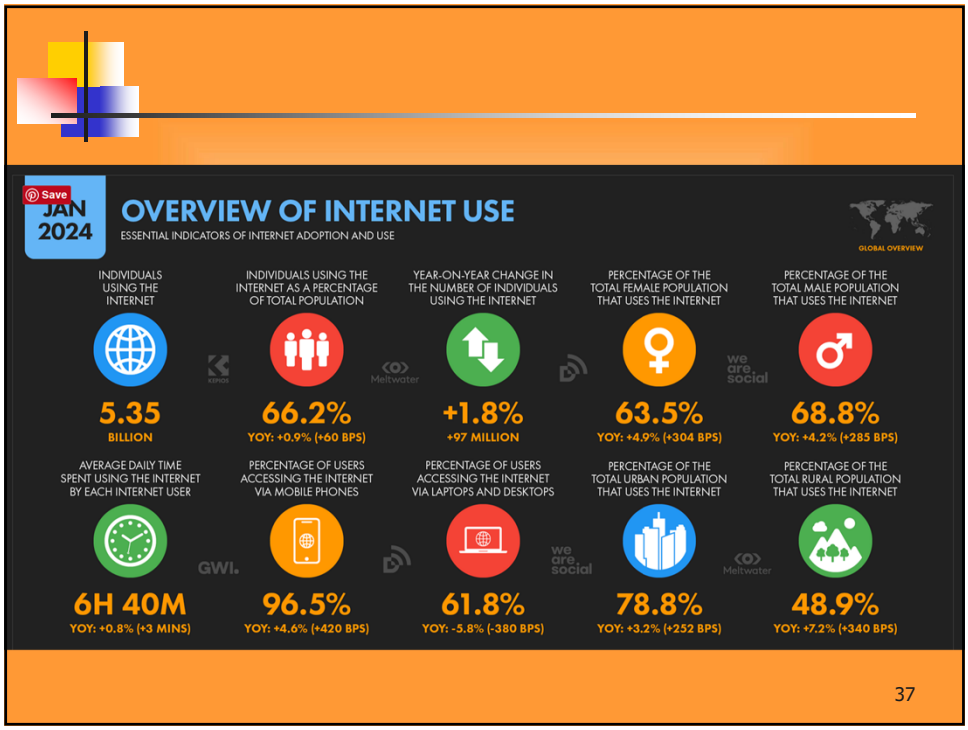
Save
JAN 2024
OVERVIEW OF INTERNET USE
ESSENTIAL INDICATORS OF INTERNET ADOPTION AND USE
GLOBAL OVERVIEW
INDIVIDUALS USING THE INTERNET
5.35
BILLION
INDIVIDUALS USING THE INTERNET AS A PERCENTAGE OF TOTAL POPULATION
66.2%
YOY: +0.9% (+60 BPS)
YEAR-ON-YEAR CHANGE IN THE NUMBER OF INDIVIDUALS USING THE INTERNET
+1.8%
+97 MILLION
PERCENTAGE OF THE TOTAL FEMALE POPULATION THAT USES THE INTERNET
63.5%
YOY: +4.9% (+304 BPS)
PERCENTAGE OF THE TOTAL MALE POPULATION THAT USES THE INTERNET
68.8%
YOY: +4.2% (+285 BPS)
AVERAGE DAILY TIME SPENT USING THE INTERNET BY EACH INTERNET USER
6H 40M
YOY: +0.8% (+3 MINS)
PERCENTAGE OF USERS ACCESSING THE INTERNET VIA MOBILE PHONES
96.5%
YOY: +4.6% (+420 BPS)
PERCENTAGE OF USERS ACCESSING THE INTERNET VIA LAPTOPS AND DESKTOPS
61.8%
YOY: -5.8% (-380 BPS)
PERCENTAGE OF THE TOTAL URBAN POPULATION THAT USES THE INTERNET
78.8%
YOY: +3.2% (+252 BPS)
PERCENTAGE OF THE TOTAL RURAL POPULATION THAT USES THE INTERNET
48.9%
YOY: +7.2% (+340 BPS)
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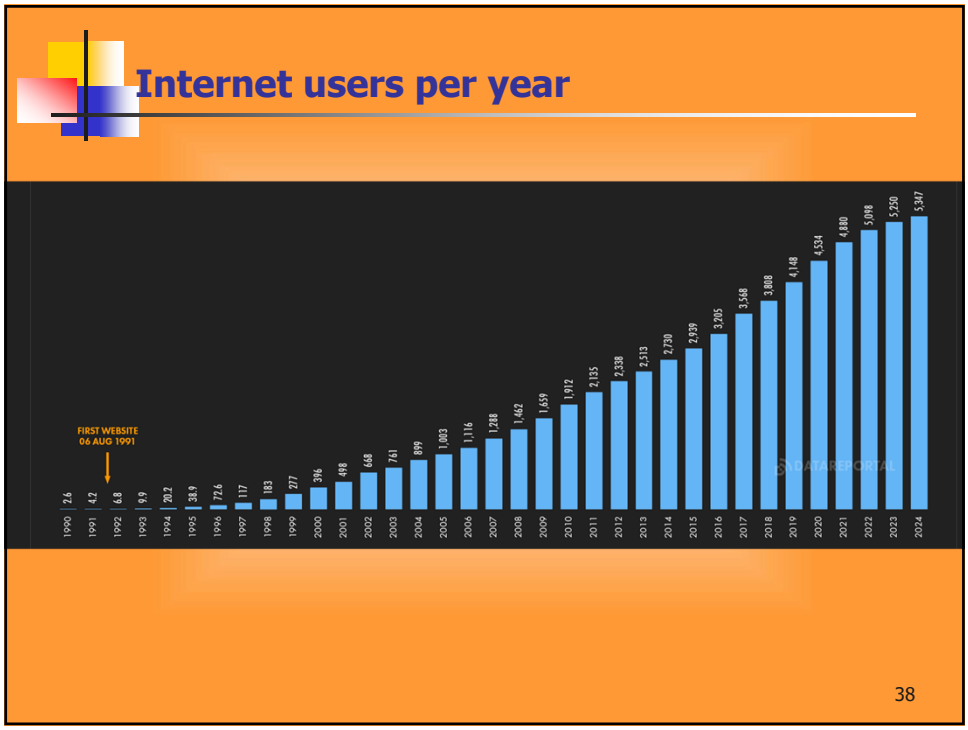
Internet users per year
FIRST WEBSITE
06 AUG 1991
1990 2.6
1991 4.2
1992 6.8
1993 9.9
1994 20.2
1995 38.9
1996 72.6
1997 117
1998 183
1999 277
2000 396
2001 498
2002 668
2003 761
2004 899
2005 1,003
2006 1,116
2007 1,288
2008 1,462
2009 1,659
2010 1,912
2011 2,135
2012 2,338
2013 2,513
2014 2,730
2015 2,939
2016 3,205
2017 3,568
2018 3,808
2019 4,148
2020 4,534
2021 4,880
2022 5,098
2023 5,250
2024 5,347
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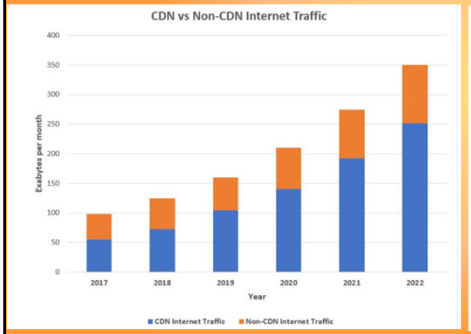
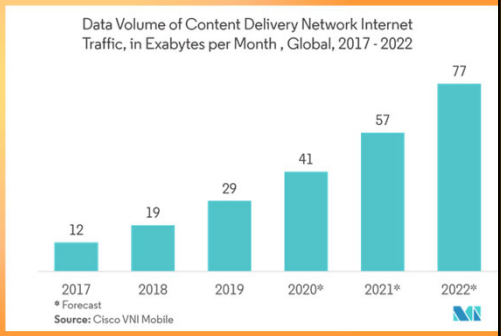
The impact of CDNs

- Changes in traffic topology are being brought about by the increasing role of Content Delivery Networks (CDNs) in data delivery.
- CDNs carry 72 percent of total Internet traffic by 2022





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The Applications in the Internet

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"Data vs voice": packet swithcing vs circuit switching

Packet switching solves everything?

- Great for burst information
  - Resource sharing
  - No cal setup time
- When excessive congestion: delays and losses
  - Needs reliable data transfer protocols
- Providing circuit switching services?
  - For multimedia applications we need bandwidth and delay
    - Problem not yet completely solved

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Transport service (operador/ISP) vs applications

- Packet loss
  - Some apps (audio/video real time) handle losses
  - Other applications (file transfer, telnet) require 100% of success in transmission
- Bandwidth
  - Some applications (multimedia) need a minimum bandwidth to be effective
  - Other applications ("elastic applications", ex. email, file transfer) use the bandwidth available
- Timing
  - Some applications (Internet voice, multiuser games) require low delays to be effective
  - Other applications (without real time requirements) do not have strict delays end-to-end.

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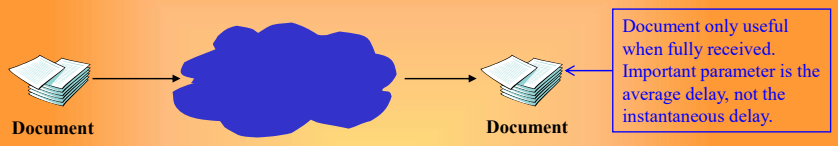
Elastic operations



- Elastic applications
  - Interactive data transfer (e.g. HTTP, FTP)
    - Sensitive to the medium delay, not to rare occurrences
  - Bulk data transfer (e.g. mail, news)
    - Not sensitive to delay (*generally, between reasonable values*)
    - Best effort works…

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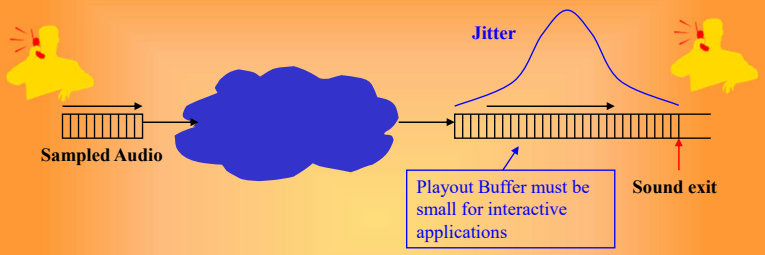
Inelastic applications



- Interactiv applications
  - Sensistive to packet delay (telephony)
  - Maximum delay may be limited
- Non-interactive applications
  - Adapt to larger ranges of delays (streaming audio, video)

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Application requirements

Applications	Losses	BW	Timing
File transfer	lossless	elastic	no
e-mail	lossless	elastic	no
Web documents	lossless	elastic	no
Real time audio/video	supports	audio: 5K-1Mbps video:10K-5Mbps	yes, 100's mseg
Streamed audio/video	supports	See above	yes, poucos segs
Interactive gaming	supports	Some Kbps	yes, 100's mseg
Finance applications	lossless	elastic	Yes and no

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Interactive flows, real-time

- Audio-Video Flows
  - streaming audio/video
  - Use buffering at receiver
- Interactive real-time:
  - Buffering in receiver very limited
  - Delay <200ms
  - jitter <200ms
  - Keep low losses
- Loss impact:
  - depends on aplication, media, and user
- Áudio:
  - Humans tolerate "bad" audio for conversation
  - Humans require "good" audio for entertainment
- Vídeo:
  - Humans tolerate "low" video quality for business
  - Humans enjoy "good" video quality for entertainment
- Synchronizing audio/video:
  - Different flows?

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Audio

QoS Requirements

- Delay < 400ms:
  - Including jitter
- Low losses are prefereable:
  - some coding systems are tolerant to low losses
- Data rates:
  - Voice ≤ 64Kb/s
  - "good" music ≥ 128Kb/s

- Time-domain sampling
- Example – coded voice:
  - Coded 64Kb/s PCM
  - Sampling 8-bit
  - 8000 samples/sec
  - 40ms "time slices" for audio
  - 320 bytes (audio) per packet
  - 48 bytes overhead
    (20 bytes IP header)
    (8 bytes UDP header)
    (20 bytes RTP header)
  - 73.6Kb/s

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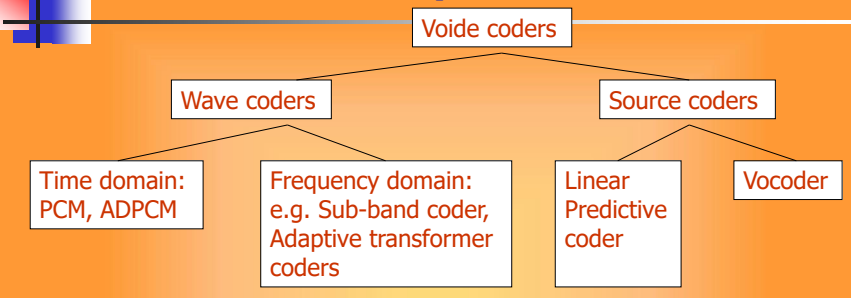
Voice coders taxonomy



- Vocoders:
  - Analyze voice, extract parameters, transmit model parameters
    - Voice synthesized by parametric models
  - LPC-10: 2.4 kbps
- Wave coders: try to preserve the wave format, not voice specific.
  - PCM 64 kbps, ADPCM 32 kpbs, CVSDM 32 kbps
- Hybrid: Try to combine the best of both… Eg: CELP

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Vídeo

QoS Requirements

- Delay < 400ms:
  - including jitter
  - Equal to audio
  - Allows synchronization of flows
- Data rate – depends of:
  - Frame size
  - Color depth
  - frame rate
  - coding

- Usually processing on frequency domain:
  - discrete cosine transform (DCT) very common
- Losses need to be low

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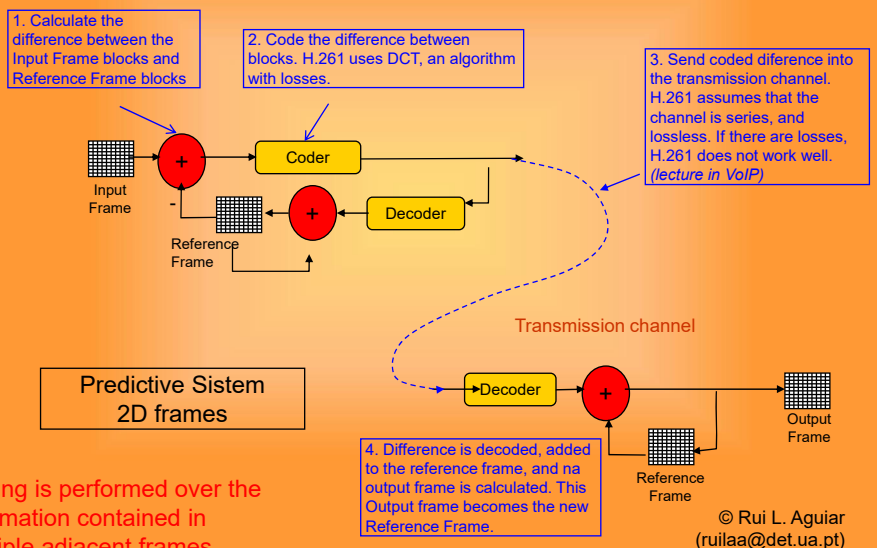
Example Standard H.261



Coding is performed over the information contained in multiple adjacent frames

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The communication network

Mobility: voice and data

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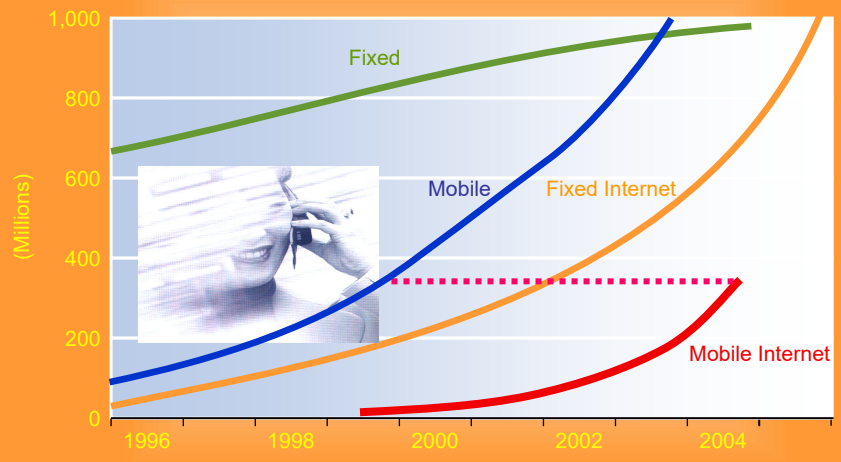
The Rush to a Billion!



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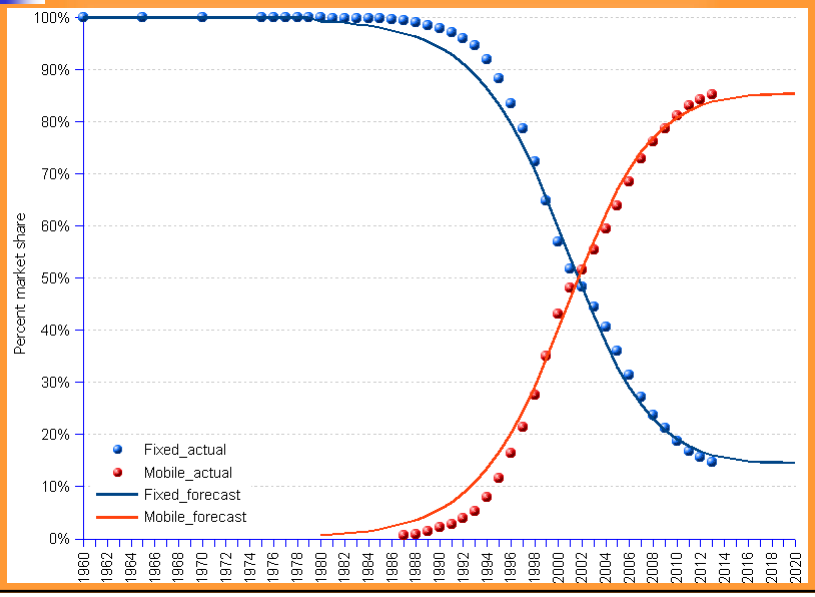
The Rush to a Billion!



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Mobile environment issues

- Mobile Networks limitations
  - Heterogeneity of multiple independent networks
  - Frequent connection dropouts
  - Limited Bandwidth
- Mobility impose limitations
  - No mobility notion at systems and applications
  - Issues with route maintenance in routers
- Mobile device limitations
  - Small battery lifetime
  - Limited capabilities

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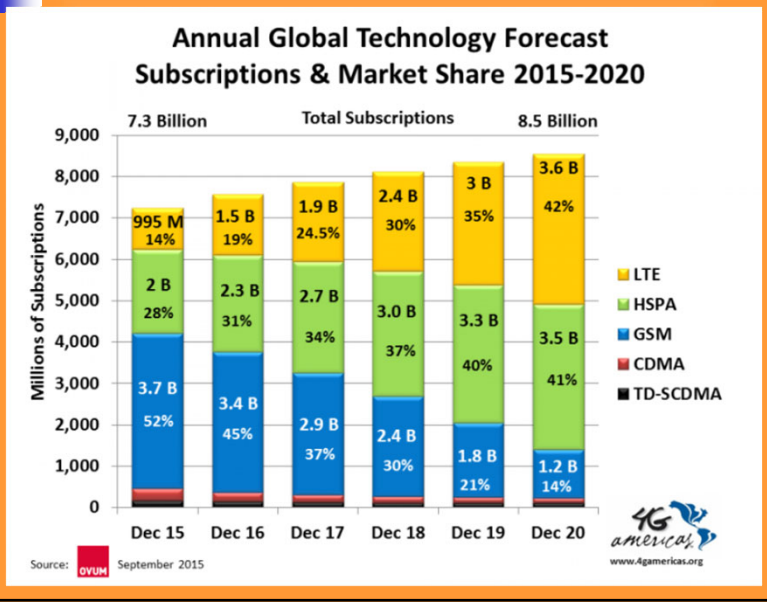
Mobile Technology Evolution



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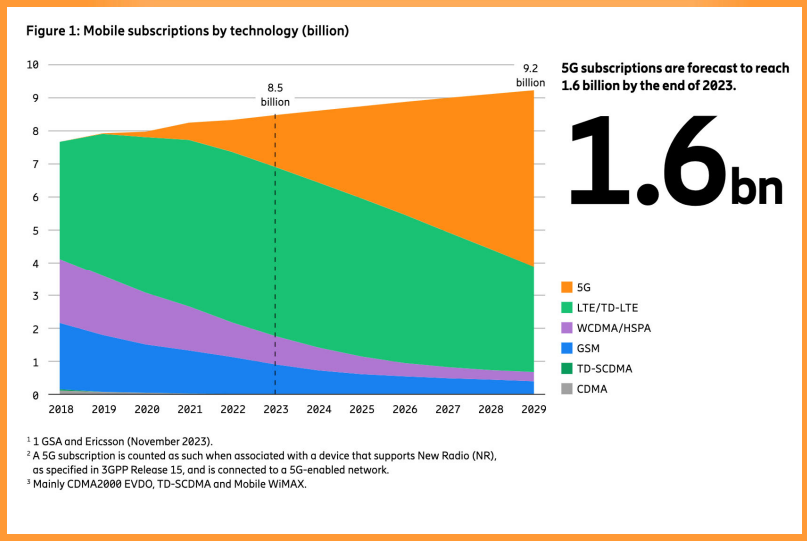
Mobile Technology Evolution



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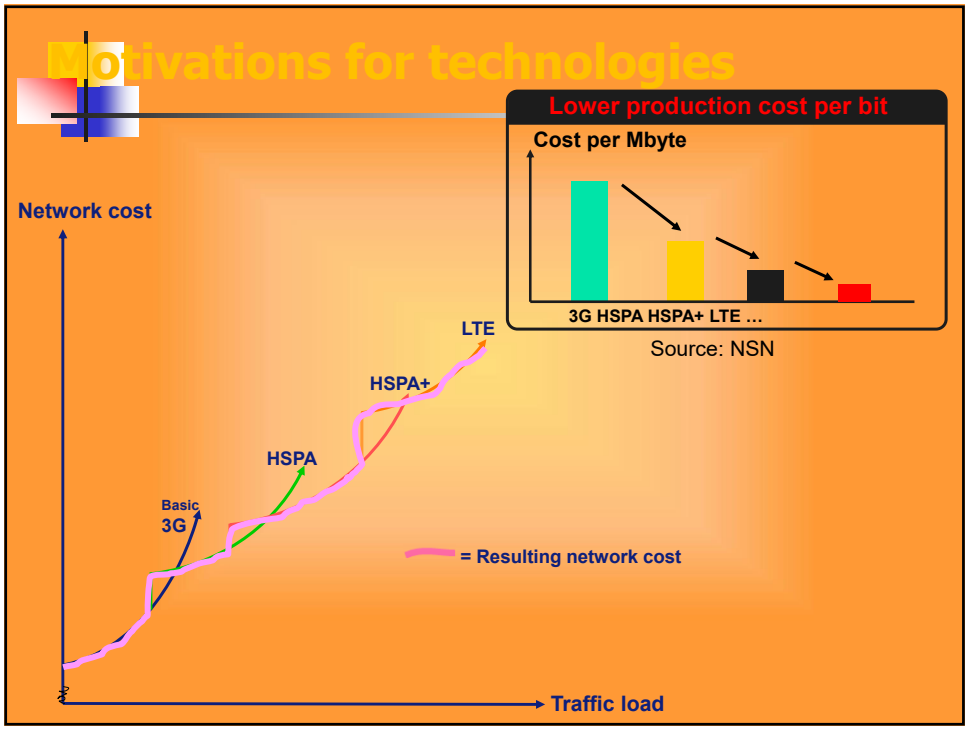
Motivations for technologies
Lower production cost per bit
Cost per Mbyte
3G HSPA HSPA+ LTE ...
Source: NSN
Network cost
LTE
HSPA+
HSPA
Basic 3G
= Resulting network cost
Traffic load

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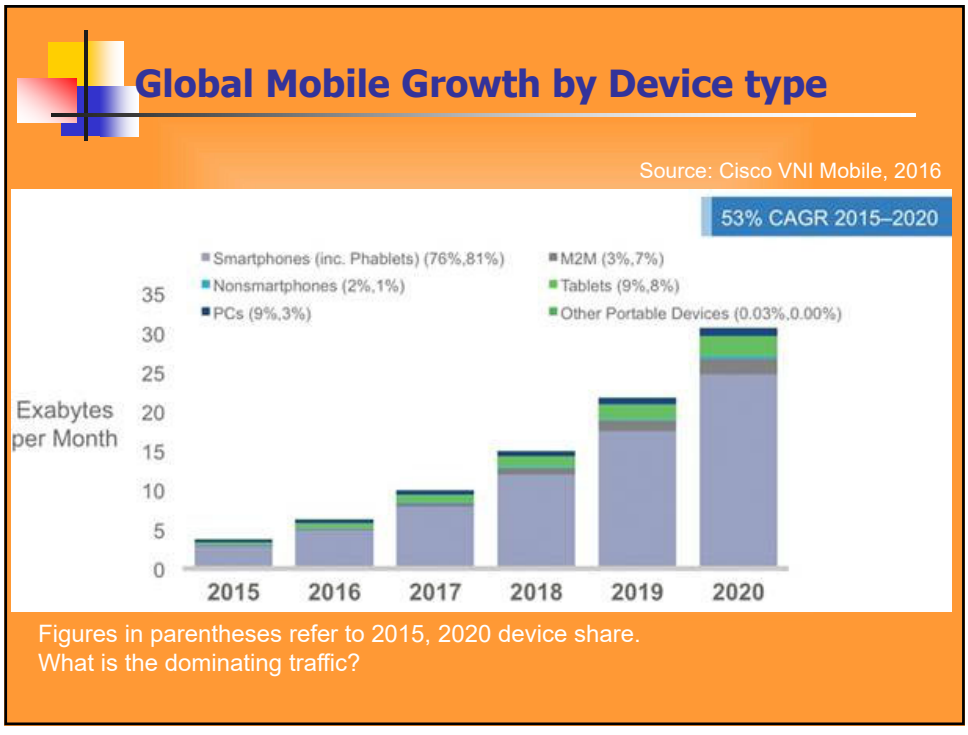
Global Mobile Growth by Device type
Source: Cisco VNI Mobile, 2016
53% CAGR 2015–2020
Smartphones (inc. Phablets) (76%,81%)
Nonsmartphones (2%,1%)
PCs (9%,3%)
M2M (3%,7%)
Tablets (9%,8%)
Other Portable Devices (0.03%,0.00%)
Exabytes per Month
35
30
25
20
15
10
5
0
2015
2016
2017
2018
2019
2020
Figures in parentheses refer to 2015, 2020 device share.
What is the dominating traffic?

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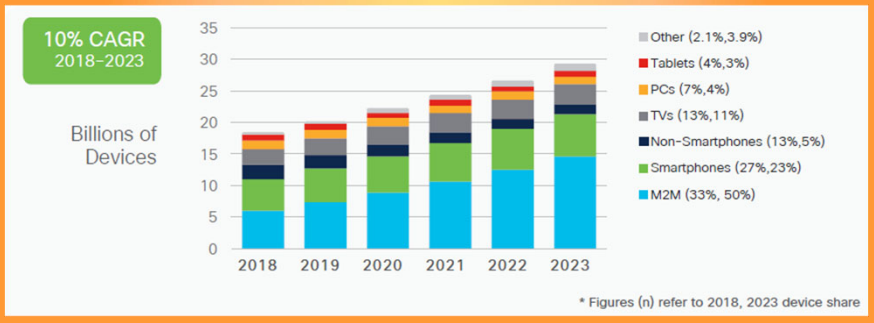
And now, also…

- M2M devices increasingly dominant
- "regular" PCs are becoming increasingly a minority
- IoT is a dominant trend



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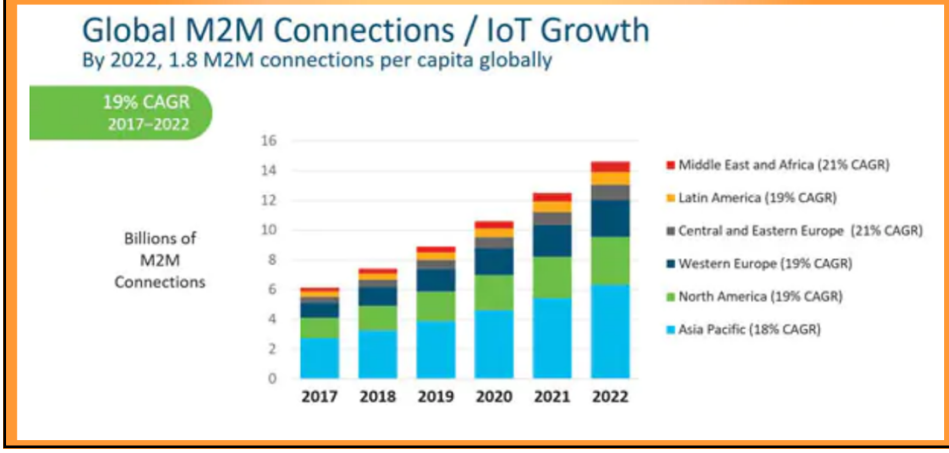
M2M developments

- IoT is increasing 20% per year, and devices are changing their formats.



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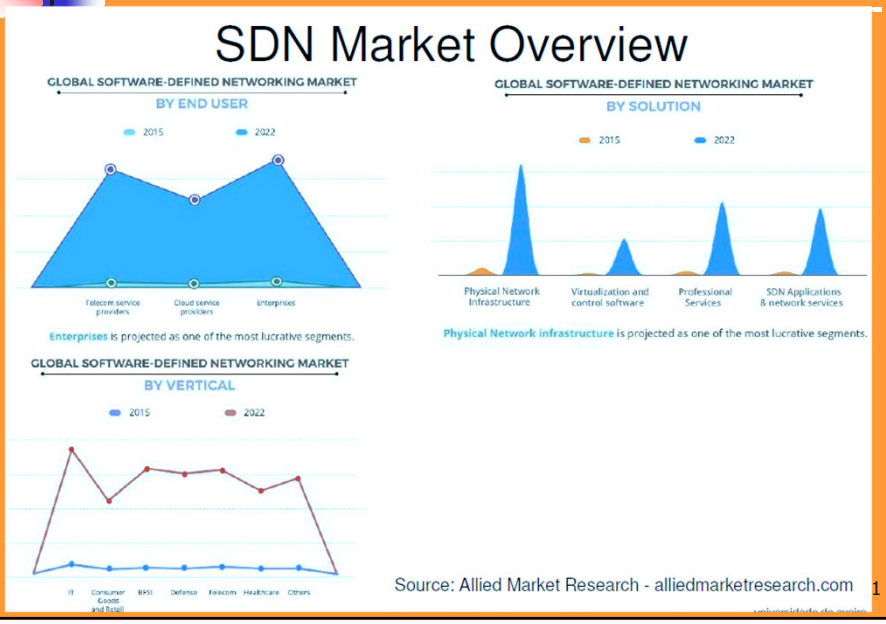
The network will need to be adaptable to all types of services



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What changed

- Voice was very profitable
- Design of networks for voice allowed the design for peak traffic (95% of peak)
  - Voice is very predictable

  Voice systems were easy to build and very profitable to operate.
- Initially, data used only the "margin" of the voice network
  - Data was a small part of traffic
  - Very profitable as well in the beginning, as it was charged at voice costs, paid by big companies, and did not have special infrastructure

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Trends: the Internet era

- Internet appeared
  - Public networks transport mosly data
  - Low entry cost in market
  - Huge growth in the data traffic
- Market liberalization impacts:
  - New operators
  - Huge competition in the profitable markets
    - Mobile service
    - Internation services
  - Competition in the data market

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Trends: the Internet crisis

- Internet Growth
  - Data rose fast to become 70% of traffic...
  - ... But only 2% of the profit of the traditional operators
  - Very low margins, not easy to invest to expand the network
  - Liberalization helped consumer, but hard on infrastructure
- Huge pressure to reduce the transmission cost, merging all traffic into the same optimized transport infrastructure
  - This has been a old trend in telecommunication networks (ISDN, BISDN, ATM, MPLS,...)

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Moving from the Telecom into the data business, operators developed:

CONVERGED NETWORKS

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Trends: the single network

- Mobile networks took over as major communication infrastructure
  - Initially as voice networks, now as data networks
- Reference system for the development of new applications
  - The app economy
  - New web interface designs
  - Novel applications (location) and systems (sensors)

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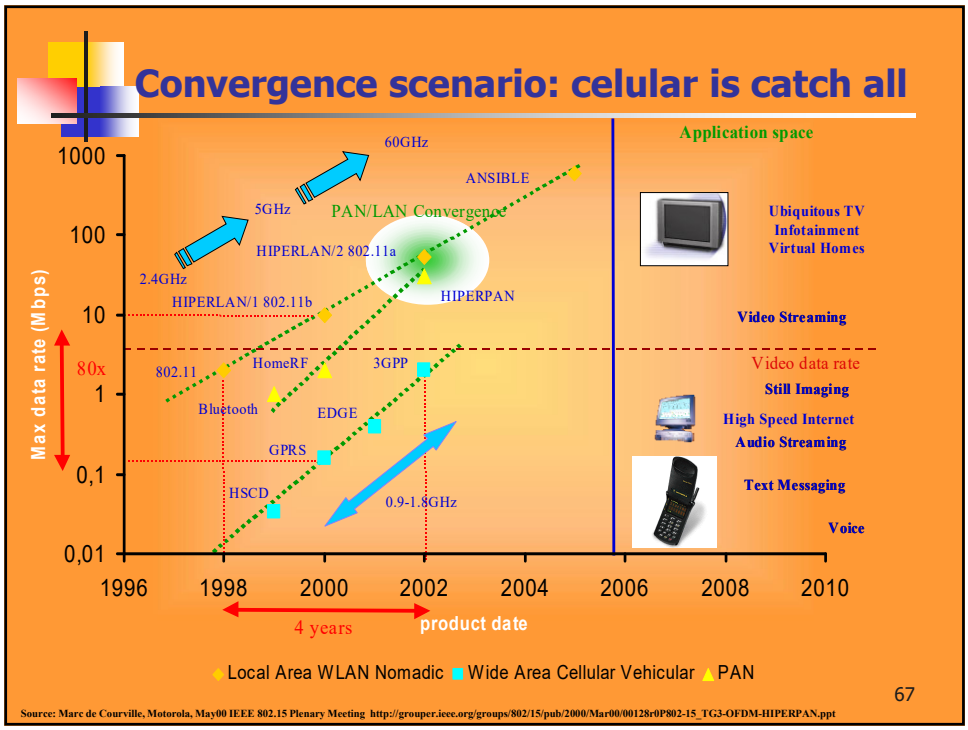
Convergence scenario: celular is catch all
Application space
60GHz
ANSIBLE
5GHz
PAN/LAN Convergence
HIPERLAN/2 802.11a
2.4GHz
HIPERPAN
HIPERLAN/1 802.11b
802.11
HomeRF
3GPP
Bluetooth
EDGE
GPRS
HSCD
0.9-1.8GHz
80x
Max data rate (Mbps)
1000
100
10
1
0,1
0,01
1996
1998
2000
2002
2004
2006
2008
2010
4 years
product date
Ubiquitous TV
Infotainment
Virtual Homes
Video Streaming
Video data rate
Still Imaging
High Speed Internet
Audio Streaming
Text Messaging
Voice
Local Area WLAN Nomadic
Wide Area Cellular Vehicular
PAN
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Source: Marc de Courville, Motorola, May00 IEEE 802.15 Plenary Meeting http://grouper.ieee.org/groups/802/15/pub/2000/Mar00/00128r0P802-15_TG3-OFDM-HIPERPAN.ppt

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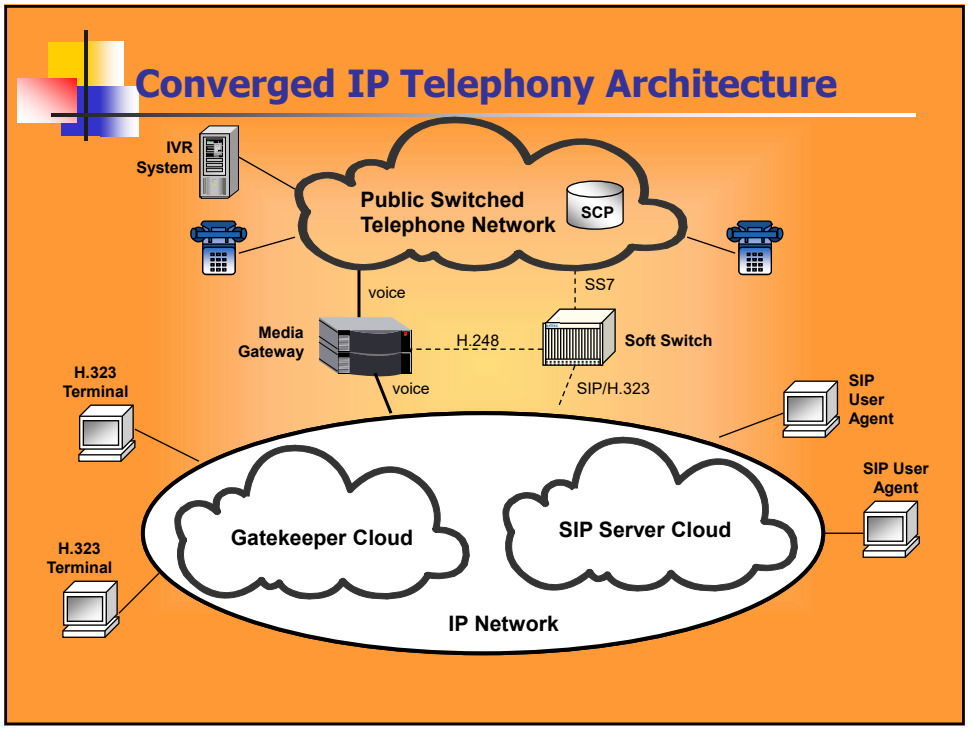
Converged IP Telephony Architecture
IVR System
Public Switched Telephone Network
SCP
SS7
voice
Media Gateway
H.248
Soft Switch
voice
SIP/H.323
H.323 Terminal
SIP User Agent
SIP User Agent
H.323 Terminal
Gatekeeper Cloud
SIP Server Cloud
IP Network

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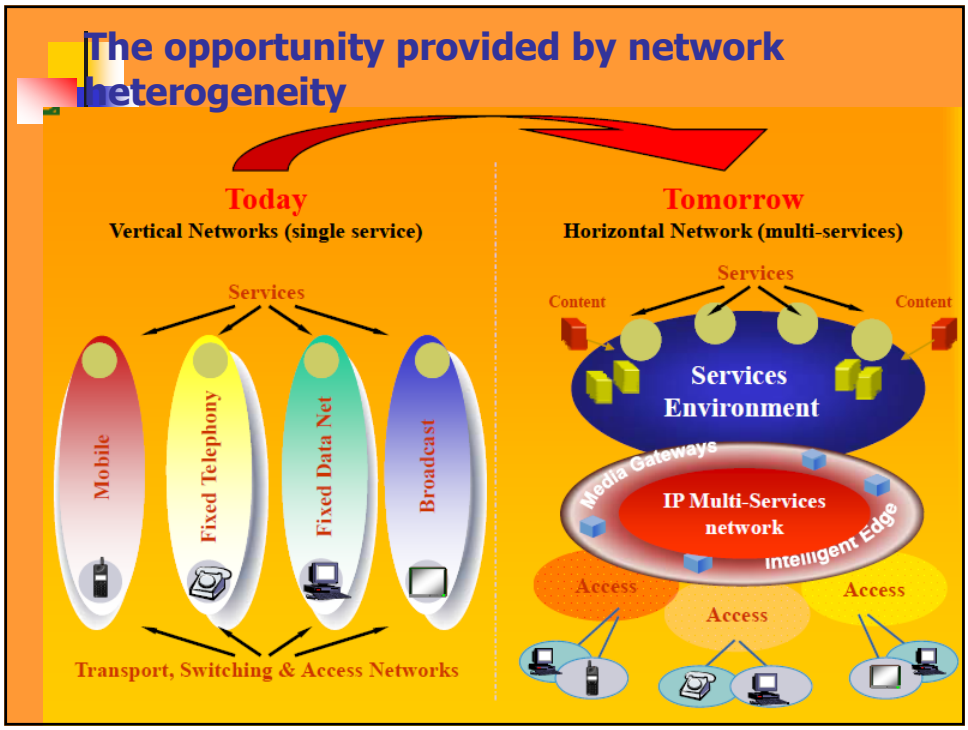
The opportunity provided by network heterogeneity
Today
Vertical Networks (single service)
Services
Mobile
Fixed Telephony
Fixed Data Net
Broadcast
Transport, Switching & Access Networks
Tomorrow
Horizontal Network (multi-services)
Services
Content
Content
Services Environment
Media Gateways
IP Multi-Services network
Intelligent Edge
Access
Access
Access

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