Arquitecturas de Redes Avançadas

Engenharia de Computadores e Telemática
4º ano, 1º semestre, 2020/2021

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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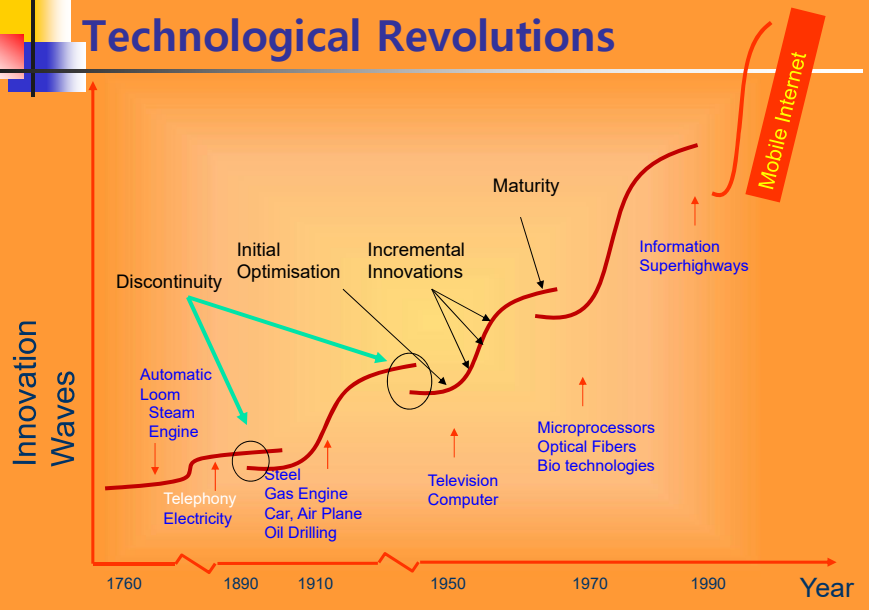
The communication network

Trends and history

Technological Revolutions



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Trends in communications

- Current telecommunication industry has been the result of different trends in the last 30 years:
  - The saturation of the telephone market, at the end of the 80ies → *The phone network*
  - The coming of age of the data world, in the early 90ies → *The Internet*
  - The pervasiveness of mobility, in the mid 90ies → *Mobility: voice and data*

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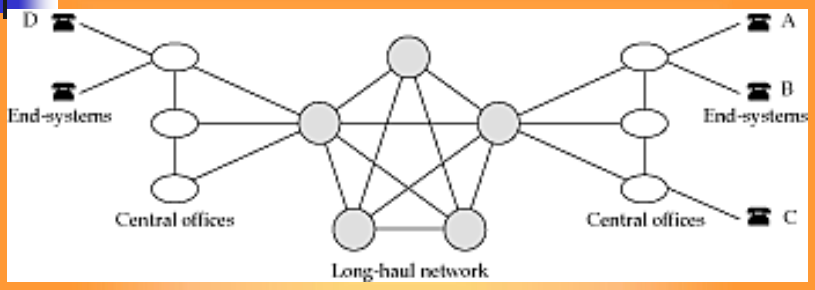
The communication network

The phone network

Telephone System



- Uses switched circuits (virtuals...)
- 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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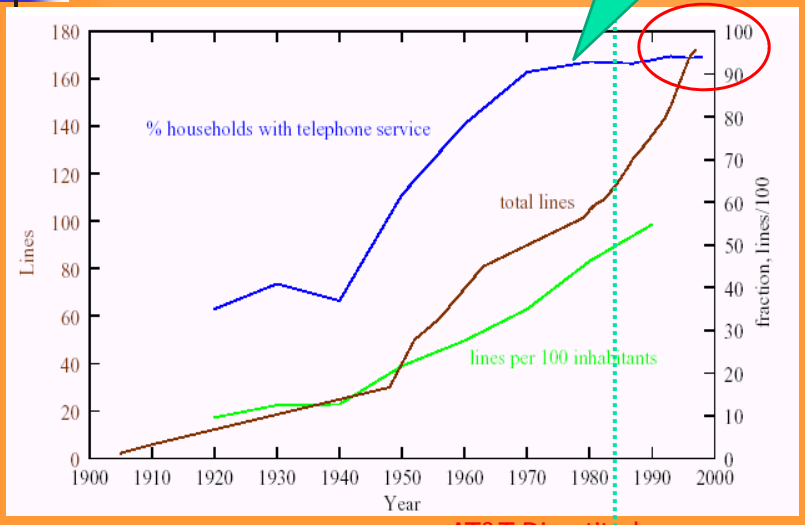
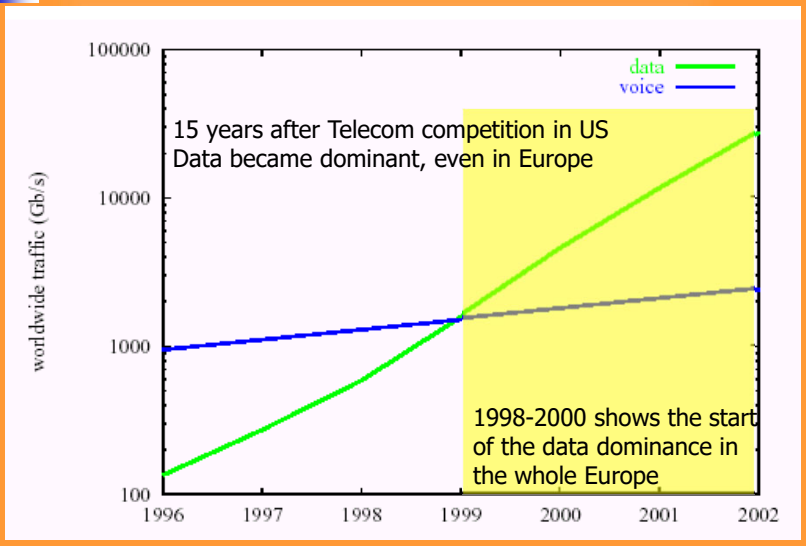
Phone service in US



AT&T Divestitude:
start of competition in telecom

Evolution: Voice vs Data



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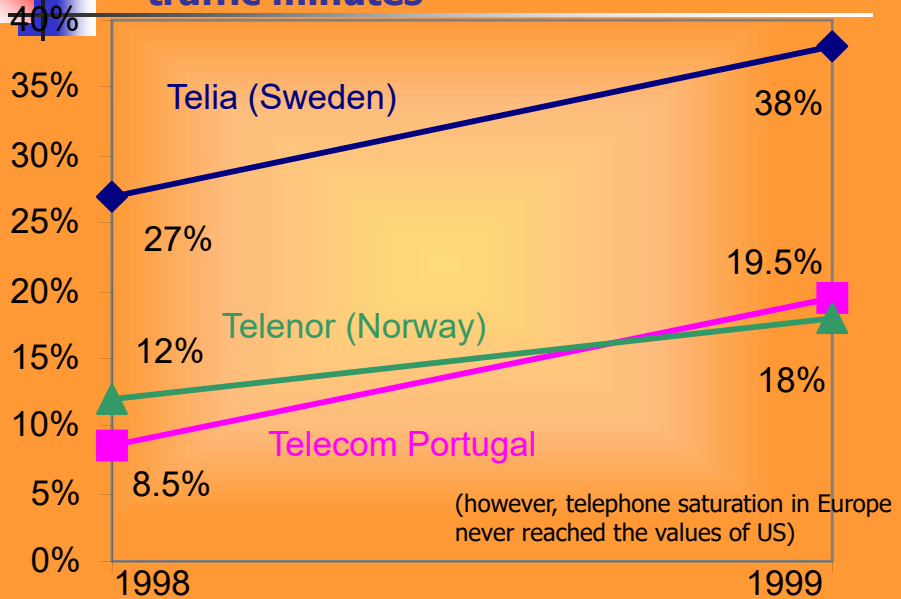
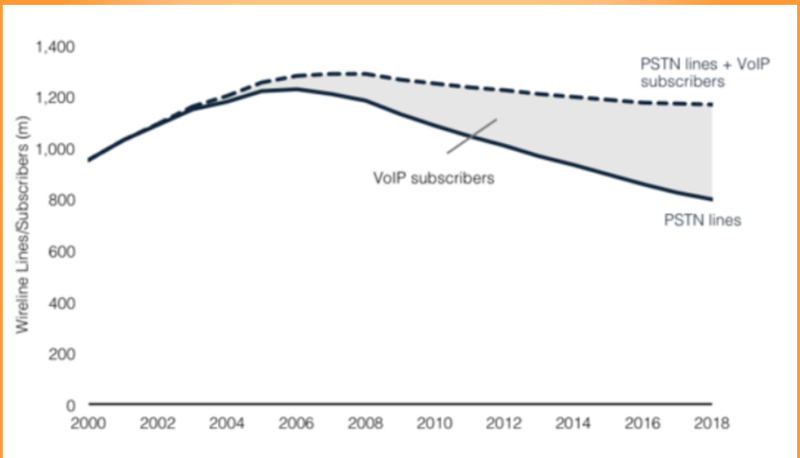
Dial-up Internet traffic as % of total traffic minutes



Source: PTO annual reports. *Note:* For Telia, Internet traffic as % of local minutes. For others, as % of total

Voice is changing its profile as well

- VoIP on the rise, even in terms of formal subscriptions



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The communication network

The Internet

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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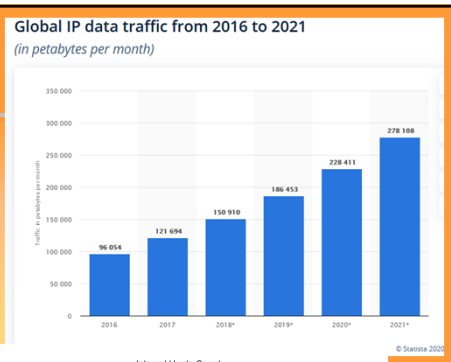
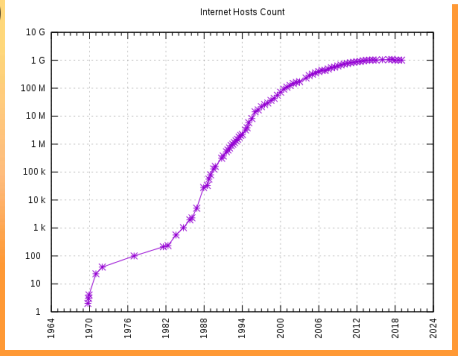
Global IP Traffic

- Total internet traffic has exploded
  - 1992, total traffic = 3TB month
  - 2014, total traffic = 450 EB month
  - 2020, total traffic = 220PB month





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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

Internet: currently

- Self-organized set of interconnected autonomous components
  - More than 90.000 autonomous domains (with more than 92K numbers allocated)
    - Single guarantee is: network running TCP-IP in the border and BGP as external routing
    - Works by packet switching
    - More than 360 millions of registered domains (URL)!
- Commercial traffic larger than non-commercial
  - Exponential growth in all numbers (number of users, traffic)
- Different machines (networks) can offer different services
  - Each user can select what it uses
- Only bi-direccional media that support communications
  - One to one (unicast, e.g. email); one to many (multi-cast, e.g., electronic news)
- NB: Internet networks are operated AUTONOMOUSLY
  - After connecting to the Internet, the network becomes PART of the Internet

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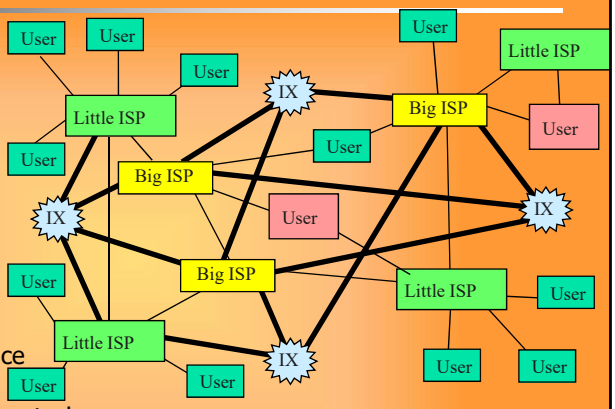
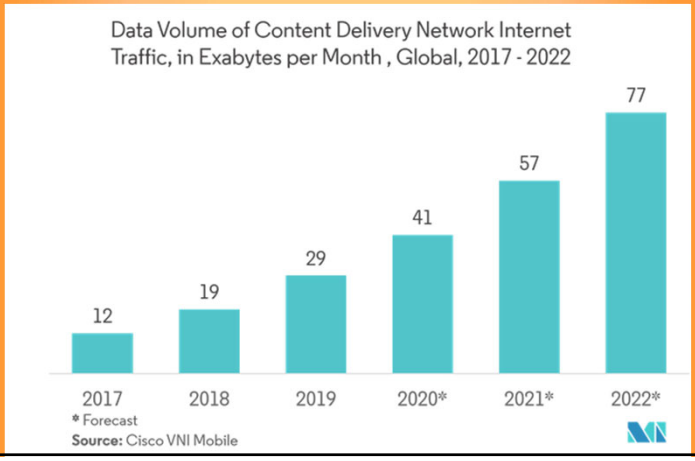
Real structure



- 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

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 will carry 72 percent of total Internet traffic by 2022



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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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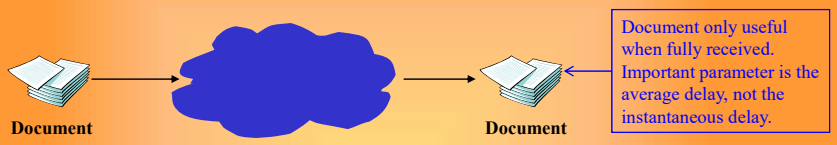
Elastic operations



- 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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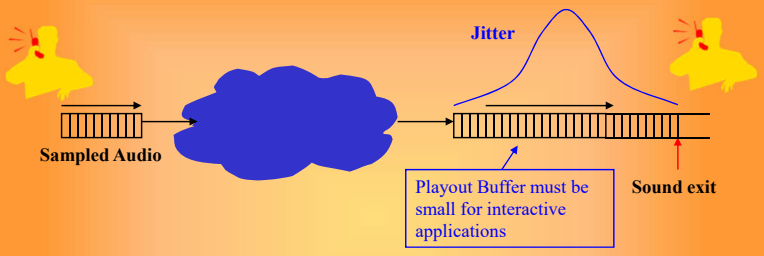
Inelastic applications



- 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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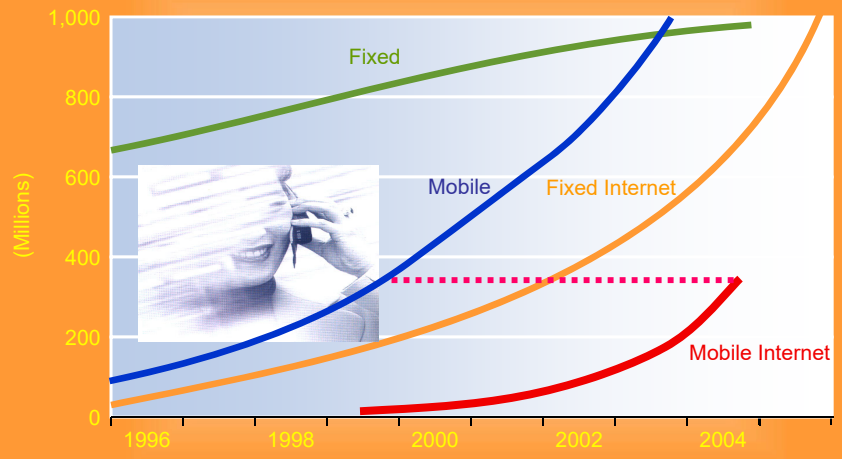
The communication network

Mobility: voice and data

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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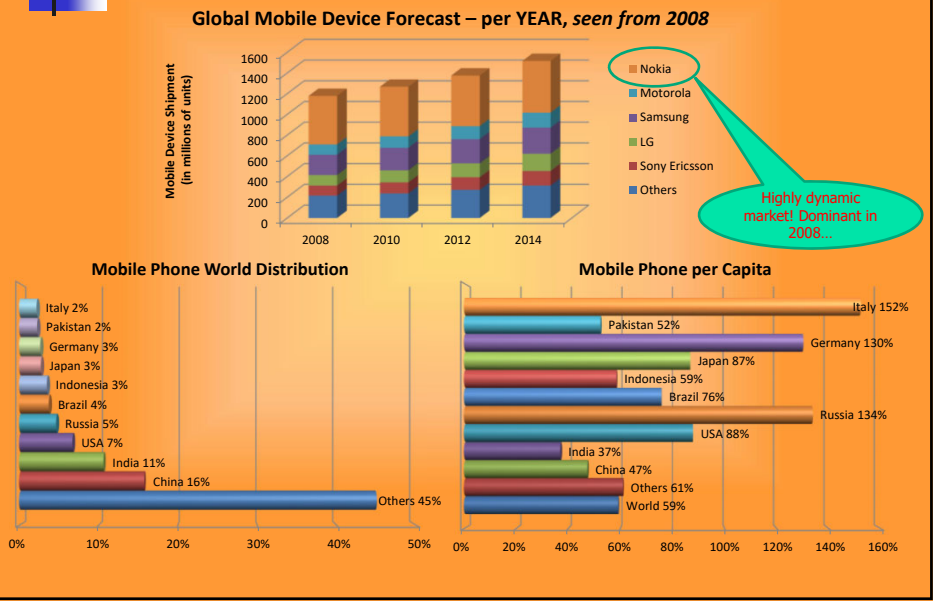
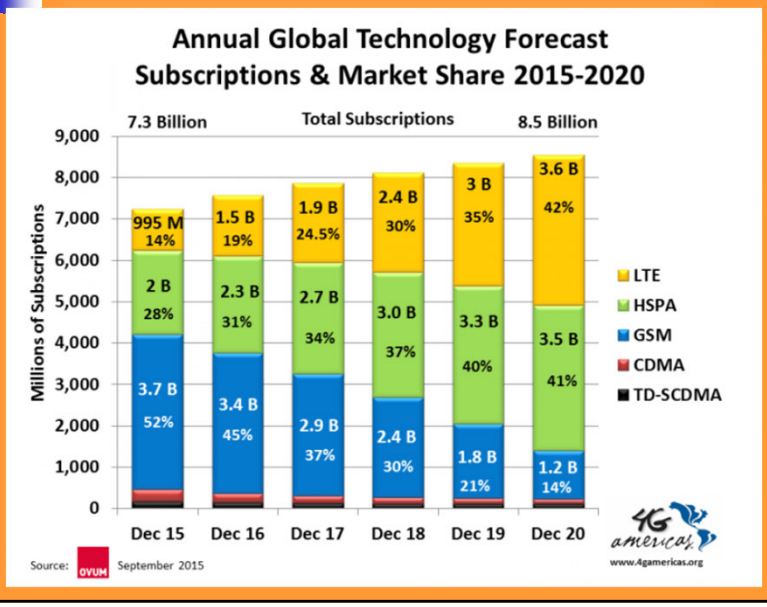
Mobile Market – Forecasts (@2008)



Mobile Technology Evolution



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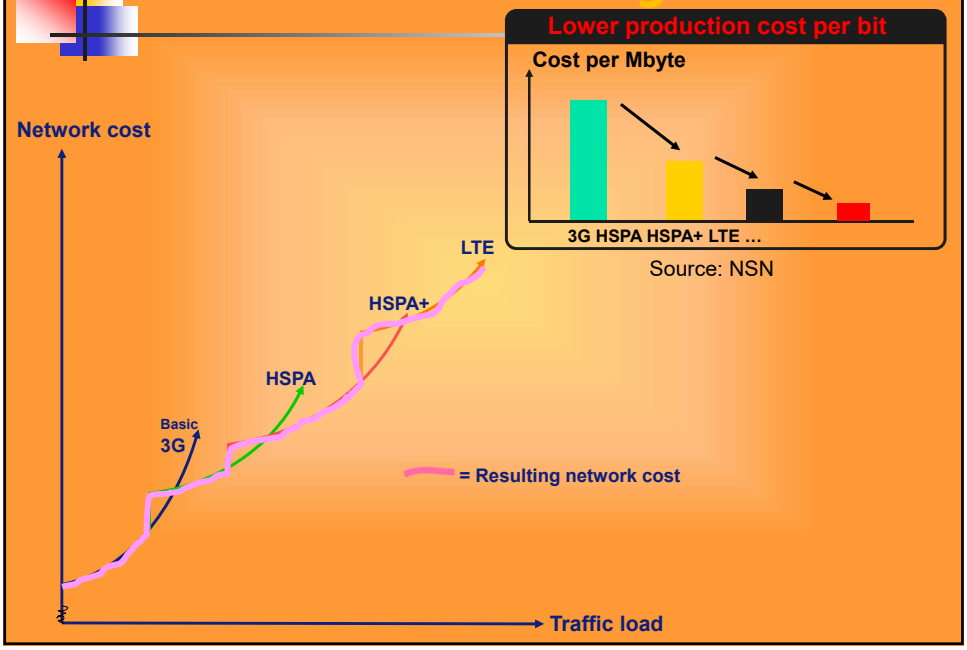
Motivations for technologies

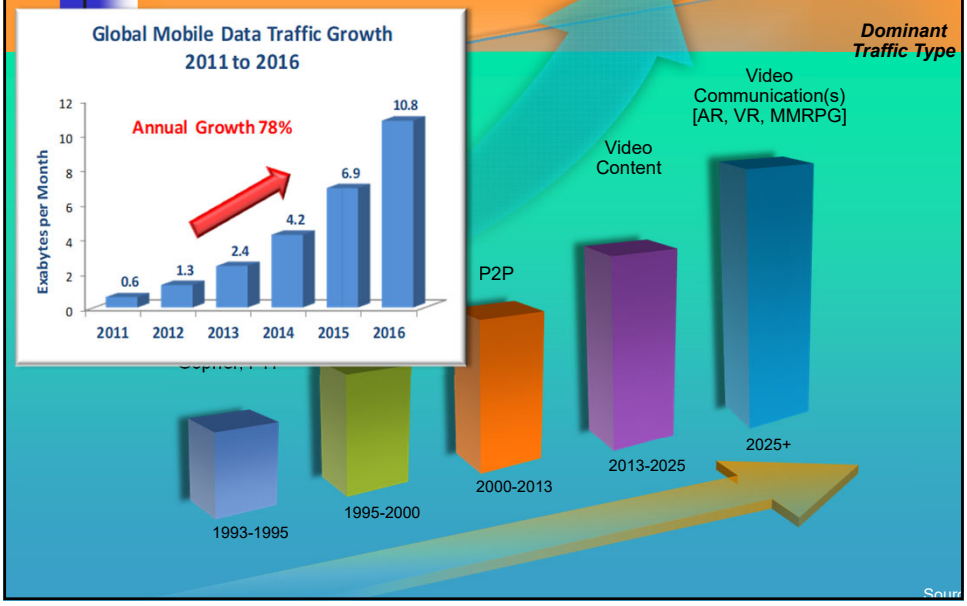


Global Mobile Growth by Device type

Source: Cisco VNI Mobile, 2016

Figures in parentheses refer to 2015, 2020 device share.
What is the dominating traffic?

Dramatic Traffic Growth Fueled by Video

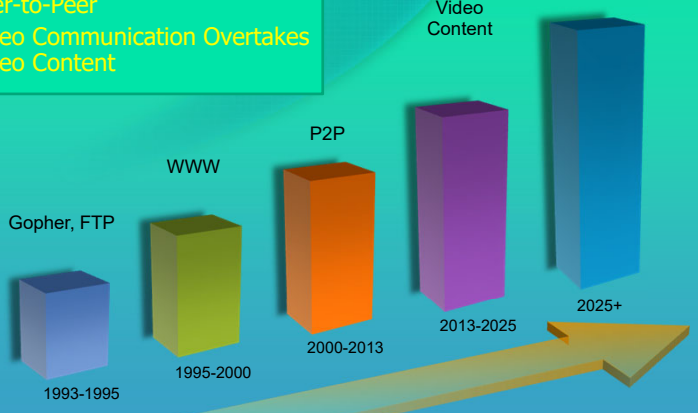


Dramatic Traffic Growth Fueled by Video

37% CAGR 2006-2011

Dominant Traffic Type

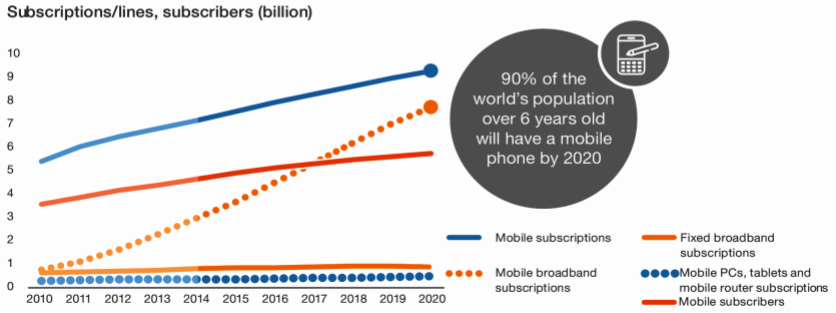
1995: Web Overtakes Gopher, FTP
2000: Peer-to-peer Overtakes Web
2010: Video Content Overtakes Peer-to-Peer
2015: Video Communication Overtakes Video Content



But it is all mobile...

Mobile Broadband

- Mobile broadband subscriptions will reach 7.7 billion globally by 2020.



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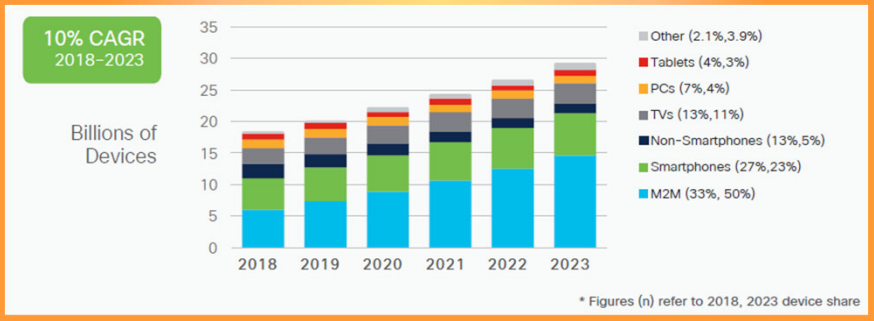
And now, also…

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



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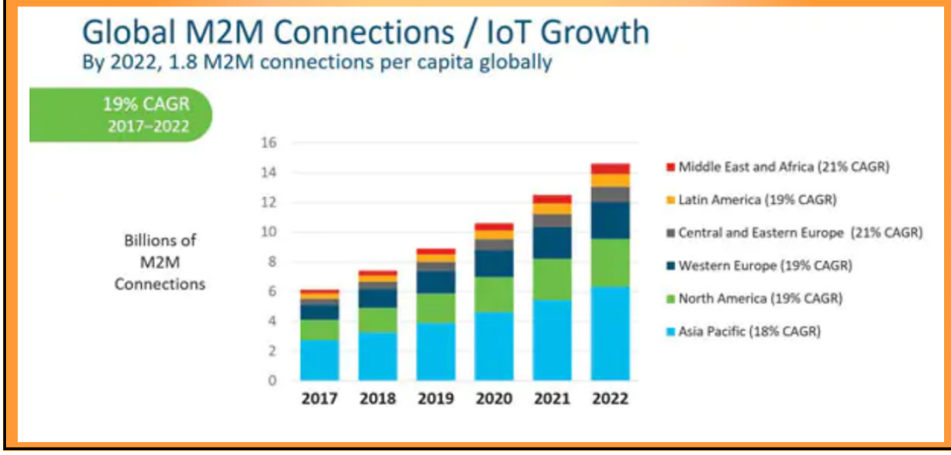
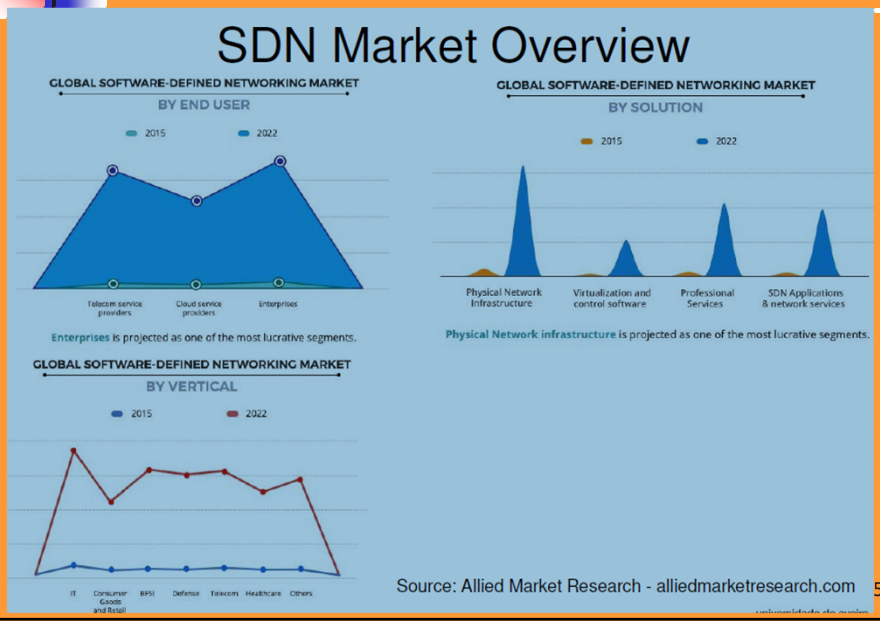
M2M developments

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



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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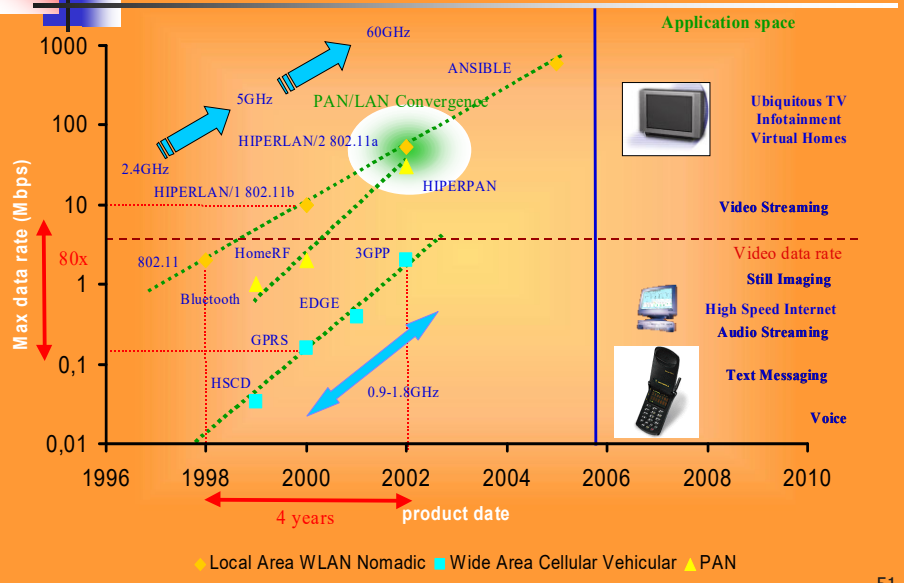
Convergence scenario: celular is catch all



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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

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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