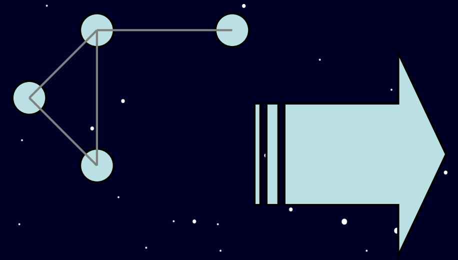
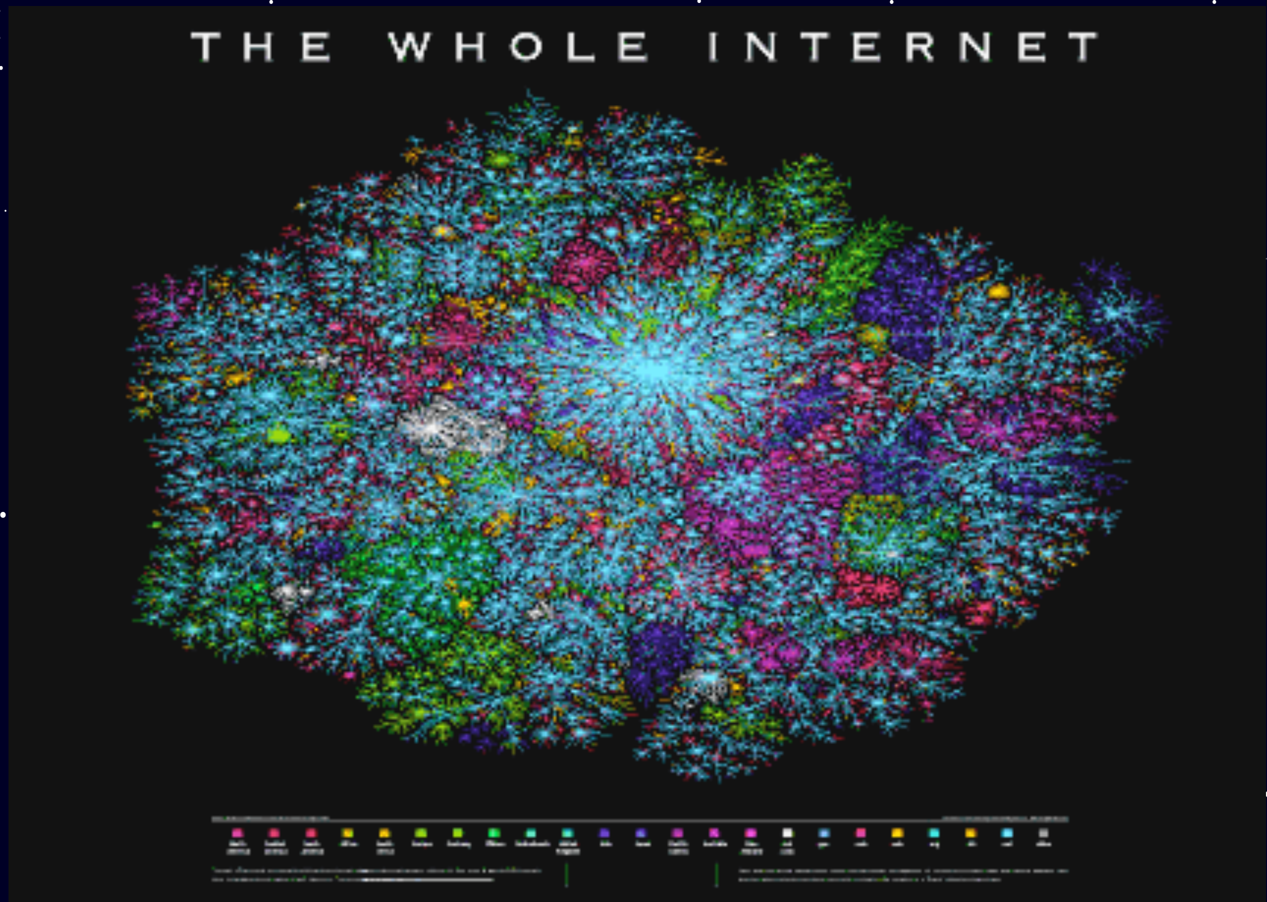
An overview of current Internet and Quality of Service

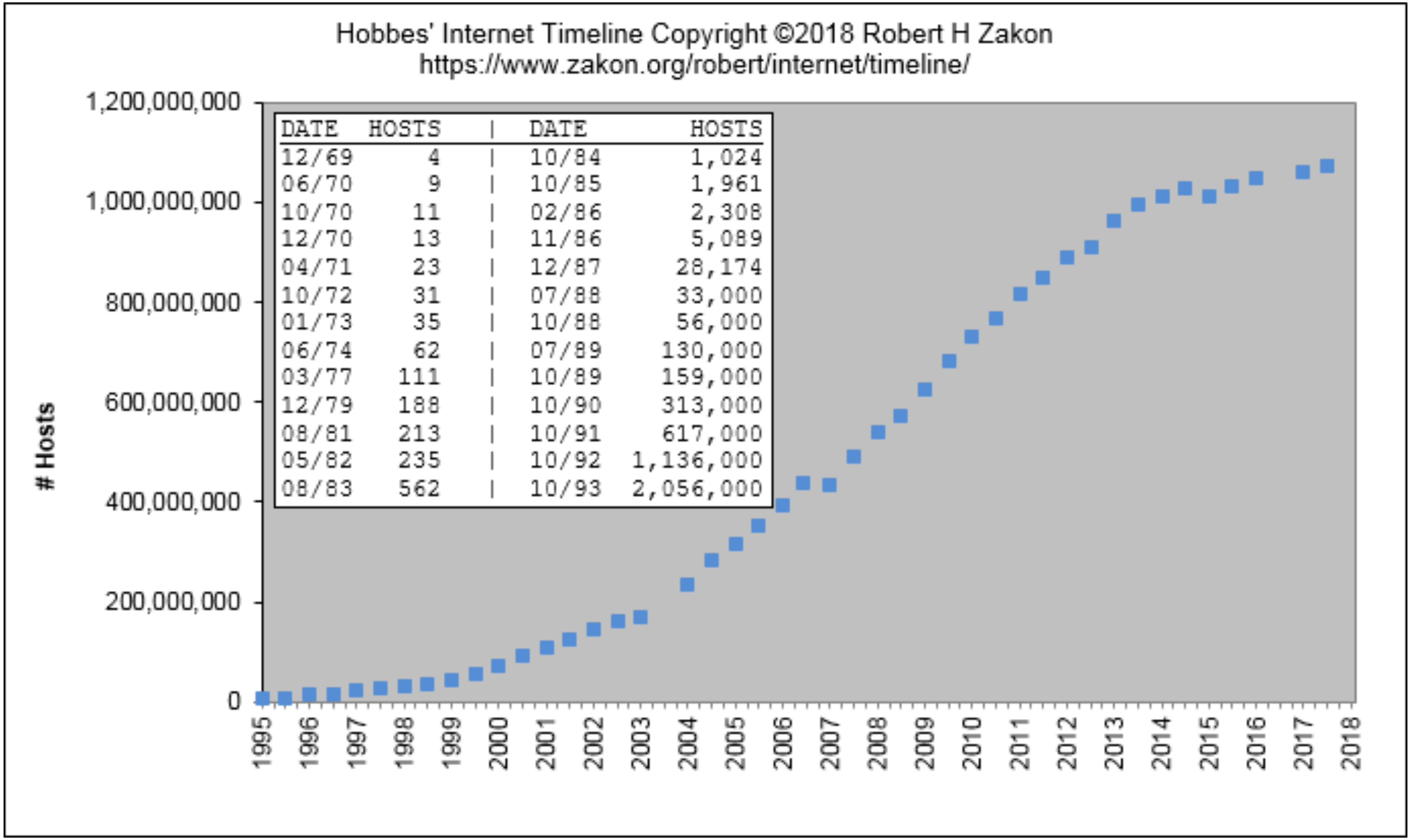
C. Pham
Université de Pau et des Pays de l'Adour
http://www.univ-pau.fr/~cpham
Congduc.Pham@univ-pau.fr

The big-bang of the Internet

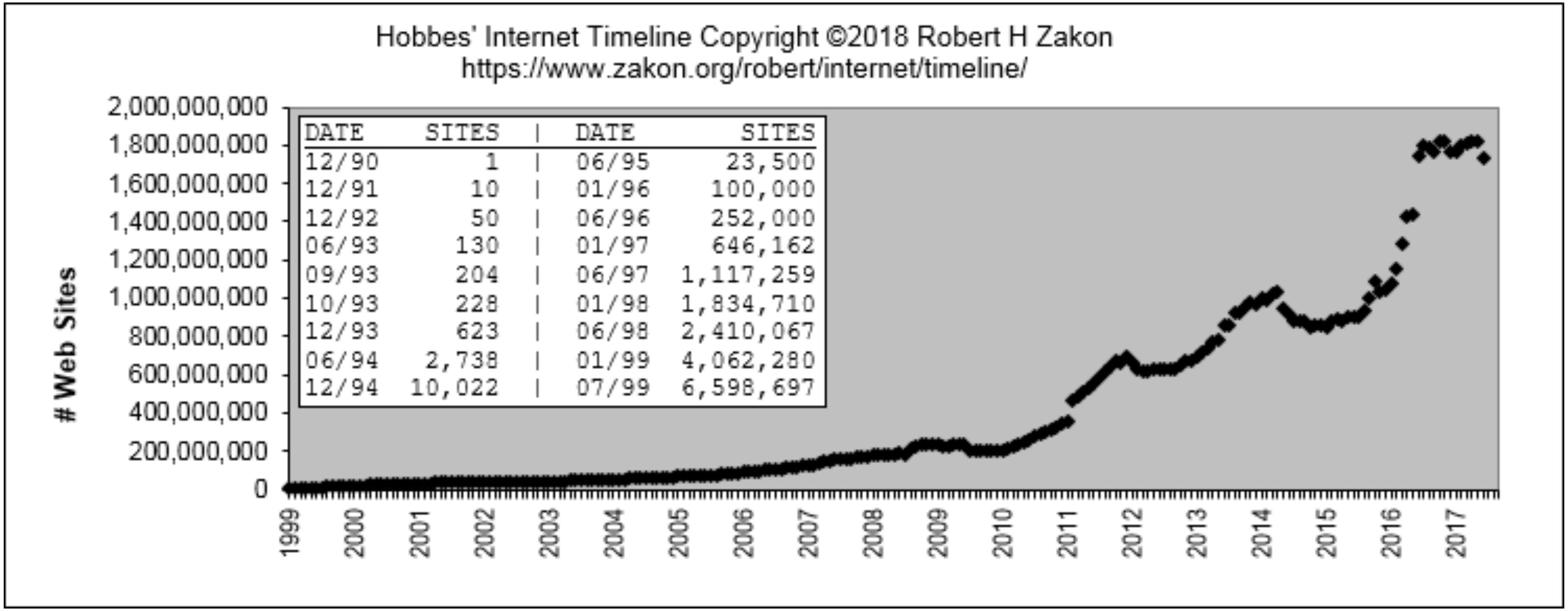




Internet host

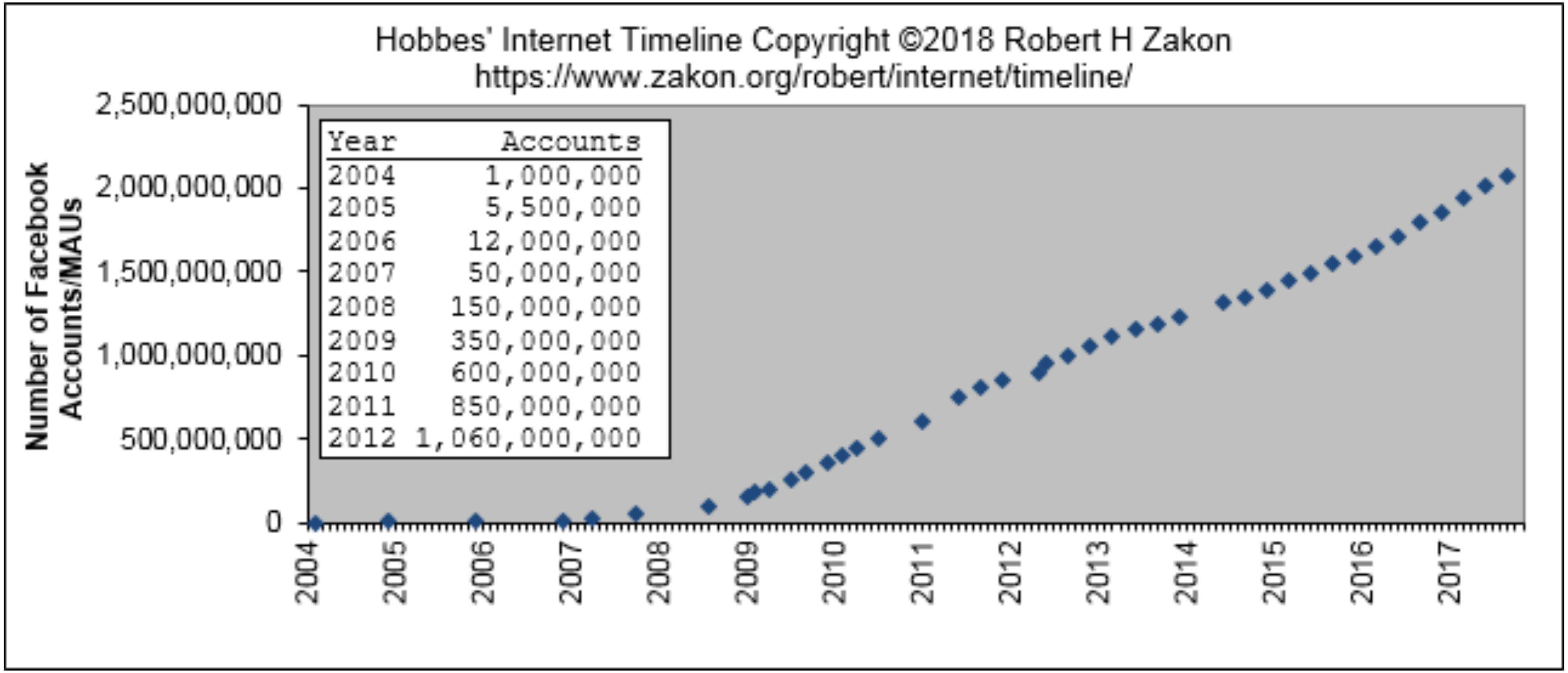


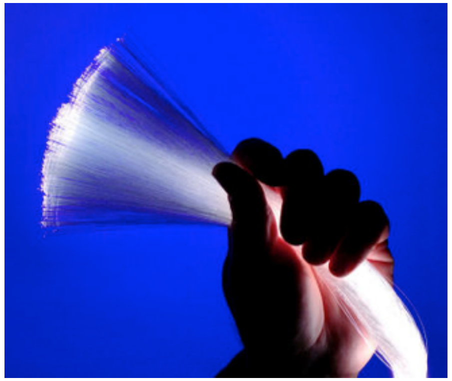
of www sites



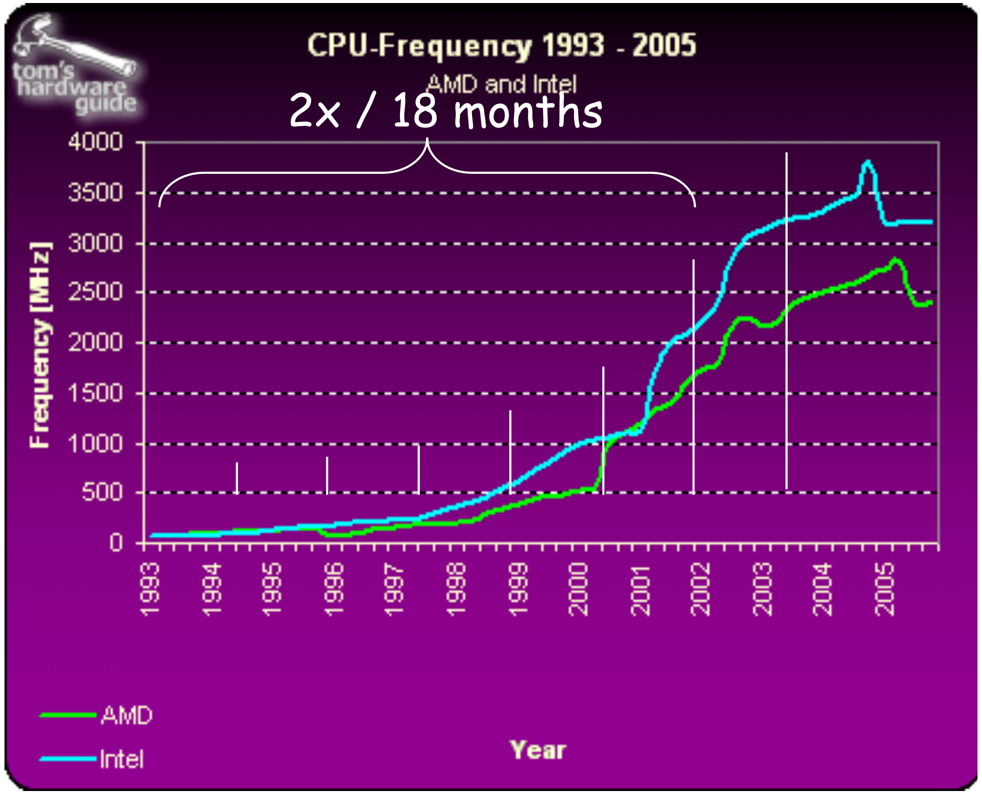
DATE	SITES	DATE	SITES
12/90	1	06/95	23,500
12/91	10	01/96	100,000
12/92	50	06/96	252,000
06/93	130	01/97	646,162
09/93	204	06/97	1,117,259
10/93	228	01/98	1,834,710
12/93	623	06/98	2,410,067
06/94	2,738	01/99	4,062,280
12/94	10,022	07/99	6,598,697

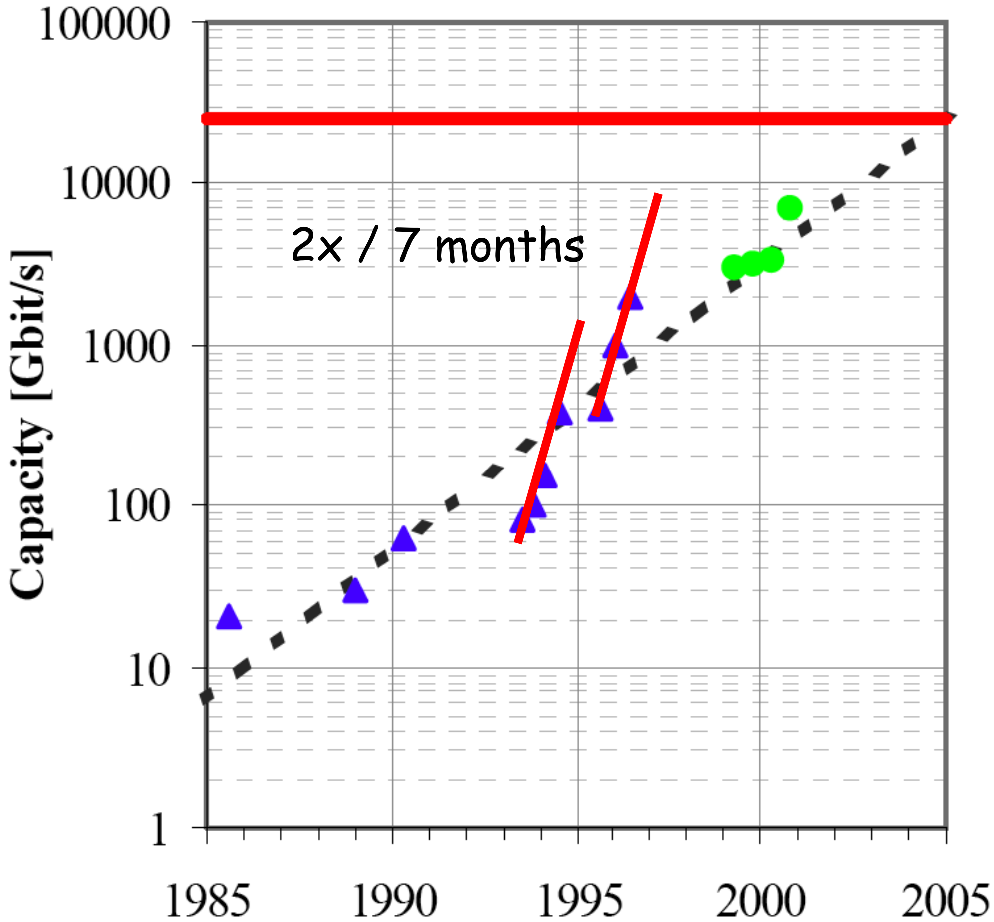
of facebook account





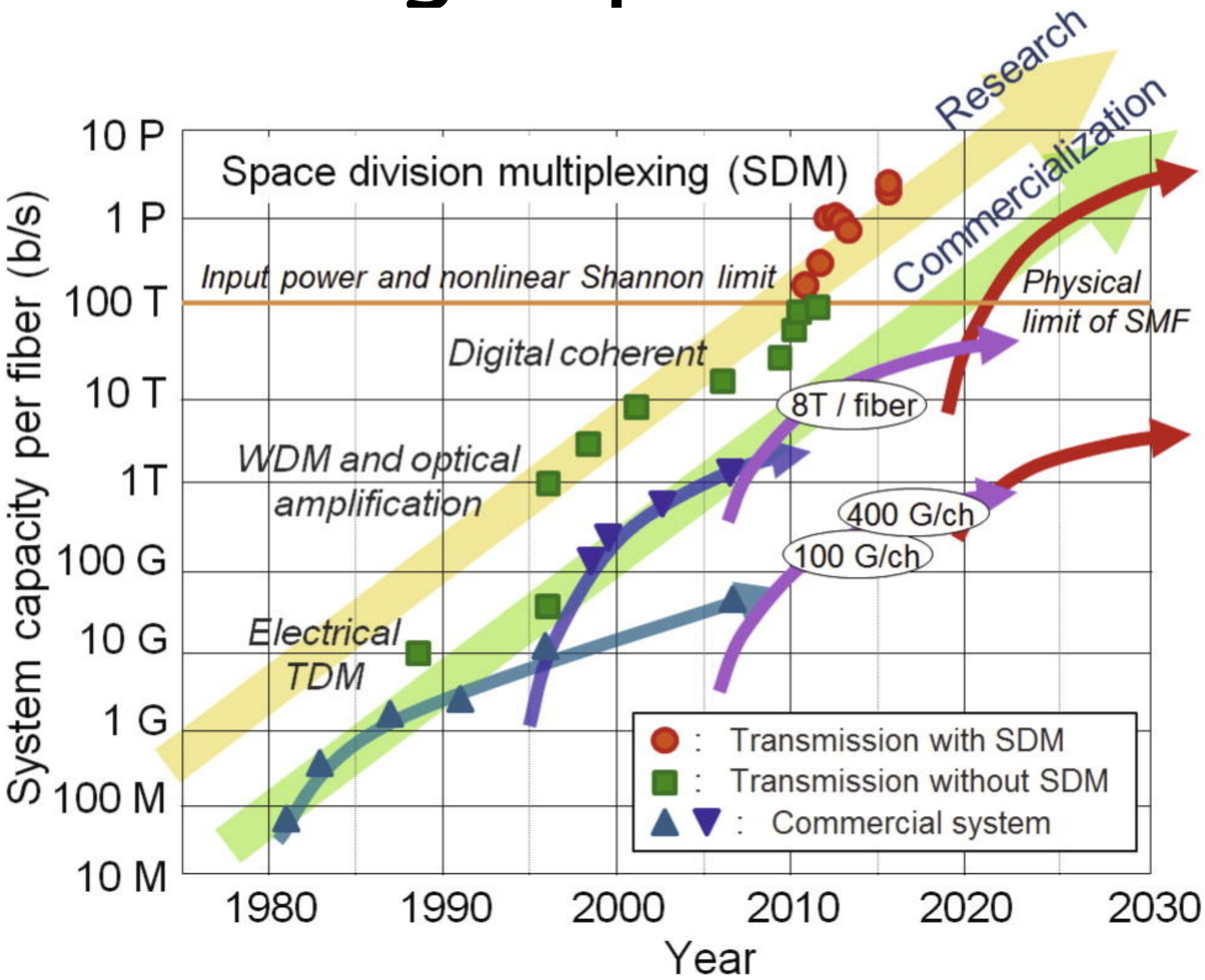
1st revolution: going optical





Source « Optical fibers for Ultra-Large Capacity Transmission » by J. Grochocinski

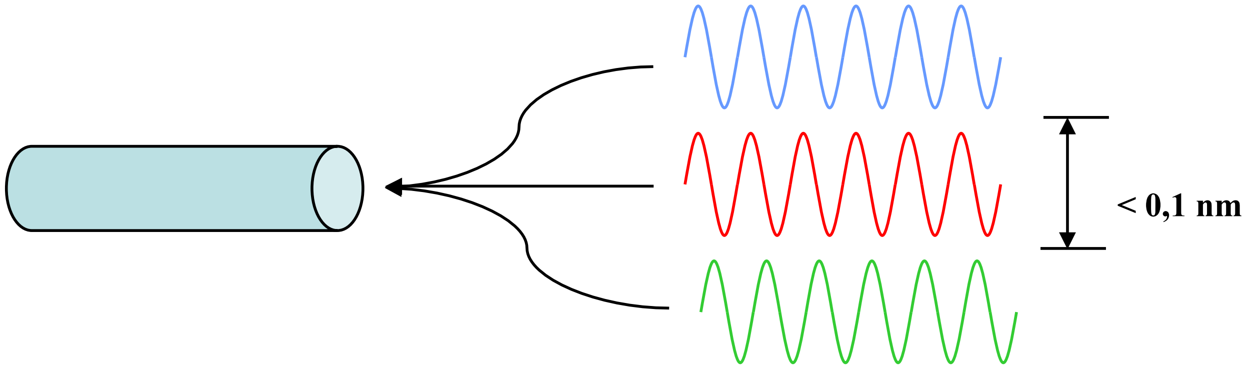
Still big improvements!

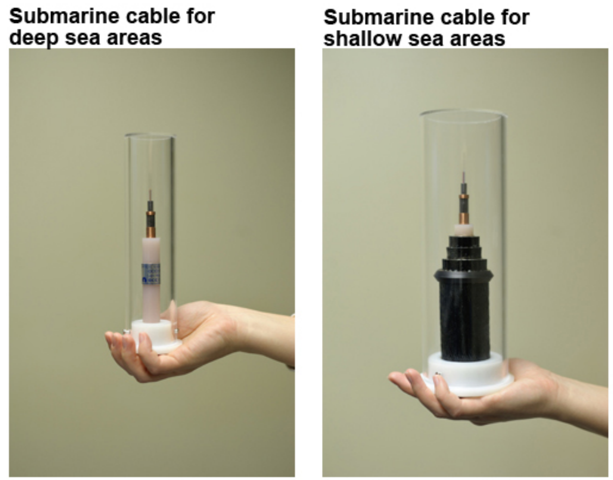


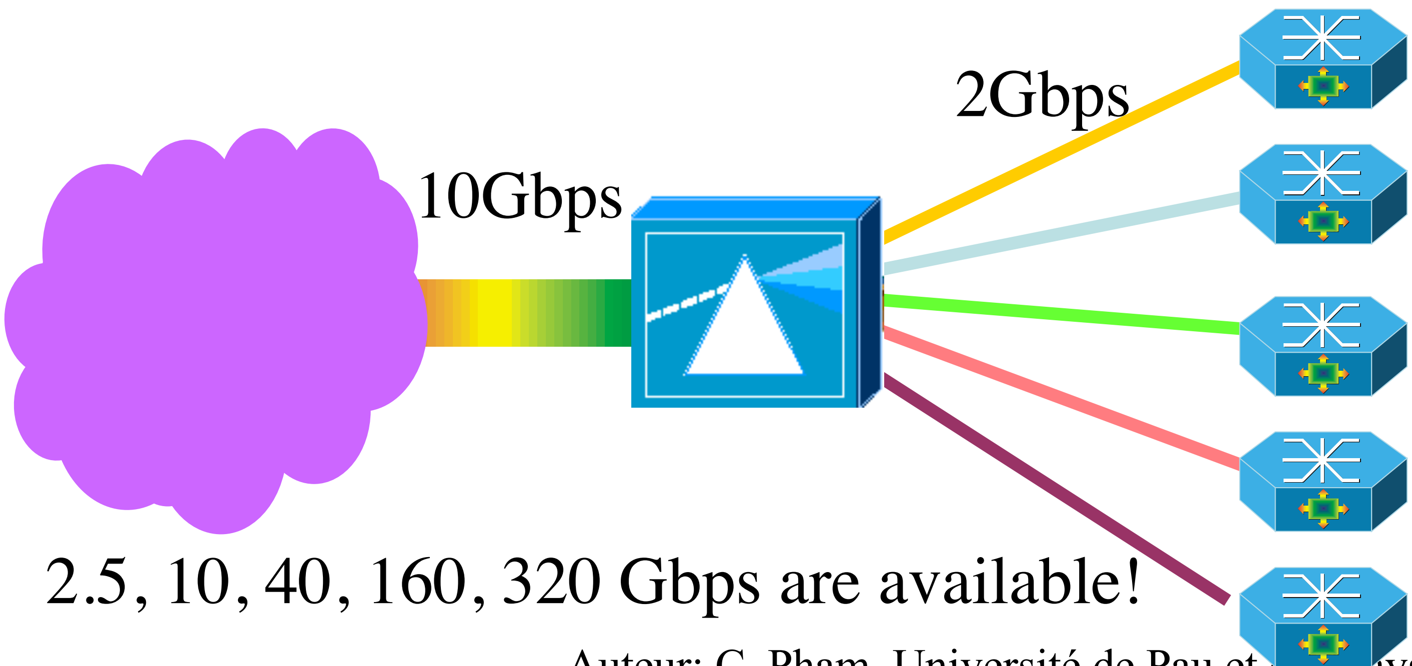
Optical Fiber Technology, Volume 35, February 2017, Pages 108-117

DWDM, bandwidth for free?

DWDM: Dense Wavelength Division Multiplexing

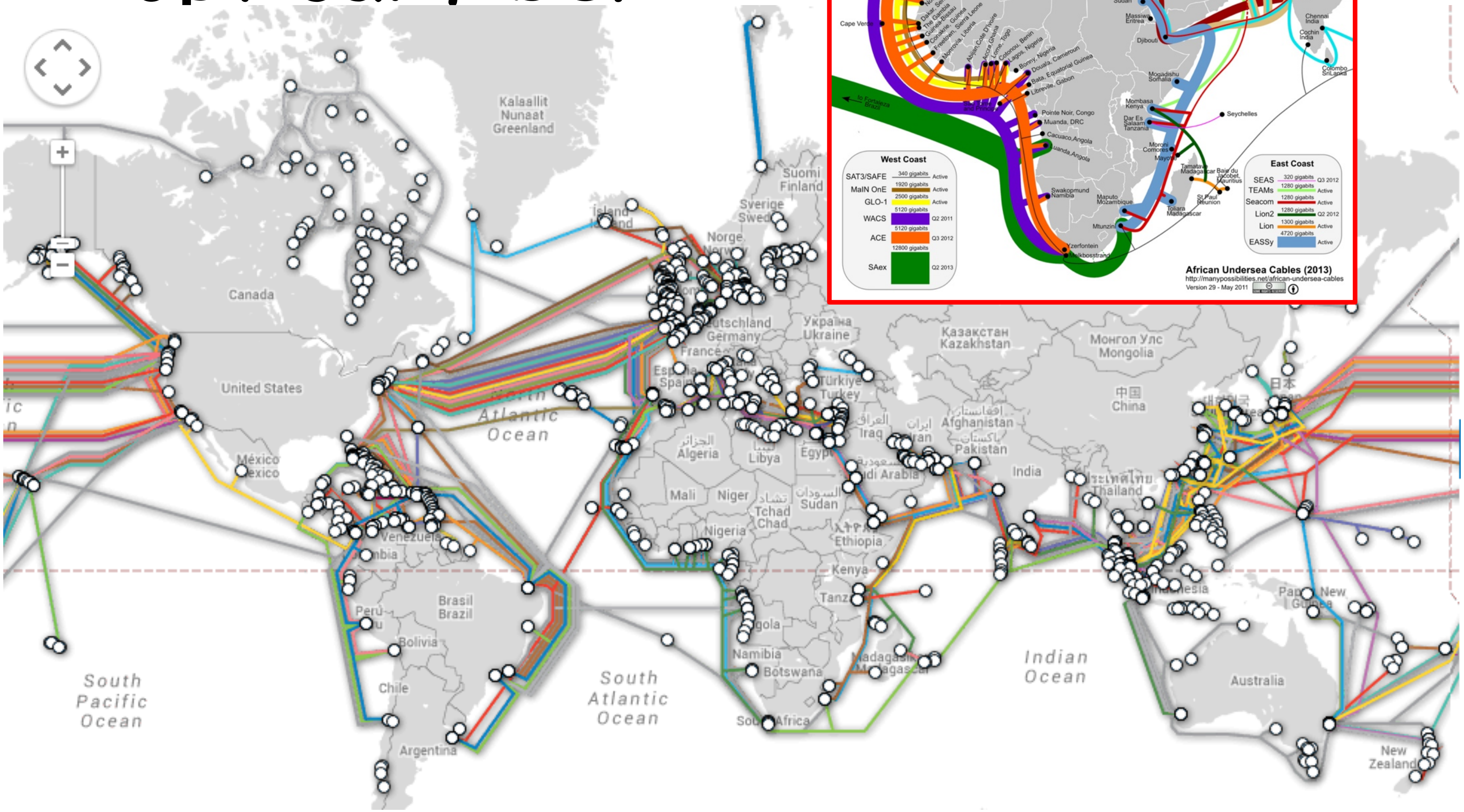




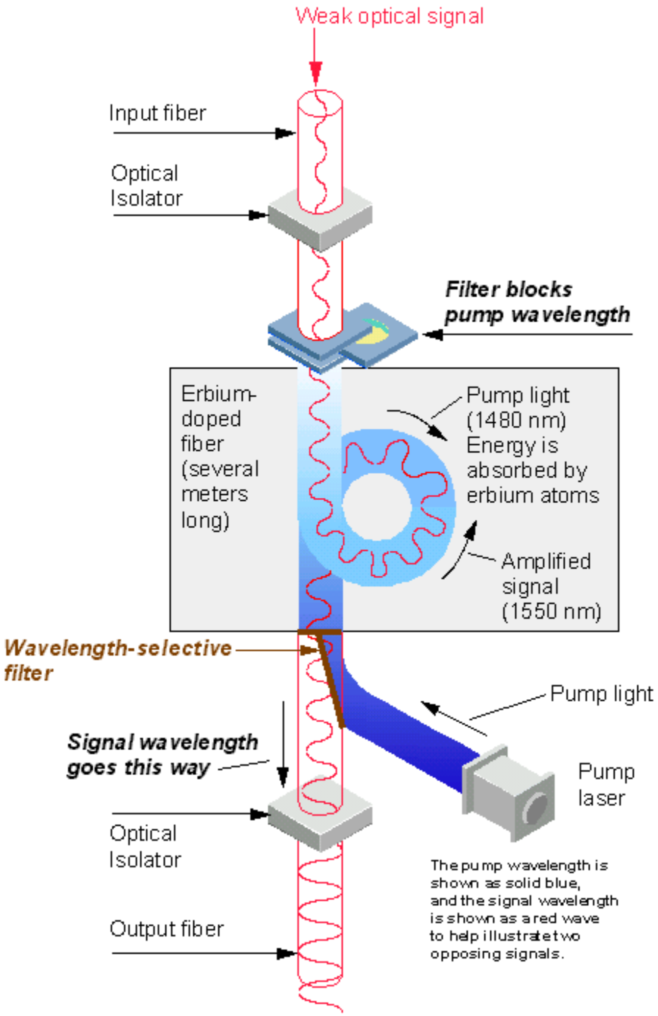


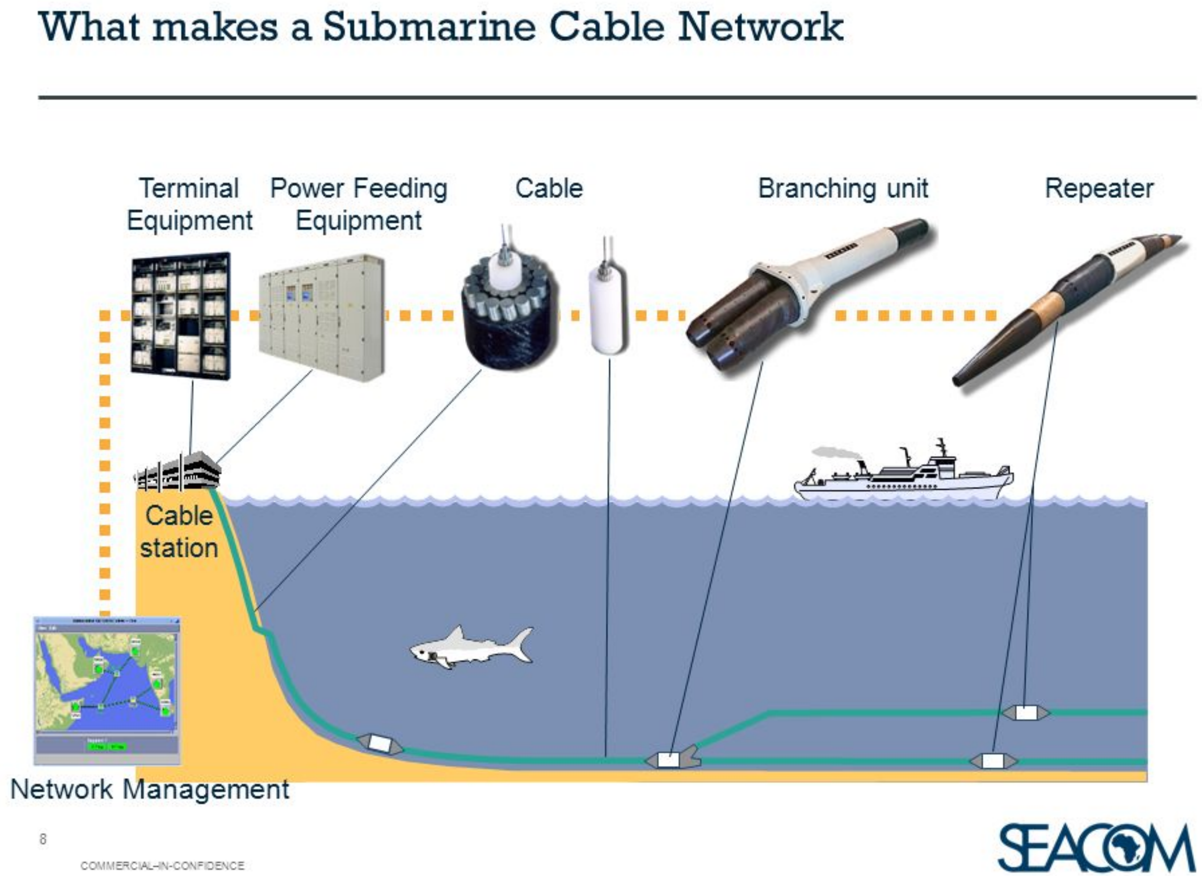
2.5, 10, 40, 160, 320 Gbps are available!

Submarine optical fiber

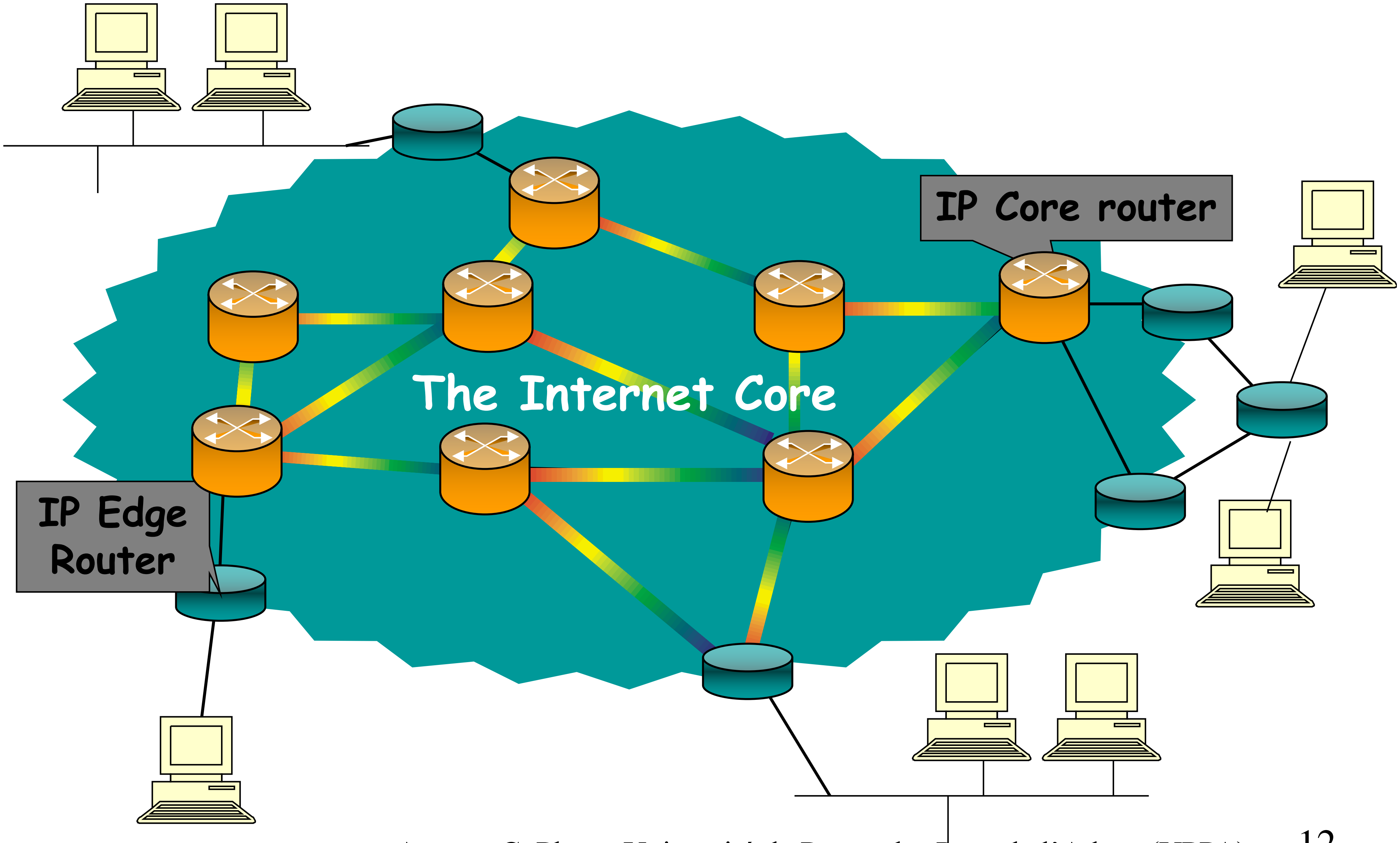


Erbium Doped Fiber Amplifier

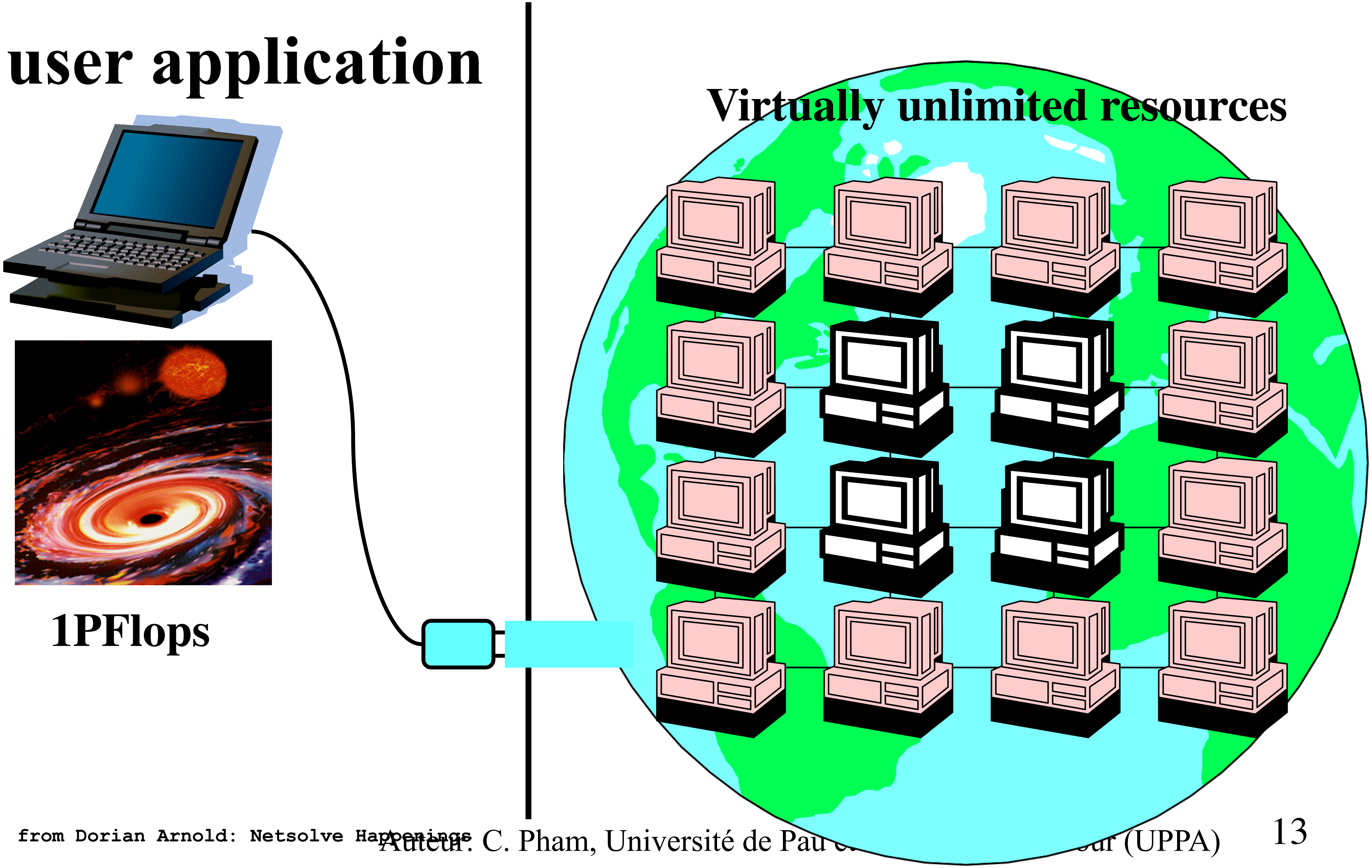




Internet core is 100% optical

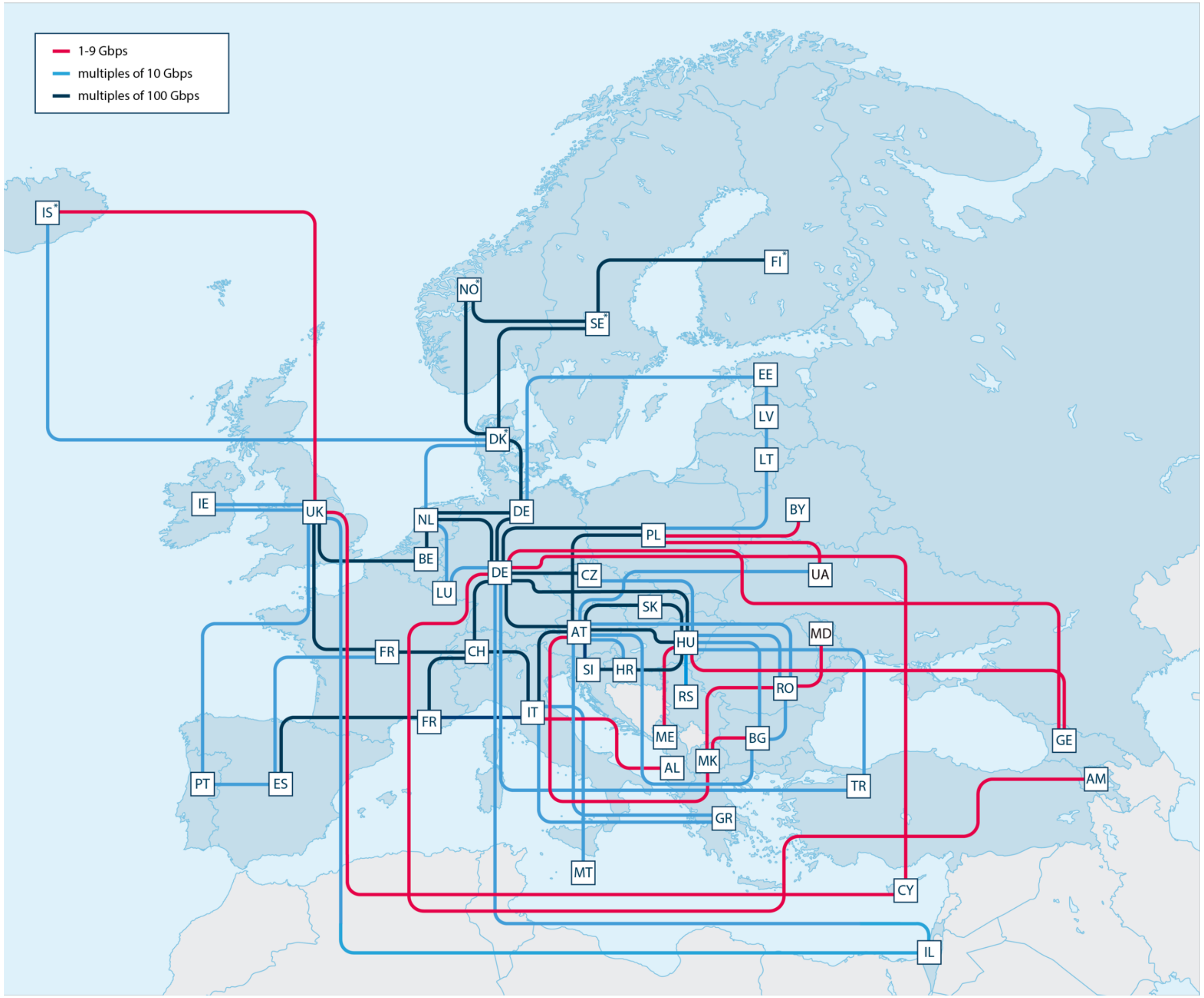


Stimulating very high speed networks

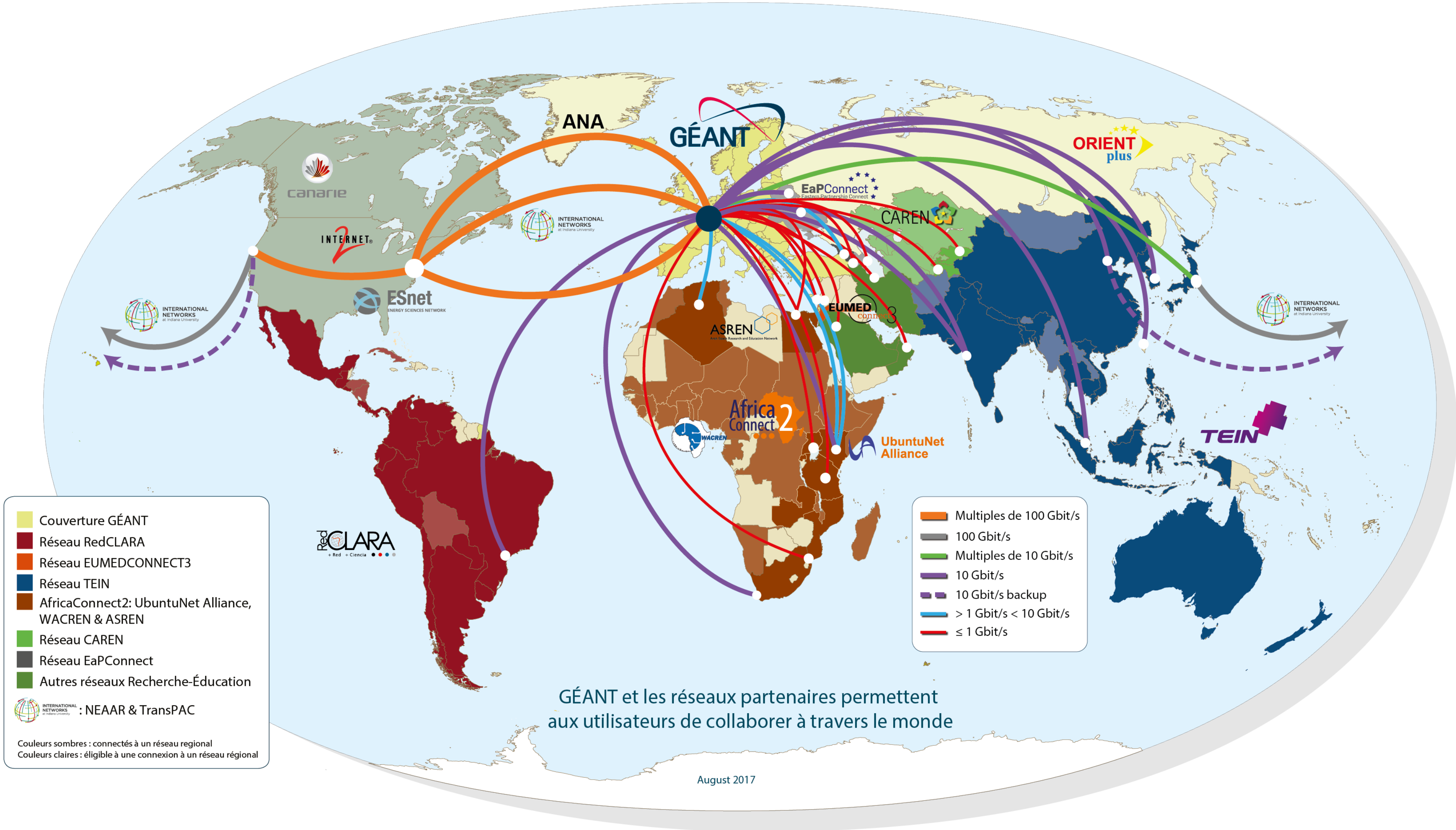


from Dorian Arnold: Netsolve Happenings

GEANT network



GEANT networks & others



Fibers everywhere?

NEWS of Dec 15th, 2004

Verizon and SBC are
dep…
in…

NEWS from Japan and South Korea

…the first
…echnology
…the
…gh-
…n
…ers

NEWS of May 31st, 2005

US Fiber-to-the-home (FTTH) installations have grow…
200…

…July,
…m wi…
test-…
in P…
…vnloa…
…n upl…

NEWS for 2009

Japan remains the overall leader in terms of the number of fiber-connected homes at 13.2 million, followed by the United States (6.05 million) and the People's Republic of China (5.96 million)

Total=24 millions!

NEWS of July, 2011

France Telecom-Orange and Free will deploy FTTH in 5 millions home distributed in 1300 cities

camp…
…ore
…160 Gbps

Making it easier?

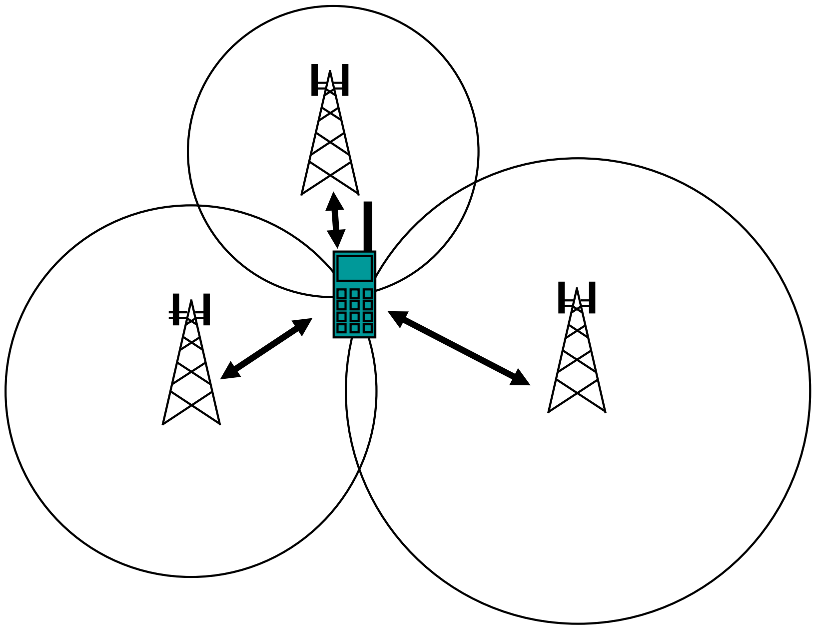
- Fibers that can be laid on the ground or burried under 20cm trench

Dr. Haruo Okamura
President
Global Plan, Inc.

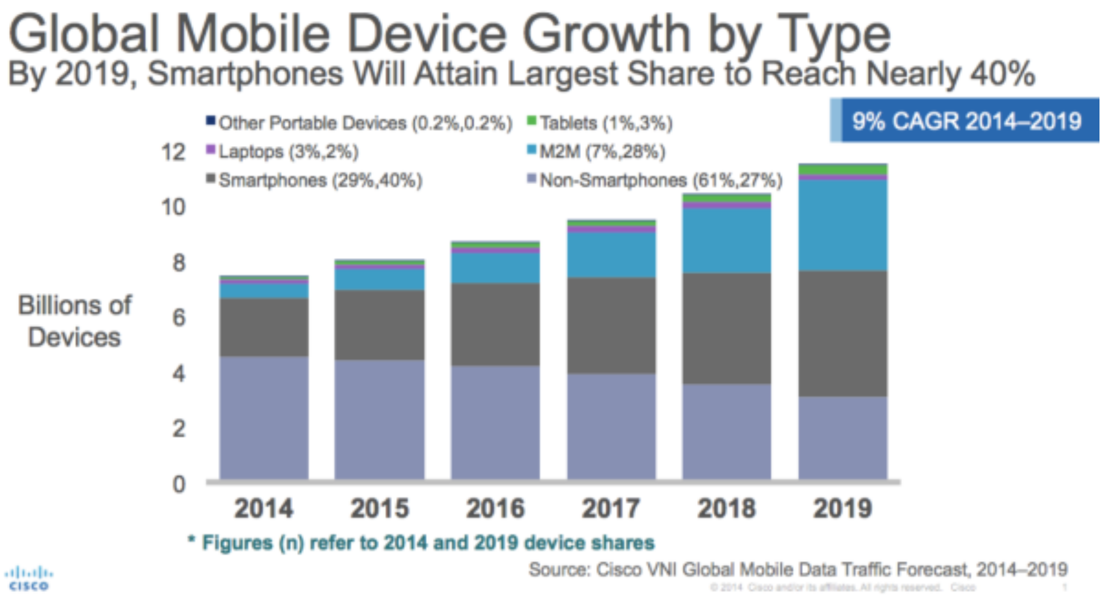
https://news.itu.int/new-itu-standard-can-help-bring-broadband-rural-communities/

2^{nd} revolution: Wireless Networks

- WiFi, WiMax
- BlueTooth, ZigBee, IrDA...
- GSM, GPRS, EDGE, 3G, 4G, 5G, ...



Mobile devices



5G?

- A set of objectives, various technologies

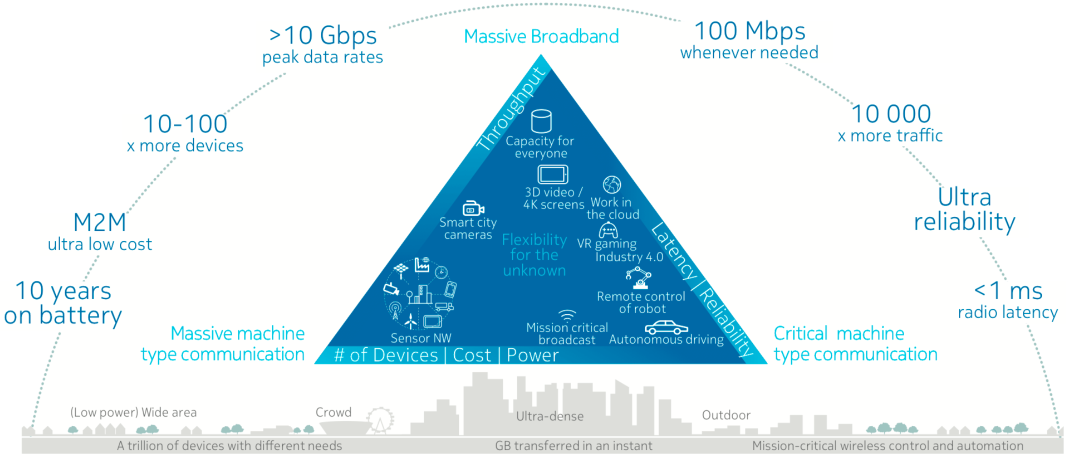
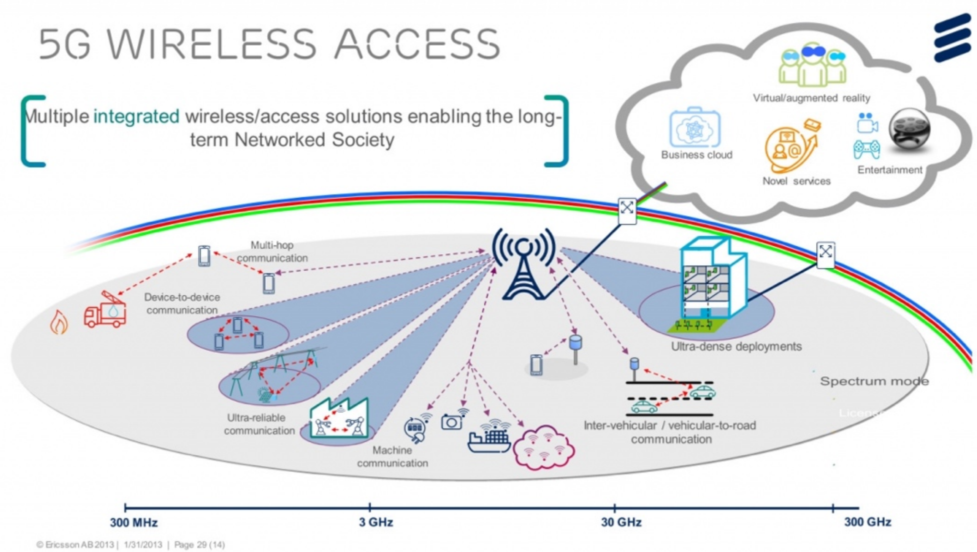
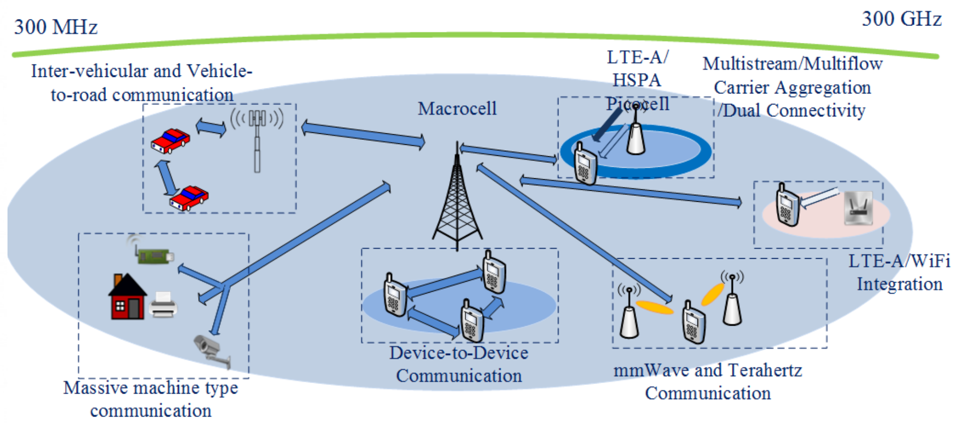
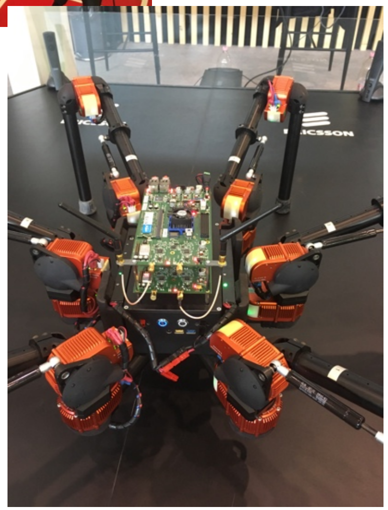


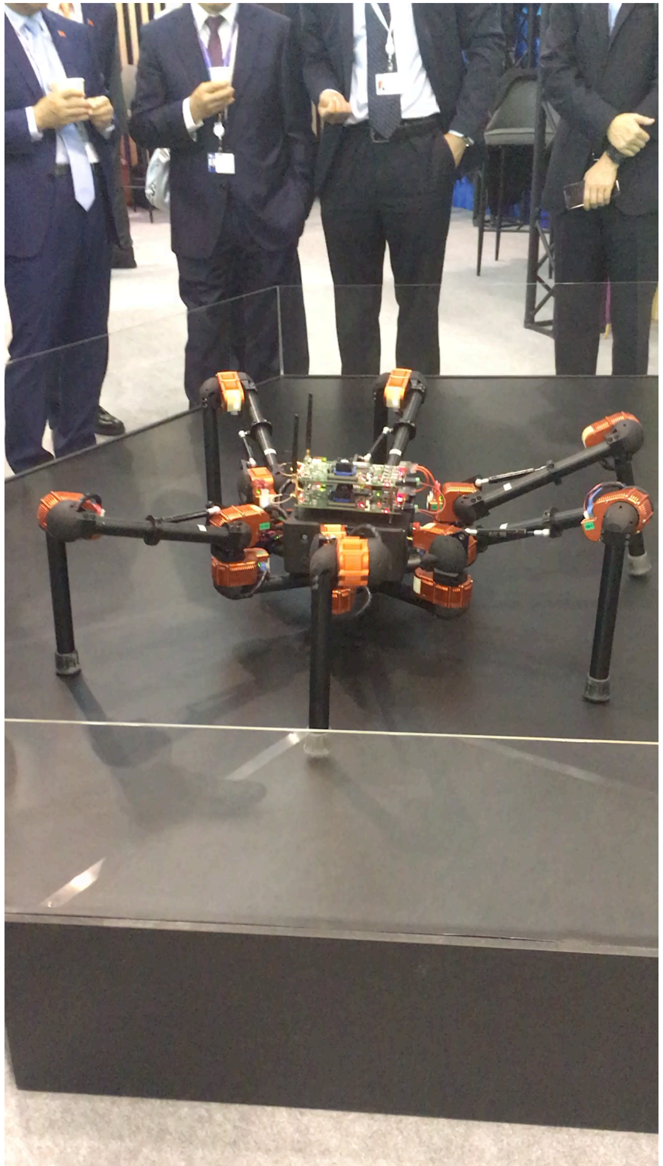
Figure 1. 5G will enable very diverse use cases with extreme range of requirements

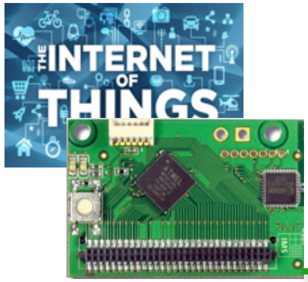




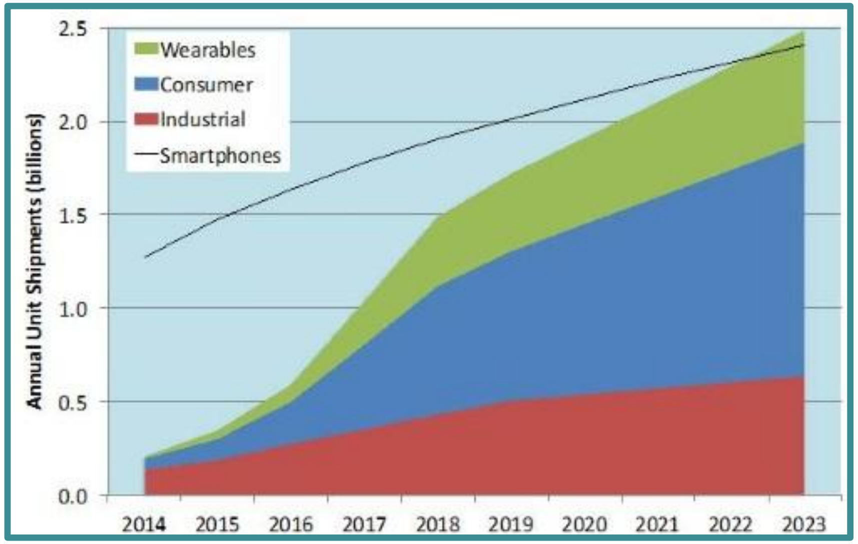
5G demo at ITU Telecom World'19

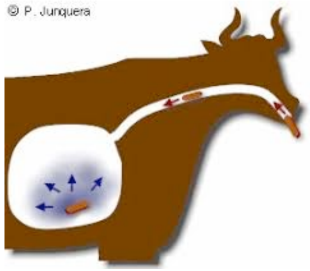






Internet of Things





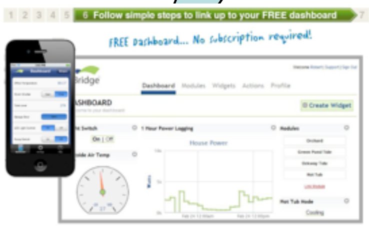
Control, optimize & instrument !

DATA ANALYSIS, OPTIMIZATION & CONTROL

PERVASIVE SYSTEMS

SENSING

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES



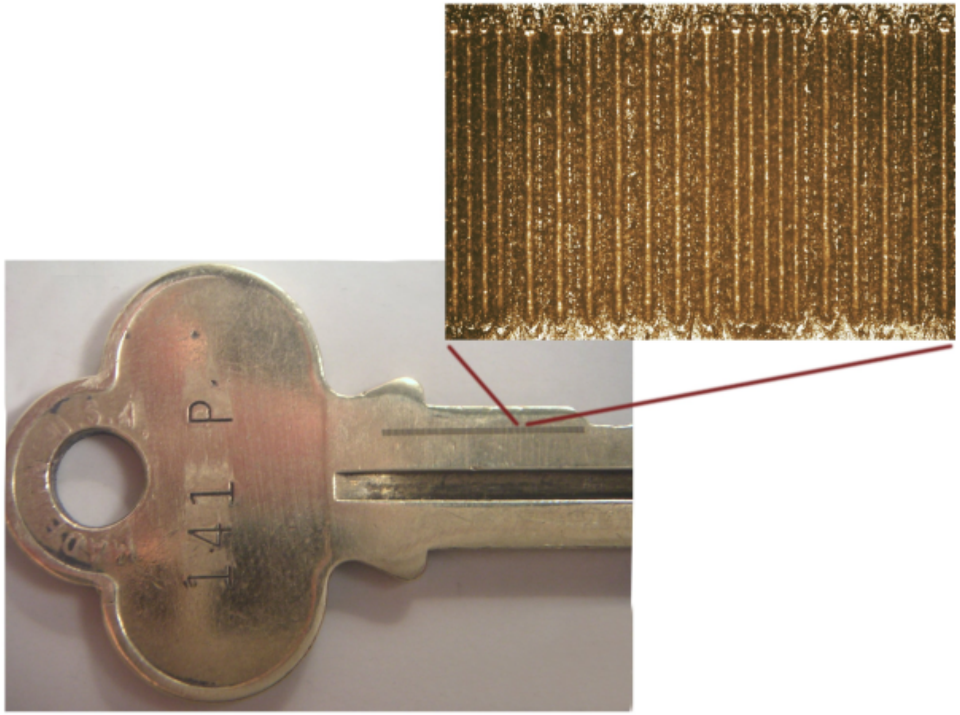
The smart broom!

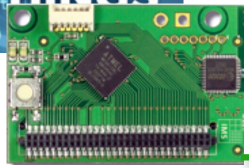
- Seen at ITU Telecom World 2018
  - Phathwa Senene at MTN booth

Interaction can takes many (unexpected) forms!

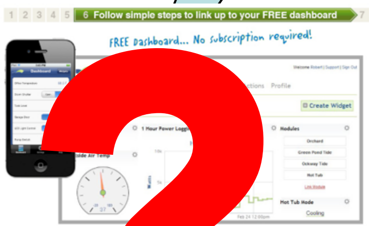
UDP Src 18.243.0.1 Dst 18.243.0.1 Port 80

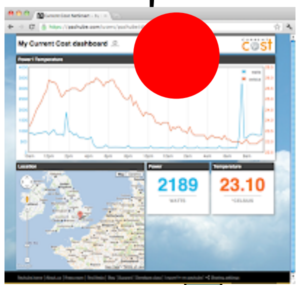
IP header UDP header





1ST ISSUE: COLLECT DATA





DATA ANALYSIS, OPTIMIZATION & CONTROL

↓

PERVASIVE SYSTEMS

↓

SENSING

↓

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES

Connectivity is a challenge

Internet of Objects 80% of volume

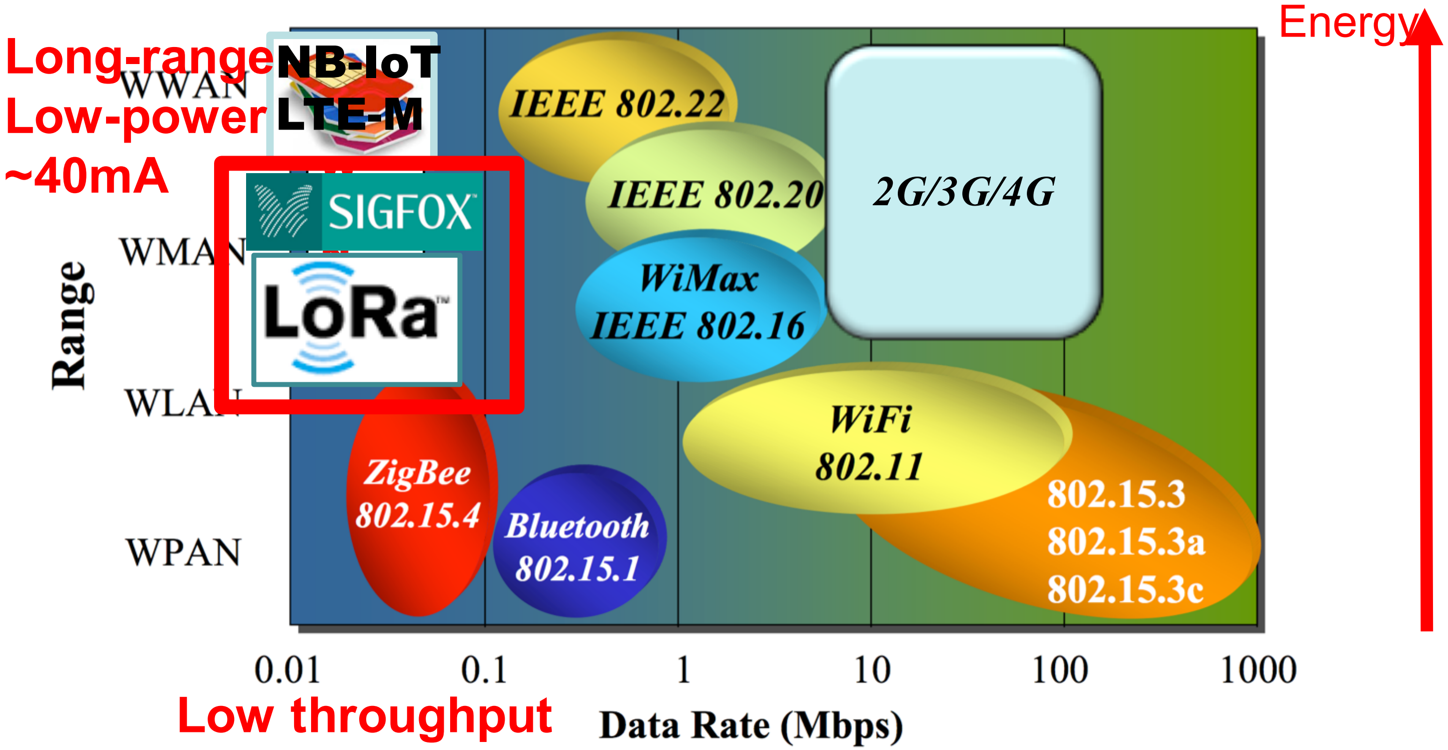
Requirements:

- How to connect Low Cost Assets or having no Energy source, non rechargeable?
- Low Cost communication
- Low Cost Infrastructure
- Low Power Technology
- Robust Communication
- Allowing Mobility
- Scalability

Slide from Semtech

Low-power & long-range radio technologies

Energy-Range dilemma



Transmitting: `TC/22.5/HUM/67.7` ; about 20 bytes with packet header
Time on air can be 1.44s with LoRa

1-HOP: STAR OF STAR

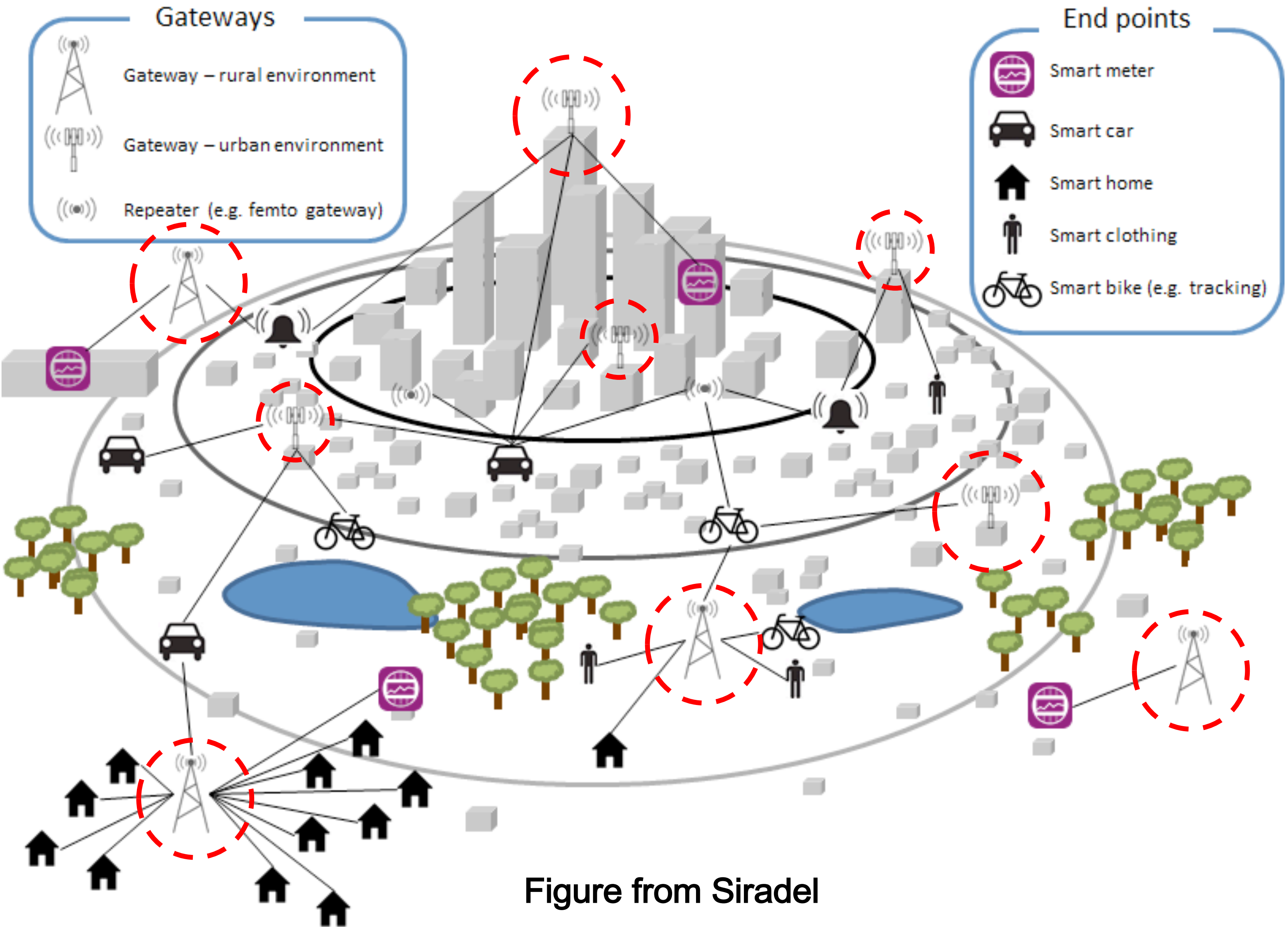


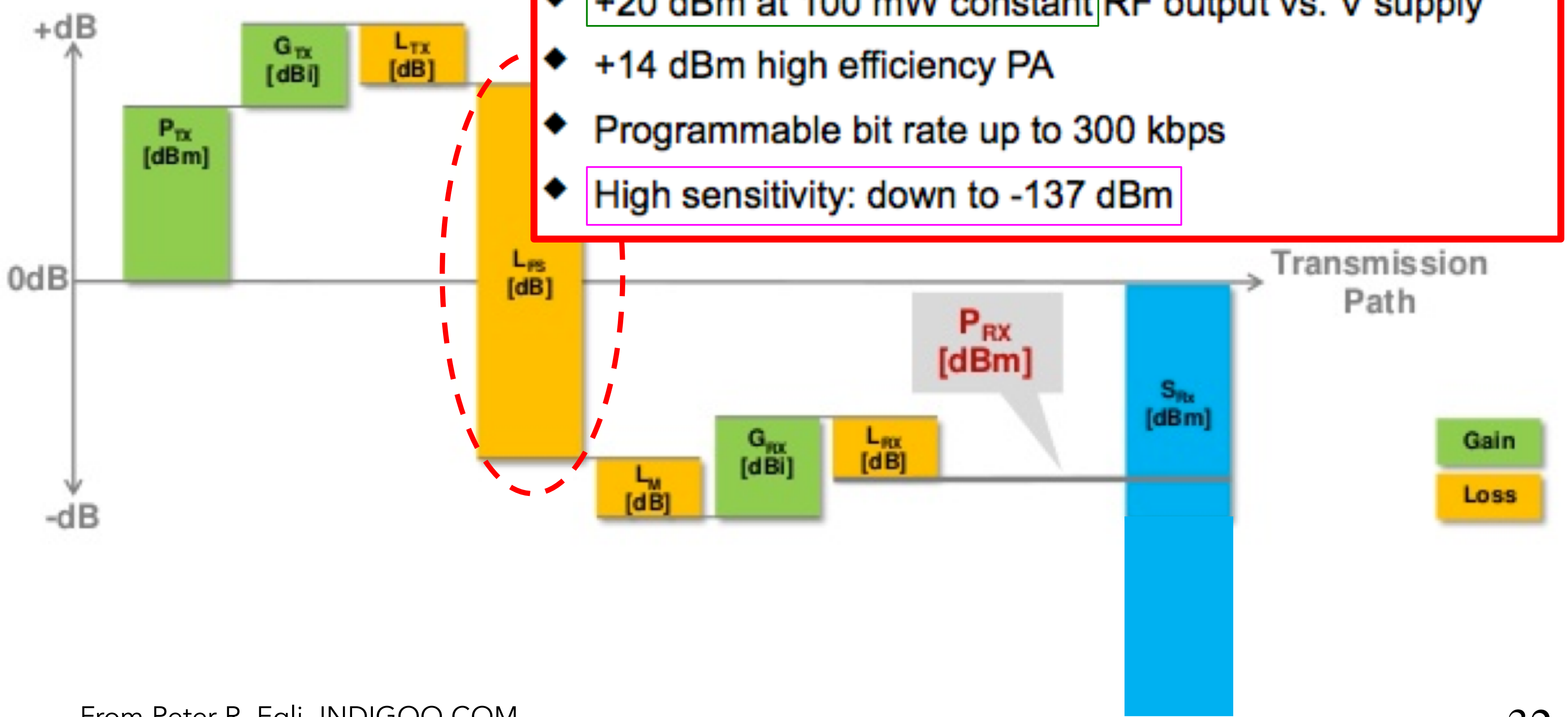
Figure from Siradel

Link budget of LPWAN

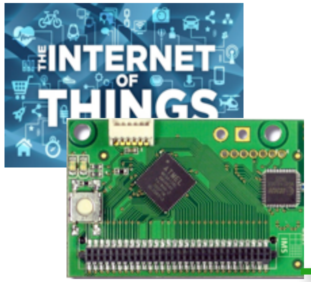
$P_{RX} = P_{TX} + G_{TX} - L_{TX} -$

KEY PRODUCT FEATURES

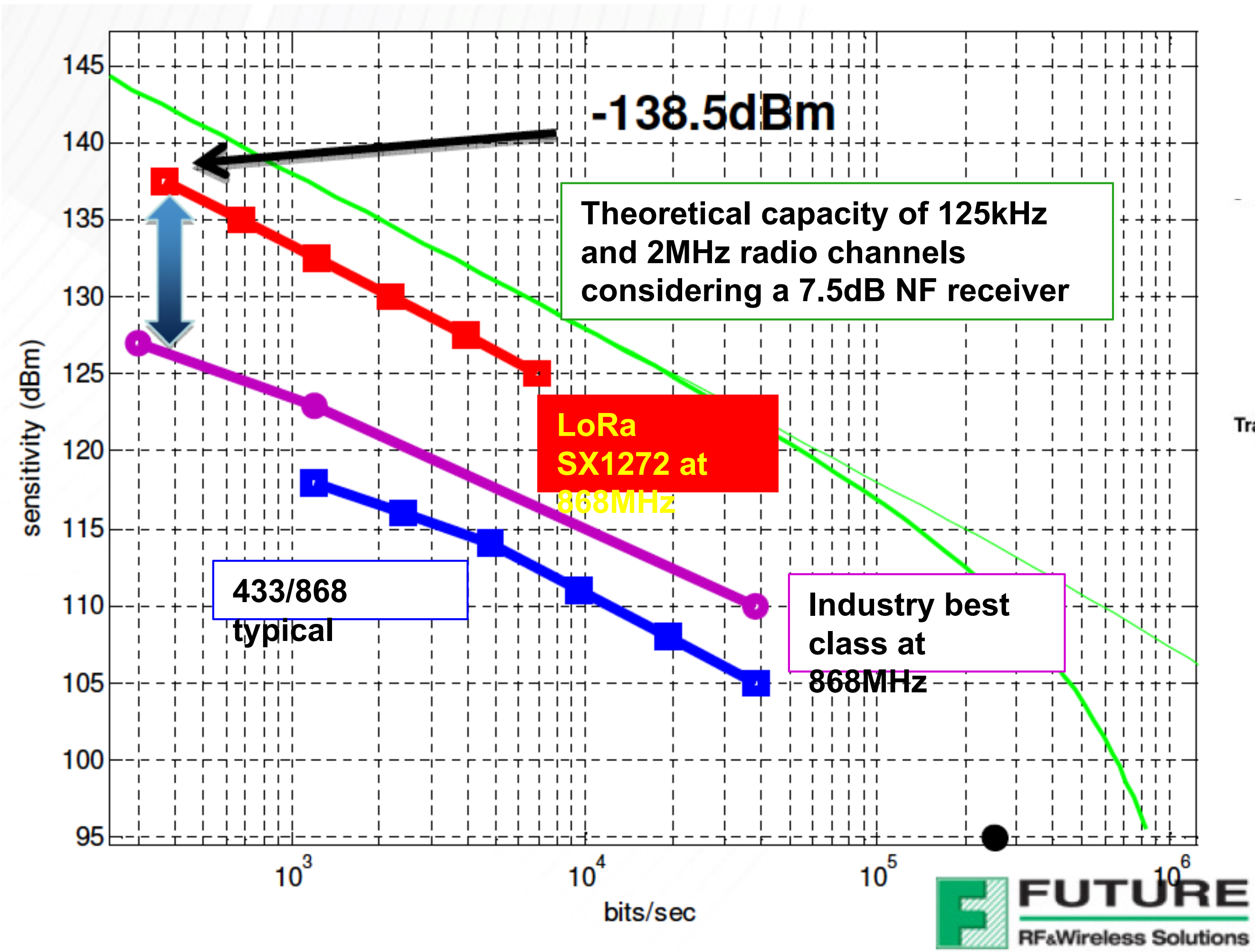
- LoRa™ Modem
- 157 dB maximum link budget
- +20 dBm at 100 mW constant RF output vs. V supply
- +14 dBm high efficiency PA
- Programmable bit rate up to 300 kbps
- High sensitivity: down to -137 dBm

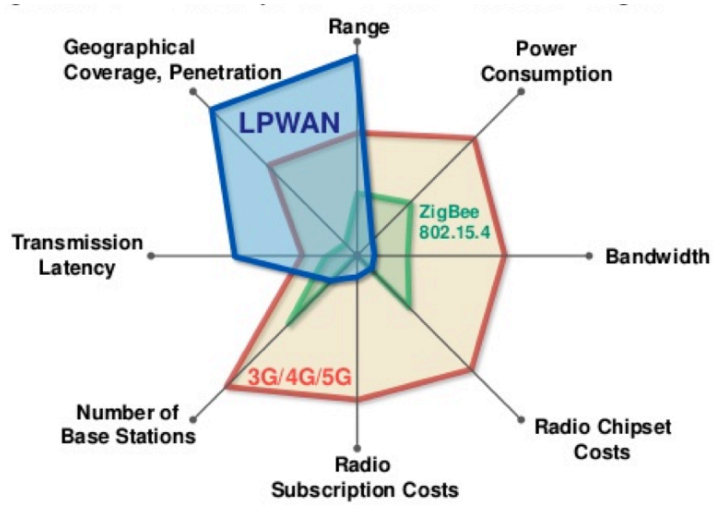


From Peter R. Egli, INDIGOO.COM



WHY THE LPWAN REVOLUTION?



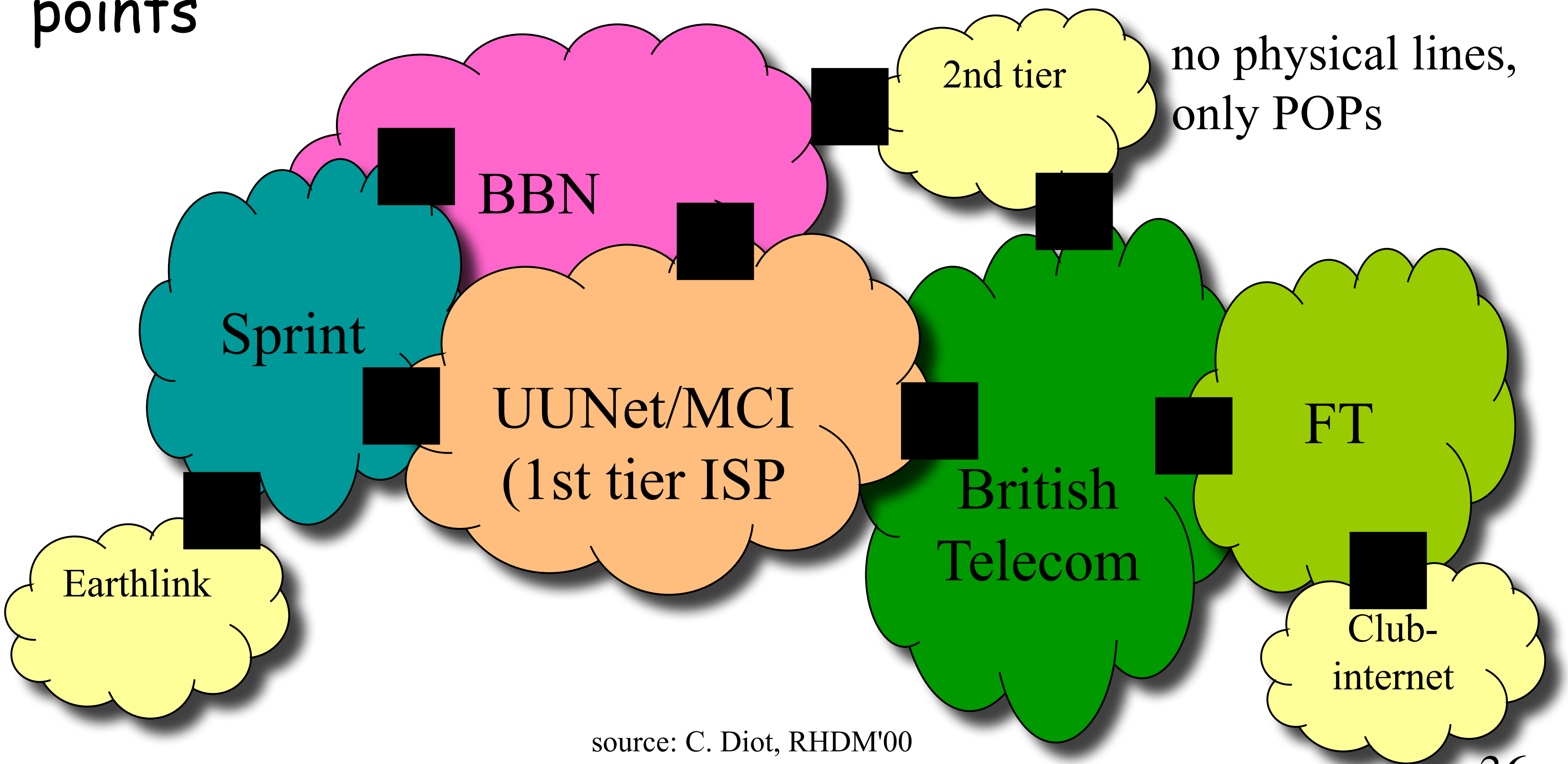


From Peter R. Egli, INDIGOO.COM

The network behind the apps/clouds

Operators and ISPs: they rule the Internet

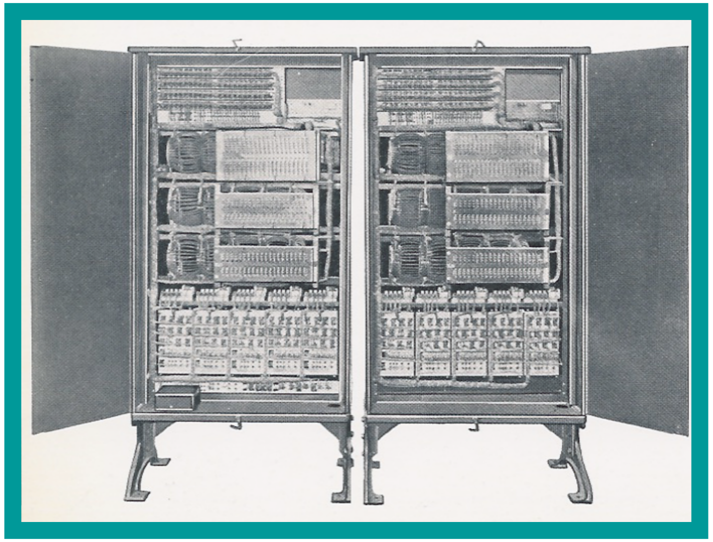
- « 1st tier ISP » own their lines.
- Interconnections happen mostly at private peering points



source: C. Diot, RHDM'00

Back in time:
The telephone system & network

First automatic Branch Exchange Almond B. Strowger, 1891…



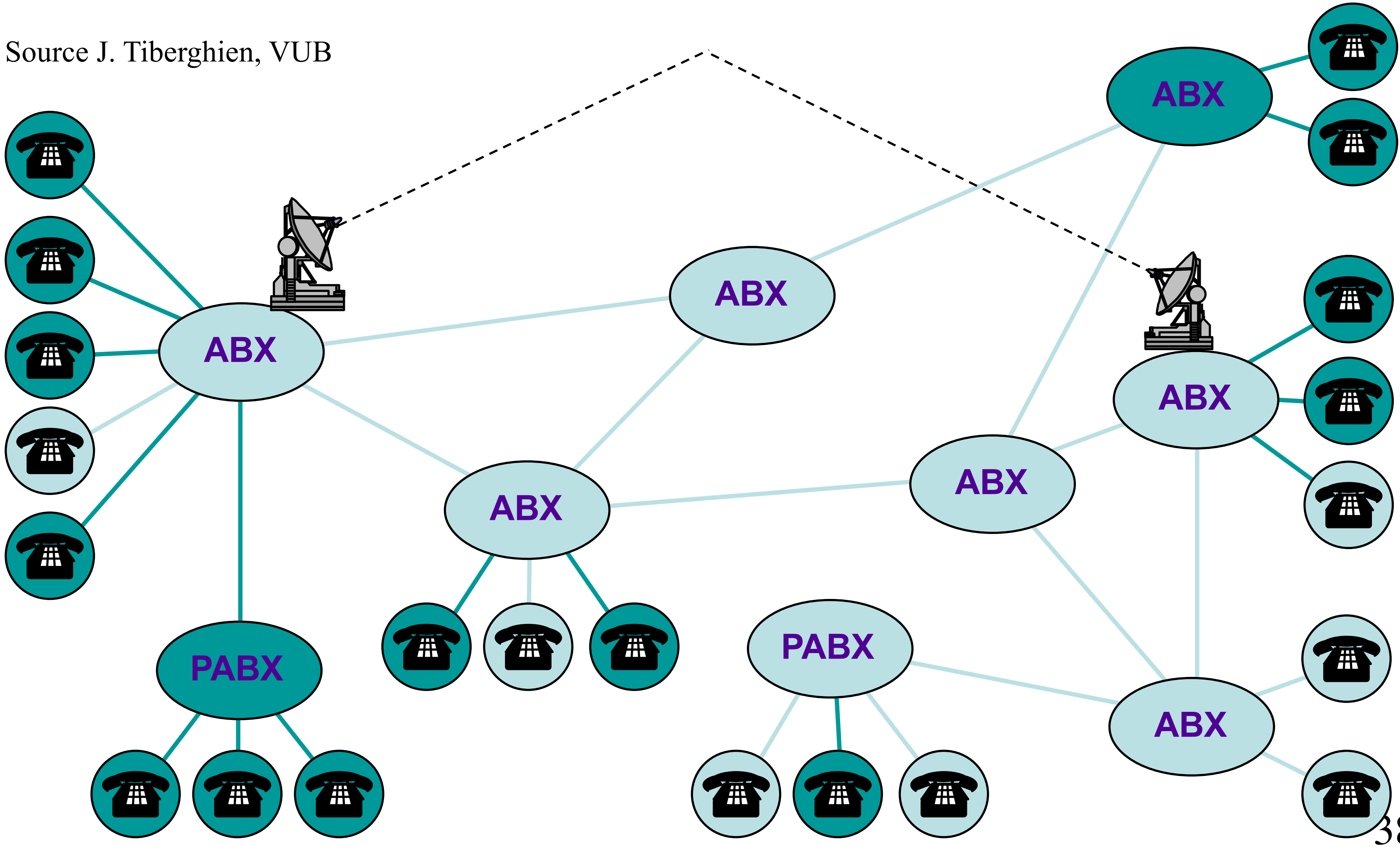
Signaling replaces the operator

Source J. Tiberghien, VUB

Back in time:
The telephone network, E.164 addressing

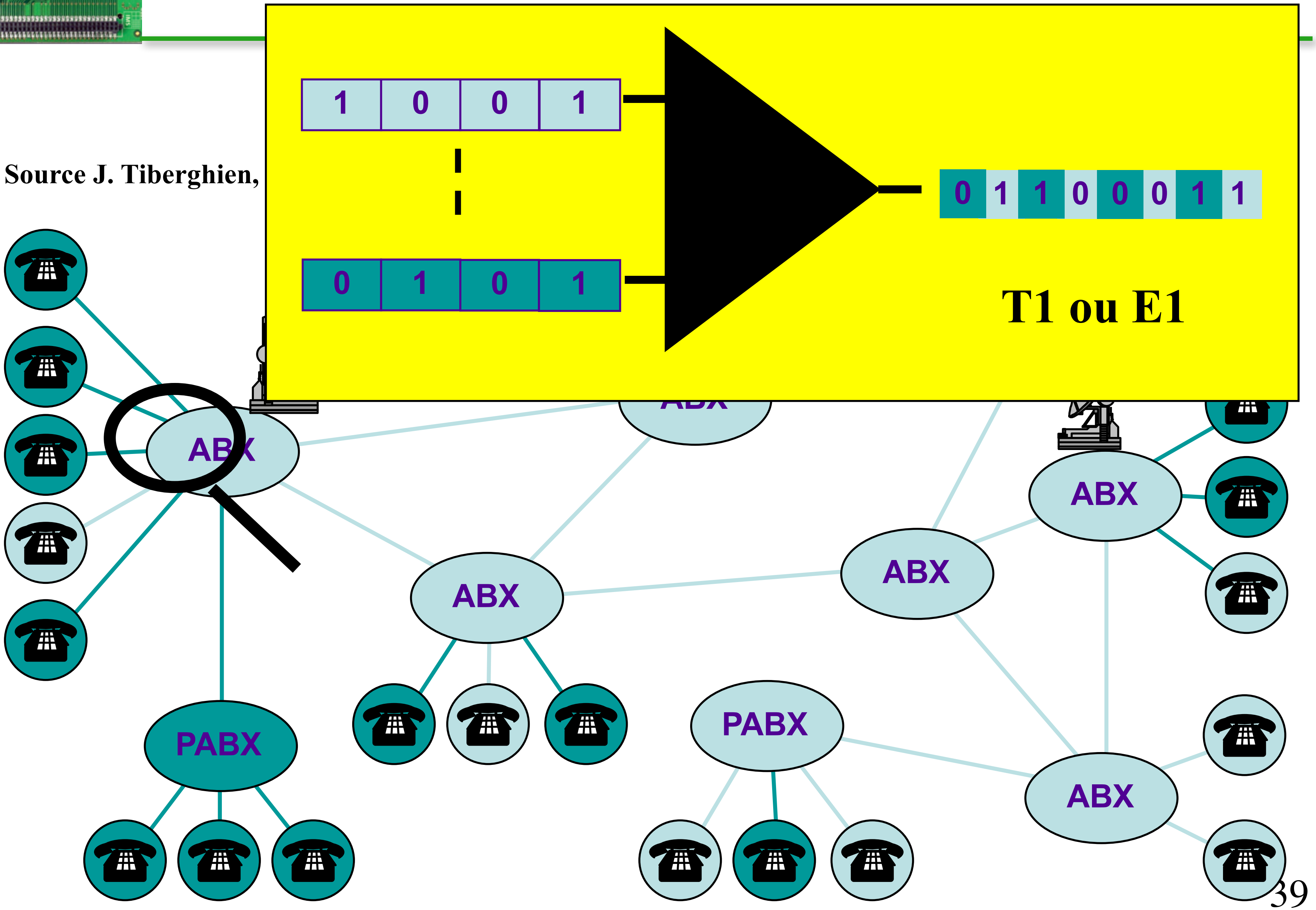
Analog / Digital

Source J. Tiberghien, VUB

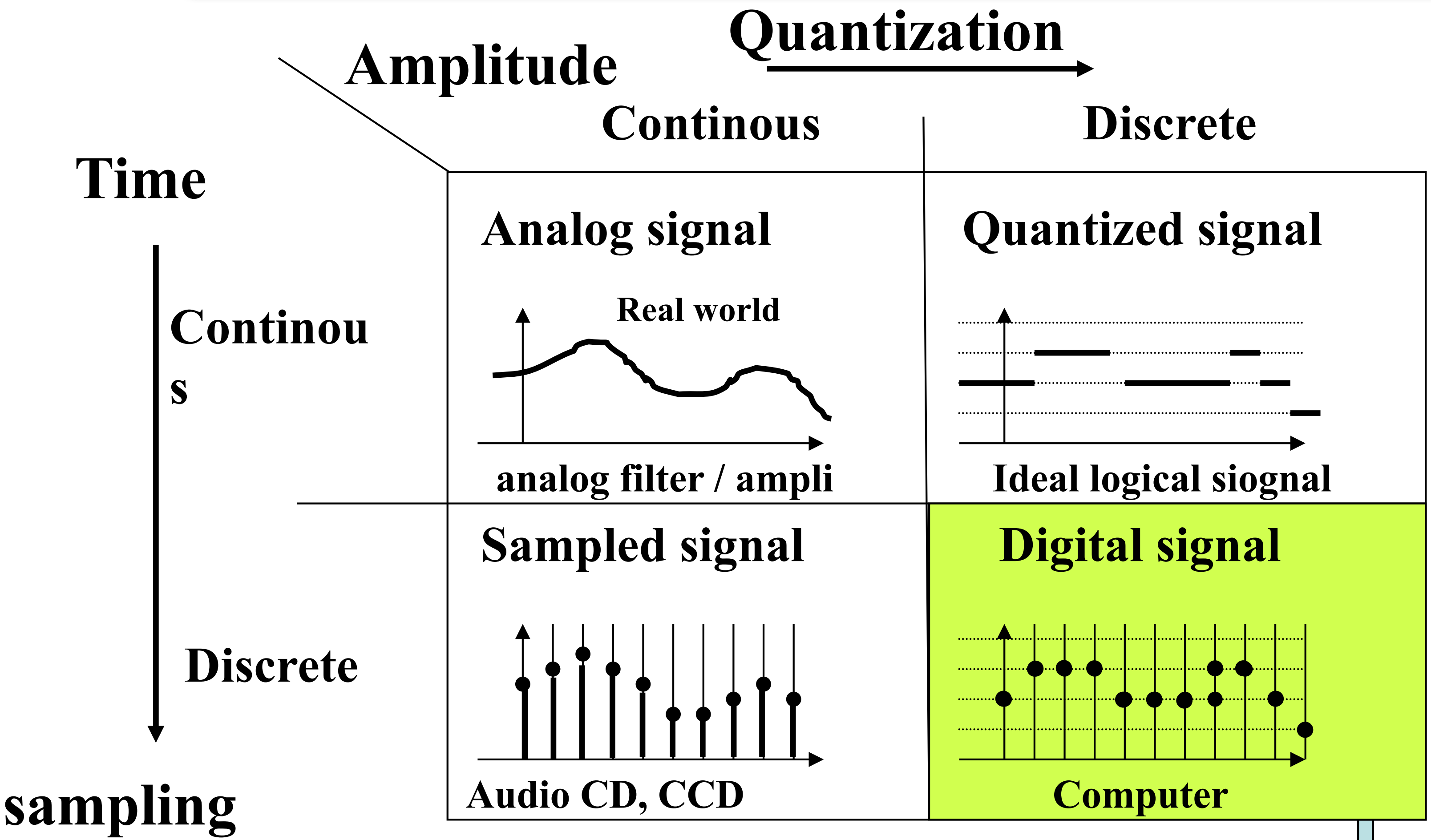


Close-up on accesses

Source J. Tiberghien,



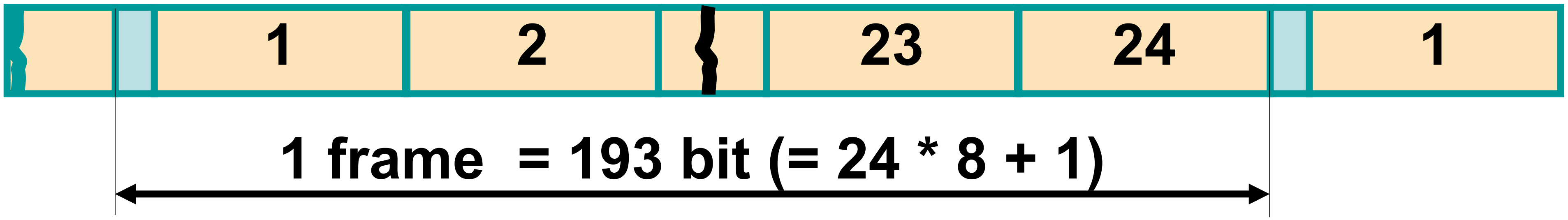
Analog voice to digital voice



Only in this case can we associate an integer value to the signal

Source F. Dupond

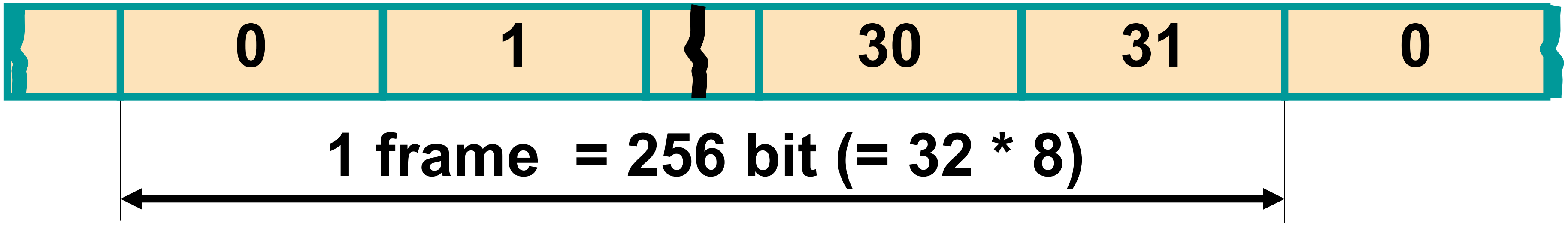
Bell D2 system (DS1/T1)
(CCITT G733)



Frame duration :	**125 μS**	**= 1 / 8000**
Number of channels :	**24**	
Frame length :	**193 bit**	**= 8 * 24 + 1**
Bit frequency :	**1544 kHz**	**= 193 / 125.10^{-6}**
Signaling :	**least significant bit stolen once every 6 frames**	
Signaling rate :	**1.3 kb/s**	**= 8000 / 6**

Frame synchronization by bit 0

CEPT 30 (E1)
(CCITT G732)



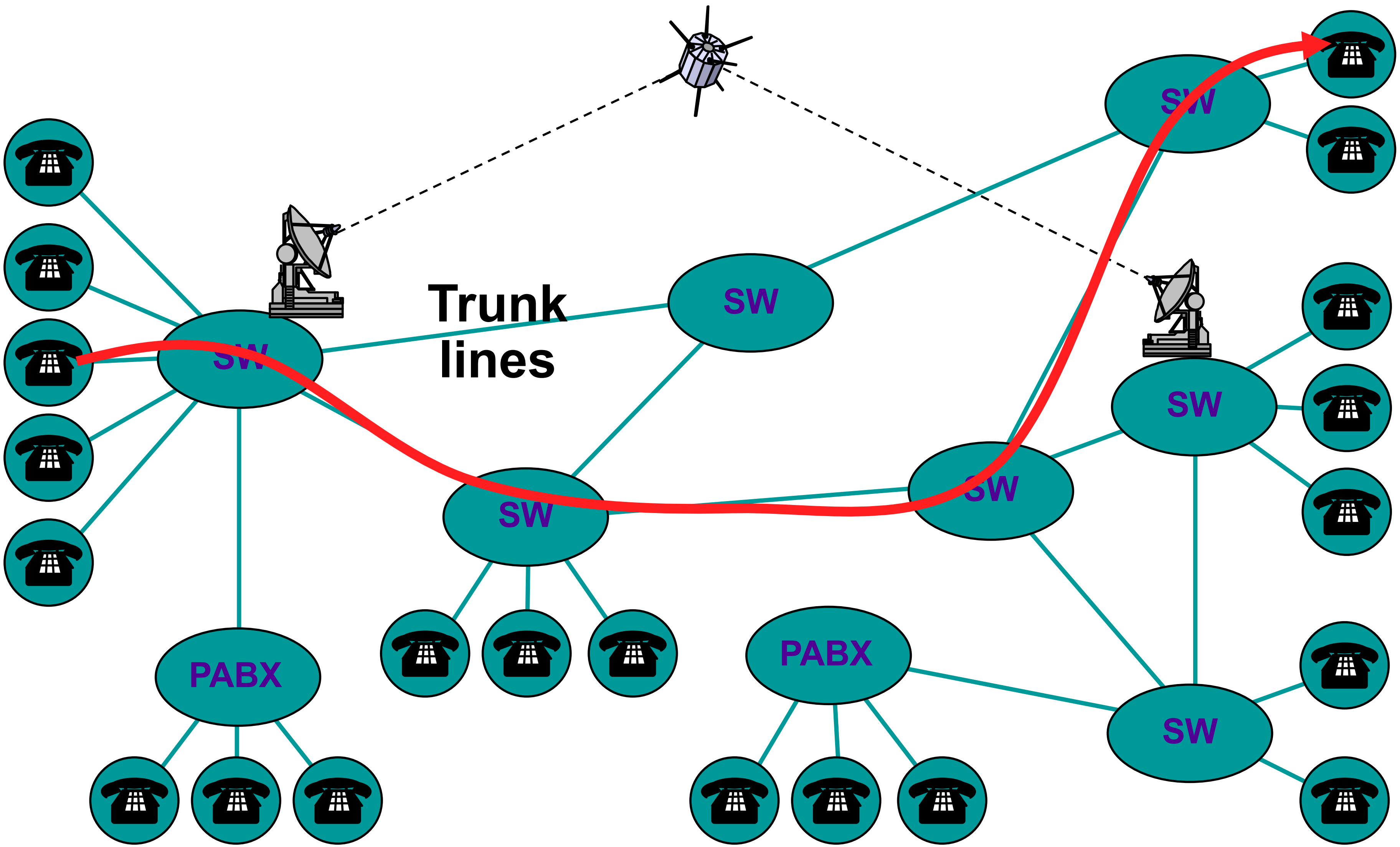
Frame duration :	**125 µS**	**= 1 / 8000**
Number of channels :	**30**	
Frame length :	**256 bit**	**= 8 * 32**
Bit frequency :	**2048 kHz**	**= 256 / 125.10^{-6}**
Signaling :	**Slot 16 reserved**	
Channel Signaling : 2 kb/s	**= 64 / 32 kb/s**	
Common Signaling :	**64 kb/s**	

Frame sync. and link management by slot 0

T1/E1 represents the main underlying technologies for dedicated leased lines: Transfix in France for example

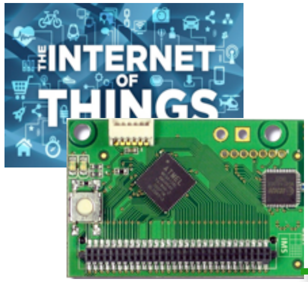
Bandwidth from 2400bps to 45Mbps (T3 in US)

The telephone circuit view



Advantages of circuits

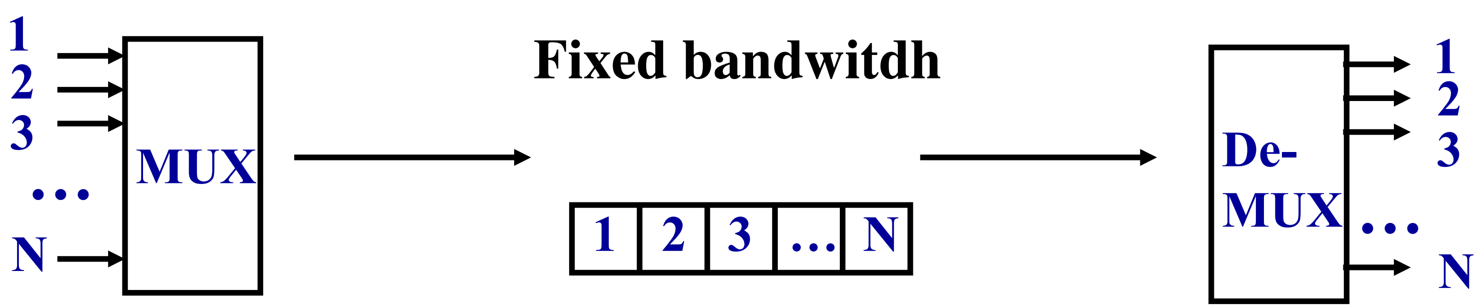
- Provides the same path for information of the same connection: less out-of-order delivery
- Easier provisioning/reservation of network's resources: planning and management features



Time Division Circuits

- Most trunks time division multiplex voice samples
- At a central office, trunk is demultiplexed and distributed to active circuits
- Synchronous multiplexor
  - N input lines
  - Output runs N times as fast as input

Simple, efficient, but low flexibility and wastes resources



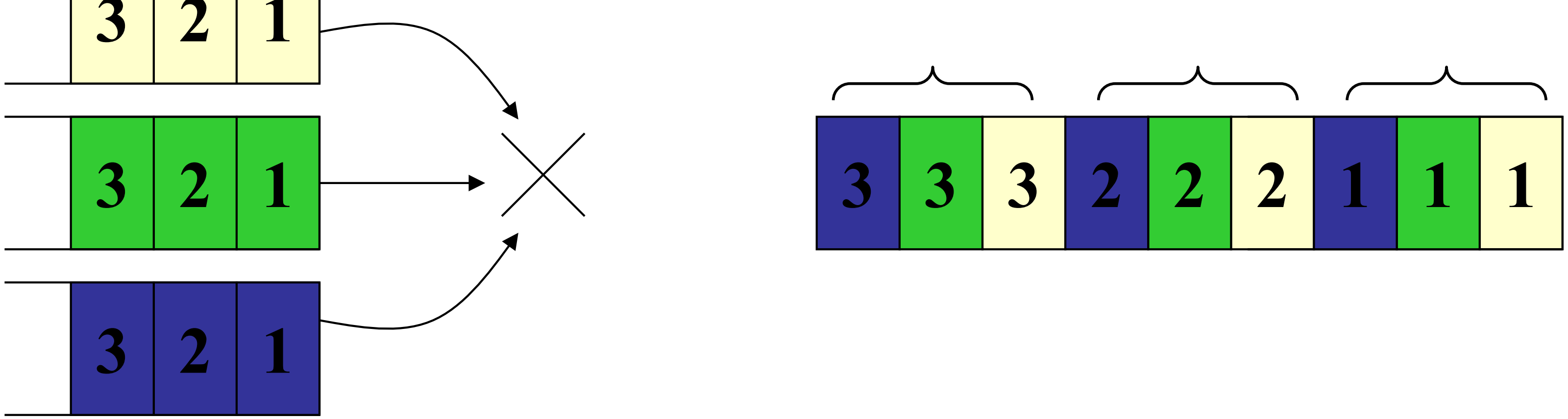
1 sample every 125us gives a 64Kbits/s channel

Plesiochronous Digital Hierarchy

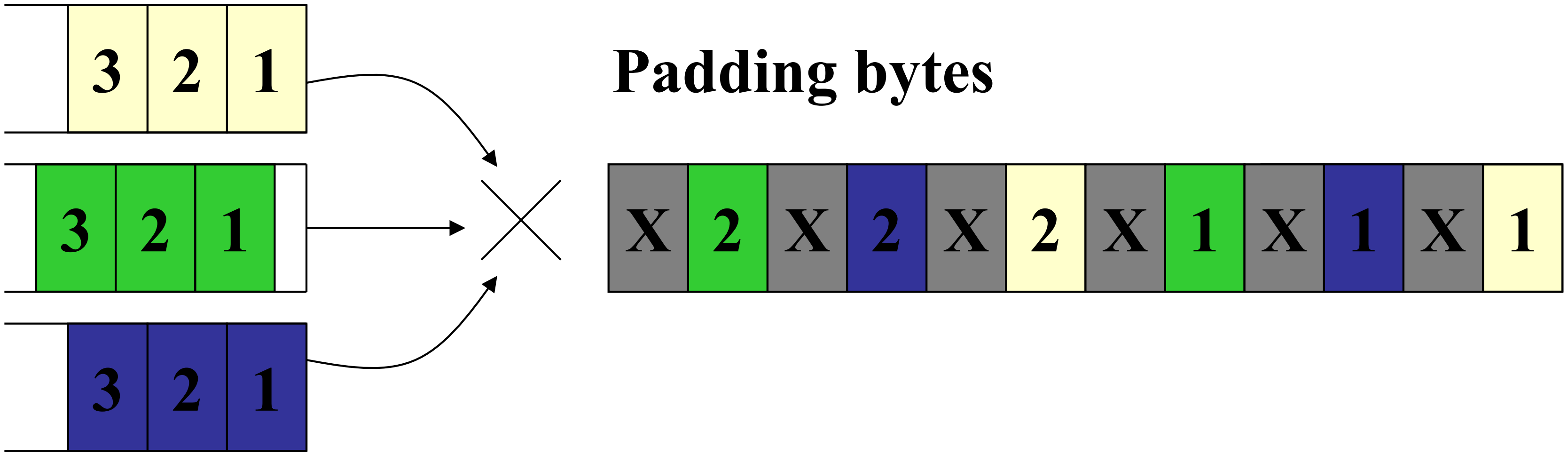
- Digital lines have been replacing analog lines, but not in one day!
- Timing amongt these lines is not perfect!
- PDH uses more throughput in the output to accomodate these not synchronized signals
- Problem is when demultiplexing the signal

PDH, no synchronism

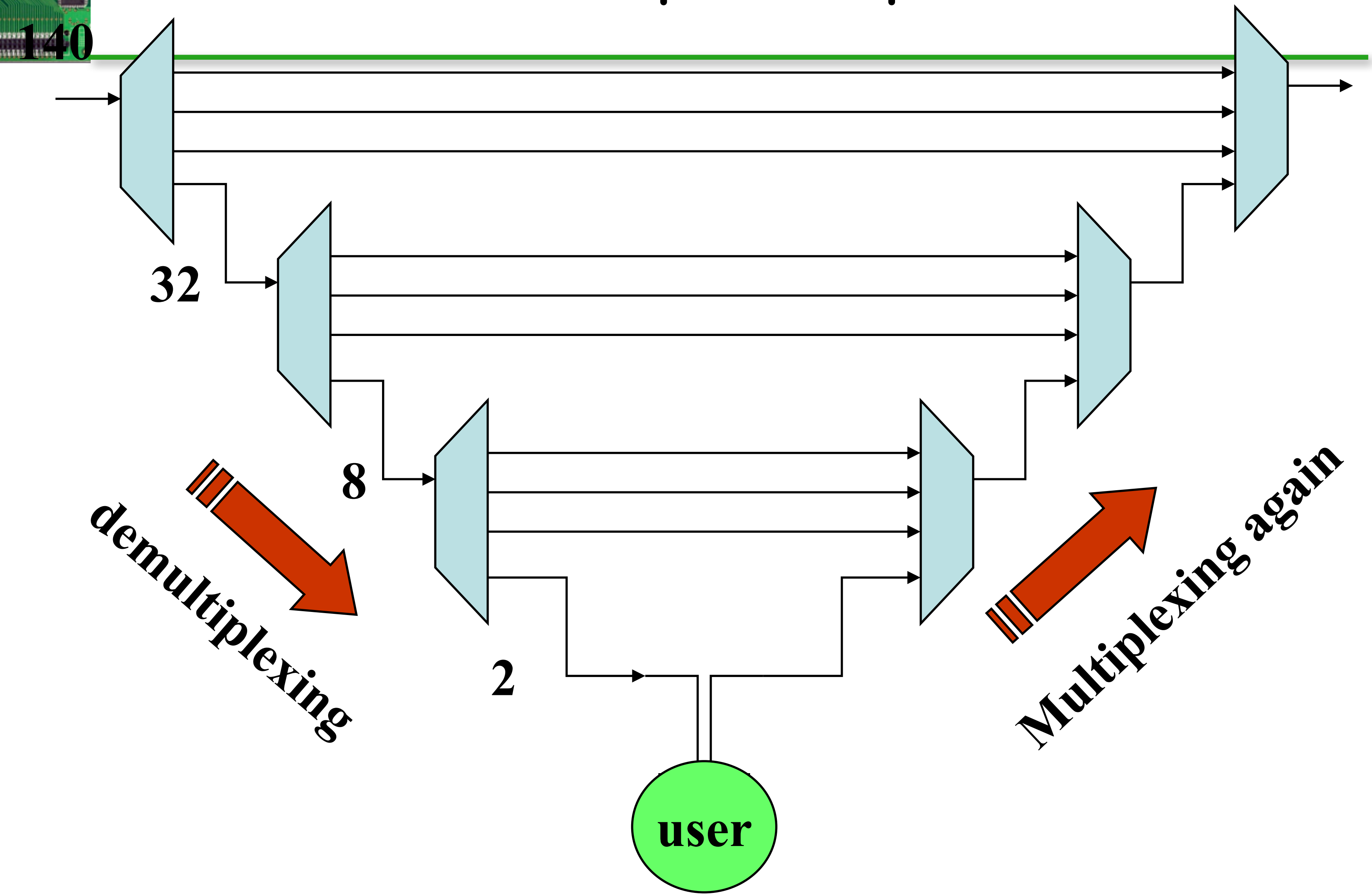
Synchronism



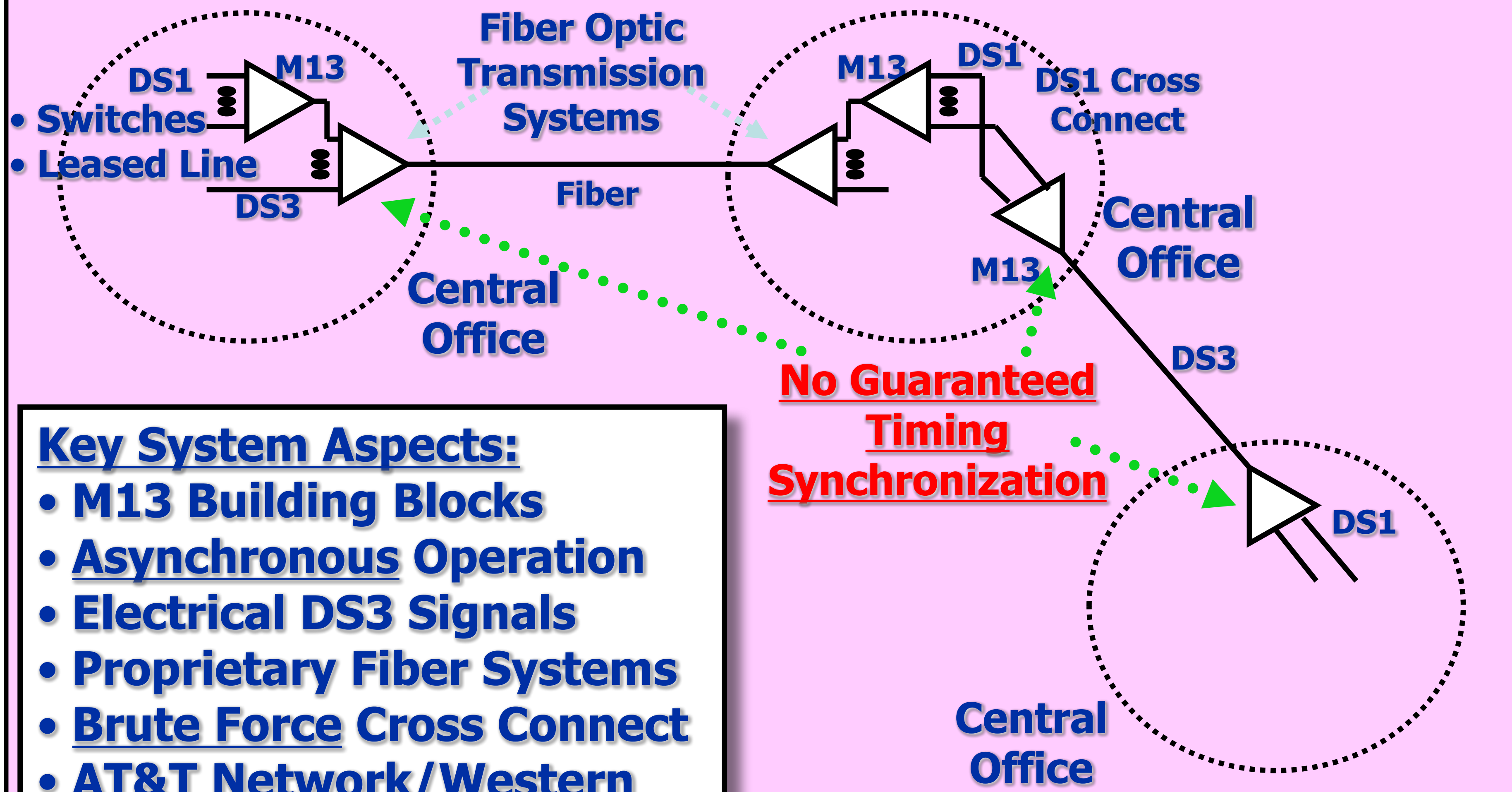
Padding bytes



PDH: Add Drop Multiplexer



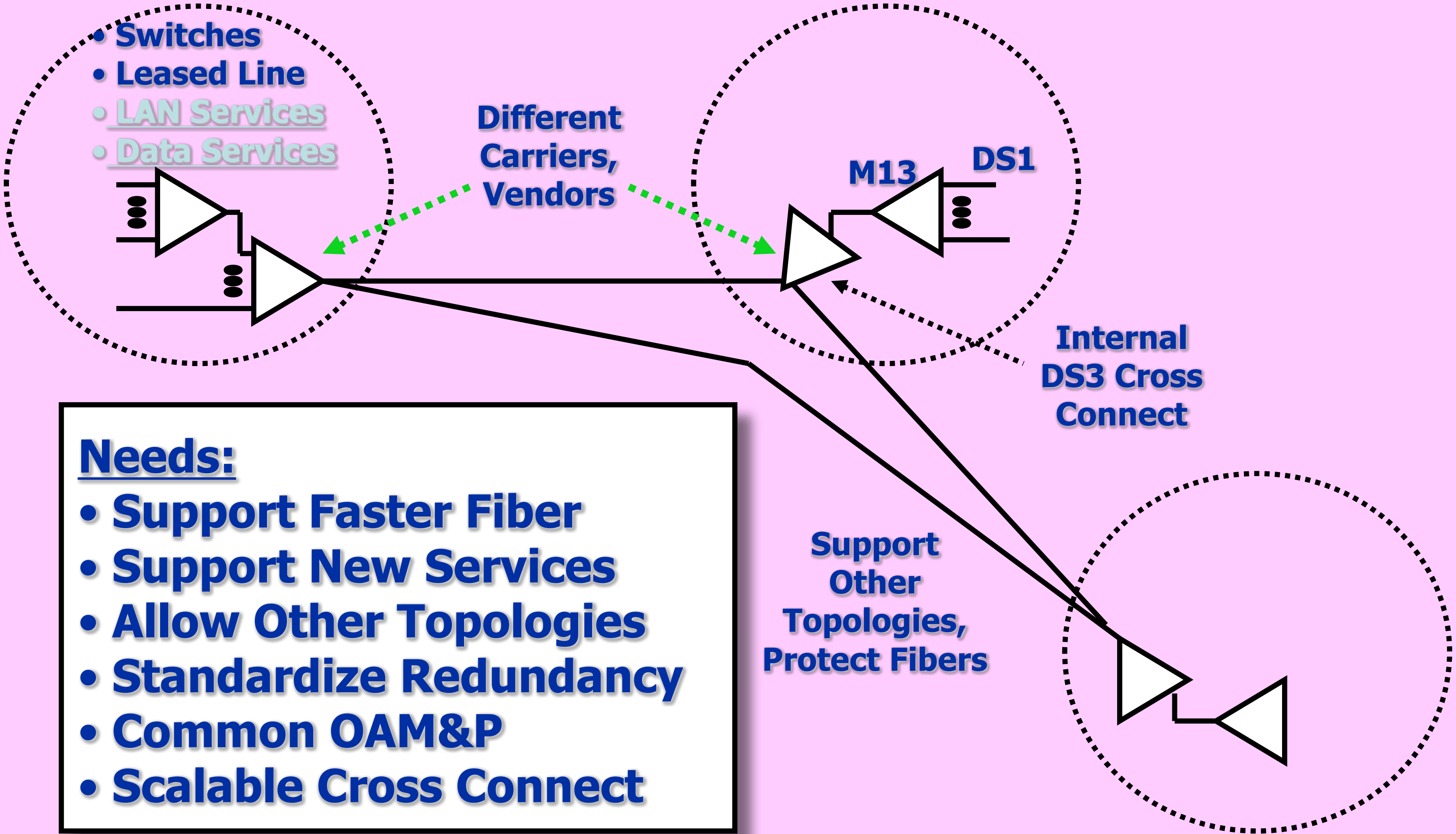
Digital Telephony in 1984



Key System Aspects:

- M13 Building Blocks
- Asynchronous Operation
- Electrical DS3 Signals
- Proprietary Fiber Systems
- Brute Force Cross Connect
- AT&T Network/Western Electric Equipment

Post-AT&T Divestiture Dilemmas



Needs:
- Support Faster Fiber
- Support New Services
- Allow Other Topologies
- Standardize Redundancy
- Common OAM&P
- Scalable Cross Connect

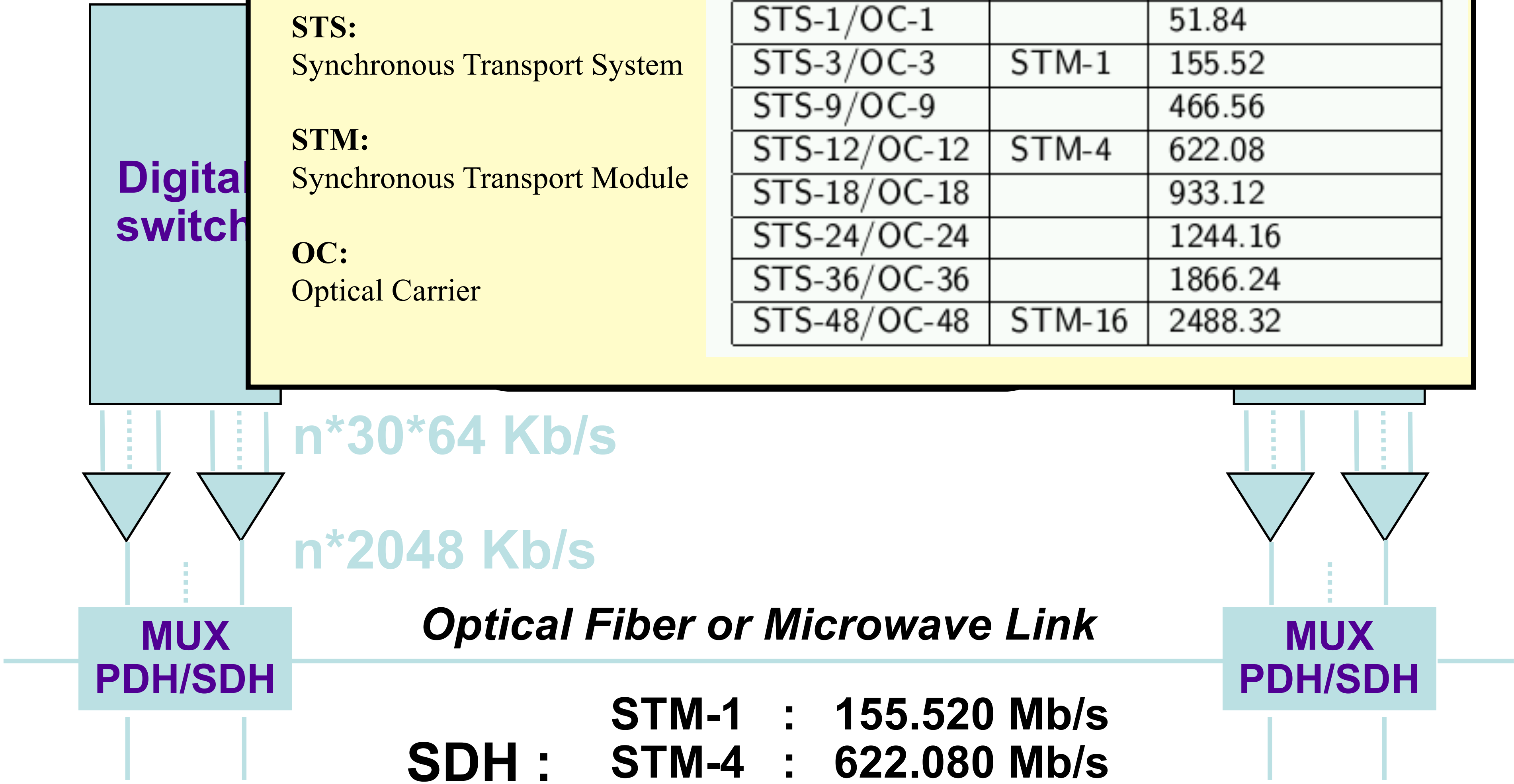
The core networks and SONET/SDH

STS:
Synchronous Transport System

STM:
Synchronous Transport Module

OC:
Optical Carrier

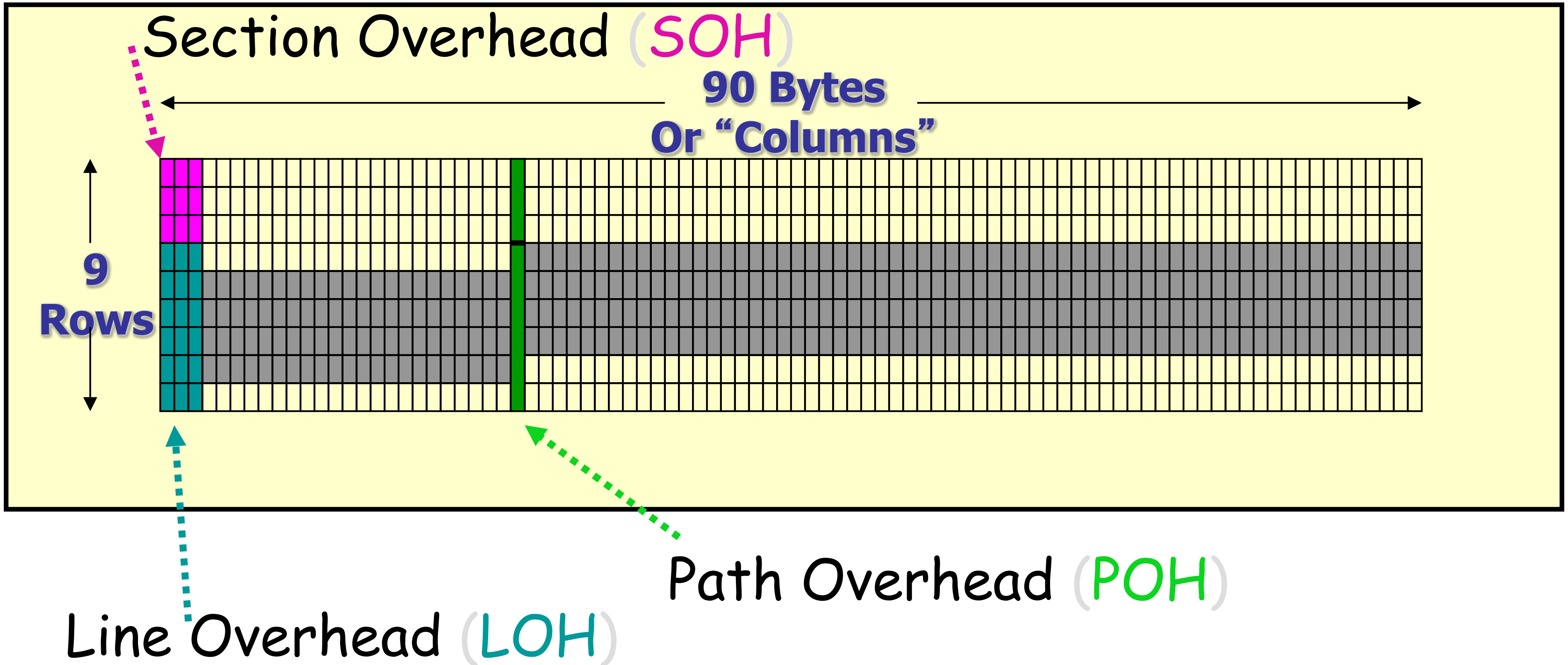
SONET	SDH	Débit (Mbits/s)
STS-1/OC-1		51.84
STS-3/OC-3	STM-1	155.52
STS-9/OC-9		466.56
STS-12/OC-12	STM-4	622.08
STS-18/OC-18		933.12
STS-24/OC-24		1244.16
STS-36/OC-36		1866.24
STS-48/OC-48	STM-16	2488.32



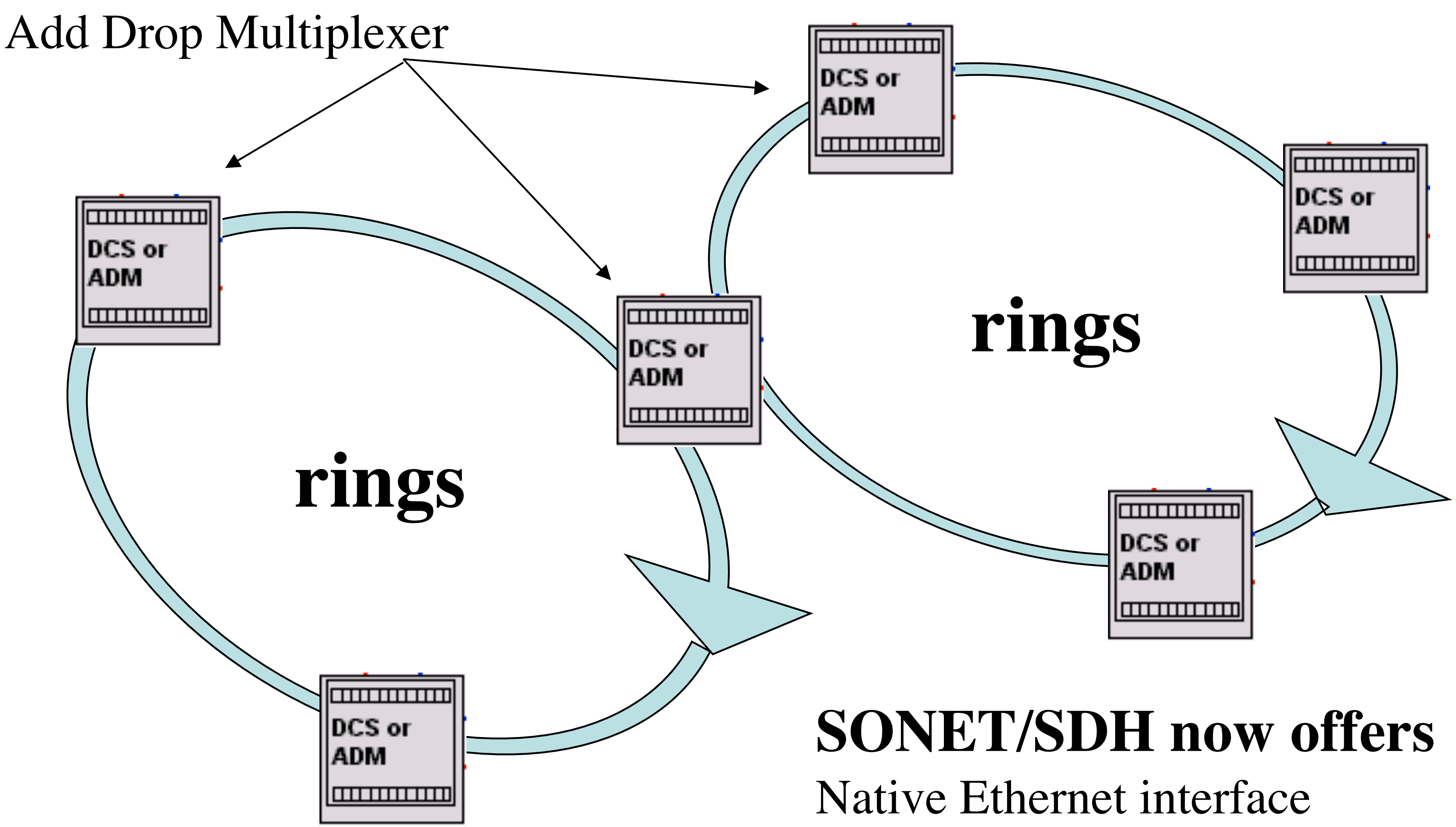
SDH :
STM-1 : 155.520 Mb/s
STM-4 : 622.080 Mb/s
STM-16 : 2488.320 Mb/s

The SONET frame

- Basic frame length is 810 bytes
  - Sent every 125us, raw throughput of 51.84 Mbits/s (STS-1)
  - Better seen as a block with 90 colomns and 9 lines
  - SDH has STM-1 which corresponds to an STS-3



SONET/SDH transport network infrastructure



SONET/SDH now offers

Native Ethernet interface

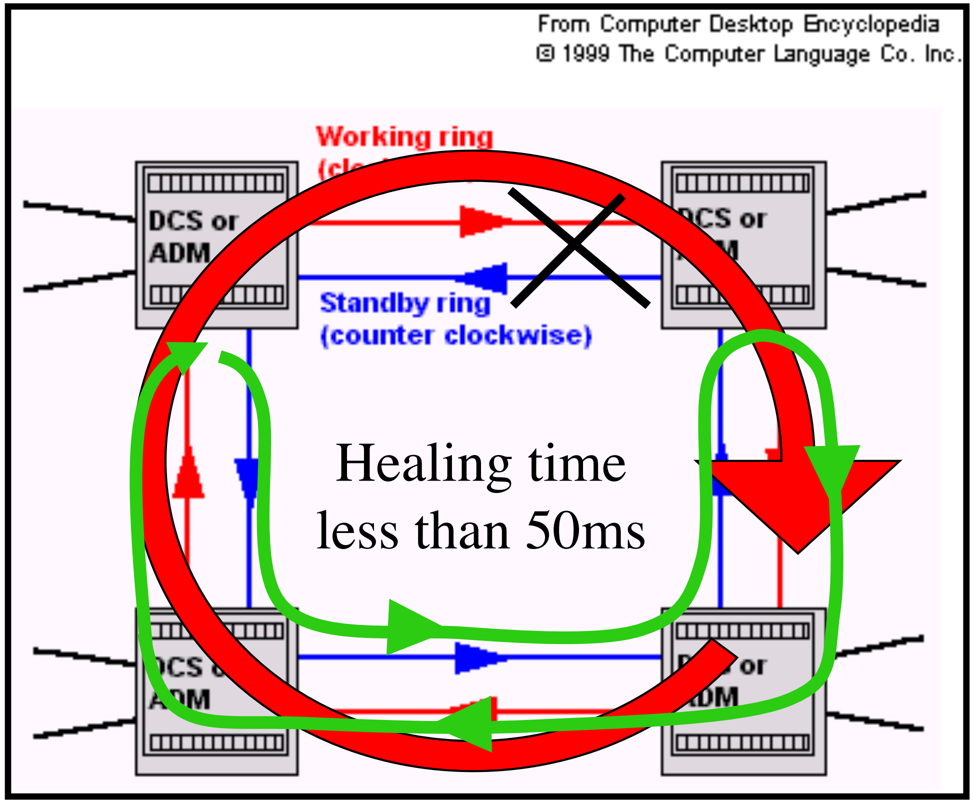
Generic Framing Procedure

Virtual Concatenation

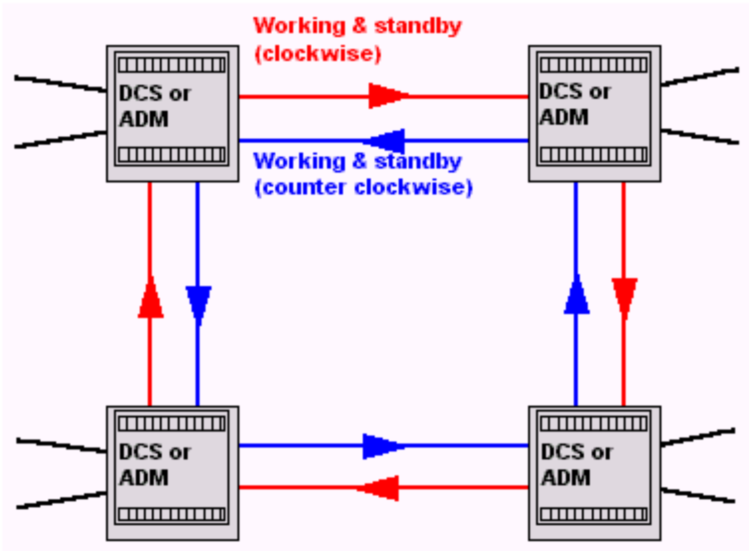
SONET/SDH and resiliency

- SONET/SDH has built-in fault-tolerant features with multiple rings
- Ex: simple case

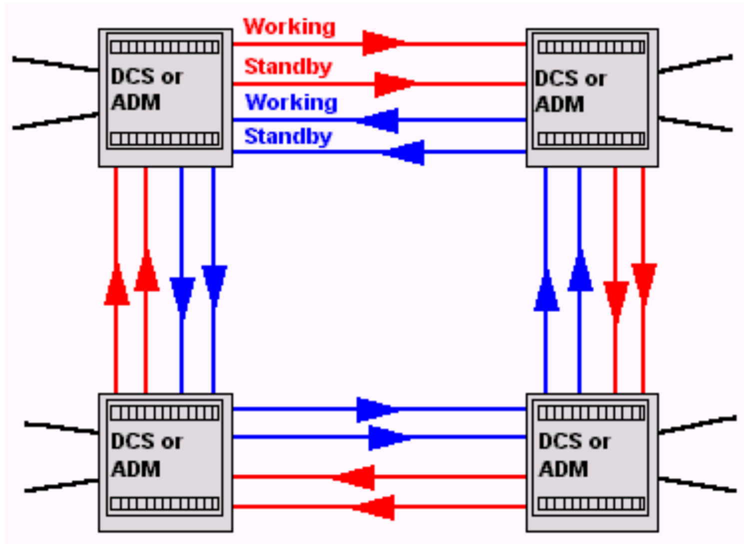
DCS
(Digital Cross-Connects)



SONET/SDH and resiliancy

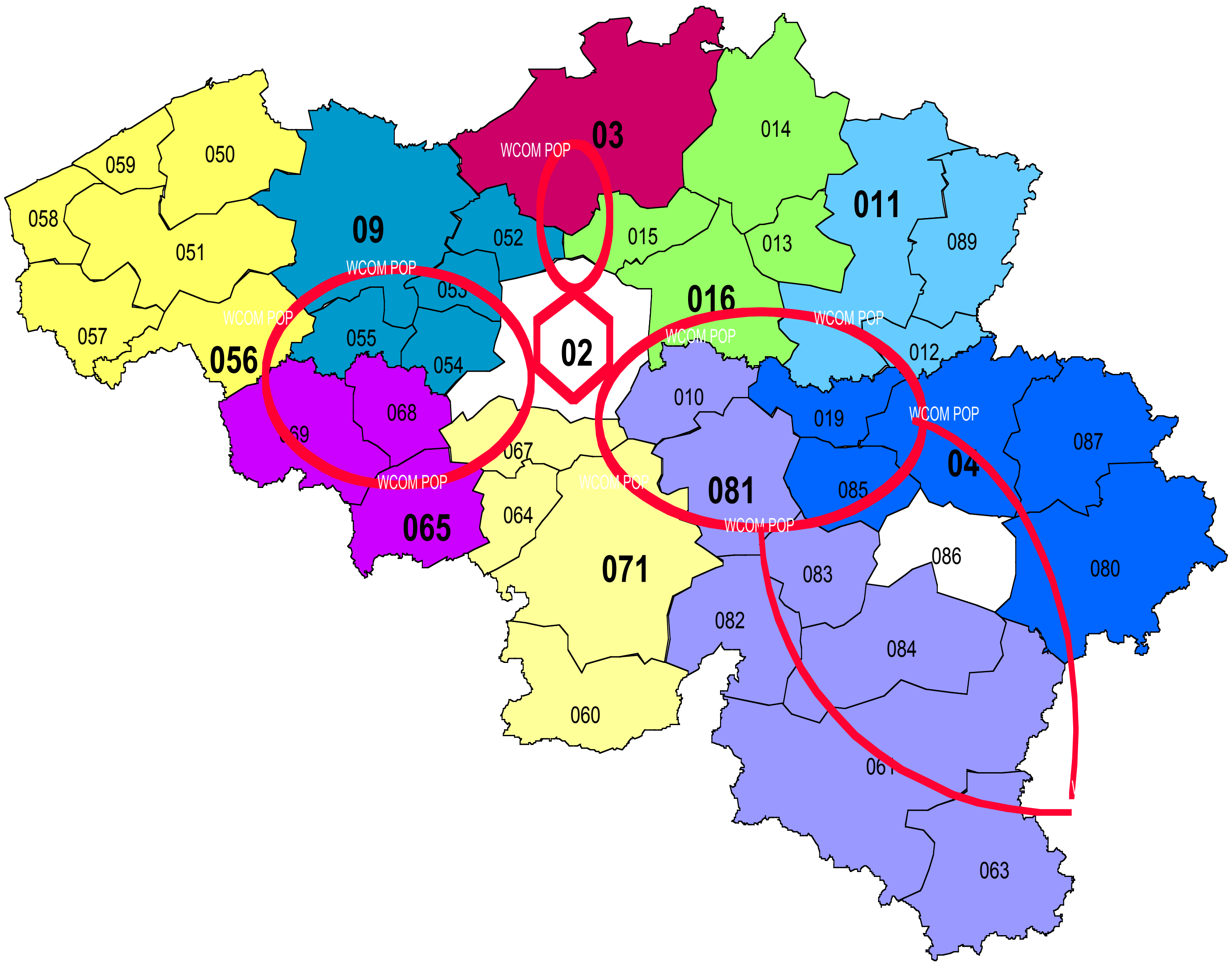


bi-directional



Found in most operators

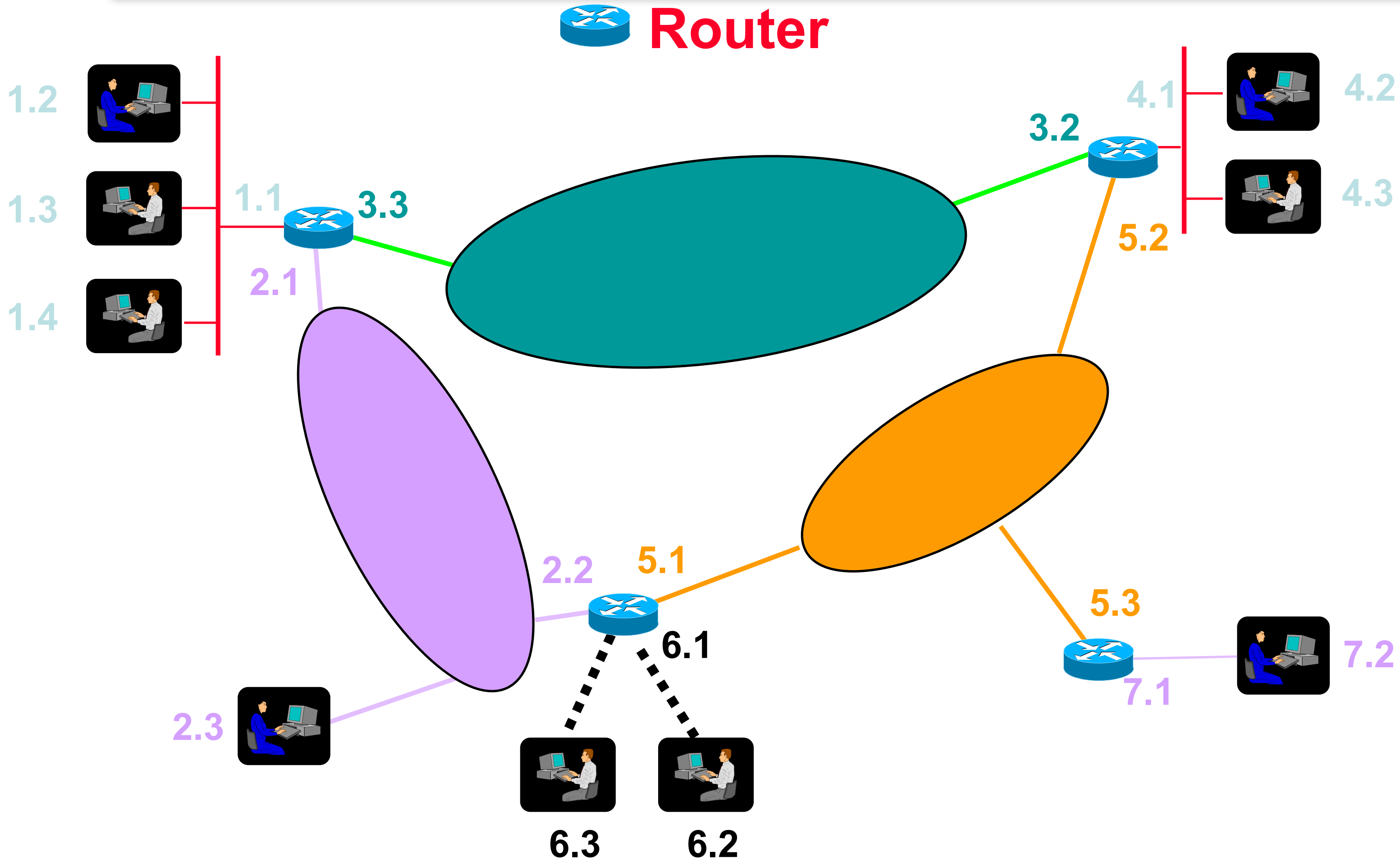
SDH Rings
The Worldcom Belgian Network



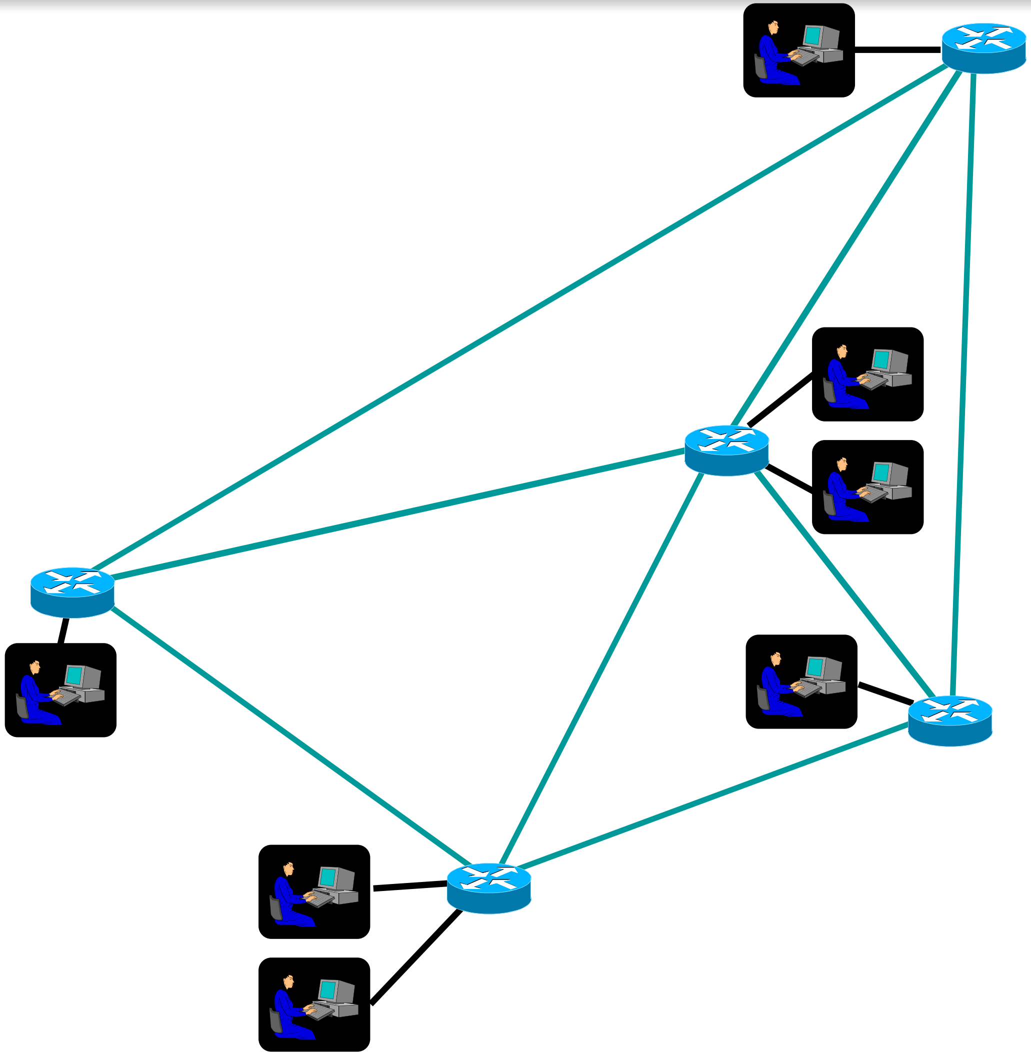
Merging IP networks and telco networks

- We saw:
  - The architecture of the Internet
  - The architecture of telco networks
- How these 2 types of networks interoperate?
  - Where?
  - With which technologies?

Example: IP networks



Directly linked Routers



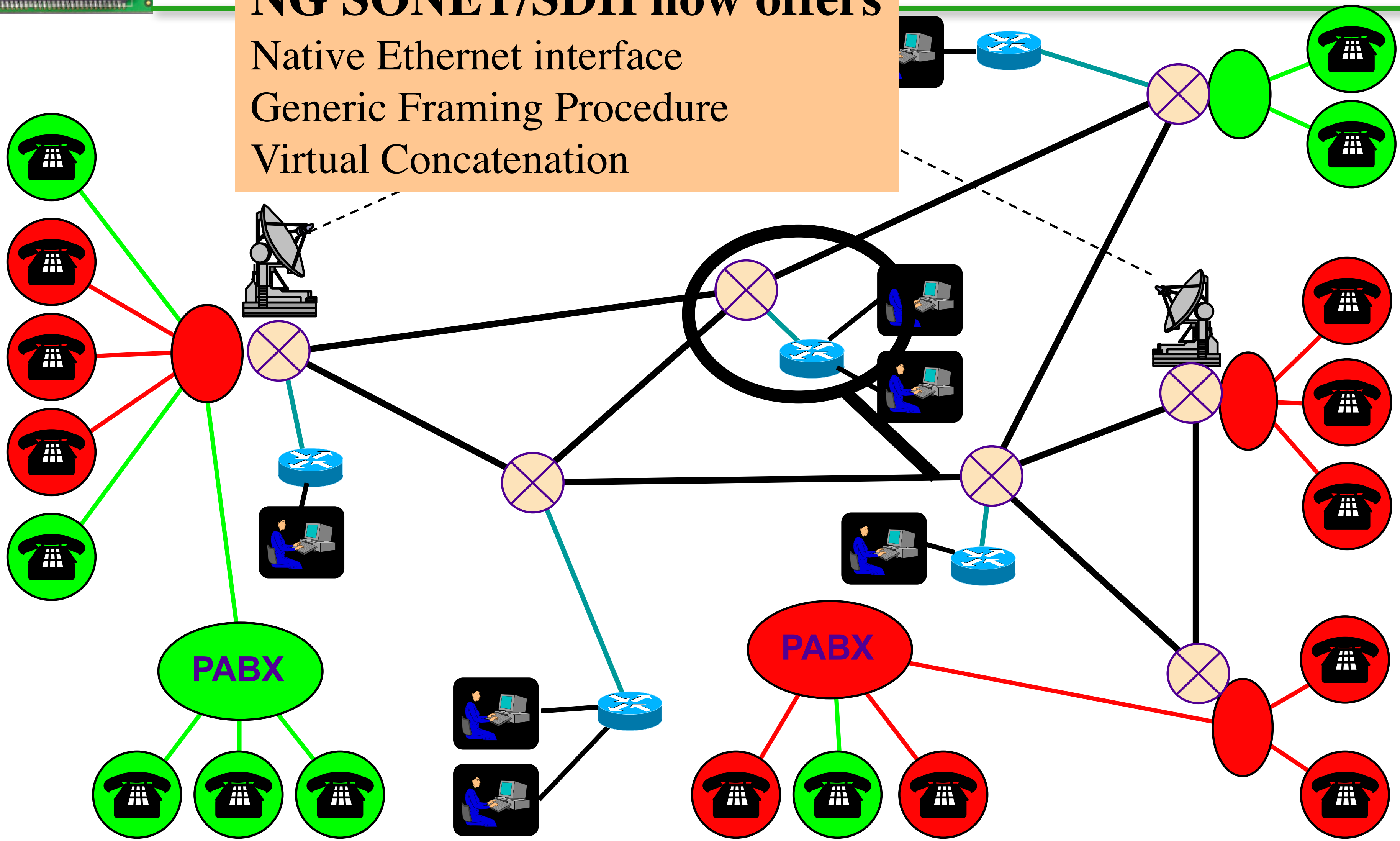
General Purpose SDH Networks

NG SONET/SDH now offers

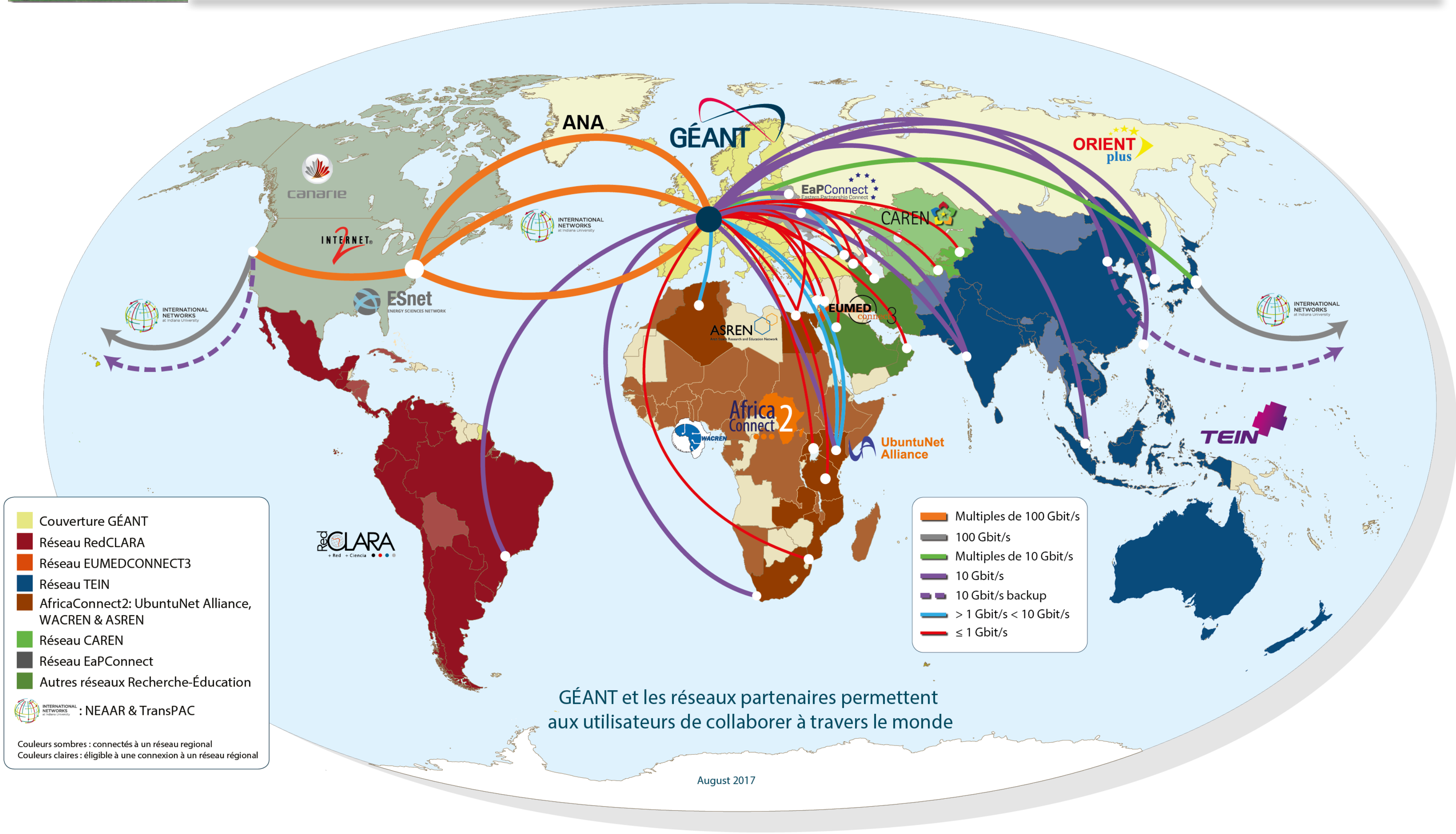
Native Ethernet interface

Generic Framing Procedure

Virtual Concatenation



THE WORLD IS HIGH-SPEED!



Is it really?

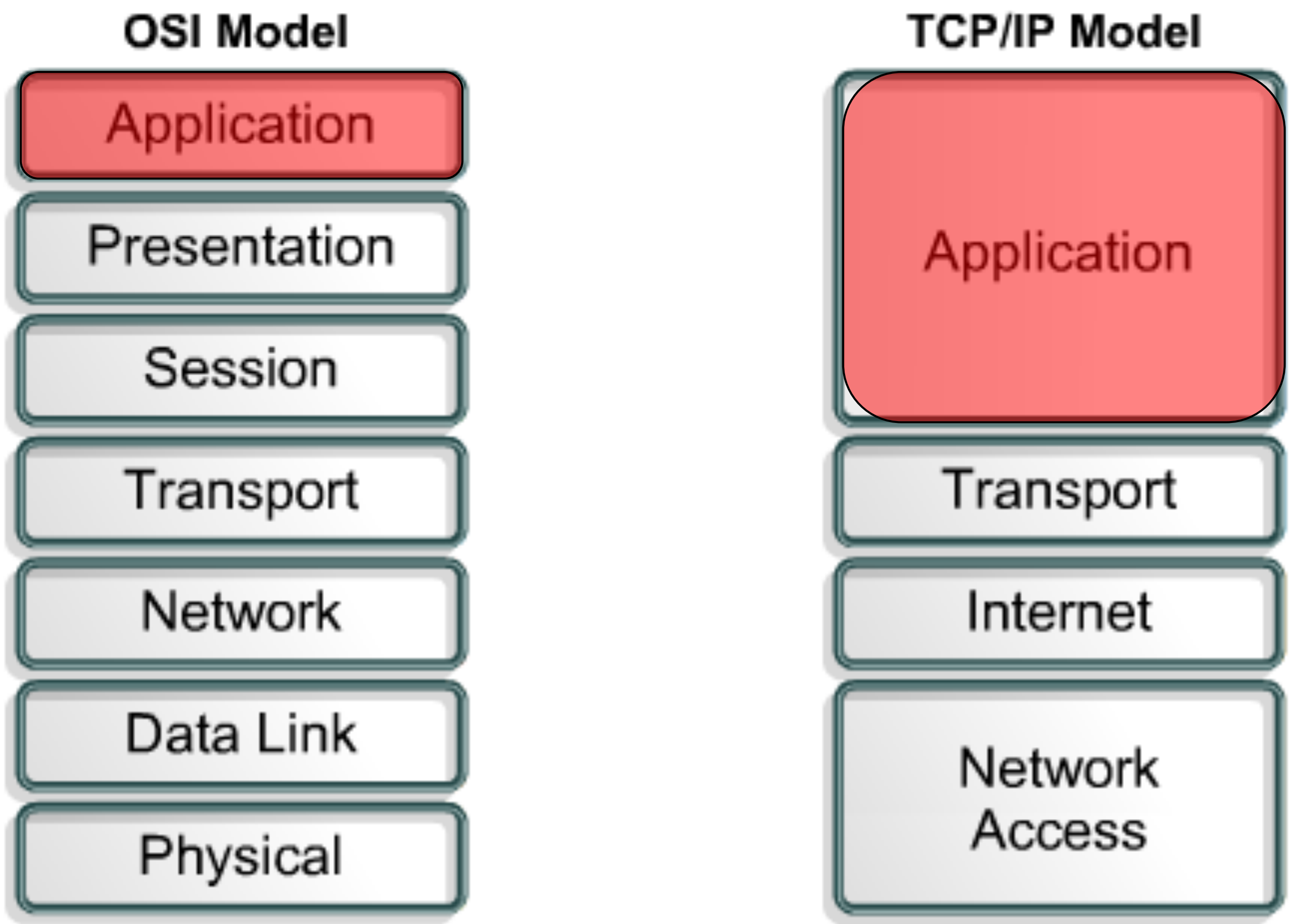
What is Quality of Service?

- Quality of service is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance
- QoS criteria are numerous and is highly dependant of the app.
  - Throughput, Delay, jitter, Loss rate, Availability, Uptime, ...
- ... Or driven by the end-user
  - Image resolution, sound quality, appropriate language, ...

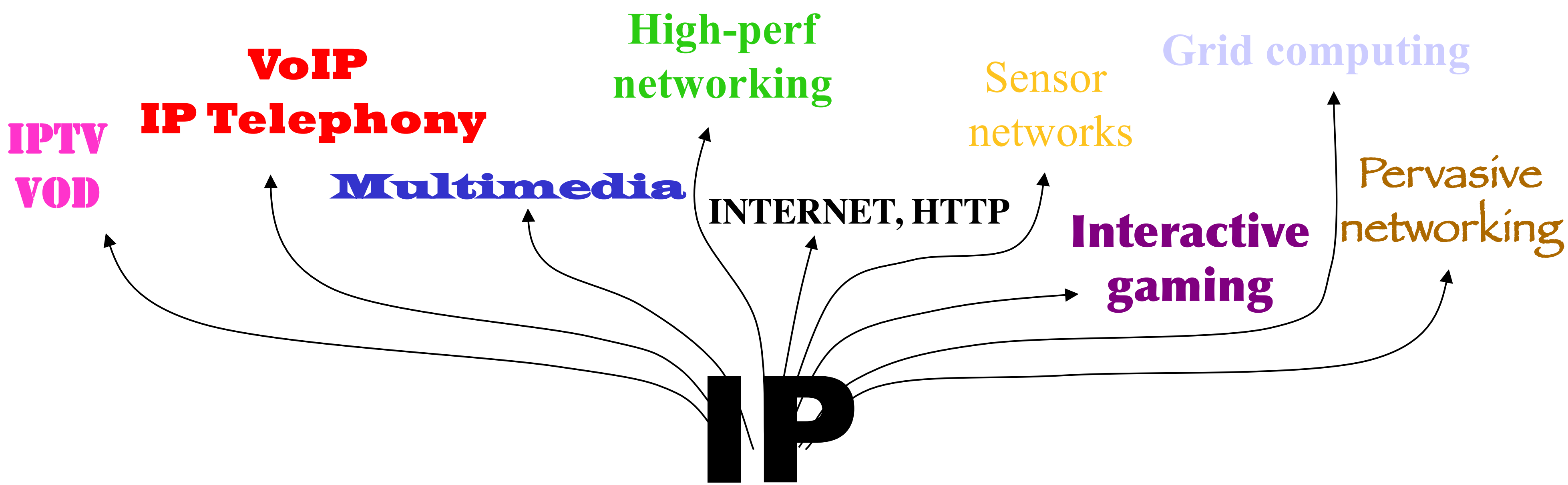
What is QoS (contd) ?

- These parameters can be measured at several granularities:
  - "micro" flow, aggregate flow, population.
- QoS considered "better" if
  - more parameters can be specified
  - QoS can be specified at a fine-granularity.
- QoS spectrum:

Where to put QoS?

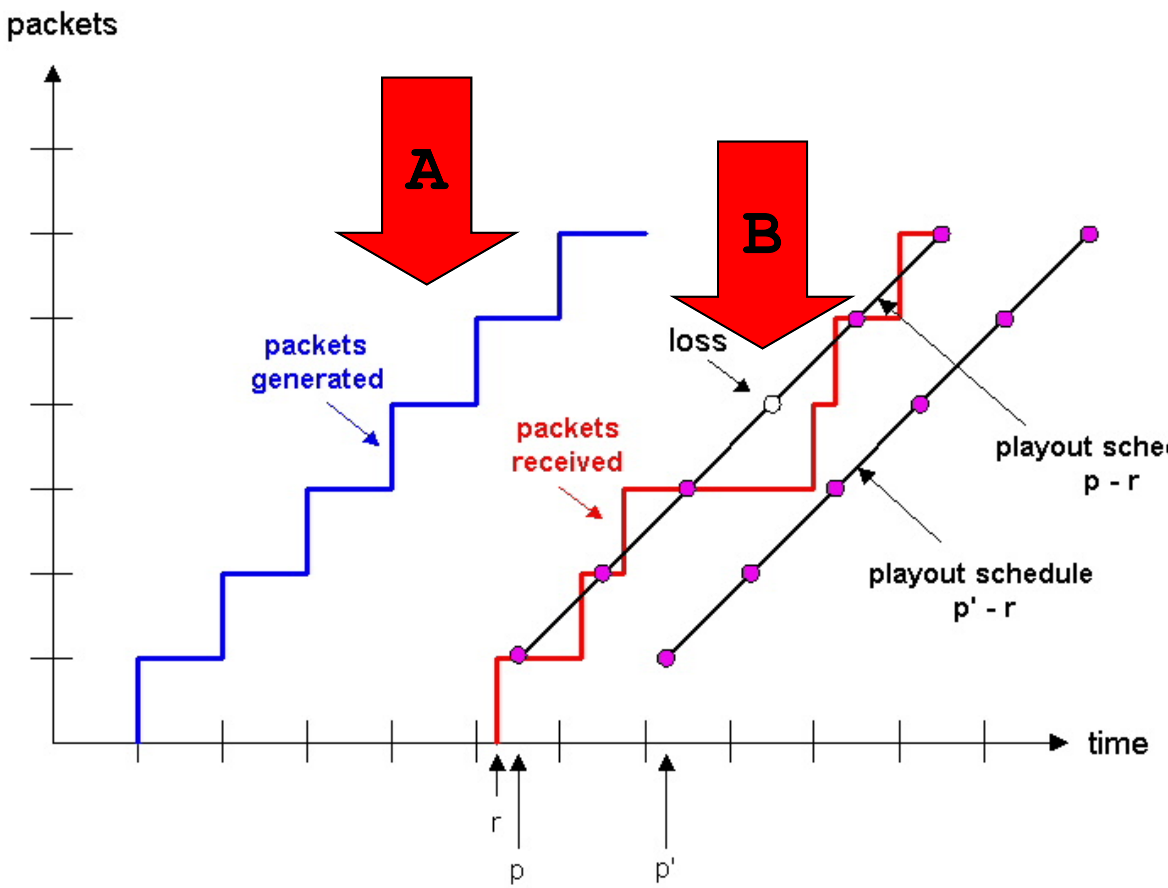


MUST maintain IP philosophy



Application layer=network as a black box

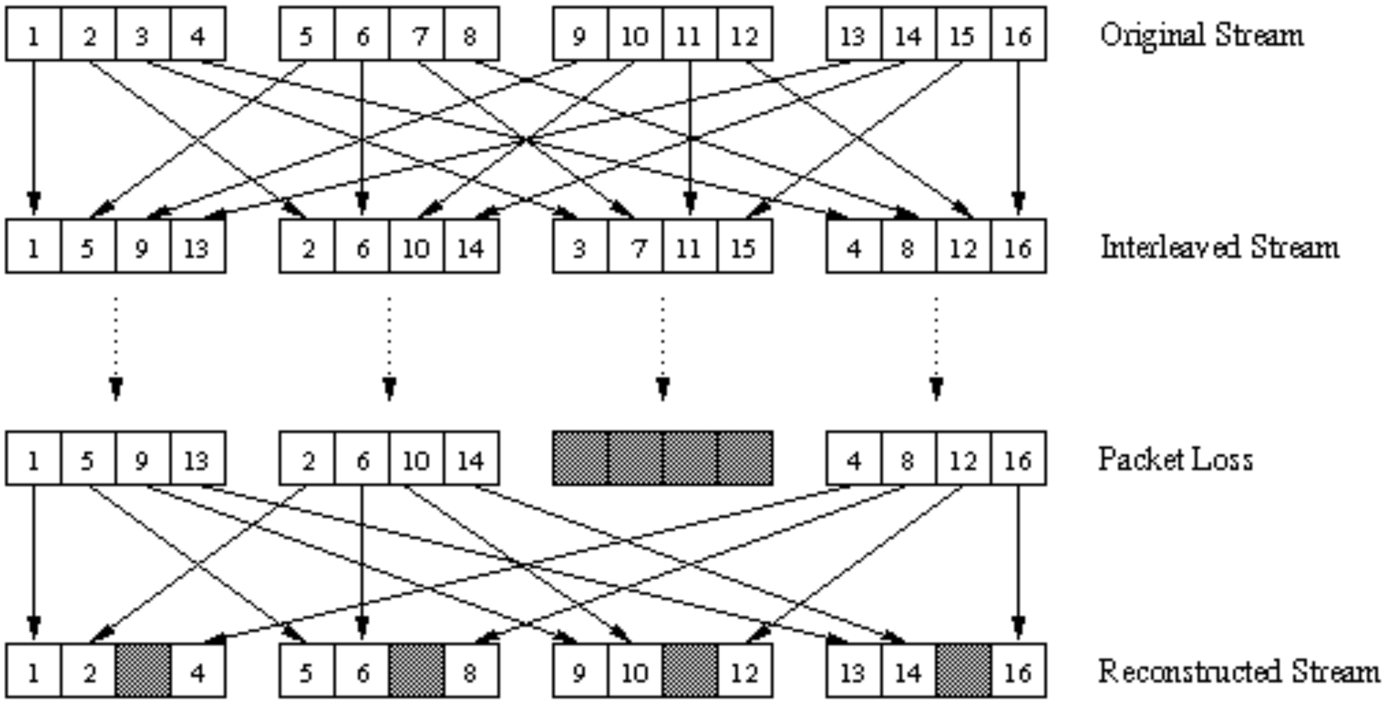
Dealing with packet jitter
Fixed playout delay



From Xavier Appé, modified by C. Pham for educational purpose only

Recovering from packet loss Interleaving

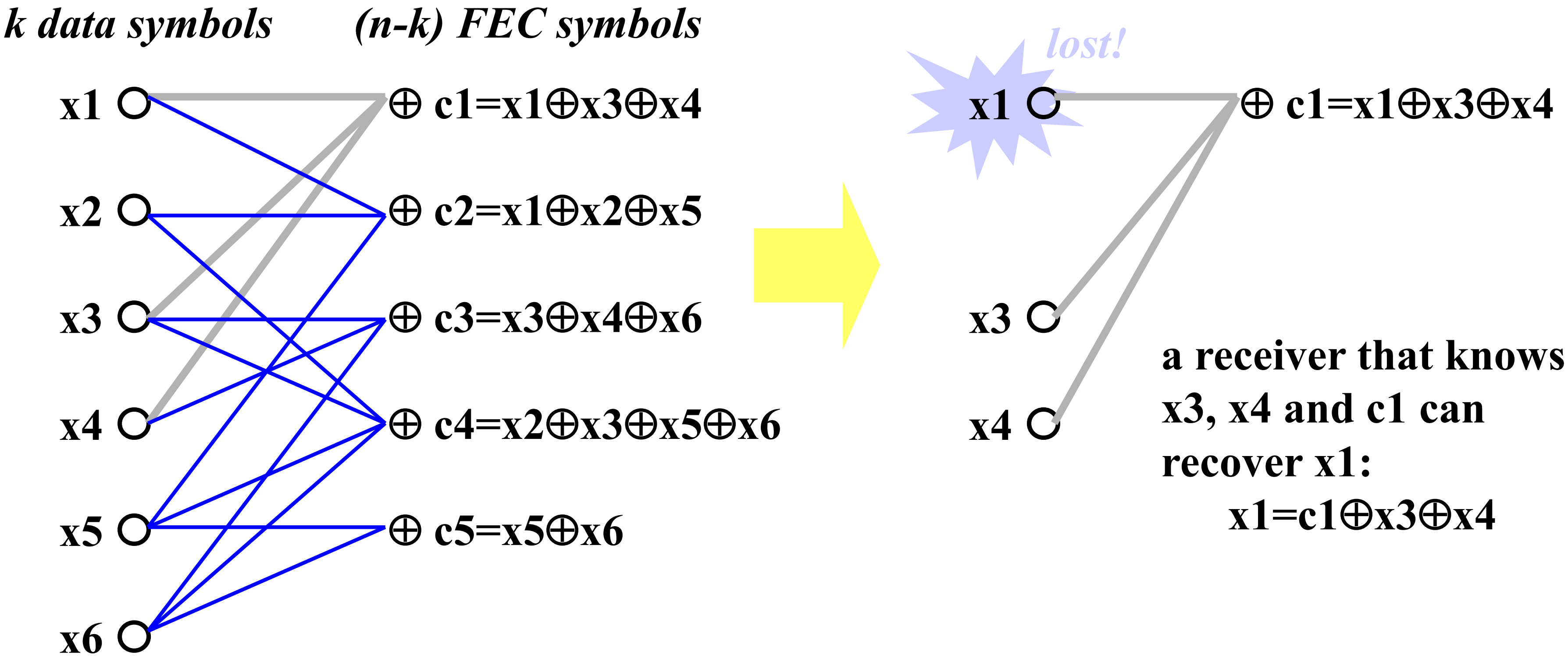
- Divide 20 msec of audio data into smaller units of 5 msec each and interleave
- Upon loss, have a set of partially filled chunks



From Xavier Appé, modified by C. Pham for educational purpose only

Large block FEC codes...

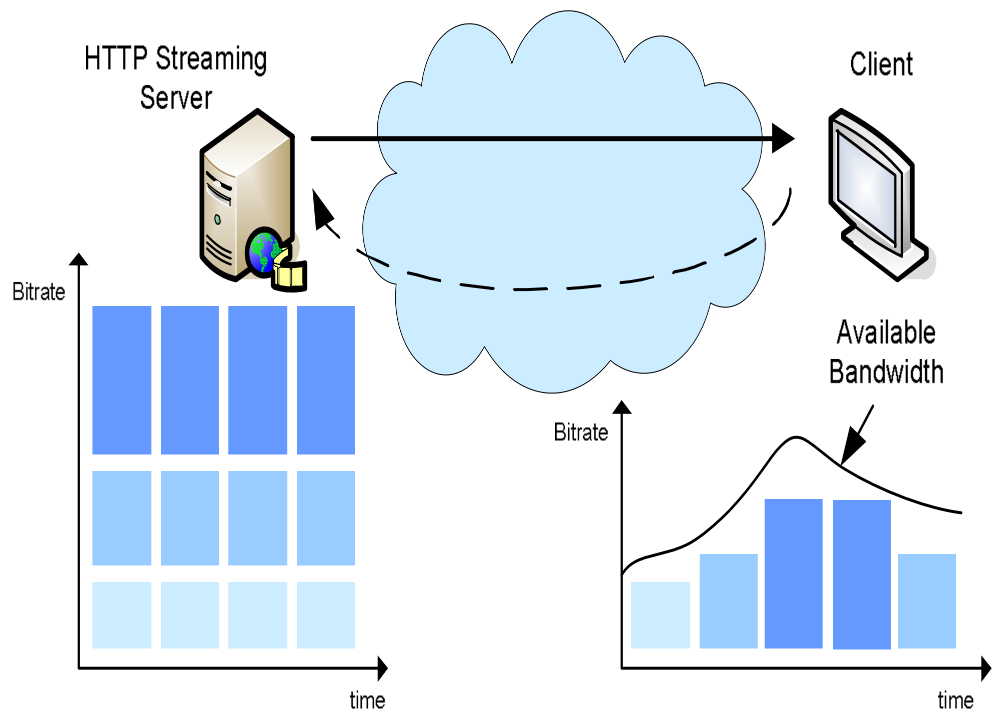
- an example: LDPC code
  - based on XOR operations (⊕)
  - uses bipartite graphs between source and FEC symbols
  - iterative decoding



From Xavier Appé, modified by C. Pham for educational purpose only

DASH: Dynamic Adaptive Streaming over HTTP

The DASH standard is a video streaming technique based on segments, available in various quality and transfered with HTTP 1.1



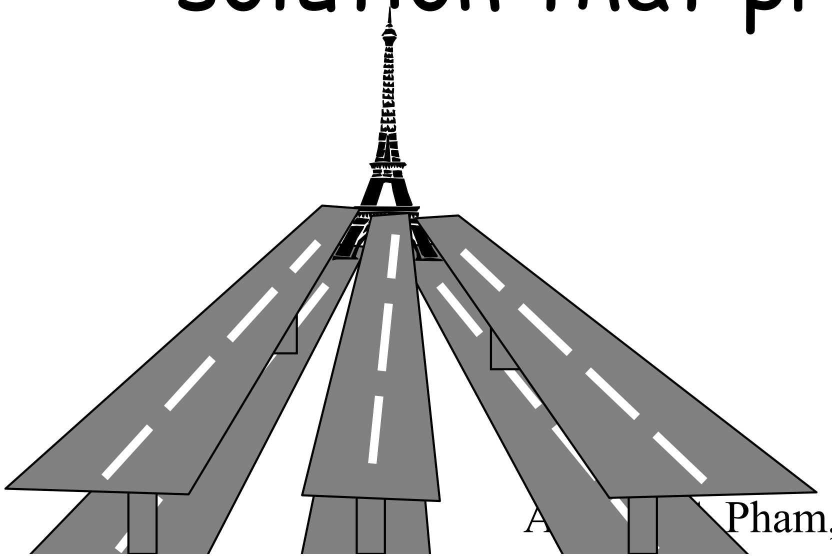
Independently decodable chunks in several formats and bitrates

Client downloads the next chunk depending on the available bandwidth

Source Yassine HADJADJAOUL

Overprovisioning in the core

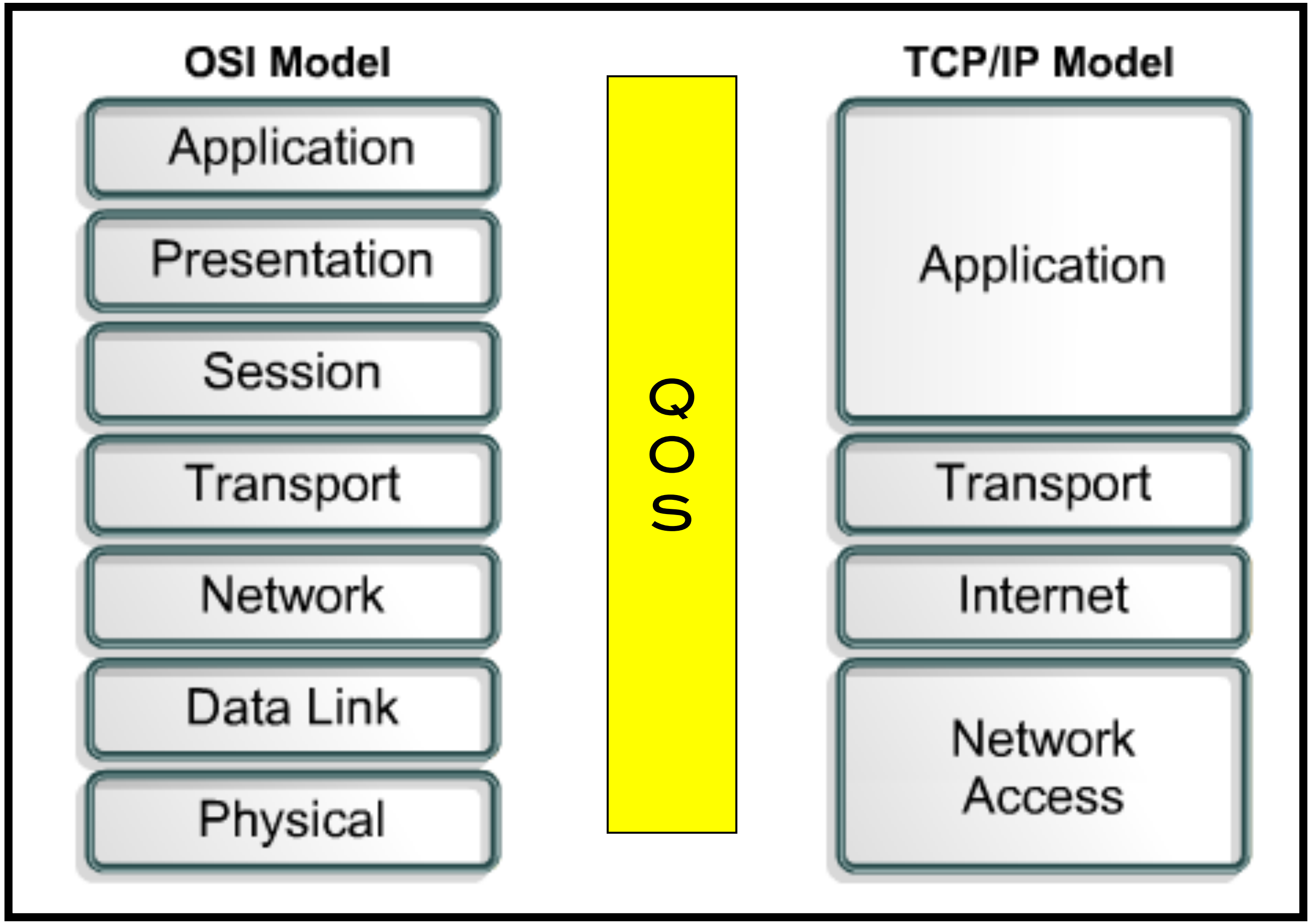
- Most operators are overprovisioning bandwidth with DWDM fibers
- 10Gbps, 40Gbps, 160 GBps, 320 Gbps
- Overprovisioning is a short-term solution that prevents optimizations



IP desired service

- Isolation: my traffic is not impacted at all by yours
- Protection: my transmission path is backed up to the nth degree by failover paths
- Throughput: I get the capacity I pay for
- Delay: Whatever pattern of packets timing I send with is preserved at the far-end

30 years of INTERNET QoS...



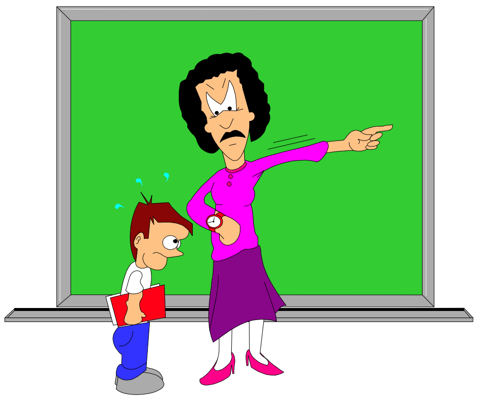
…have shown the power of selfishness!

WHY SHOULD I BOTHER WITH QOS WHEN…

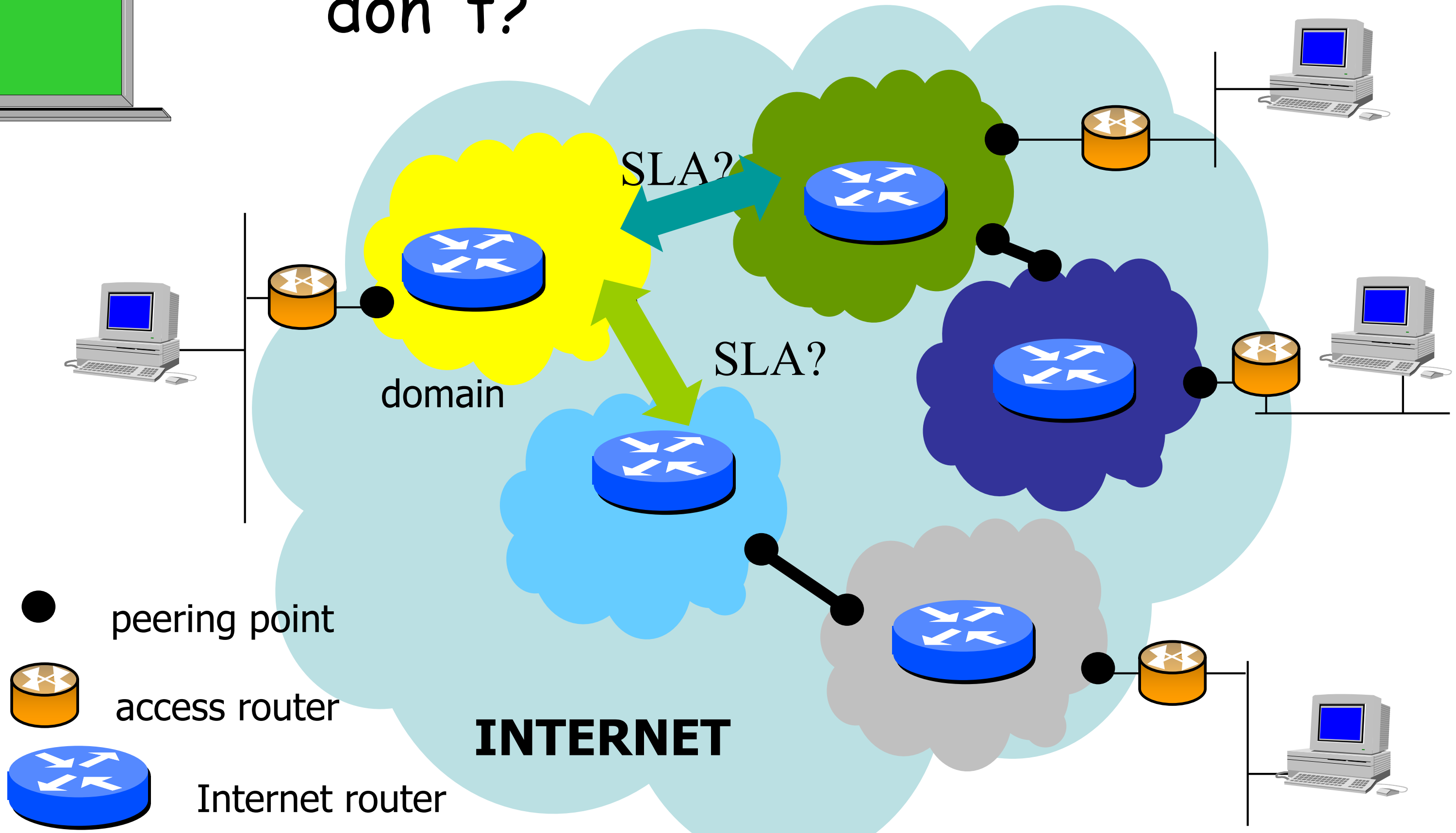
…OTHERS DON'T DO IT?

It's not my fault!

« environmental problems often have impacts beyond borders »



- What's the point of deploying QoS if others don't?



Current Internet's QoS

Q

IT WORKS!

So why change?

Sustainable development

- "meets the needs of the present without compromising the ability of future generations to meet their own needs" [Brundtland Report, 1987]
- Trade-off between performance and needs: « why are we producing? »
- Use the right ressource, at the right place, at the right time

a new dimension of global responsibility—
not only to planetary resources but also to planetary fairness

Is overprovisioning harmful?

- NO: overprovisioning is not very costly. Adding new wavelengths is quick. Customers are happy and quick return on investment!

- YES: while overprovisioning, alternative solutions are not deployed. High risk that relying too much on old technologies makes upgrades impossible (c.f. IPv6, TCP,…)

Lessons learned from sustainable development

- Limit globalization
- Limit the pursuit of continued economic prosperity
- Redistribute labour, wages,...
- Promote the use of local resources
- Change mentality

Community networks?

CONNECTED COMMUNITIES
CONFINE

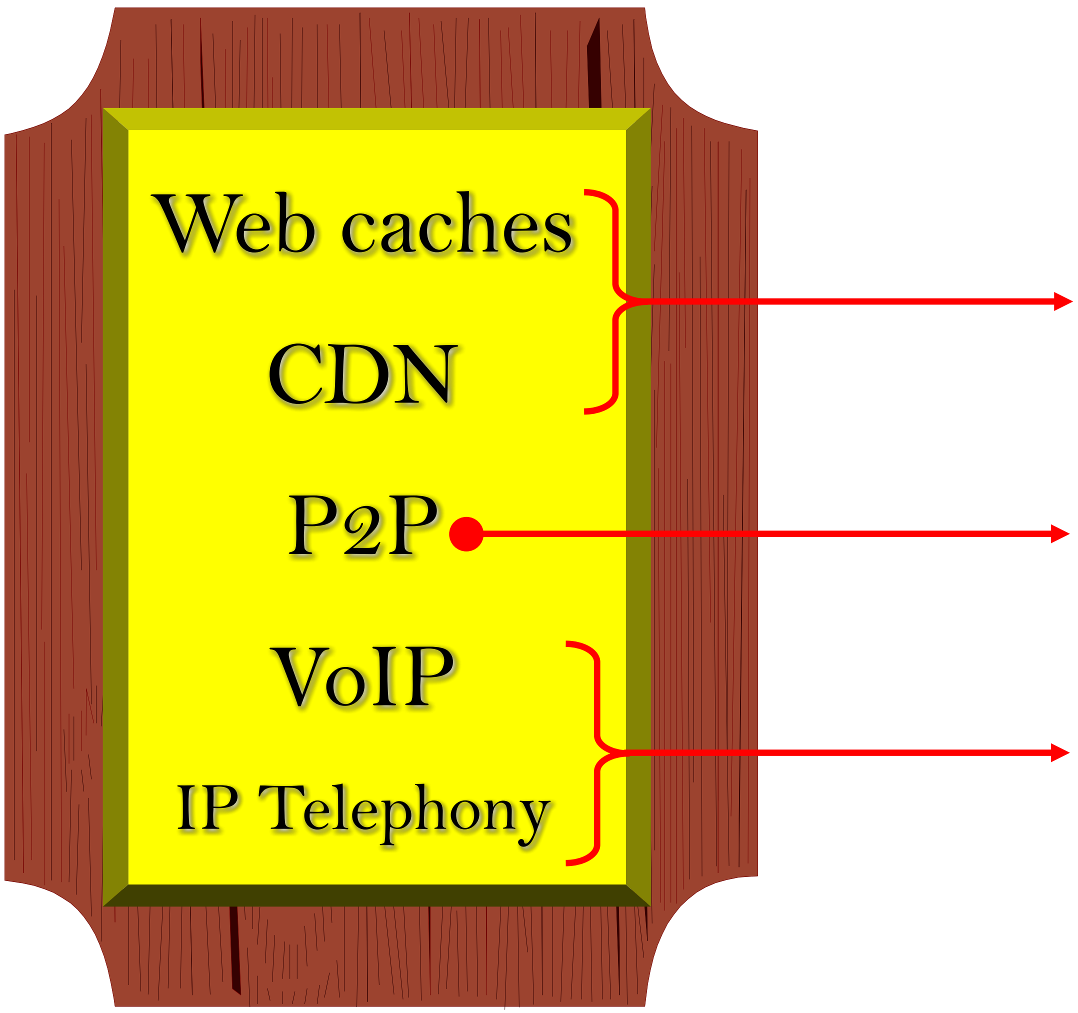
Limitations of the current Internet

- Bandwidth
  - Raw bandwidth is not a problem: DWDM
  - Provisioning bandwidth on demand is more problematic
- Latency
  - Mean latencies on Internet is about 80-160ms
  - Bounding latencies or ensuring lower latencies is a problem
- Loss rate
  - Loss rate in backbone is very low
  - End-to-End loss rates, at the edge of access networks are much higher
- Communication models
  - Only unicast communications are well-defined: UDP, TCP
  - Multi-parties communication models are slow to be deployed

Net Neutrality or Not?

- NN or NNN? That's the question!
- NN = dumb network!
- Internet's success is in a large part debtful to what's called Net Neutrality (IP neutrality)

Some NN success stories

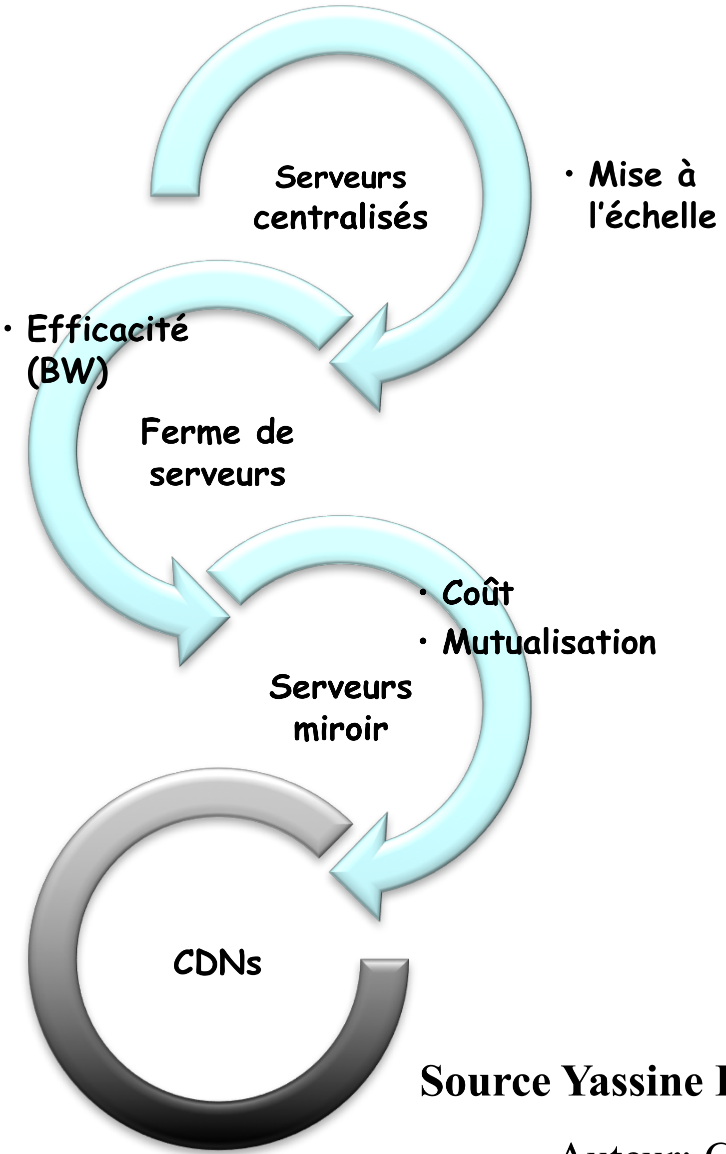


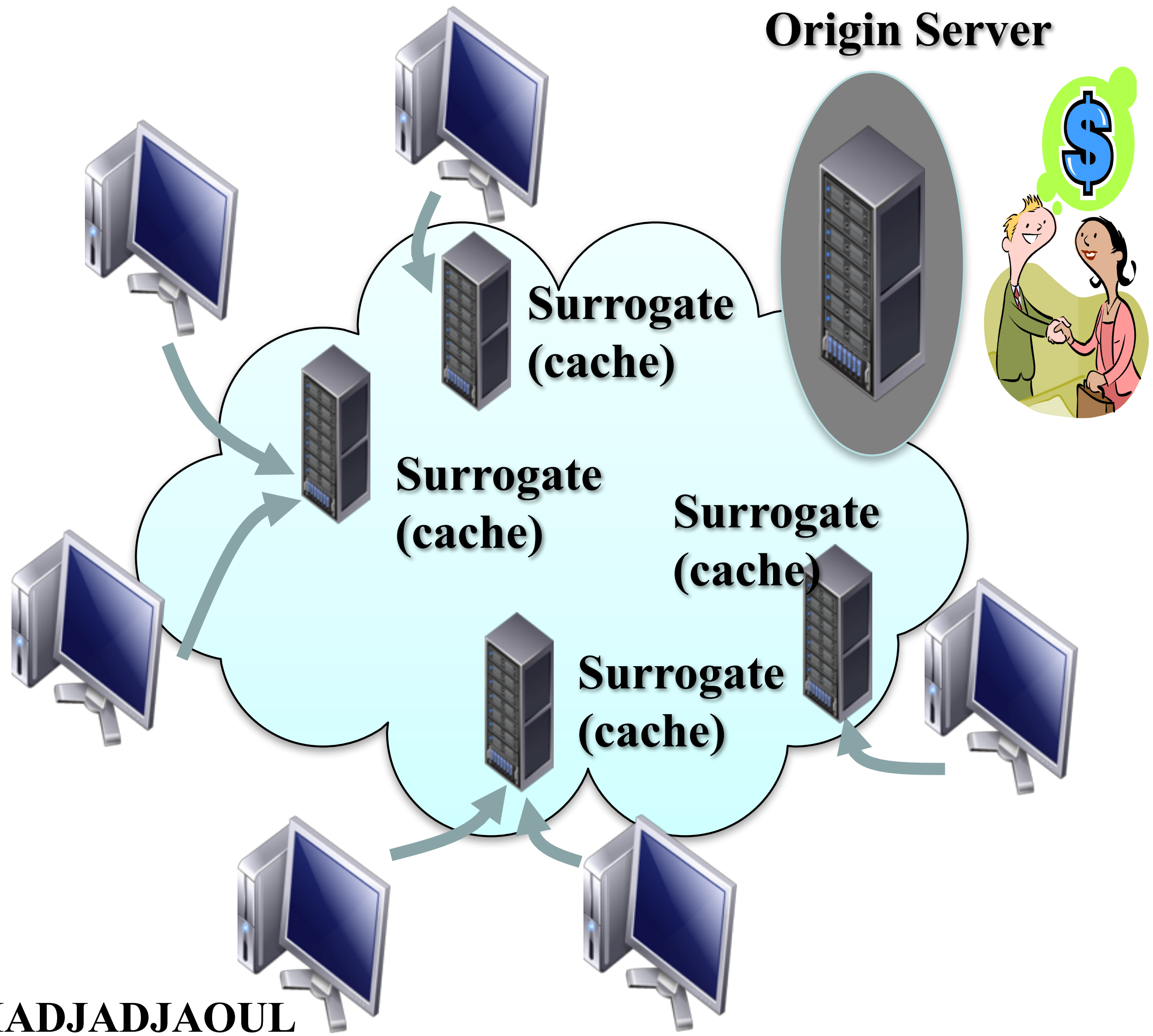
Distribution of resources, use of local resources

Distribution & Overprovisioning

Overprovisioning!

CDN





Source Yassine HADJADJAOUL

The Akamai EdgePlatform:

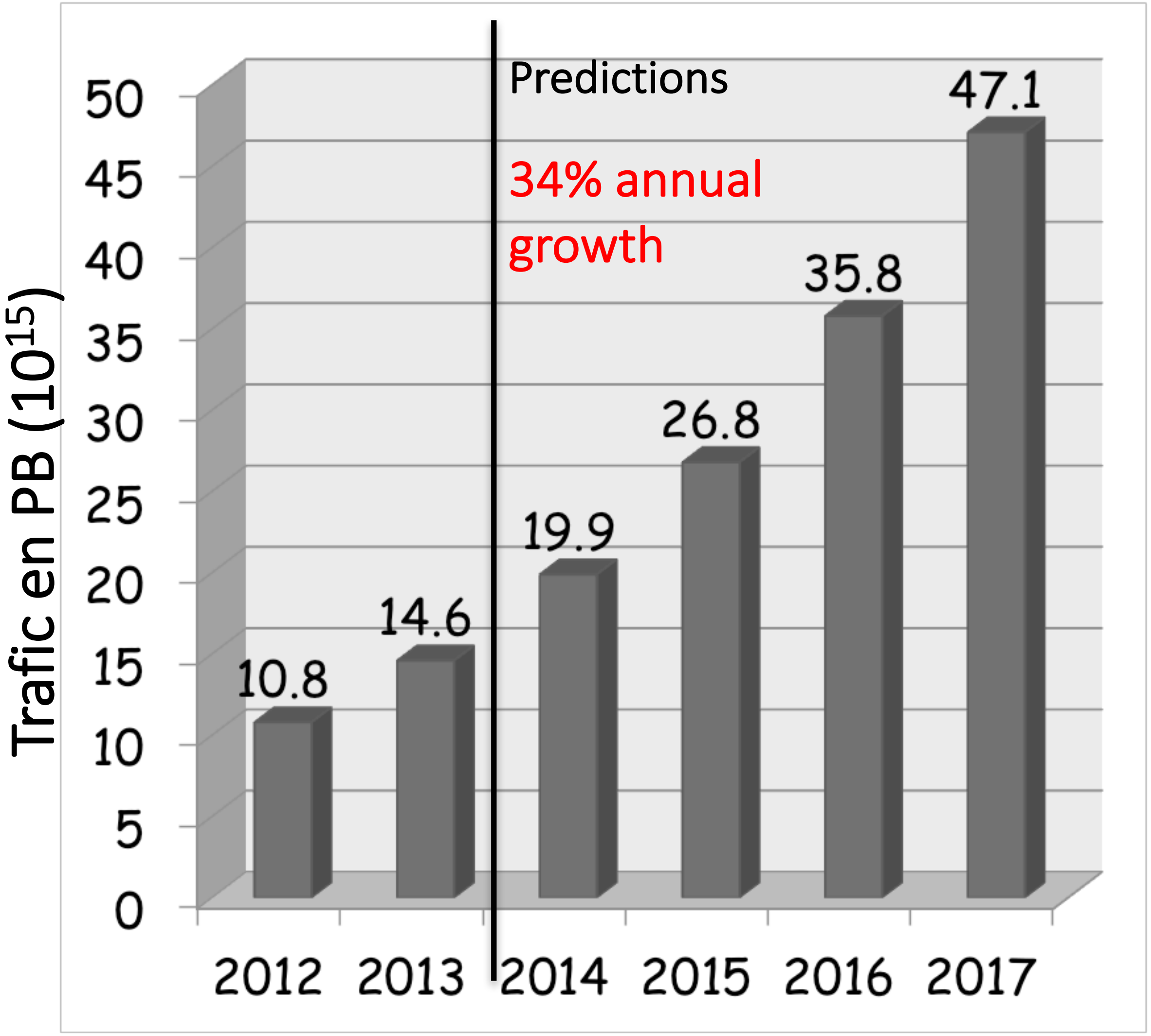
85,000+ Servers	1700+ POPs	950+ Networks	660+ Cities	72+ Countries

Resulting in traffic of:

5.4 petabytes / day
790+ billion hits / day
436+ million unique clients IPs / day

Source Yassine HADJADJAOUL

CDNs traffic evolution

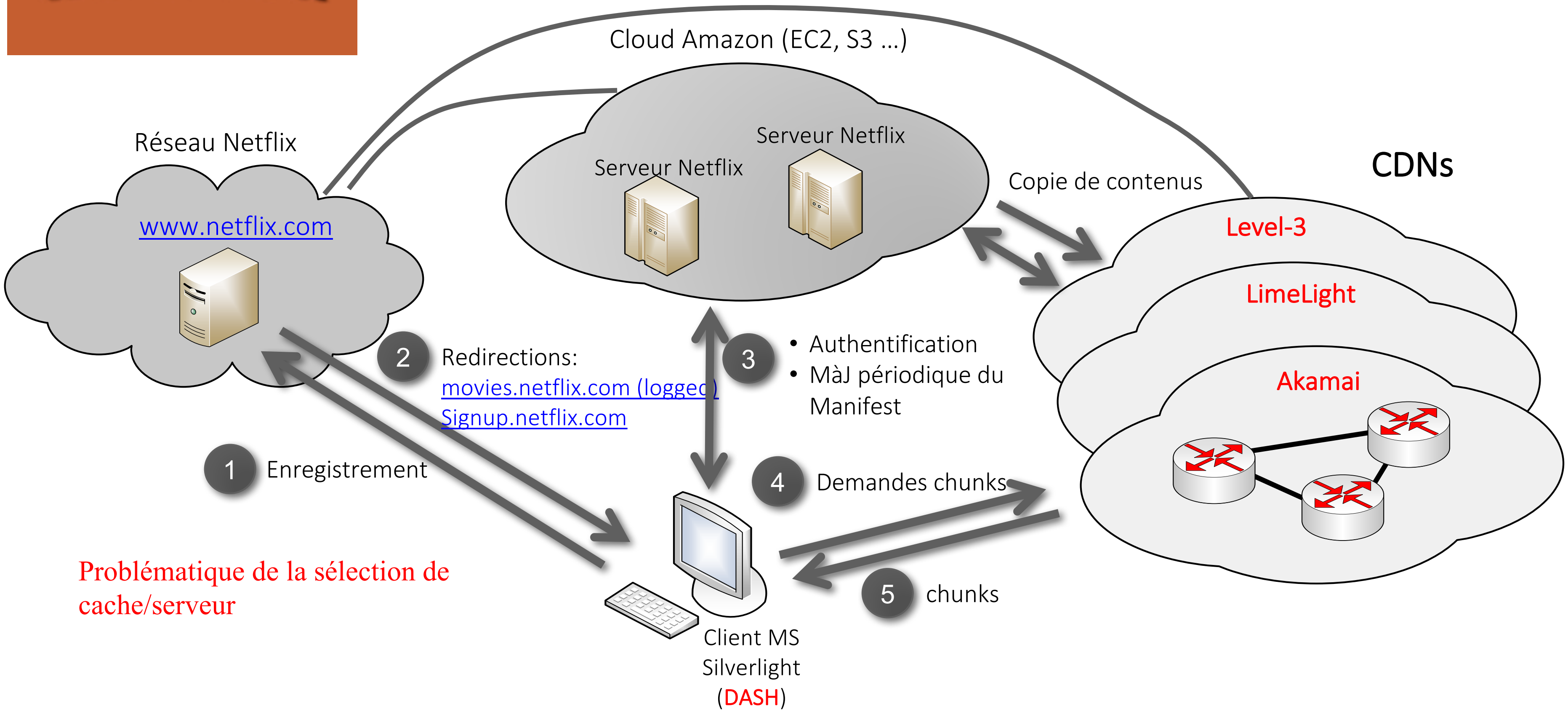


Source Yassine HADJADJAOUL

- Dominating method for streaming.
  - 51% of Internet traffic will go through CDNs in 2017 (34% in 2012).
  - 65% of video traffic on Internet will go through CDNs in 2017 (53% in 2012)

Typical architecture

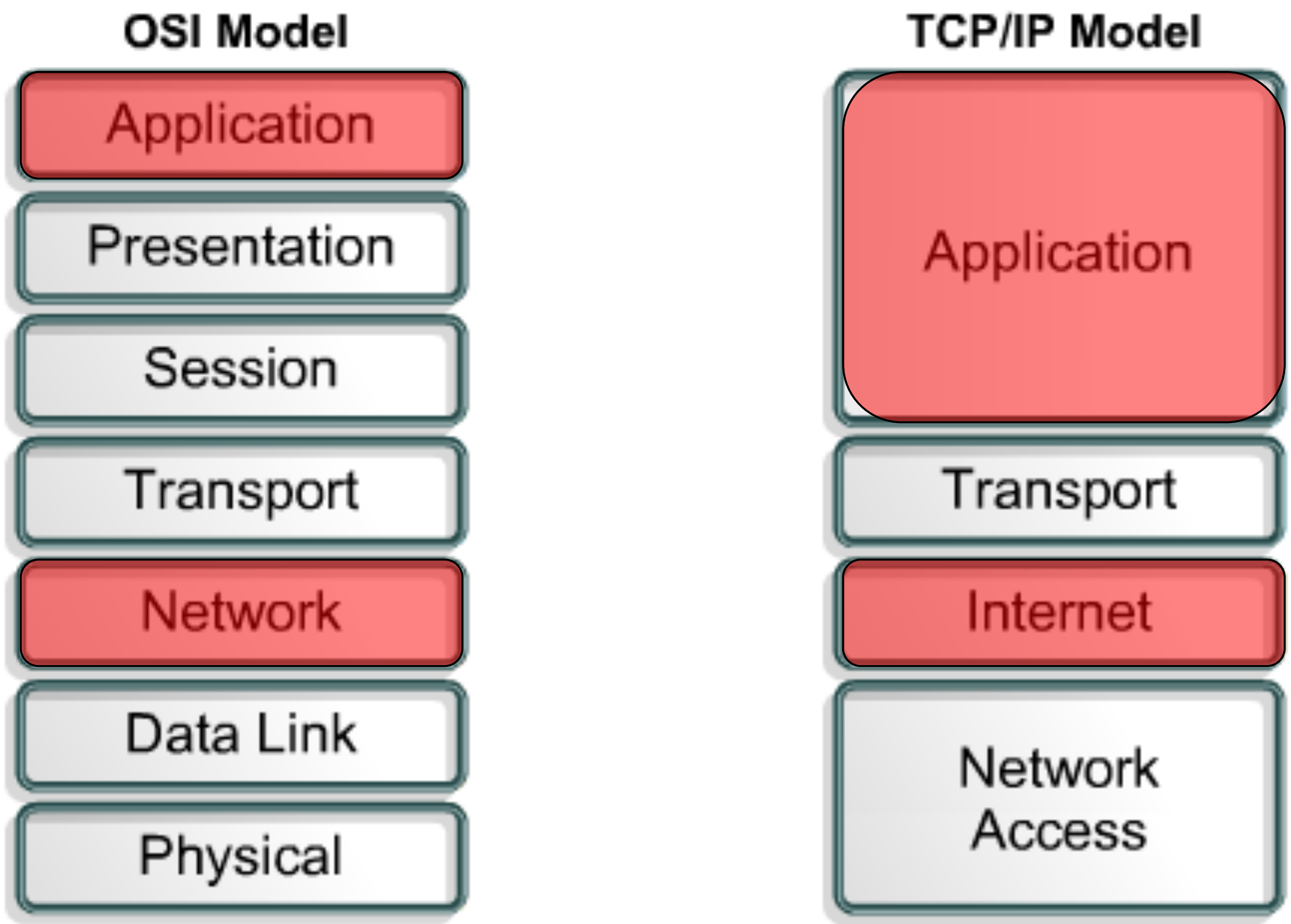
Source Yassine HADJADJAOUL



Problématique de la sélection de cache/serveur

V. K. Adhikari, Y. Guo, F. Hao, M. Varvello, V. Hilt, M. Steiner, and Z.-L. Zhang. INFOCOM, page 1620-1628. IEEE, (2012)

Where to put QoS?



Internet Routers

©cisco

©Juniper

©Procket Networks

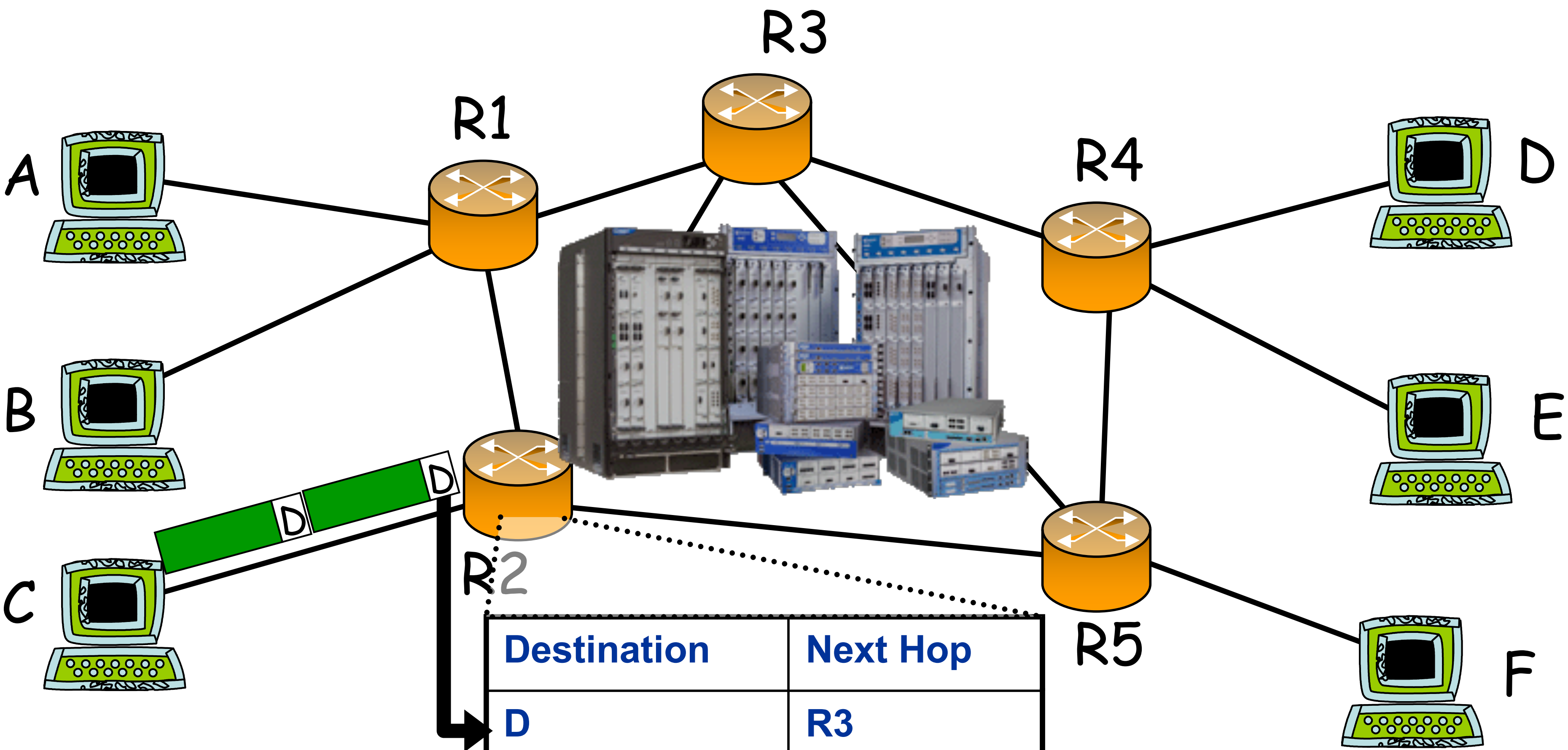
©Alcatel

©Nortel Networks

©Lucent

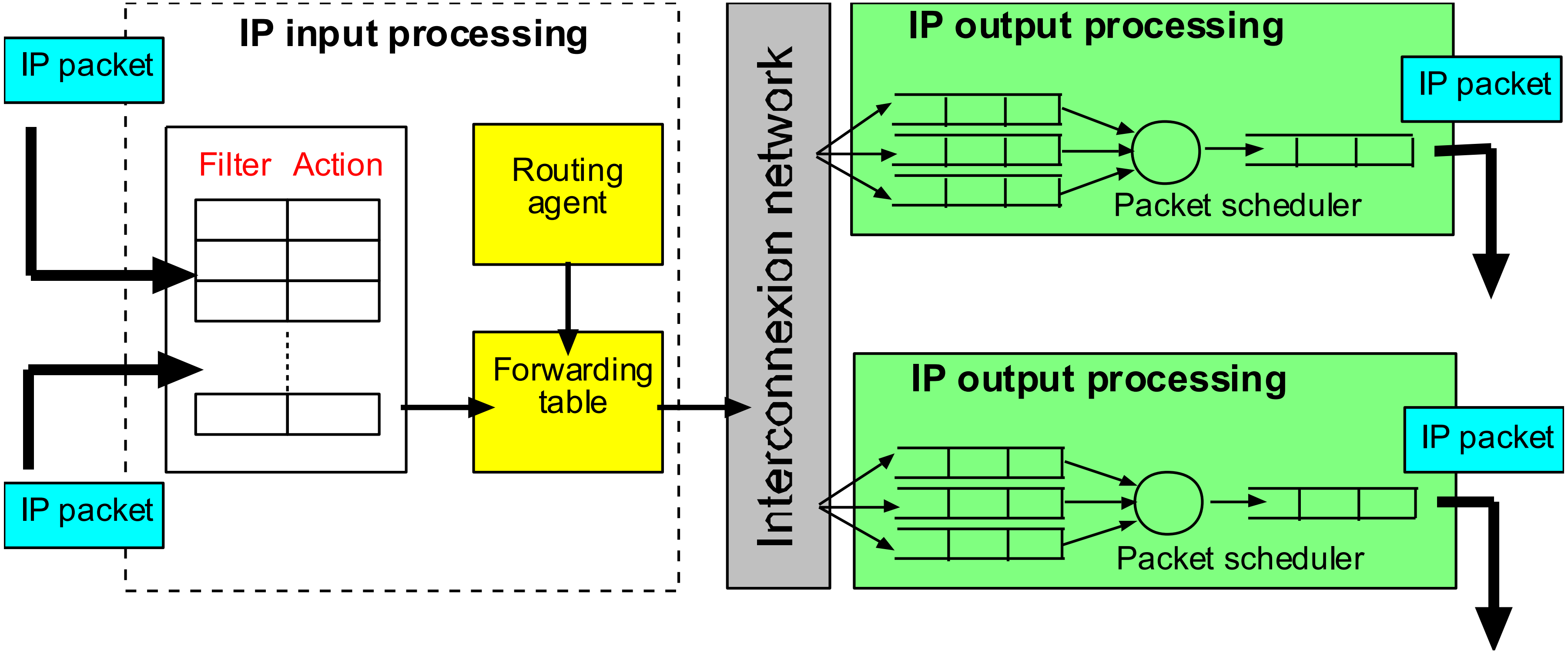
and more…

If no NN then give more power to routers!



Destination	Next Hop
D	R3
E	R3
F	R5

General architecture of an IP router



- receives input packets,
- sends packets to output buffers,
- transmits packets.

In 2000, I had a dream: active networking!

- Programmable nodes/routers
- Customized computations on packets
- Standardized execution environment and programming interface
- No killer applications, only a different way to offer high-value services, in an elegant manner
- However, adds extra processing cost

Motivations behind Active Networking

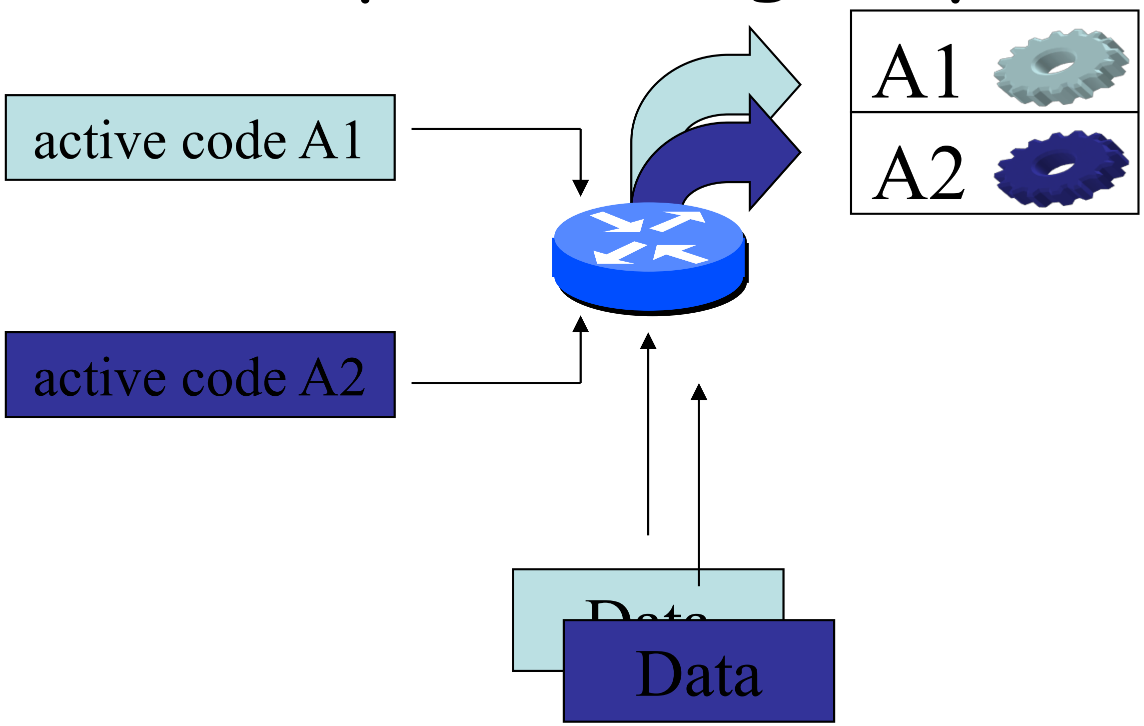
- From the user perspective
  - applications can specify, implement, and deploy (on-the-fly) customized services and protocols
- From the operator perspective
  - reduce the latency/cost for new services deployment/management
- From the network perspective
  - globally better performances by reducing the amount of traffic

Active networks implementations

- Discrete approach (operator's approach)
  - Adds dynamic deployment features in nodes/routers
  - New services can be downloaded into router's kernel
- Integrated approach
  - Adds executable code to data packets
  - Capsule = data + code
  - Granularity set to the packets

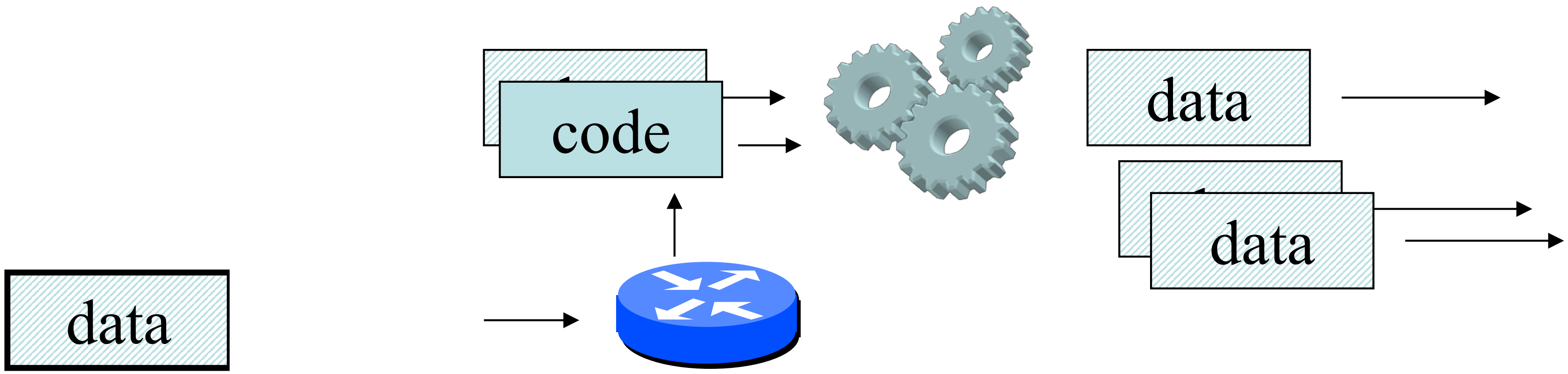
The discrete approach

- Separates the injection of programs from the processing of packets



The integrated approach

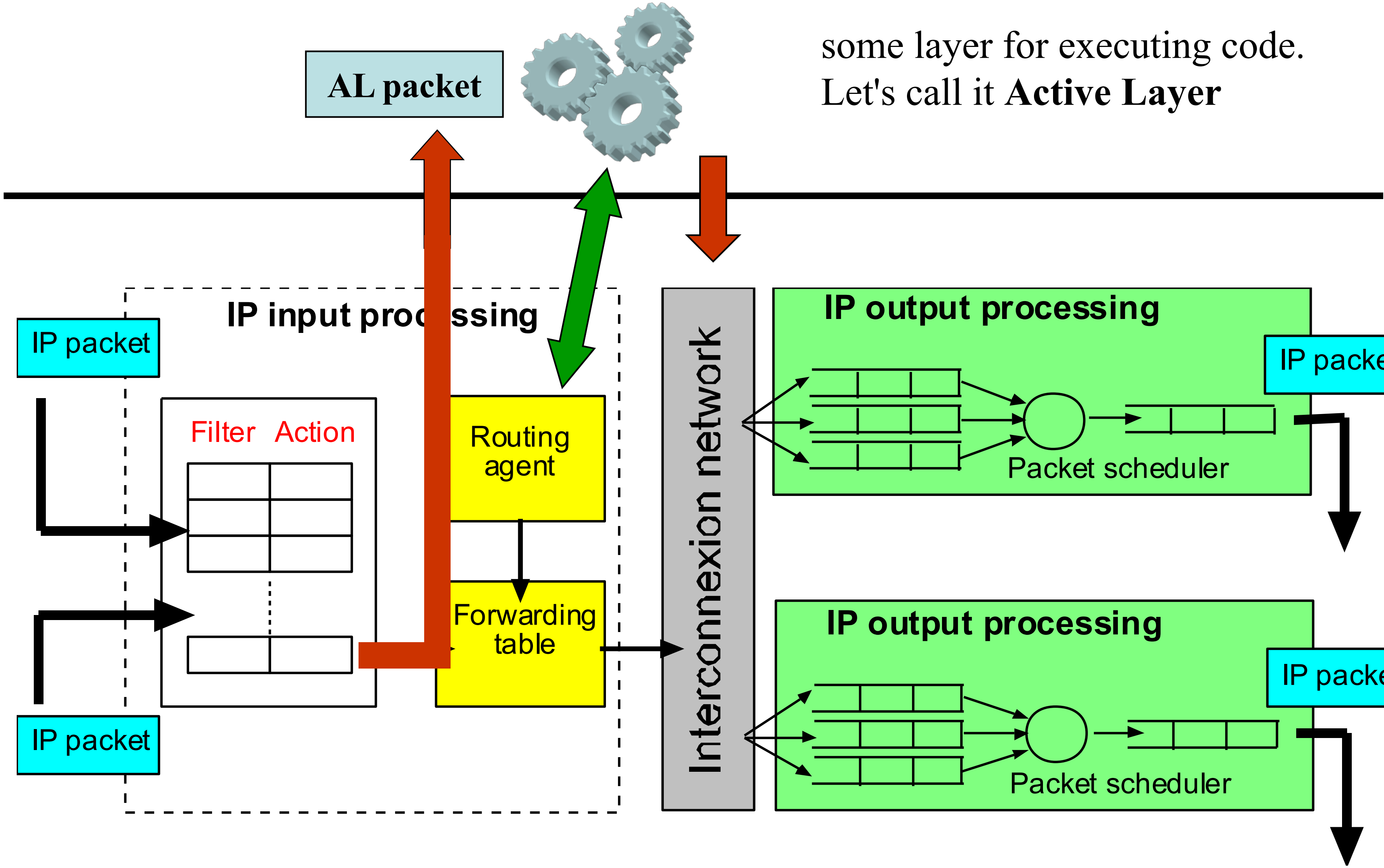
- User packets carry code to be applied on the data part of the packet



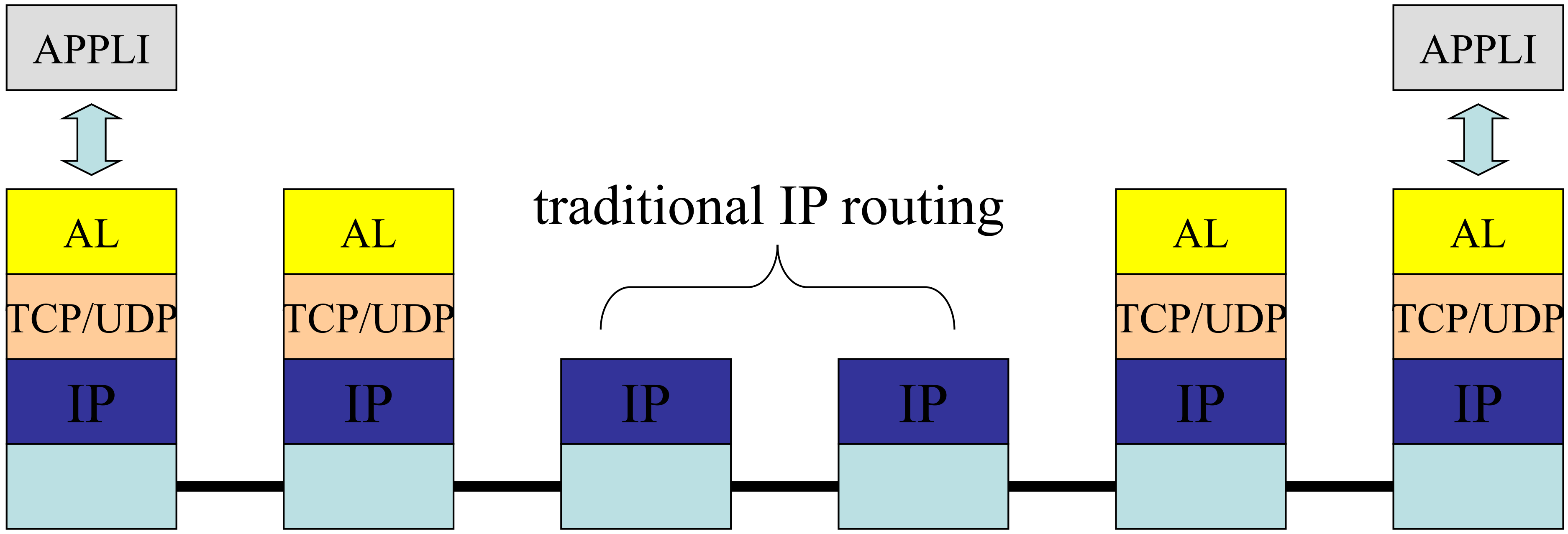
- High flexibility to define new services

An active router

some layer for executing code.
Let's call it **Active Layer**



Interoperability with legacy routers



Active network revisited

- Software Defined Networking (SDN) wants to decouple the control plane from the data plane.
- Network Function Virtualization (NFV) complements SDN by using commodity servers to run network services software versions that previously were hardware-based.
- Somehow similar to discrete active/programmable network concepts
- Better perception from the user because controlled by operators and hardware vendors
- Made possible with advances in virtualization techniques

How to upgrade the Internet for QoS?

- Approach: de-couple end-system evolution from network evolution
- End-to-end protocols: TCP, RTP, H.323, etc to spur the growth of adaptive multimedia applications
  - Assume best-effort or better-than-best-effort clouds
- Network protocols: IntServ, DiffServ, RSVP, MPLS, COPS …
  - To support better-than-best-effort capabilities at the network (IP) level