An overview of Quality of Service in networking

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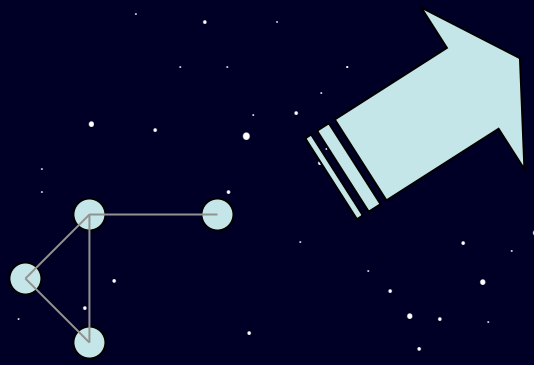
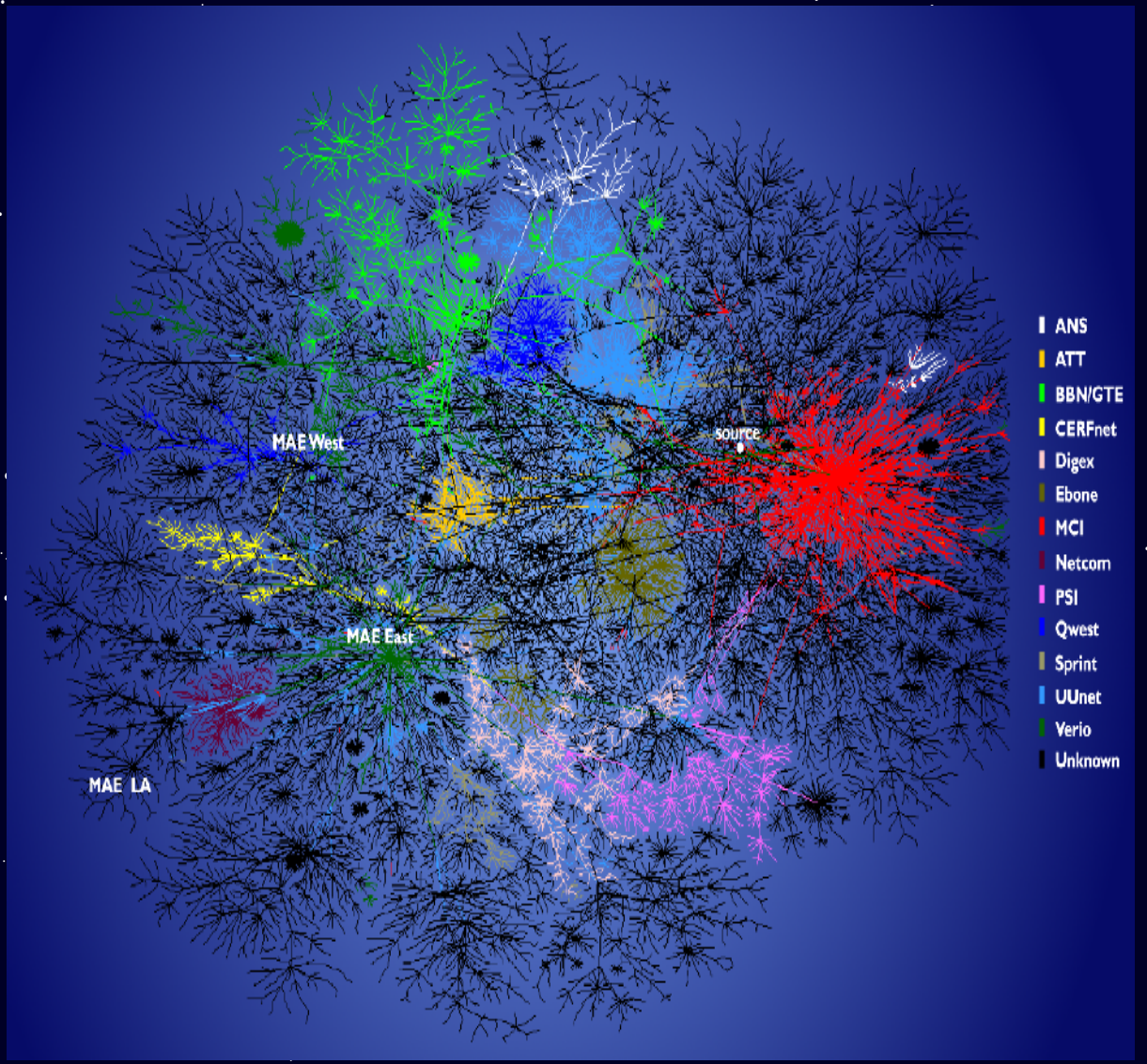
Outline

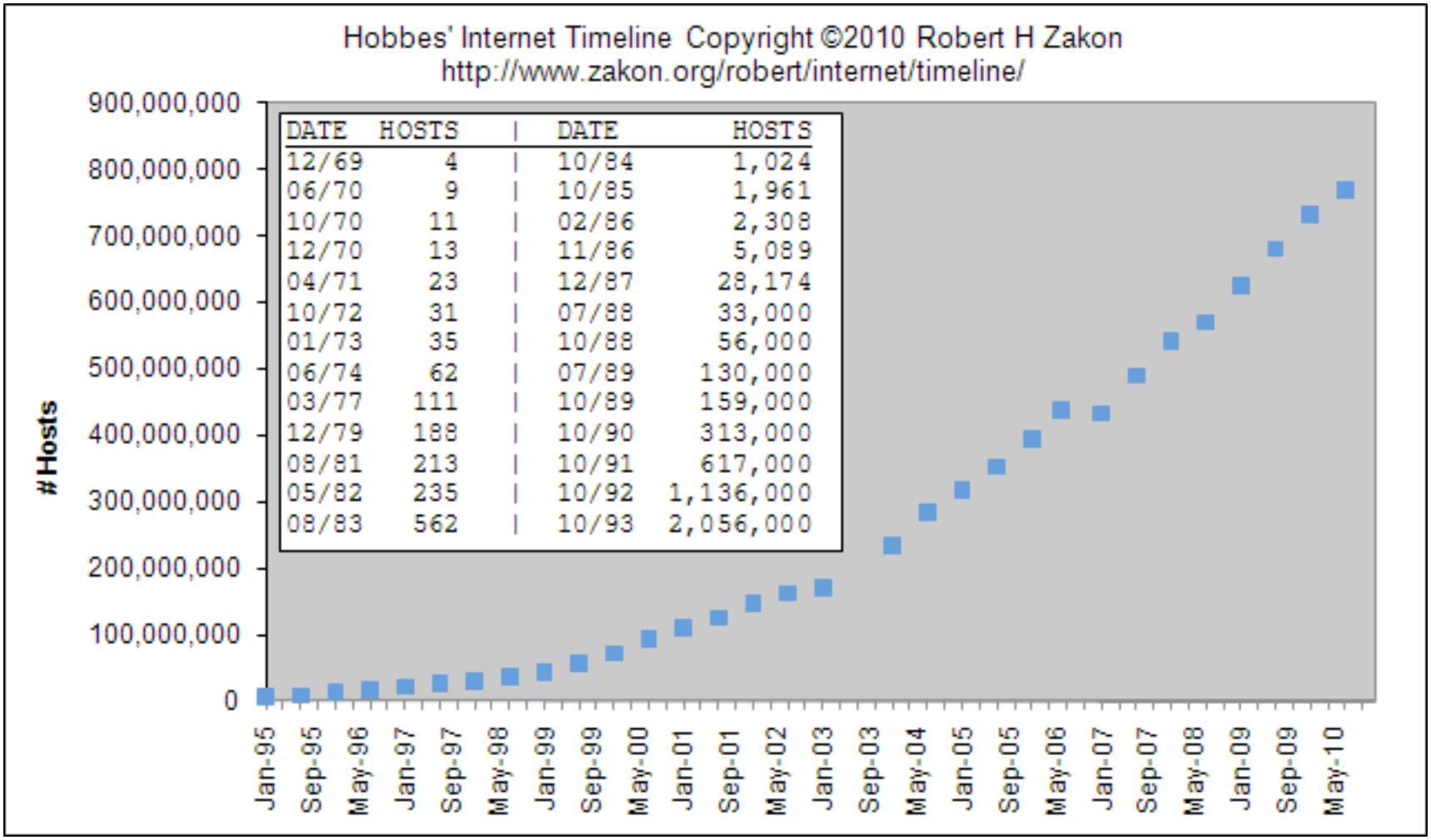
- What is Quality of Service?
- Review of high-speed wired networks
- Quality of Service in wired networks
- Quality of Service in wireless networks
- Test-case: Quality of Service for Wireless Sensor Networks

The big-bang of the Internet



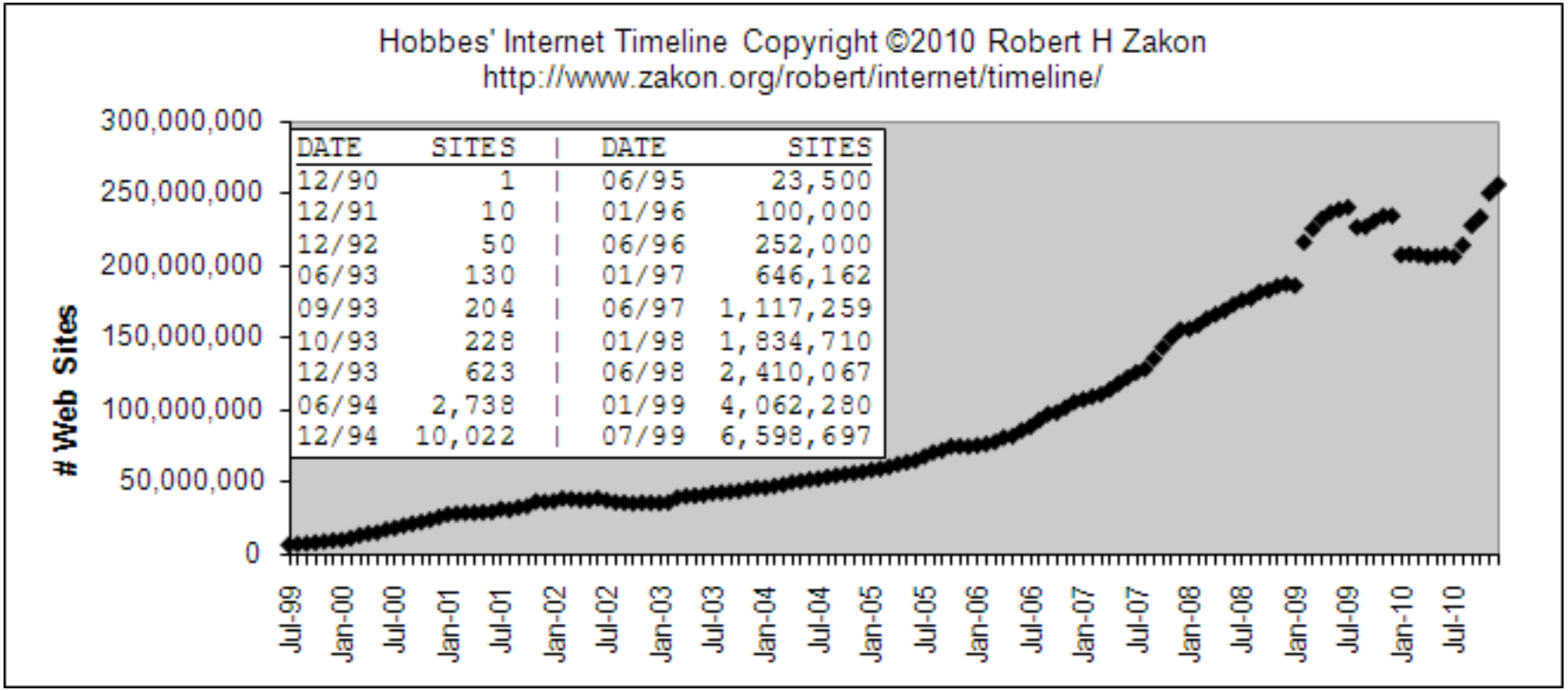


Internet host



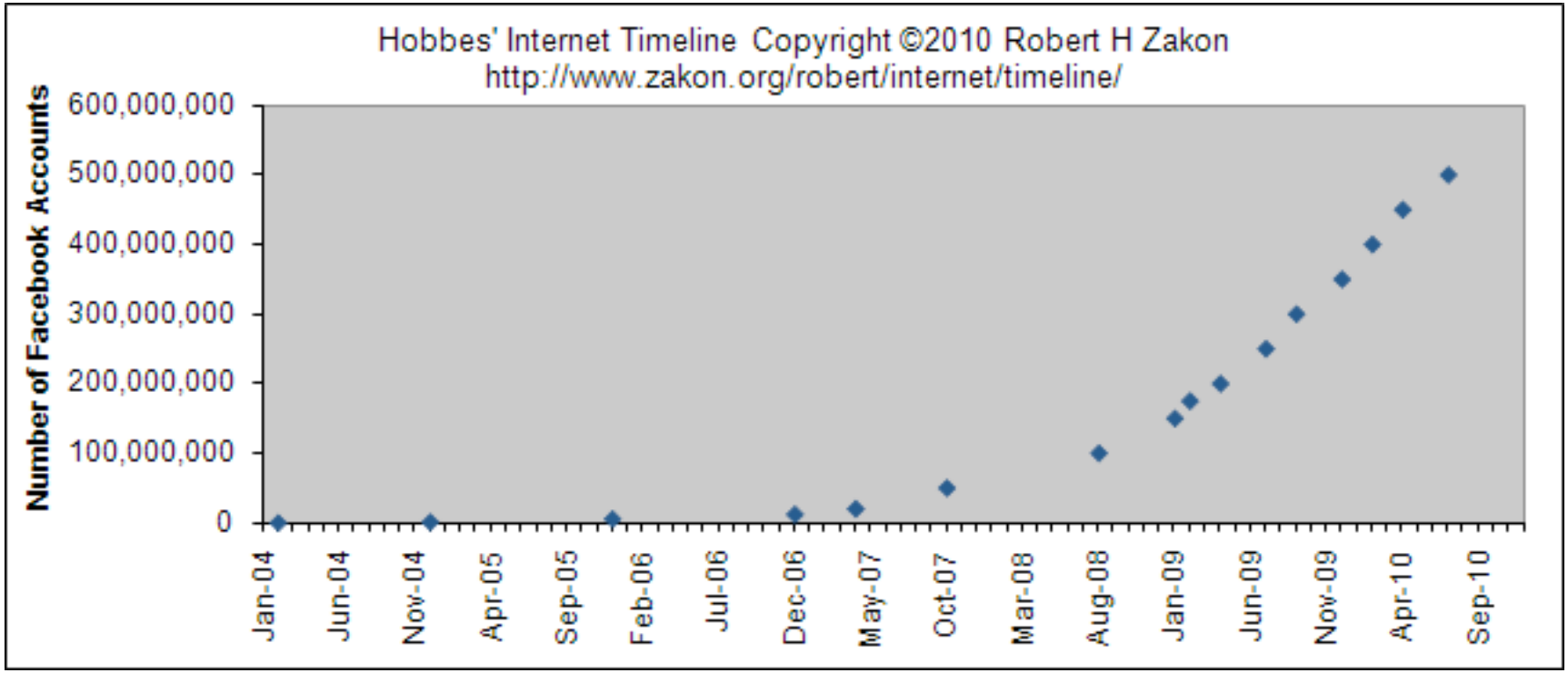
DATE	HOSTS	DATE	HOSTS
12/69	4	10/84	1,024
06/70	9	10/85	1,961
10/70	11	02/86	2,308
12/70	13	11/86	5,089
04/71	23	12/87	28,174
10/72	31	07/88	33,000
01/73	35	10/88	56,000
06/74	62	07/89	130,000
03/77	111	10/89	159,000
12/79	188	10/90	313,000
08/81	213	10/91	617,000
05/82	235	10/92	1,136,000
08/83	562	10/93	2,056,000

of www sites

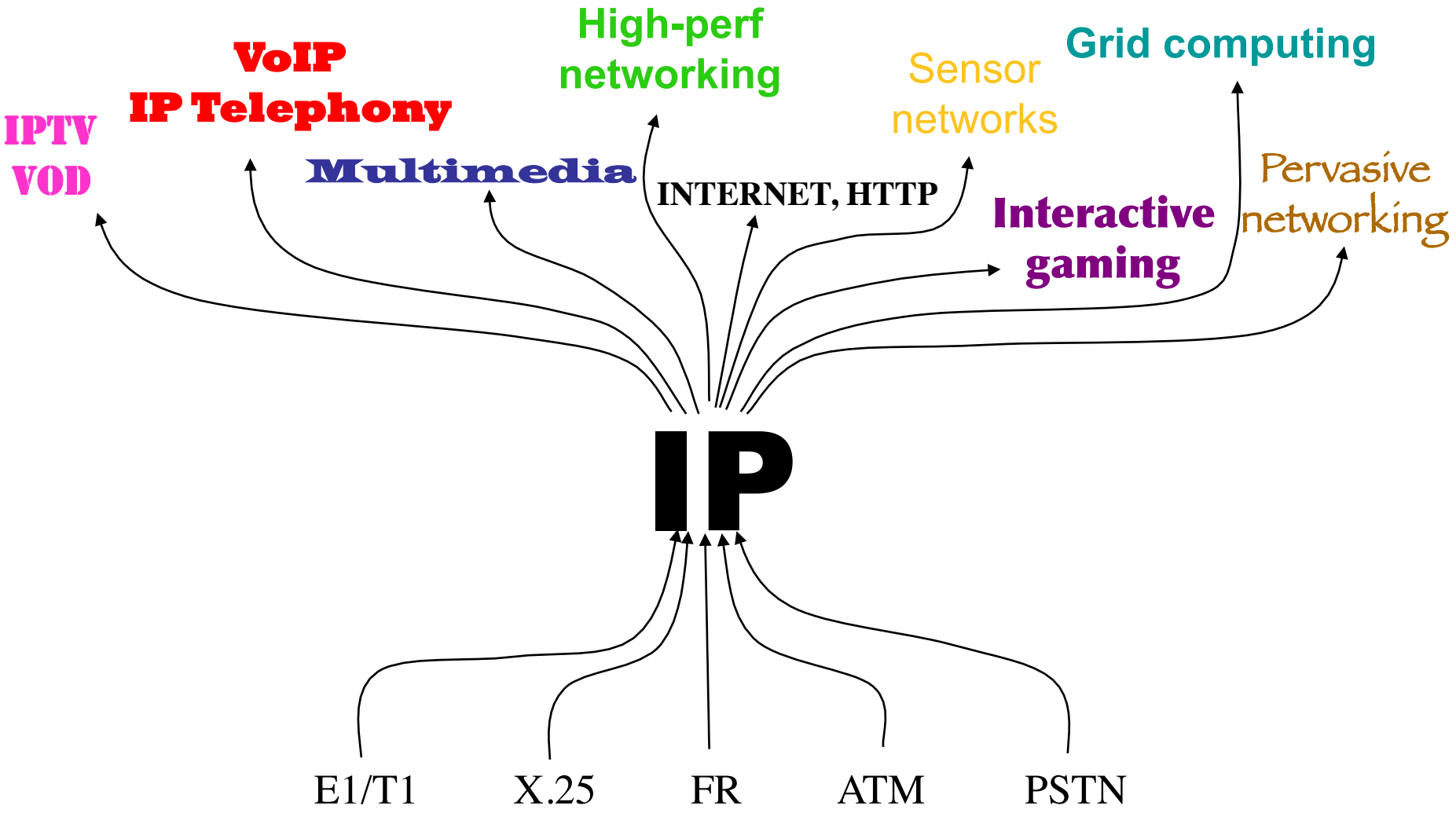


DATE	SITES	DATE	SITES
12/90	1	06/95	23,500
12/91	10	01/96	100,000
12/92	50	06/96	252,000
06/93	130	01/97	646,162
09/93	204	06/97	1,117,259
10/93	228	01/98	1,834,710
12/93	623	06/98	2,410,067
06/94	2,738	01/99	4,062,280
12/94	10,022	07/99	6,598,697

of facebook account



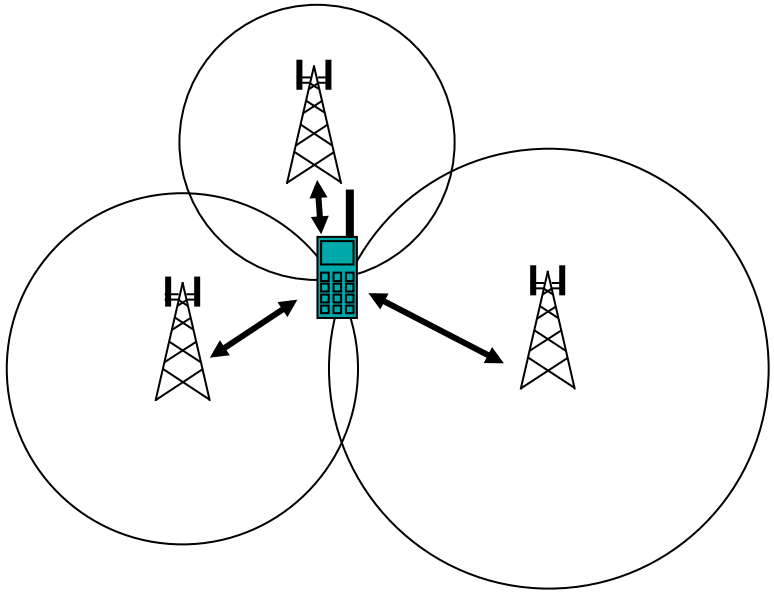
Towards all IP



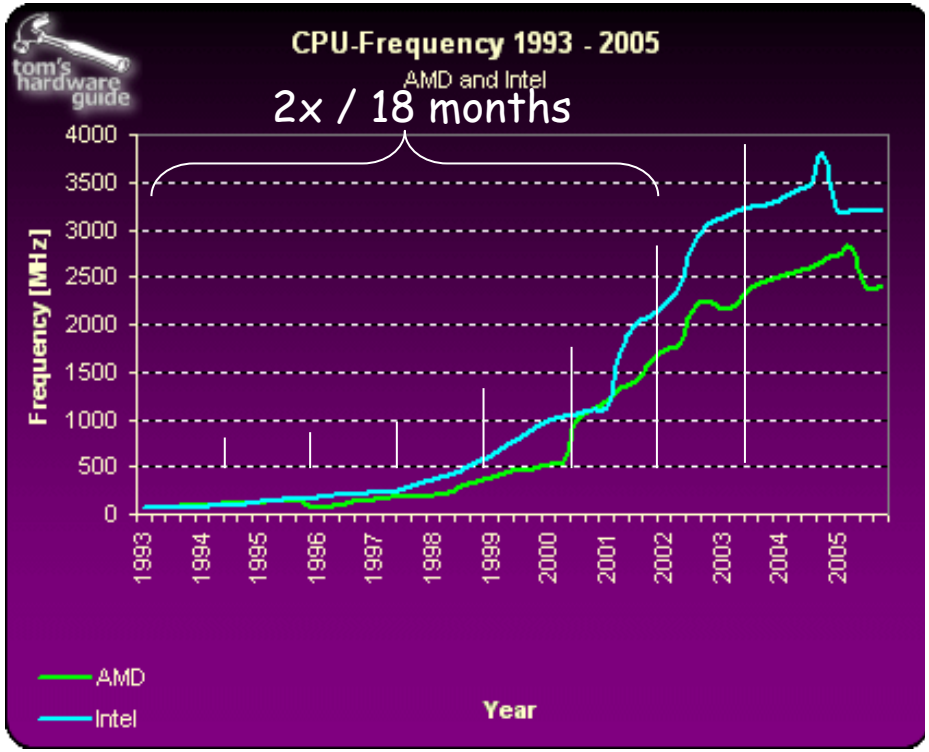
A whole new world for IP

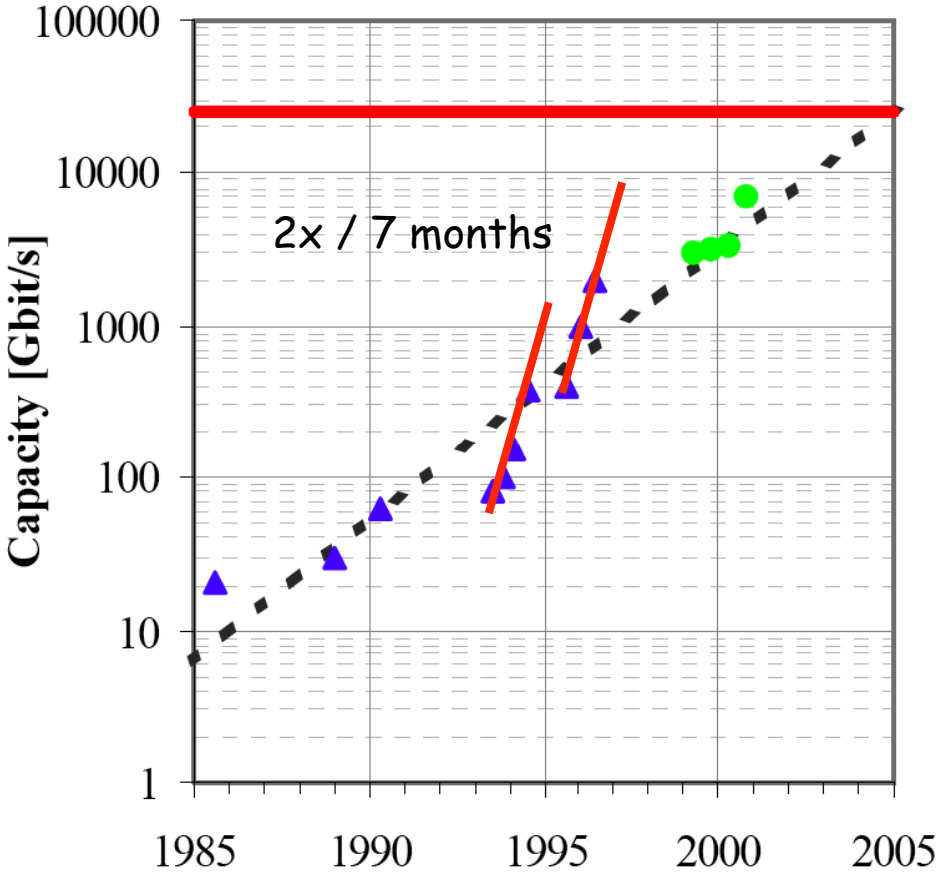
1st revolution: Wireless Networks

- WiFi, WiMax
- BlueTooth, ZigBee, IrDA…
- GSM, GPRS, EDGE, UMTS, 4G,…



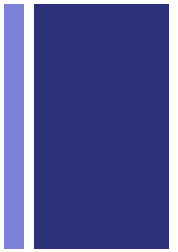
2nd revolution: going optical





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

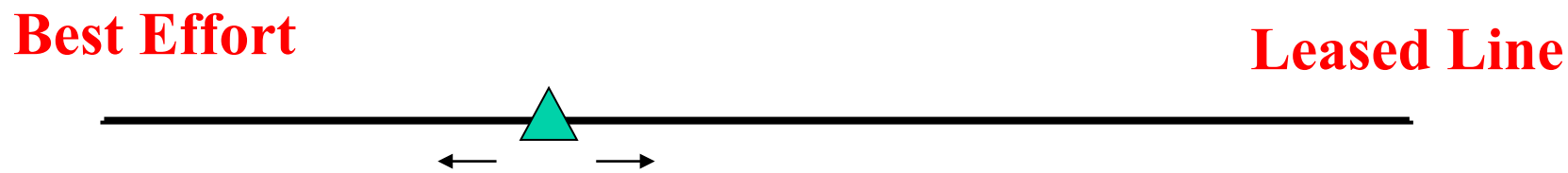
What is Quality of Service?



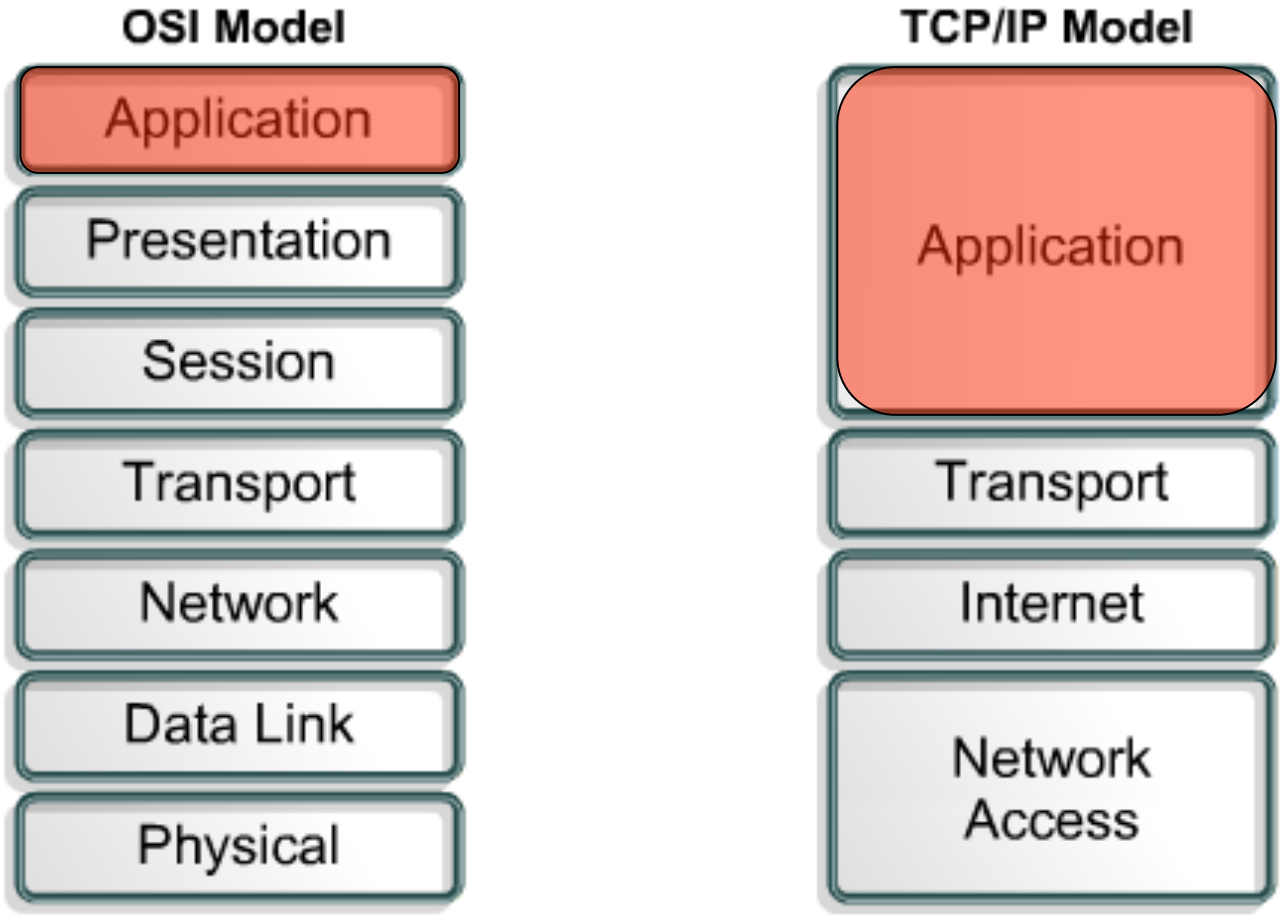
- Quality of service is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance
- QoS criteria are numerous and is highly dependant of the app.
  - Throughput, Delay, jitter, Loss rate, Availability, Uptime, ...
- ... Or 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:

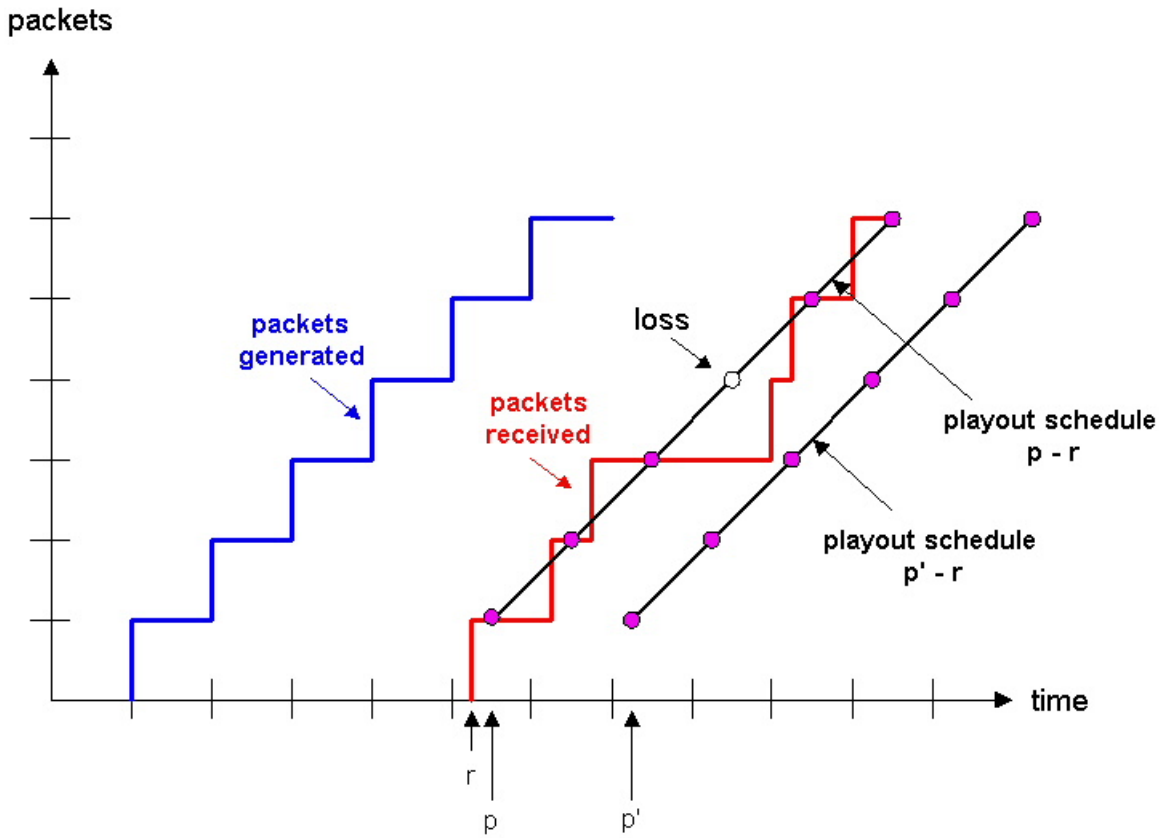


Where to put QoS?



Application layer=network as a black box

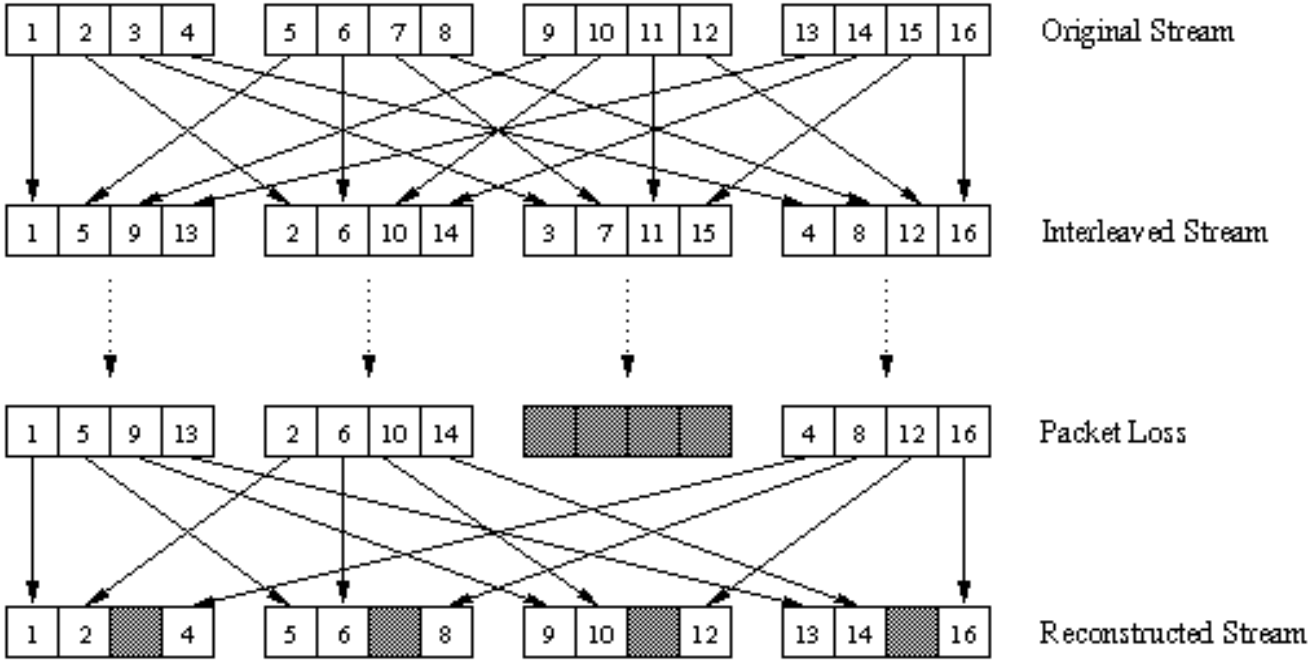
Dealing with packet jitter
Fixed playout delay



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

Image quality?
Uncompressed BMP

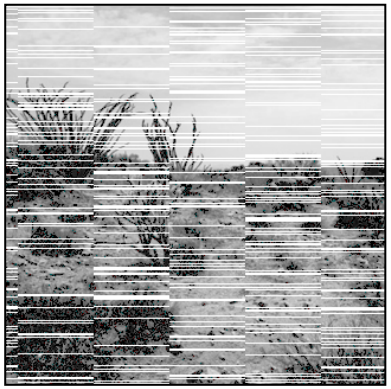
Original 320x320
256 gray levels,
BMP 102400 bytes

Max TX rate = 250 kps
(IEEE 802.15.4)

Minimum latency = 6.46s

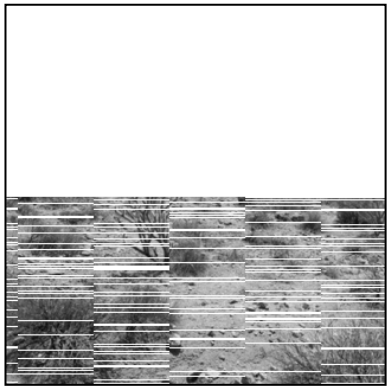
Cannot really use the compressed version of BMP using RLE.

1617 packets, 64 bytes payload, one hop
Loss rate: 20%, No loss bursts (radio), No duty-cycling



1340 out of 1617
packets received

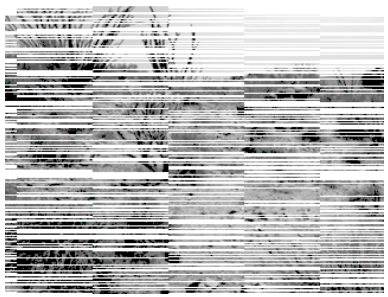
1303 out of 1617
packets received



674 out of 1617
packets received

With loss bursts (radio)

921 out of 1617
packets received



689 out of 1617
packets received

913 out of 1617
packets received

Image quality?
Standard JPG

427 packets, 64 bytes payload, one Hop
Loss rate: 20%, No loss bursts (radio), No duty-cycling

Original 320x320
256 gray levels,
JPG 27303 bytes

Max TX rate = 250 kps
(IEEE 802.15.4)

Minimum latency = 1.61s

Encoding cost of JPEG2000 is too high for these devices.

348 out of 427
packets received

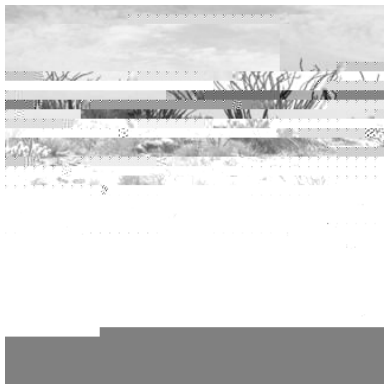
351 out of 427
packets received

9 out of 12 images
could not be decoded

349 out of 1617
packets received

With loss bursts (radio)

258 out of 427
packets received



270 out of 427
packets received

8 out of 12 images
could not be decoded

269 out of 427
packets received

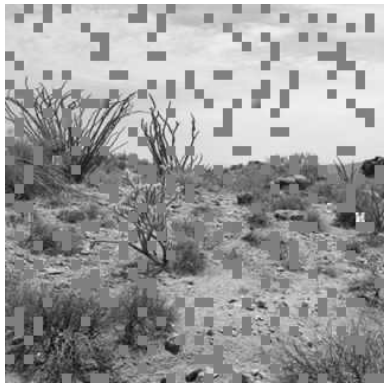
Improving image robustness

302 packets, 64 bytes payload, one Hop
Loss rate: 20%, No loss bursts (radio), No duty-cycling

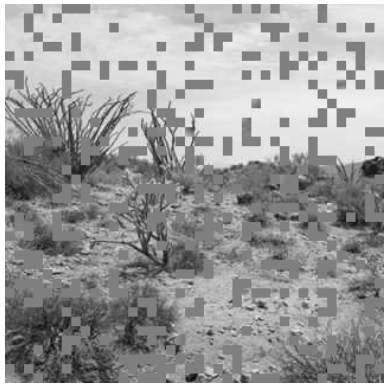
Original 320x320
256 gray levels,
WSN specific 17199 bytes

Max TX rate = 250 kps
(IEEE 802.15.4)

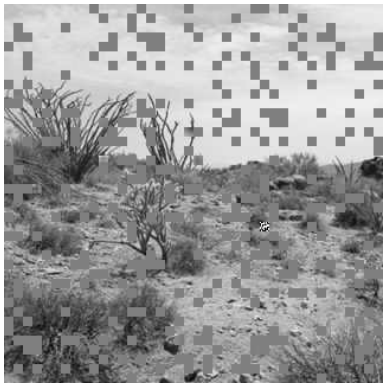
Minimum latency = 1.14s



248 out of 302
packets received

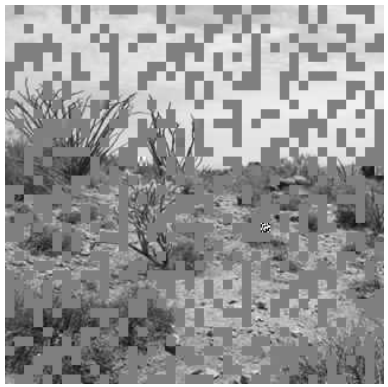


236 out of 302
packets received

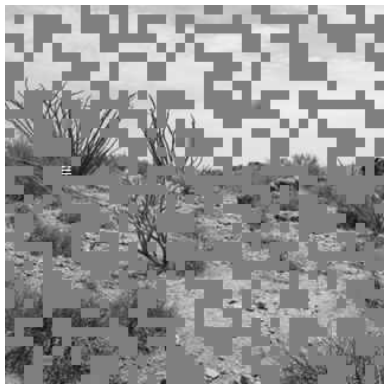


243 out of 302
packets received

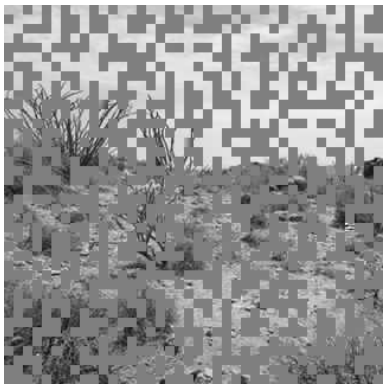
With loss bursts (radio)



188 out of 302
packets received



167 out of 302
packets received

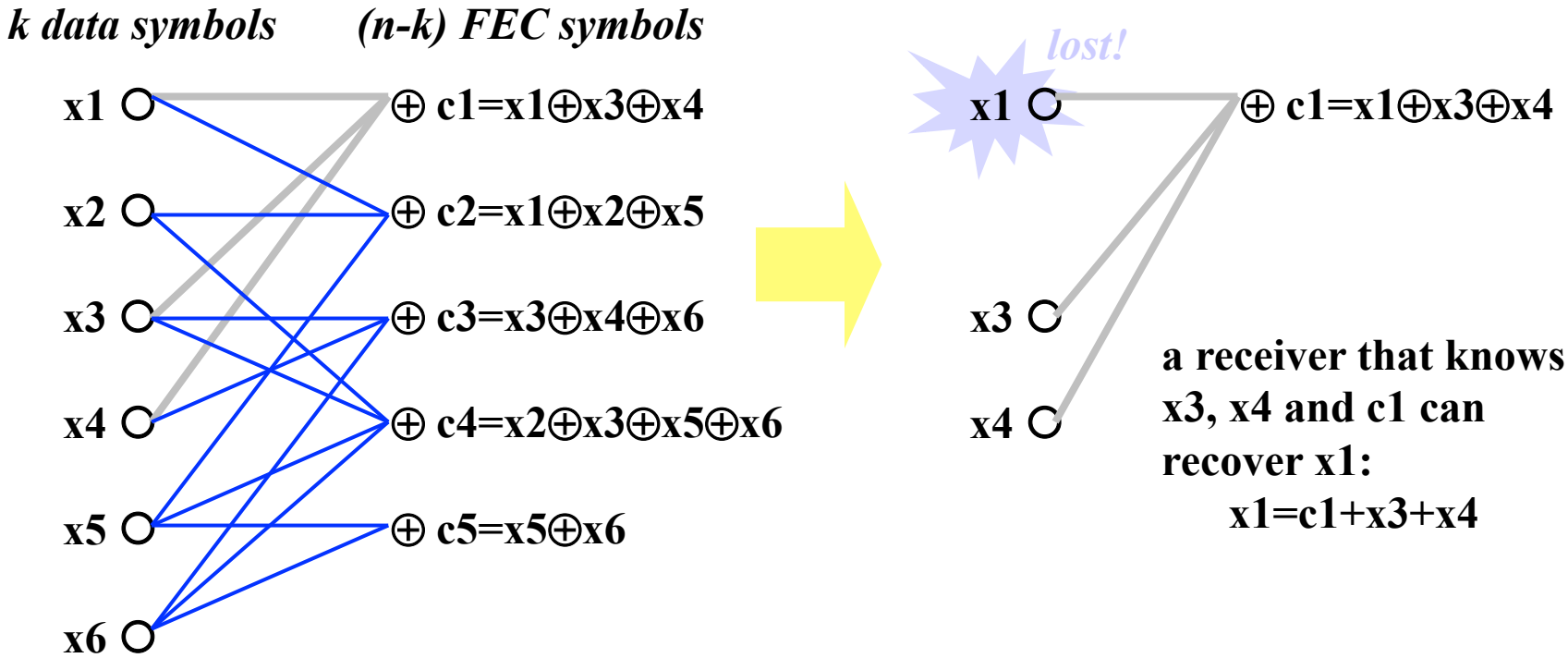


158 out of 302
packets received

Collaboration with CRAN laboratory, Nancy, France, for robust image encoding techniques for WSN.

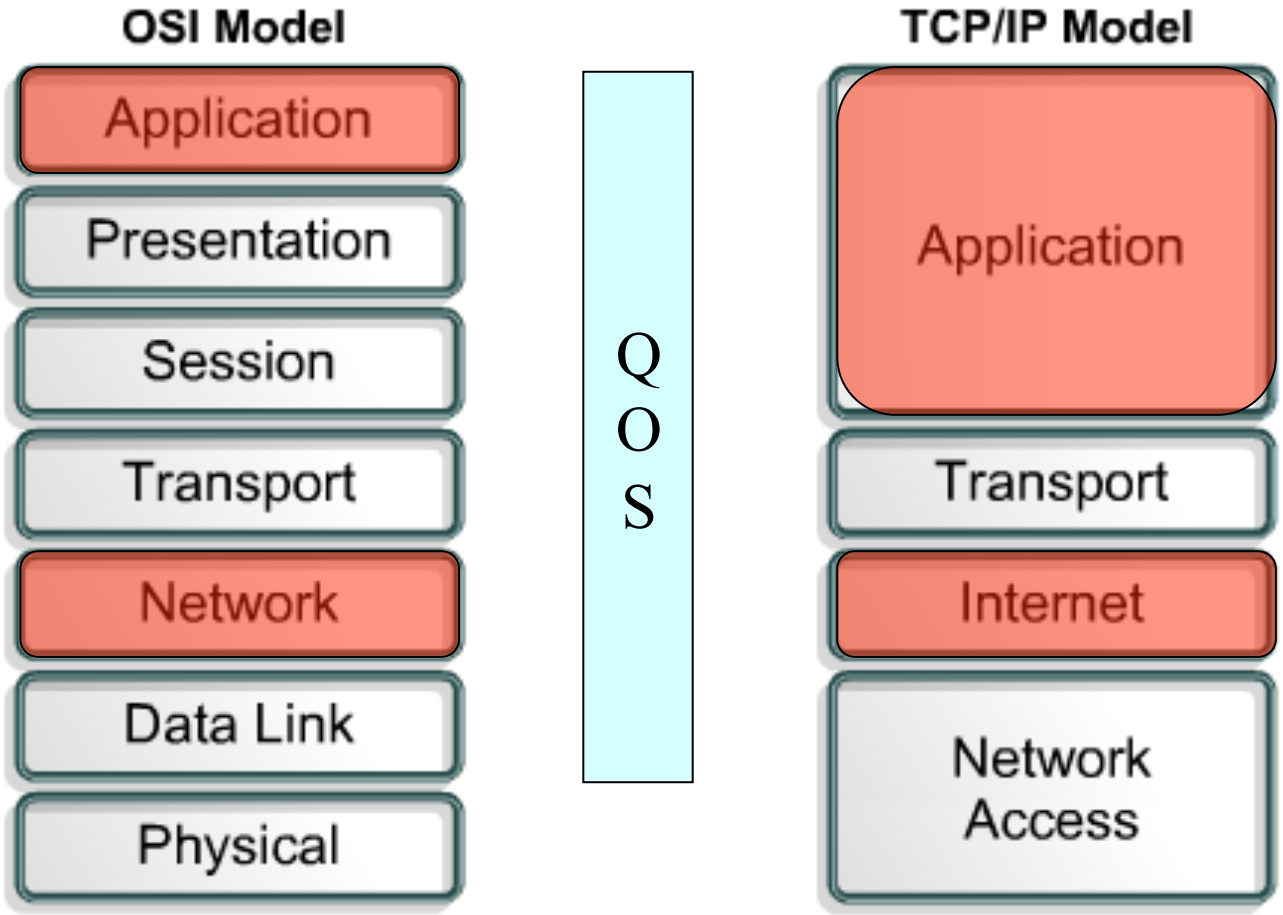
Large block FEC codes...

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



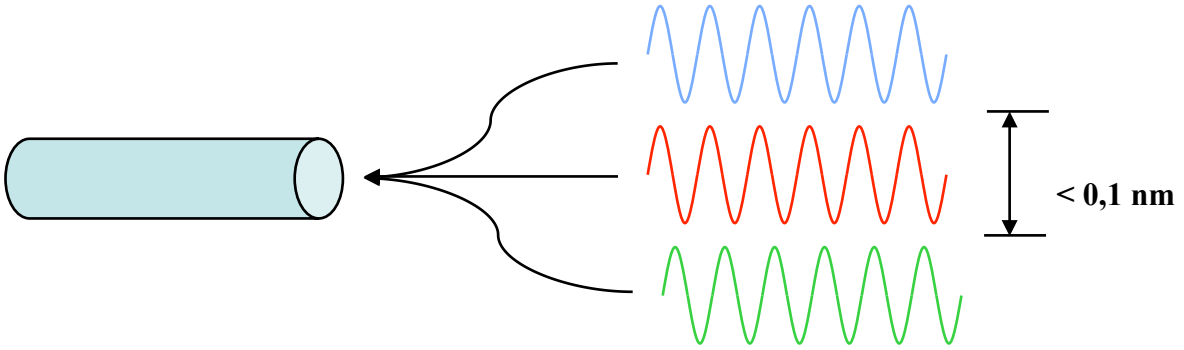
From Xavier Appé, modified by C. Pham for educational purpose only

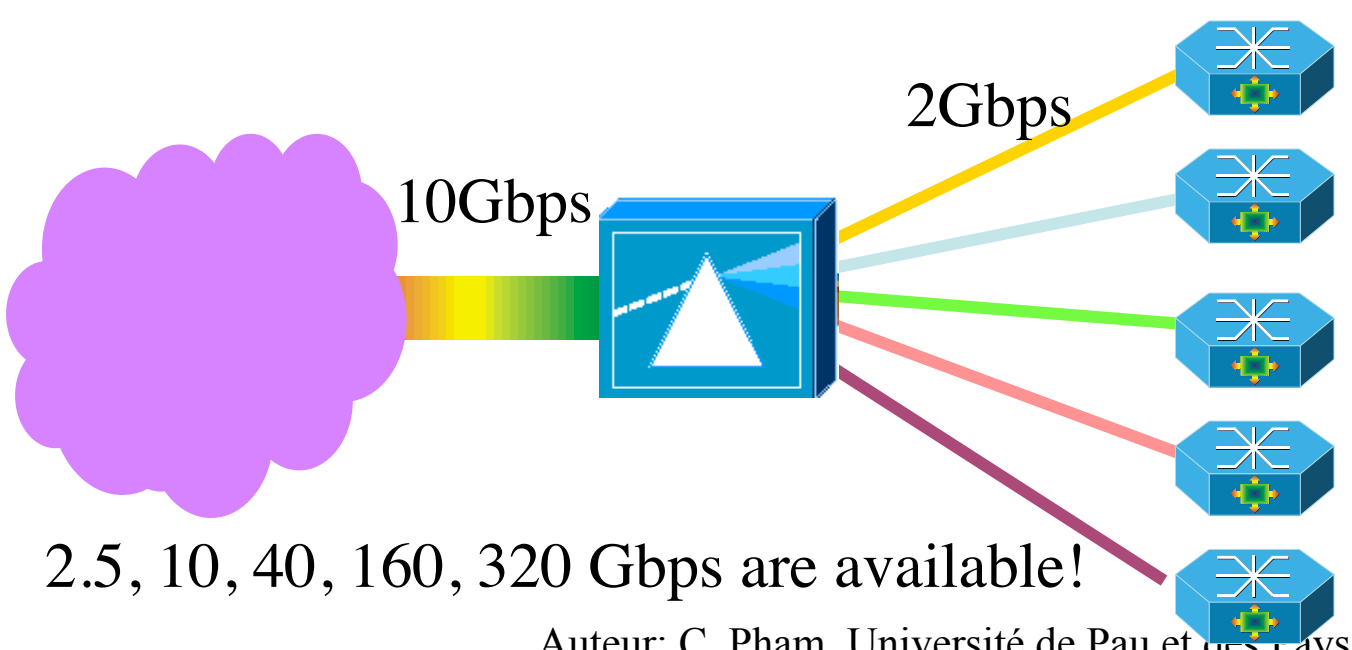
Where to put QoS?



DWDM, bandwidth for free?

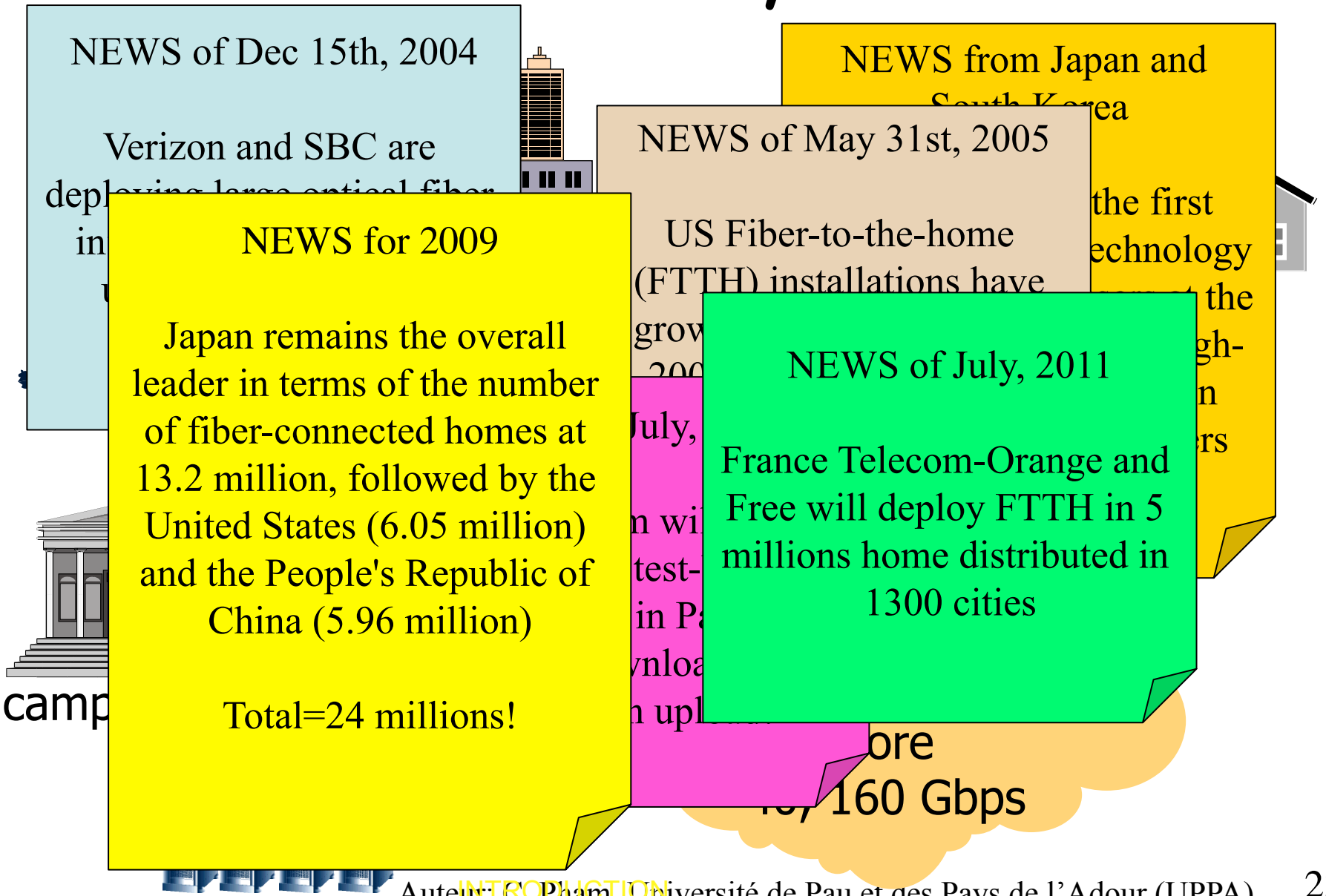
DWDM: Dense Wavelength Division Multiplexing



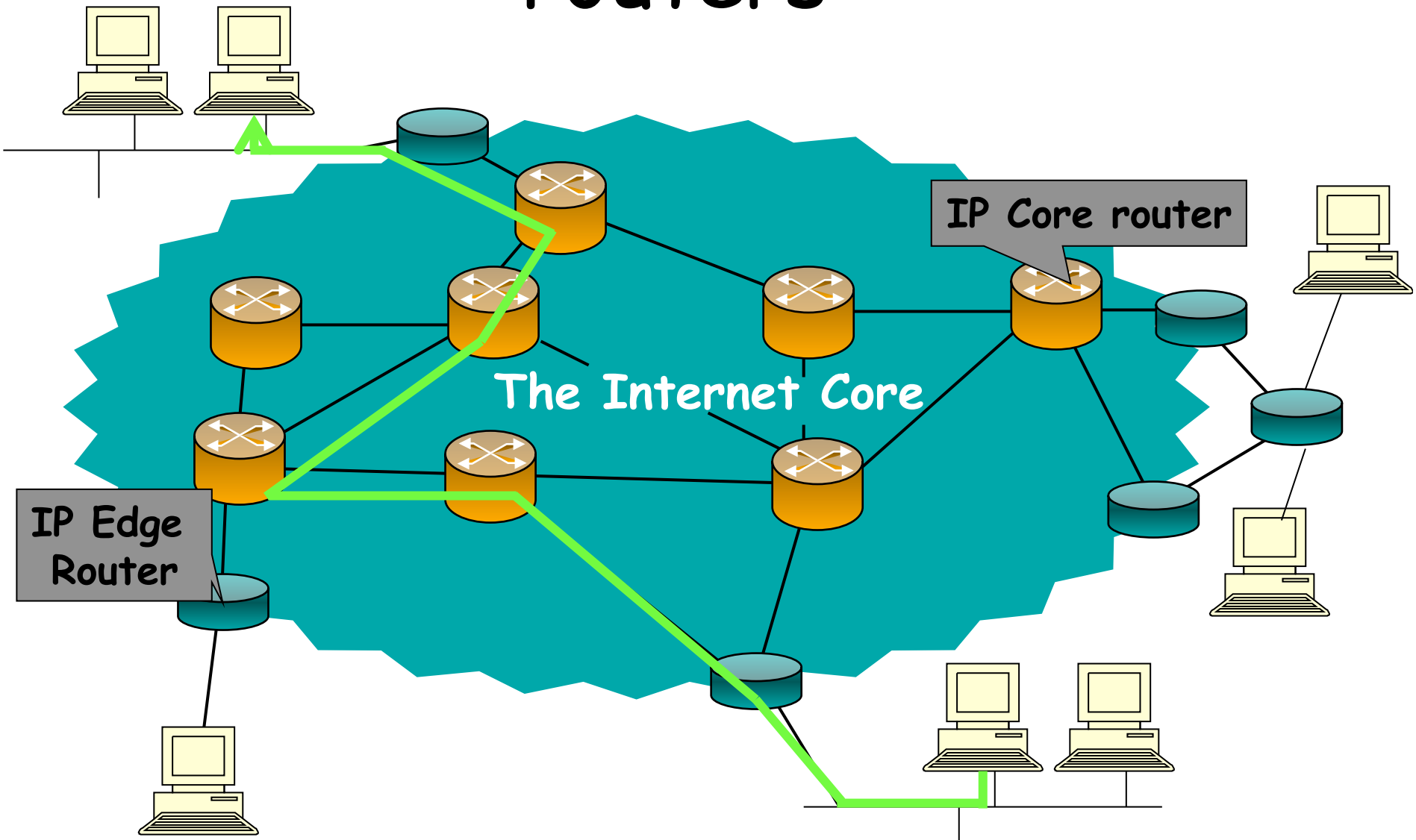


2.5, 10, 40, 160, 320 Gbps are available!

Fibers everywhere?



"The Internet is a mesh of routers"



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High Performance Routers

©Juniper

©Procket Networks

©Alcatel

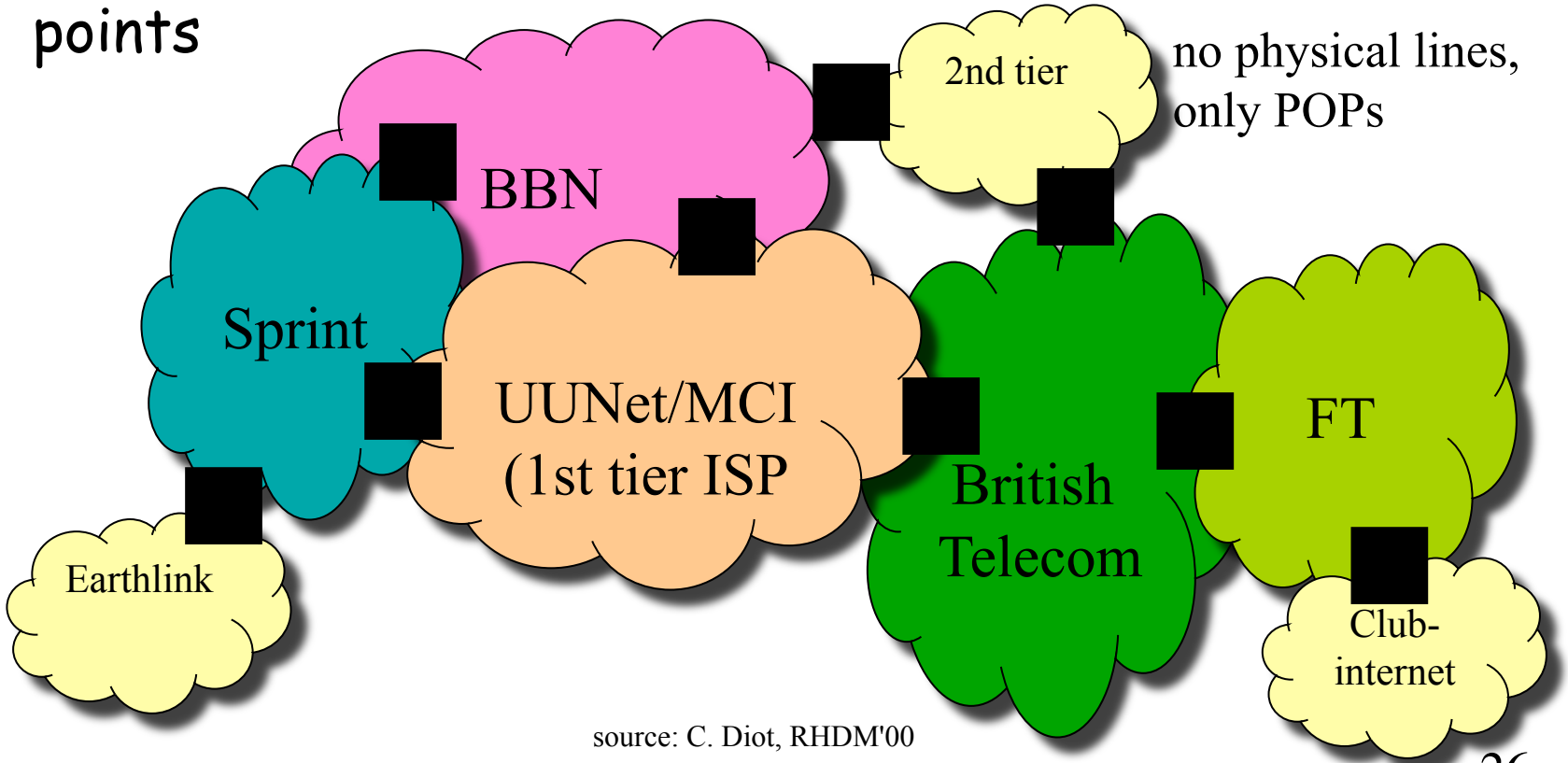
©Nortel Networks

©Lucent

and more…

Operators and ISPs: they rule the Internet

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

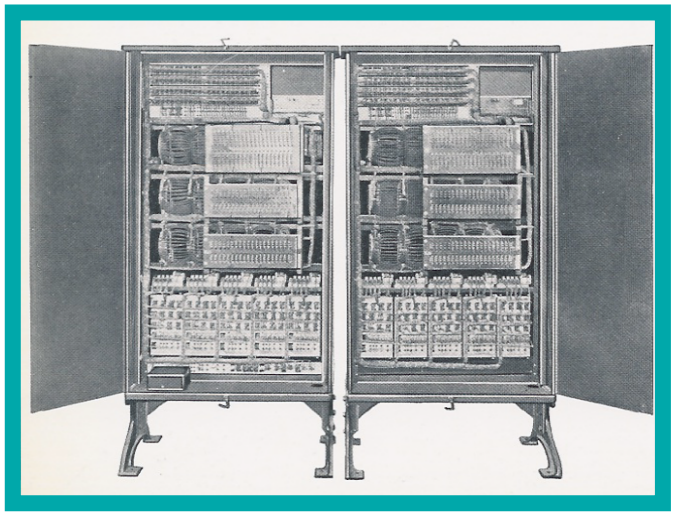


source: C. Diot, RHDM'00

Back in time:
The telephone system & network

First automatic Branch Exchange Almond B. Strowger, 1891…

Signaling replaces the operator

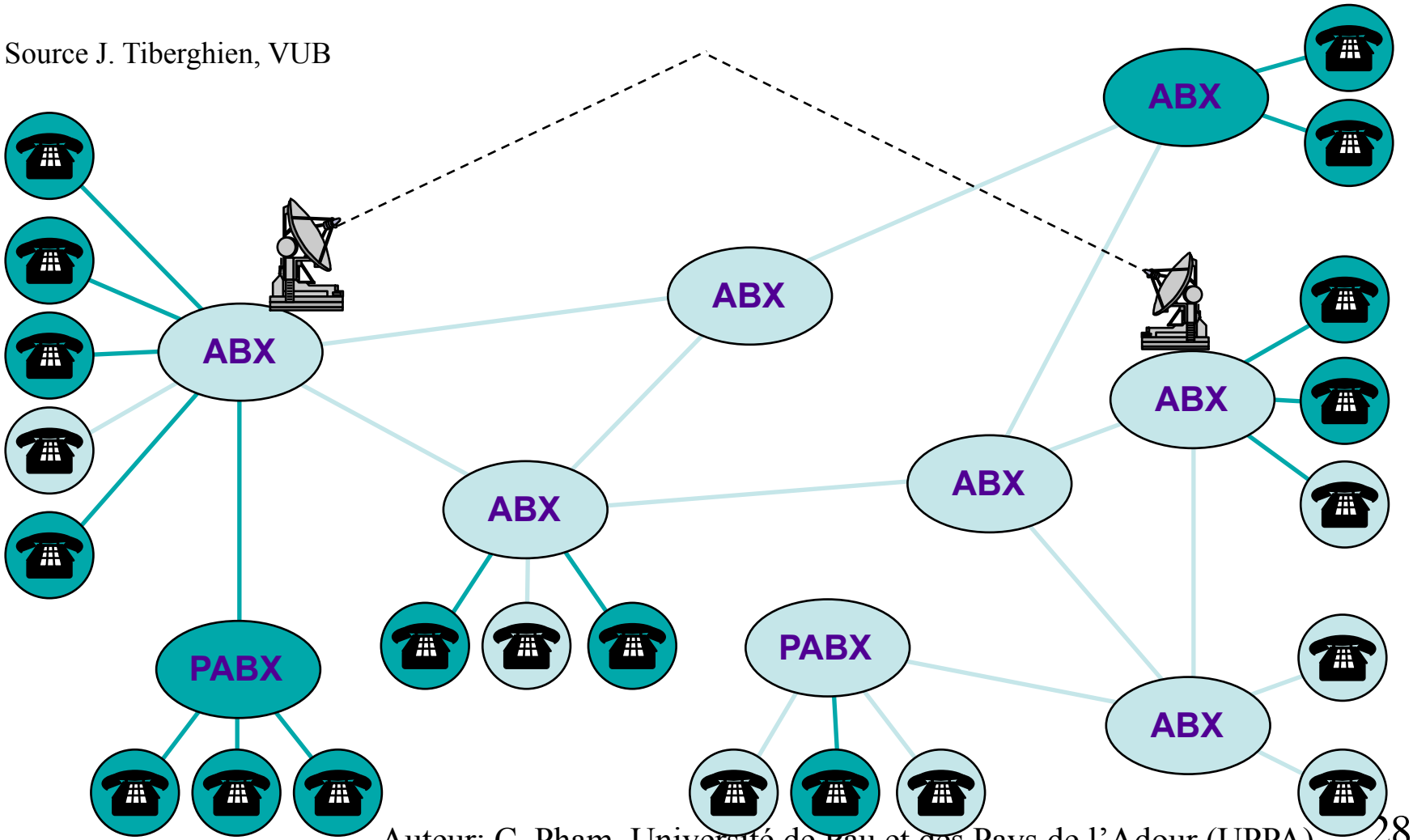


Source J. Tiberghien, VUB

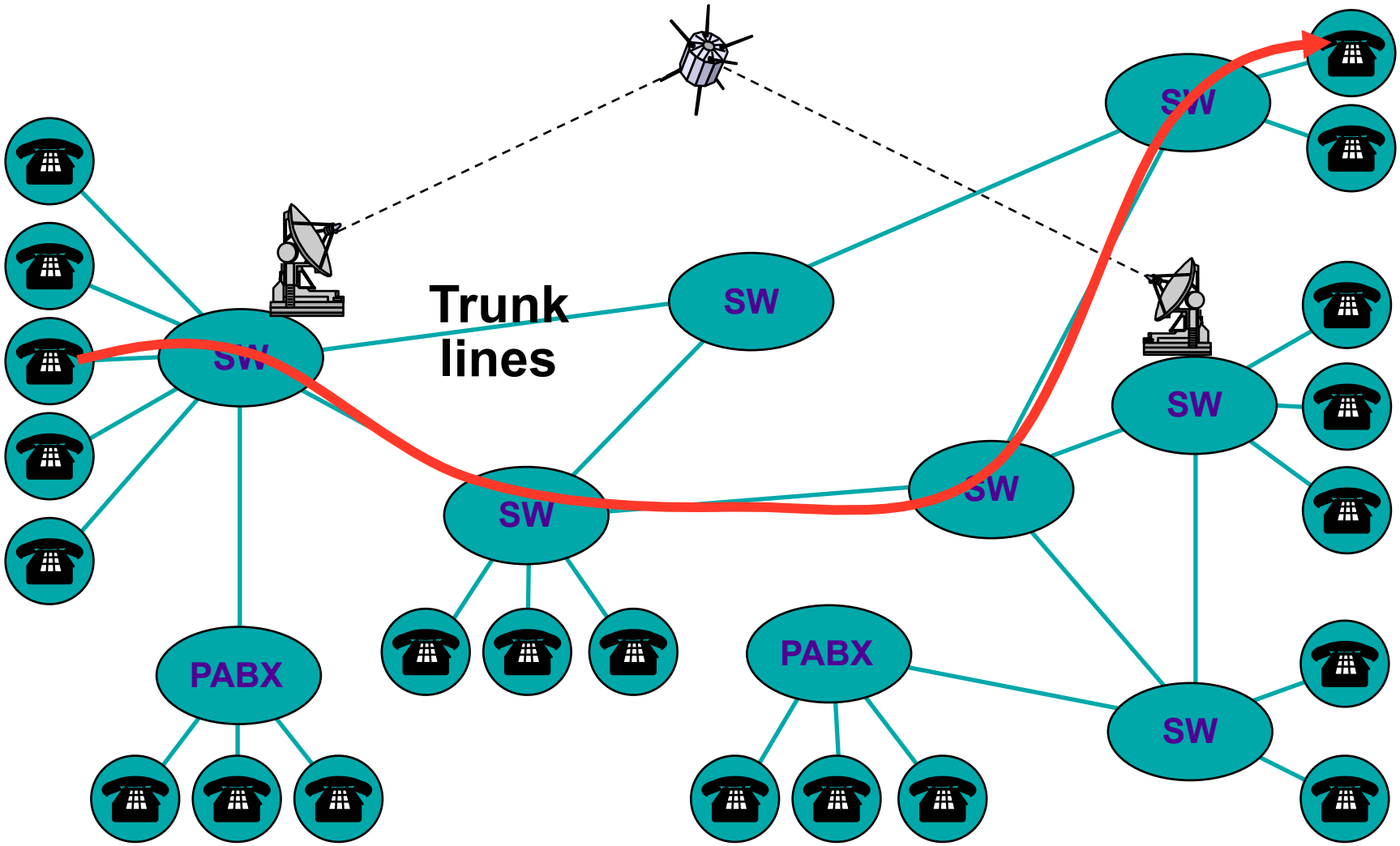
Back in time:
The telephone network, E.164 addressing

Analog / Digital

Source J. Tiberghien, VUB



The telephone circuit view



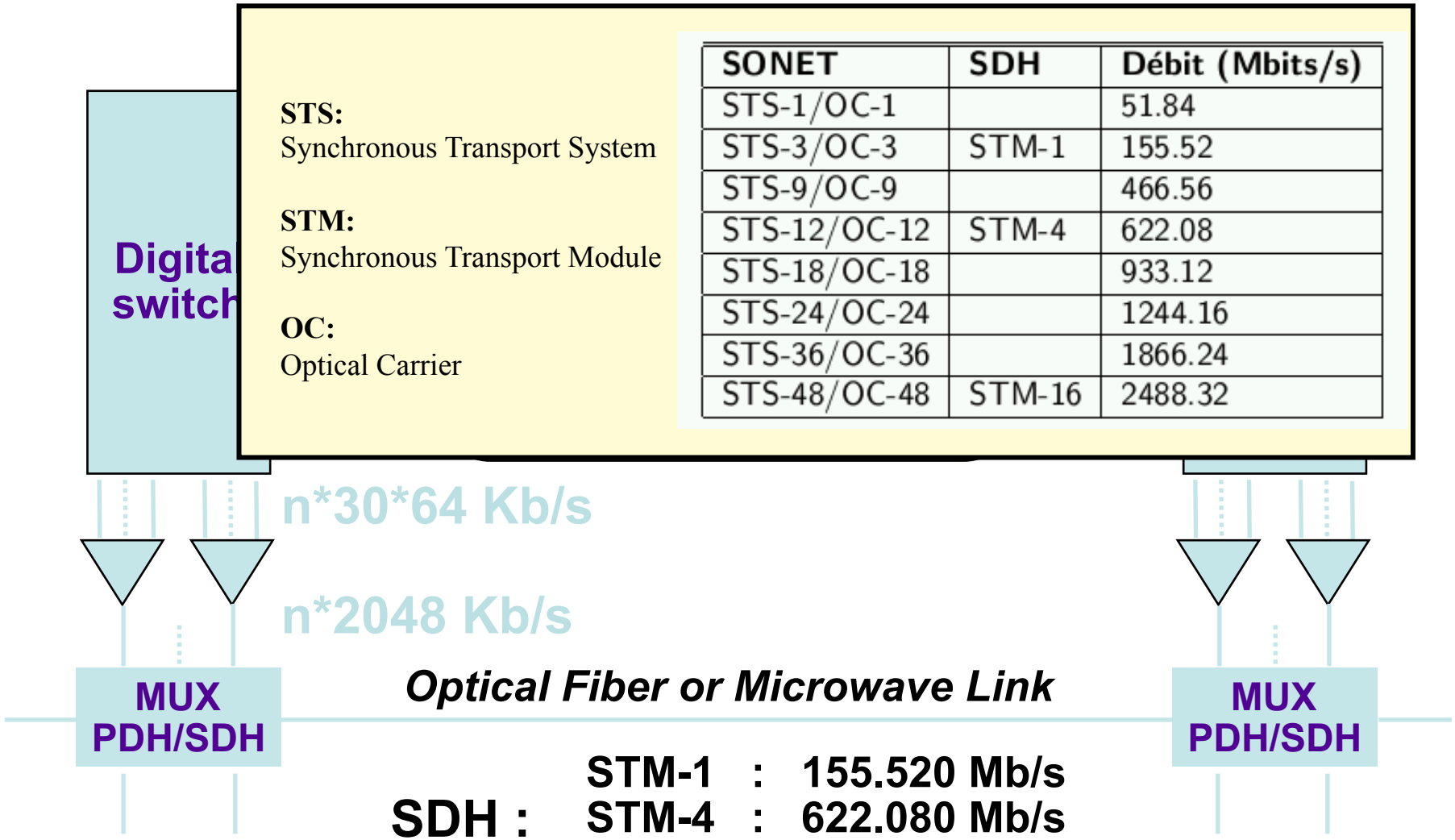
The core networks and SONET/SDH

STS:
Synchronous Transport System

STM:
Synchronous Transport Module

OC:
Optical Carrier

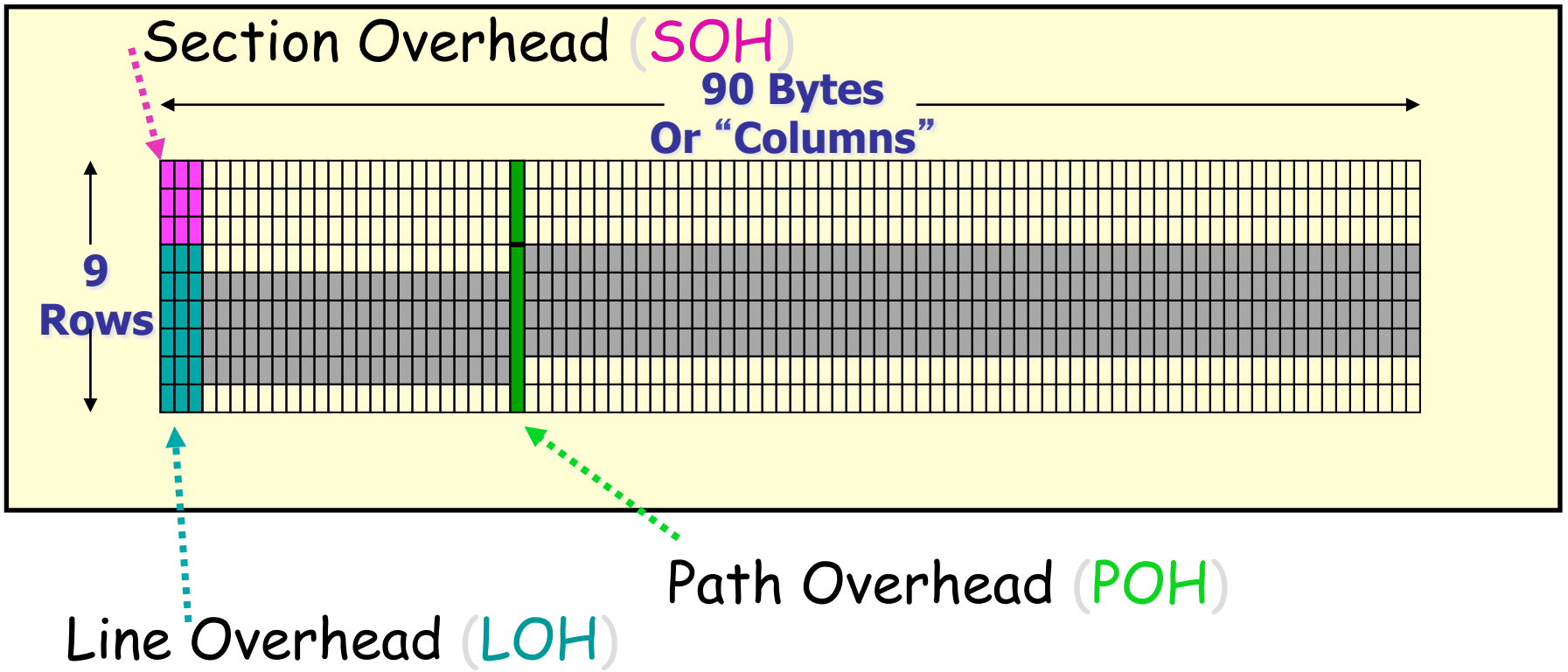
SONET	SDH	Débit (Mbits/s)
STS-1/OC-1		51.84
STS-3/OC-3	STM-1	155.52
STS-9/OC-9		466.56
STS-12/OC-12	STM-4	622.08
STS-18/OC-18		933.12
STS-24/OC-24		1244.16
STS-36/OC-36		1866.24
STS-48/OC-48	STM-16	2488.32



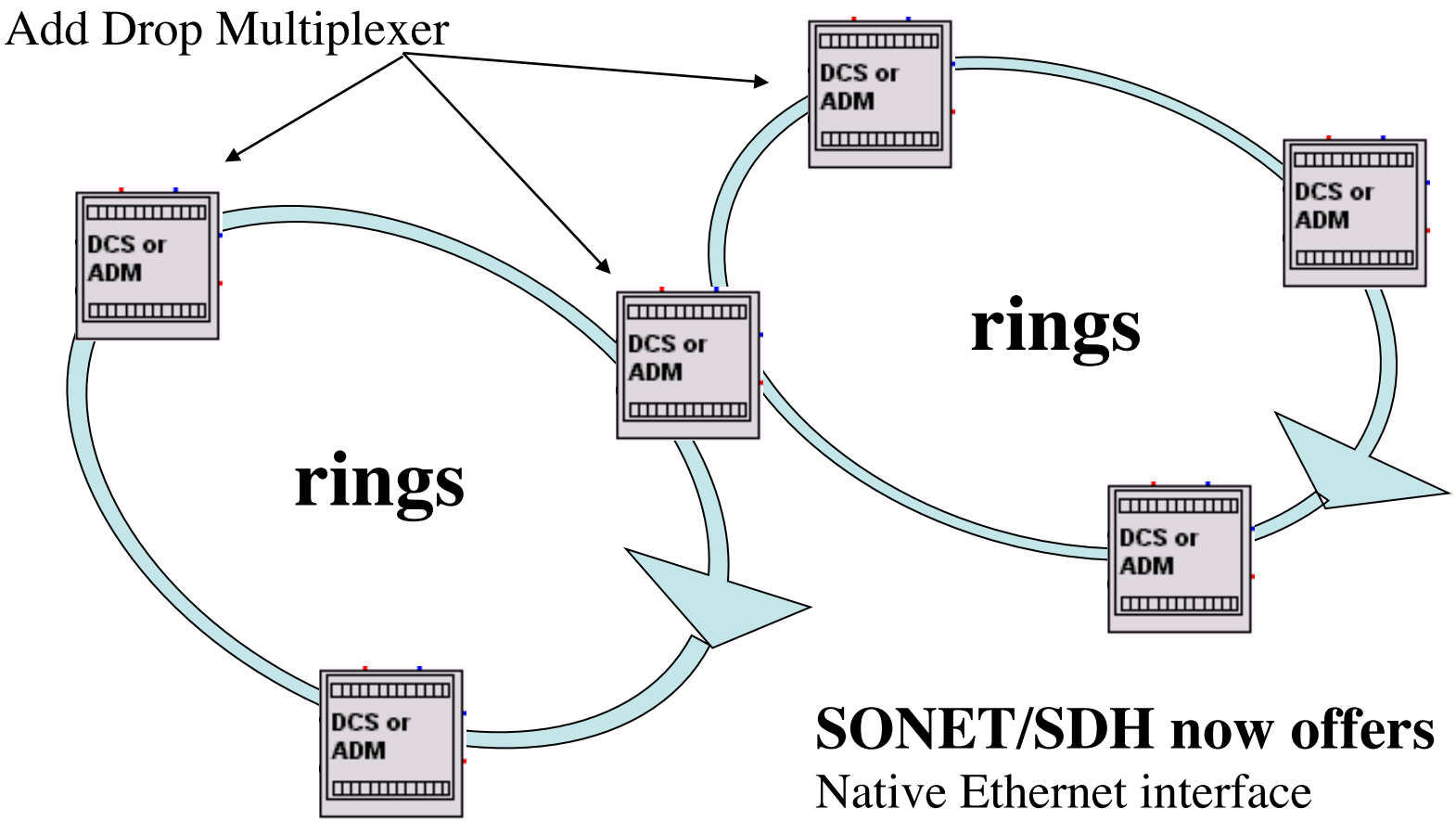
SDH : **STM-1 : 155.520 Mb/s**
STM-4 : 622.080 Mb/s
STM-16 : 2488.320 Mb/s

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

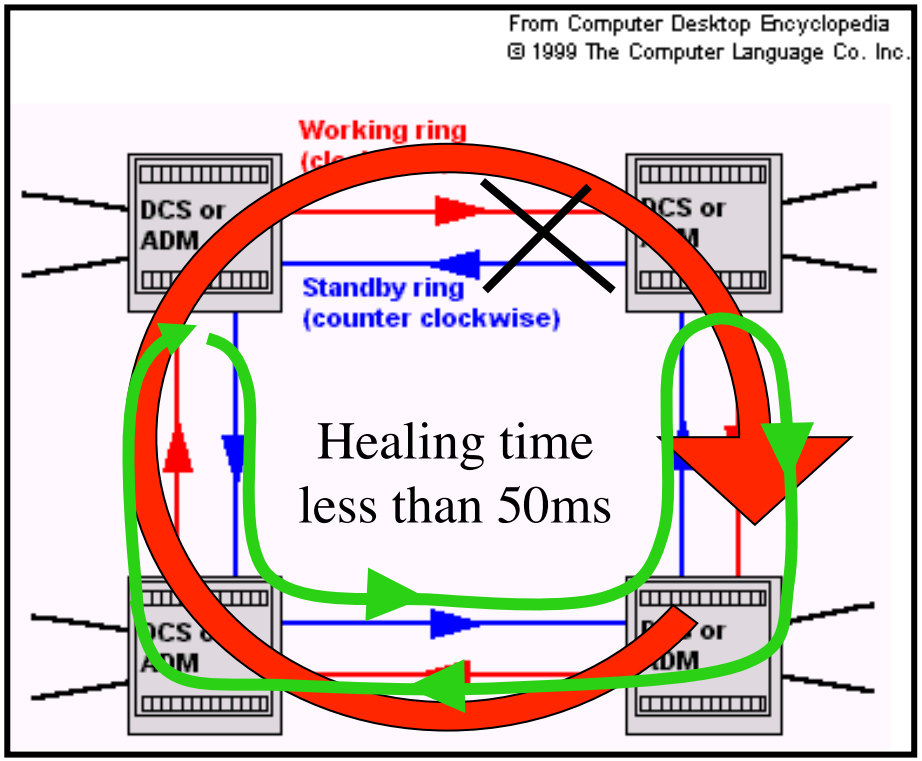
Generic Framing Procedure

Virtual Concatenation

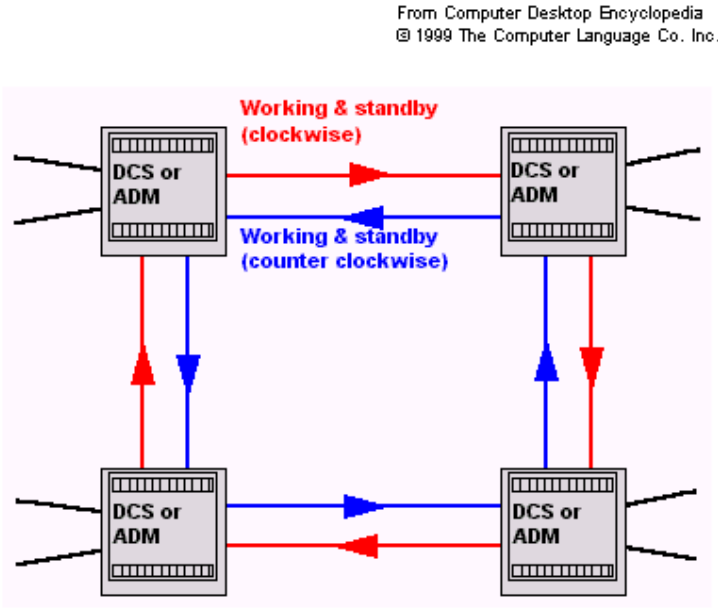
SONET/SDH and resiliency

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

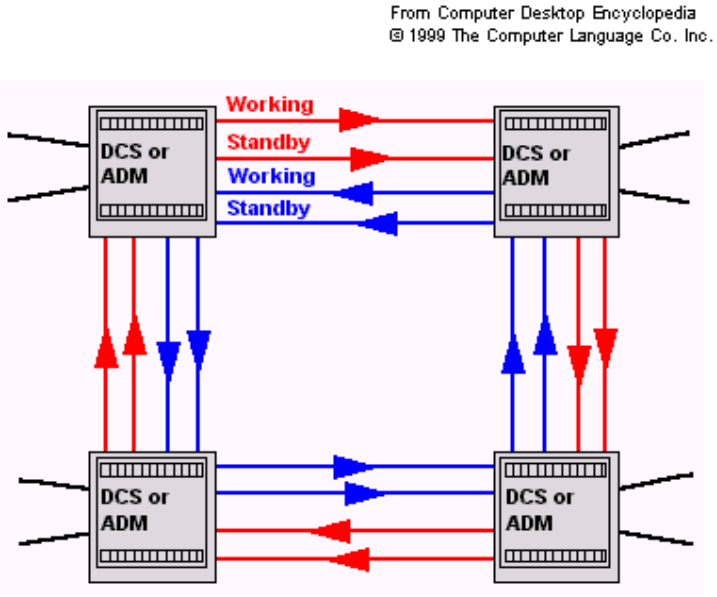
DCS
(Digital Cross-Connects)



SONET/SDH and resiliancy

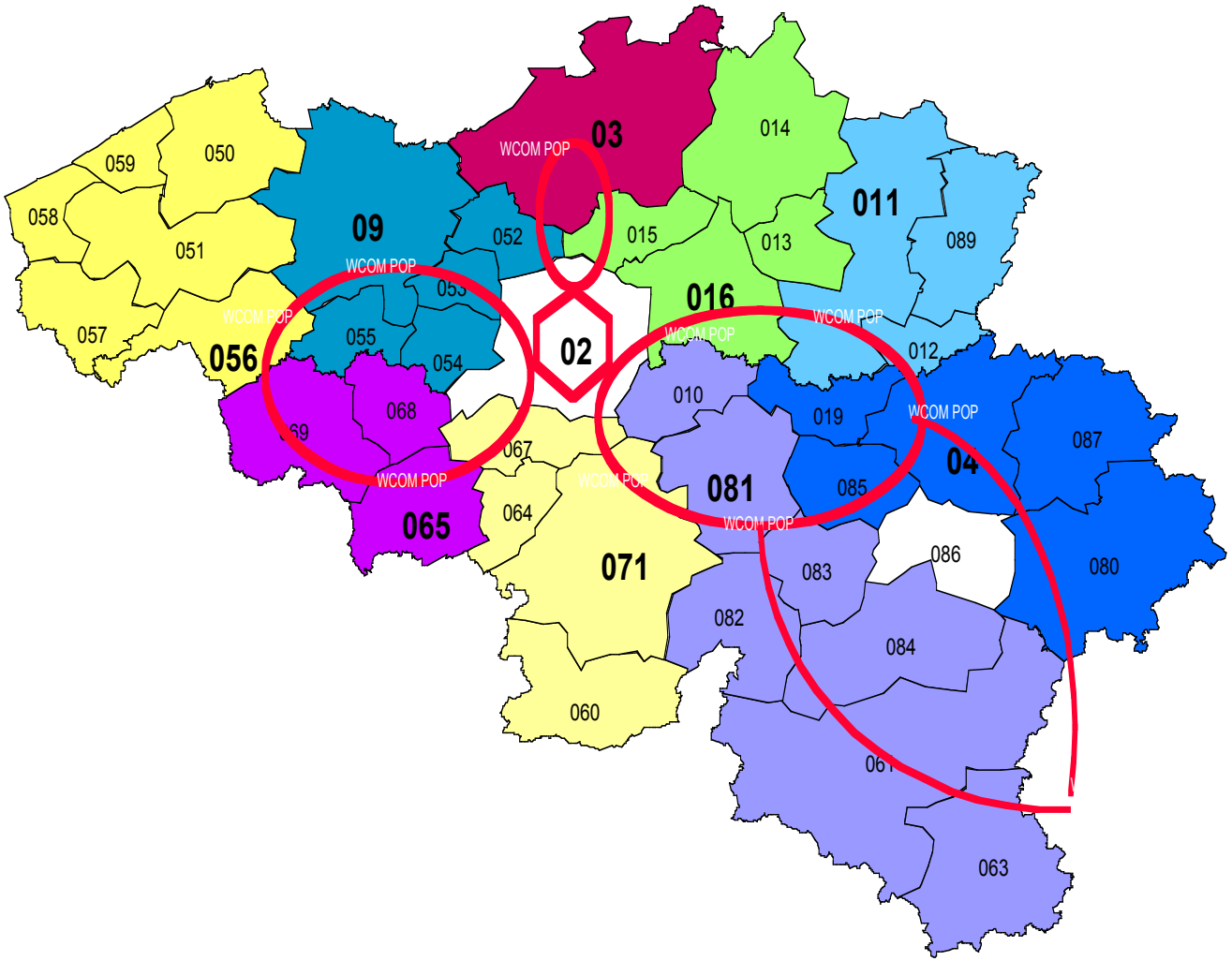


bi-directional



Found in most operators

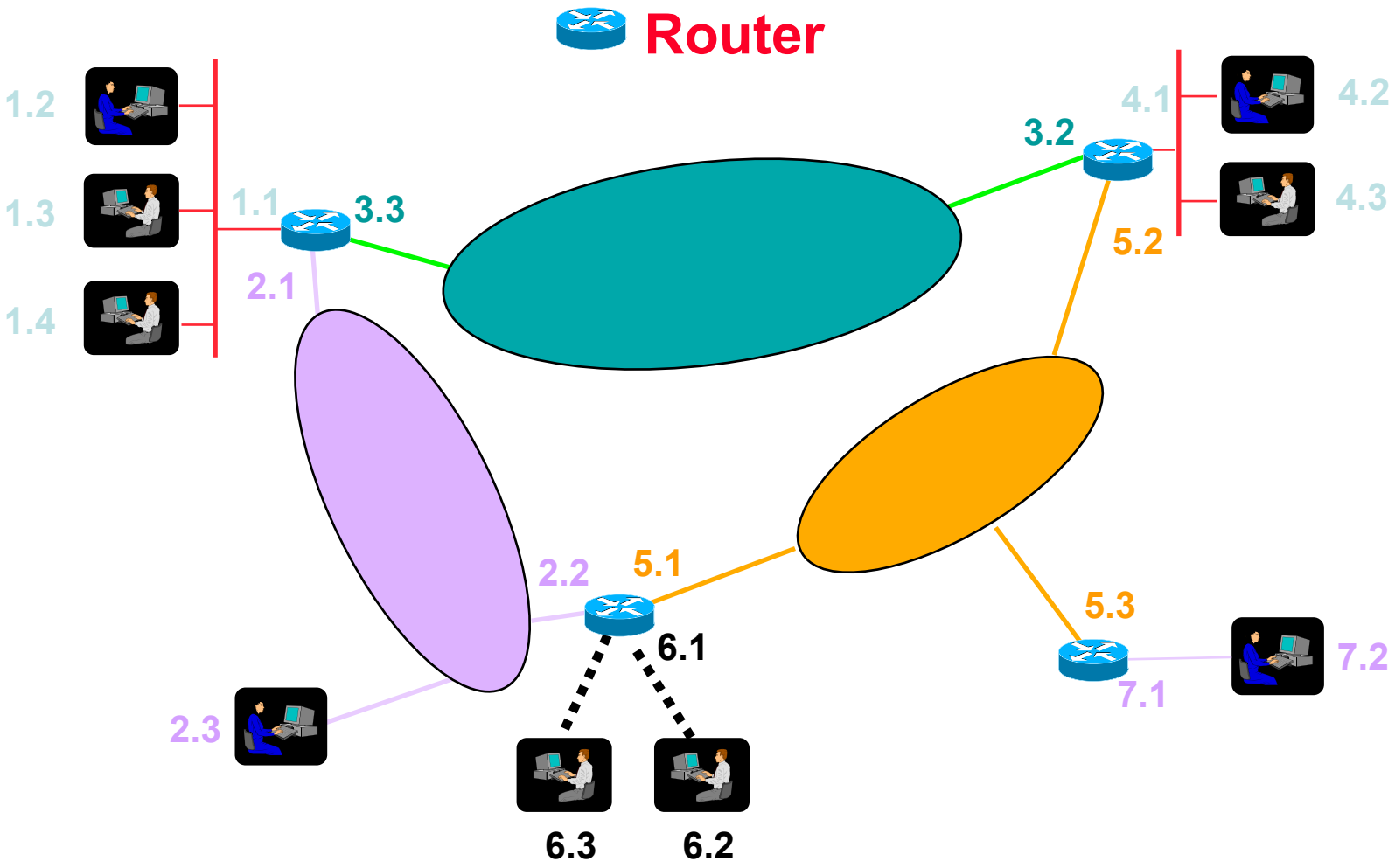
SDH Rings
The Worldcom Belgian Network



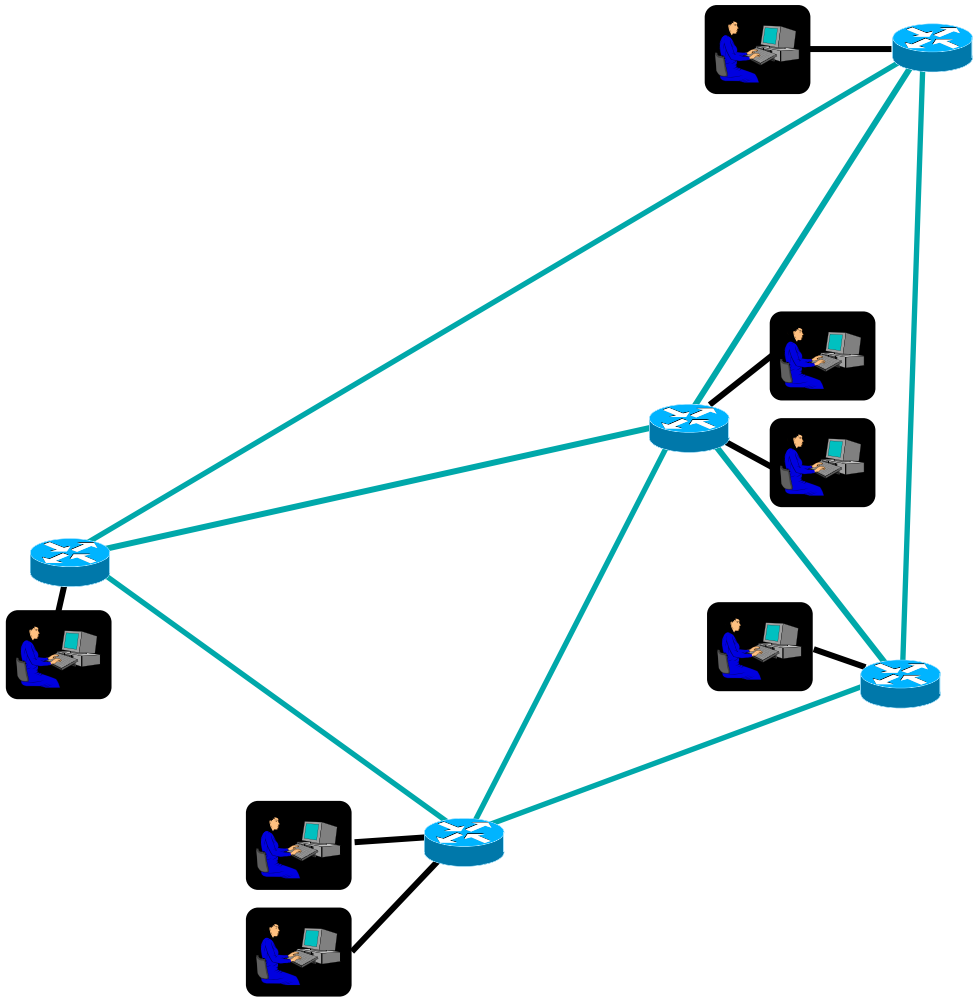
Merging IP networks and telco networks

- 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



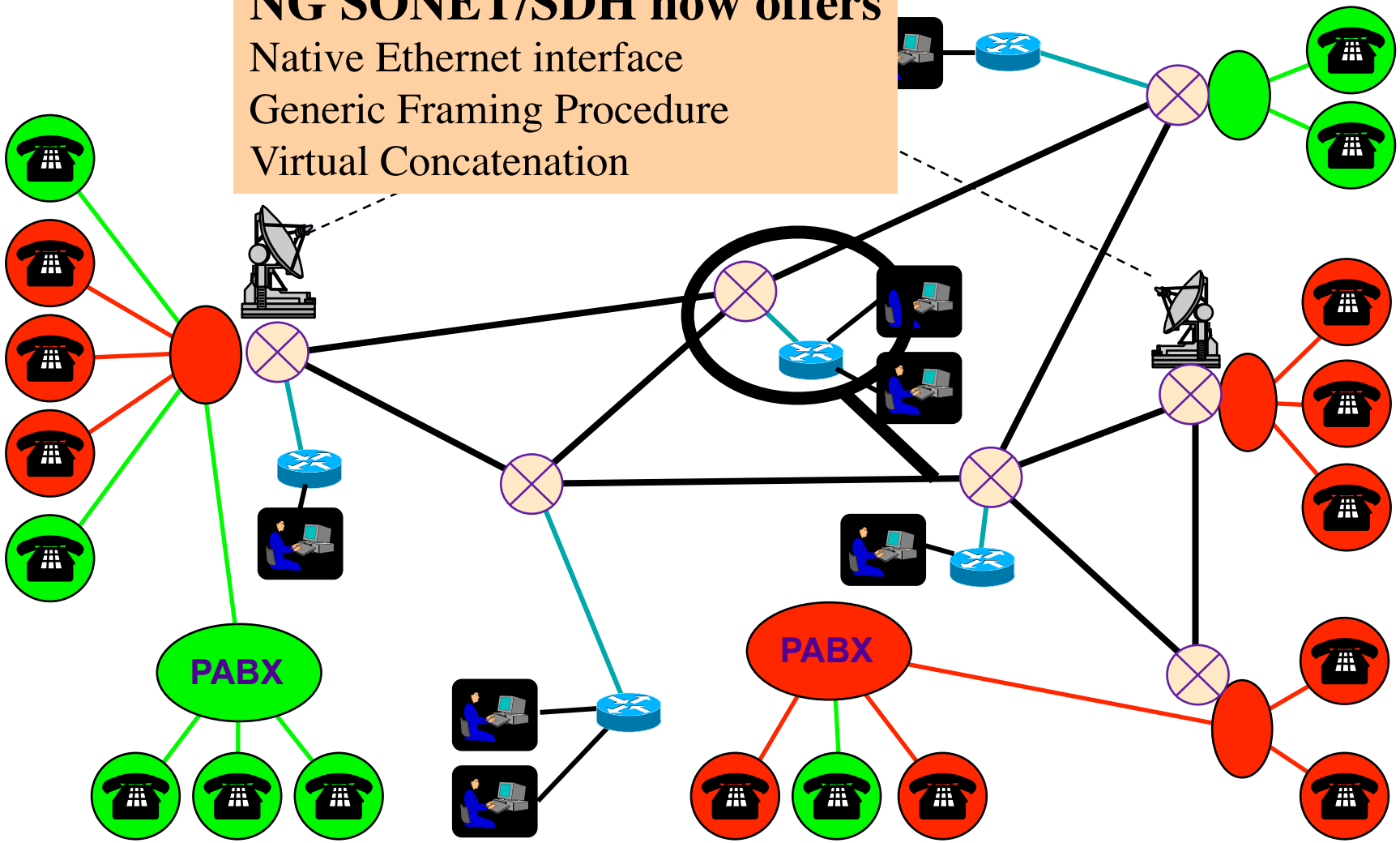
General Purpose SDH Networks

NG SONET/SDH now offers

Native Ethernet interface

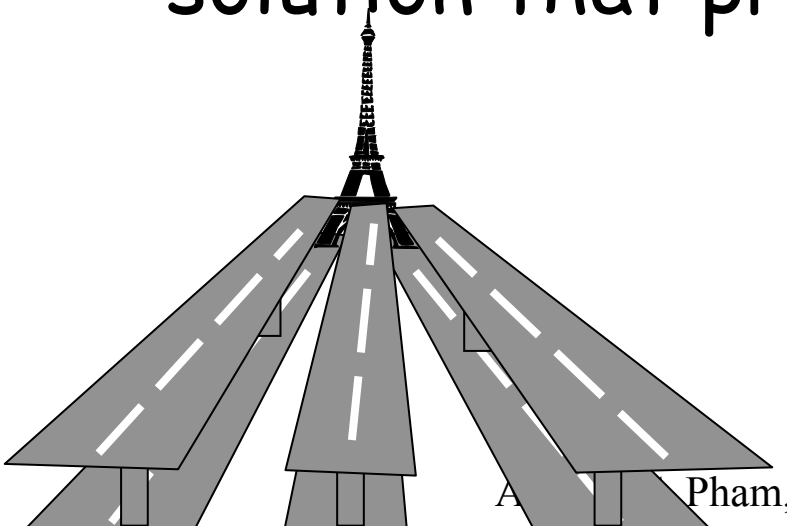
Generic Framing Procedure

Virtual Concatenation



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



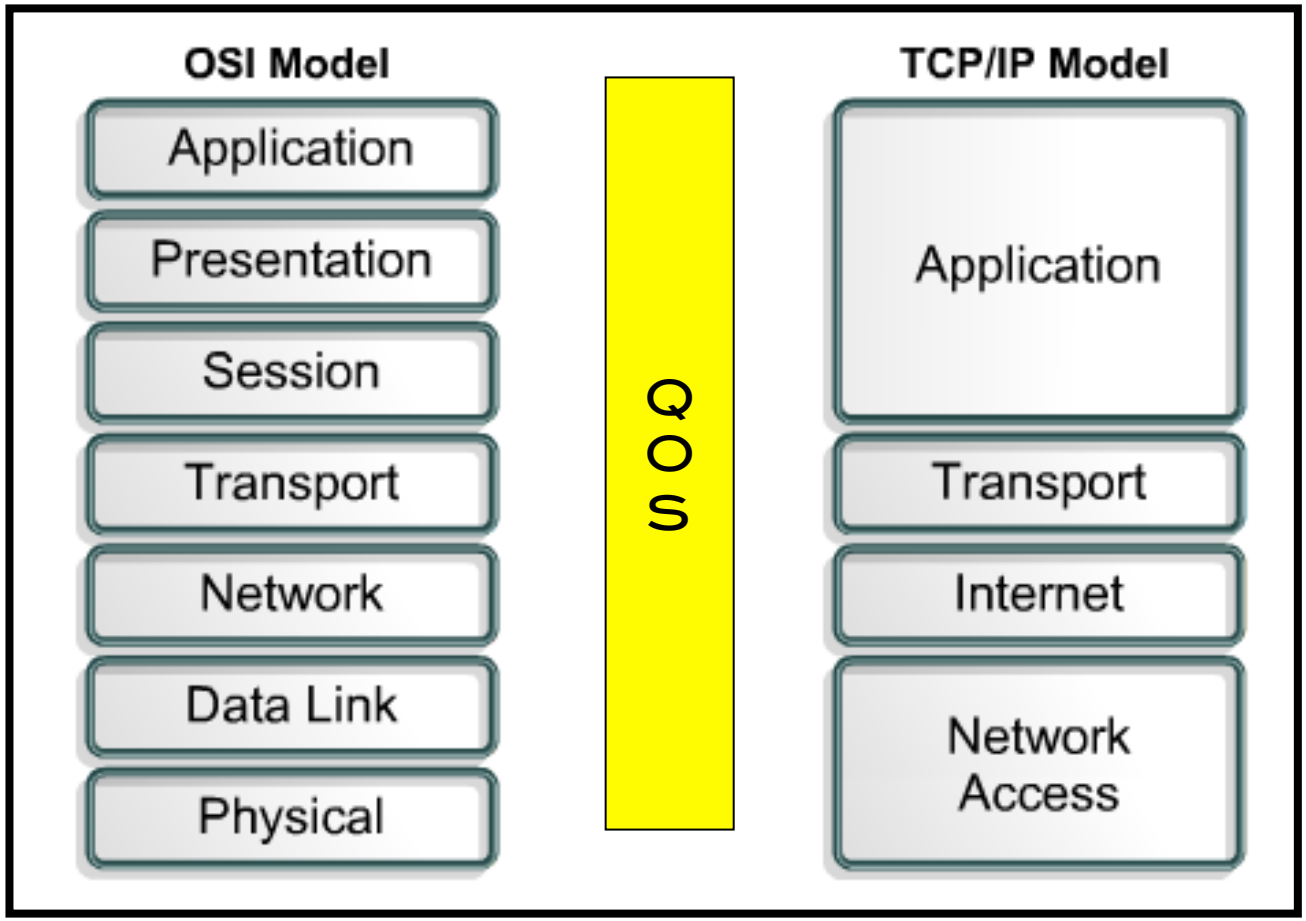
IP desired service

- 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

The throughput quest

P2P, WEB,…

30 years of INTERNET QoS…



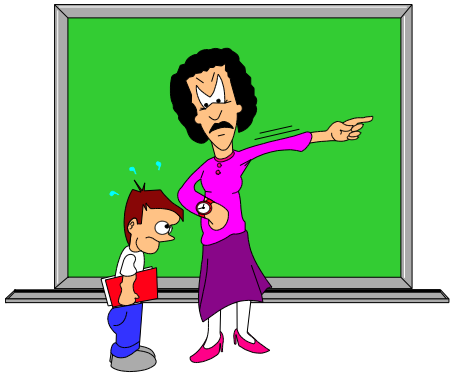
…have shown the power of selfishness!

WHY SHOULD I BOTHER WITH QOS WHEN…

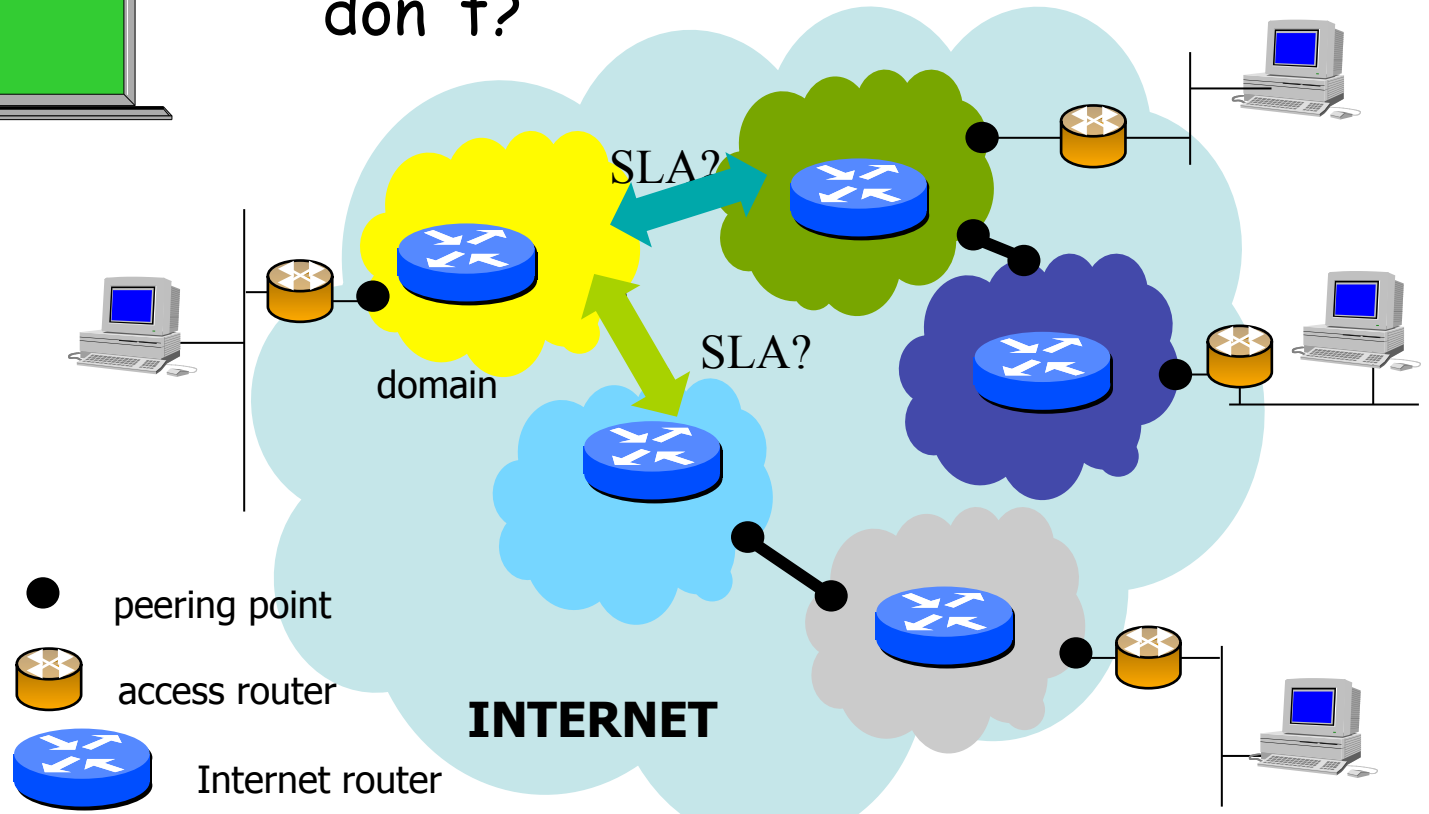
…OTHERS DON'T DO IT?

It's not my fault!

« environmental problems often have impacts beyond borders »



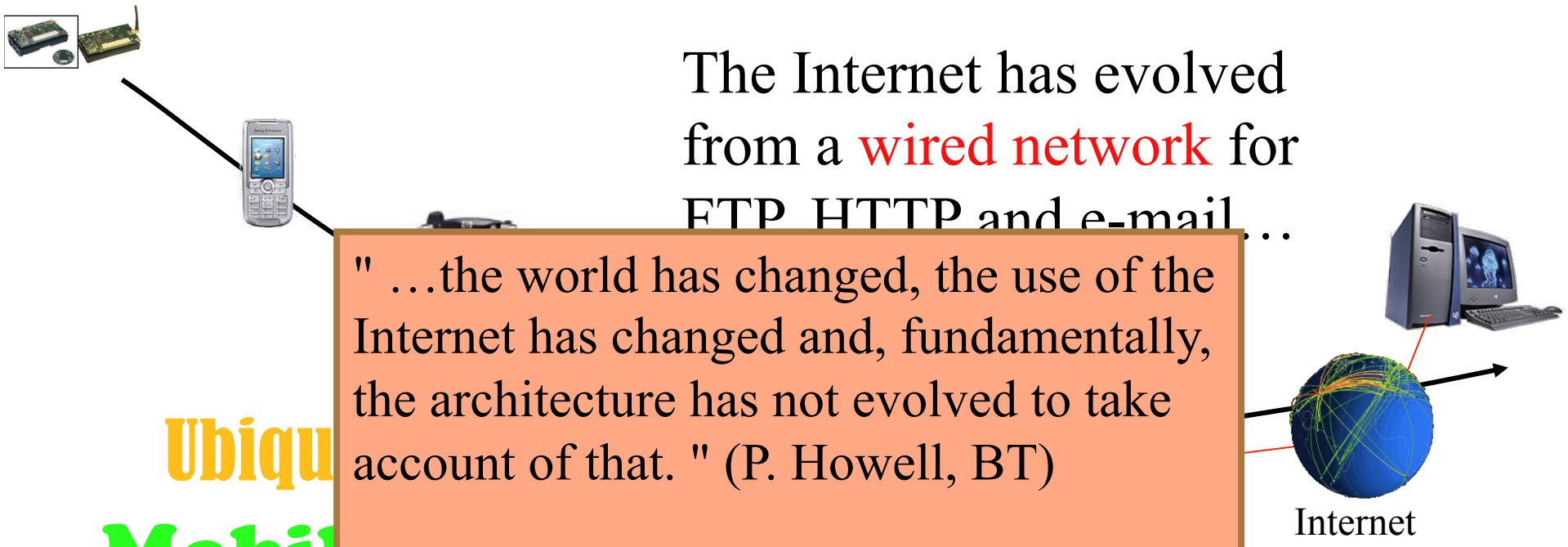
- What's the point of deploying QoS if others don't?



Current Internet's QoS

SO WHY CHANGE?

What's wrong?



The Internet has evolved from a wired network for FTP, HTTP and e-mail…

" …the world has changed, the use of the Internet has changed and, fundamentally, the architecture has not evolved to take account of that. " (P. Howell, BT)

Ubiqu

Mobil

Ad-Hoc

Telephony

MULTIMEDIA

Streaming

… to a fantastic infrastructure with a large variety of communicating devices and high diversity of access and traffic characteristics

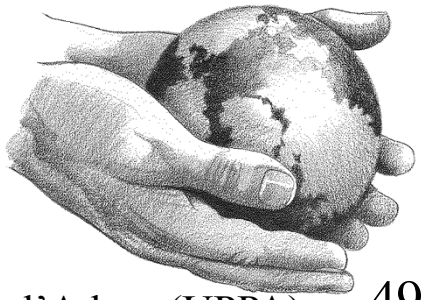
Limitations of the current Internet

- 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

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: o ly.
  Addin
  Custor n on
  invest
- YES: w ive
  solutic that
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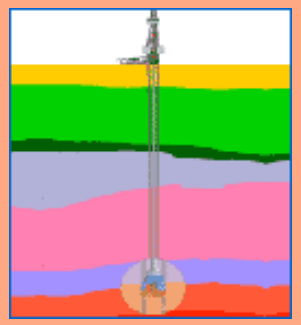


Each new oilfield discovery delays research and development of alternative energies

Lessons learned from sustainable development

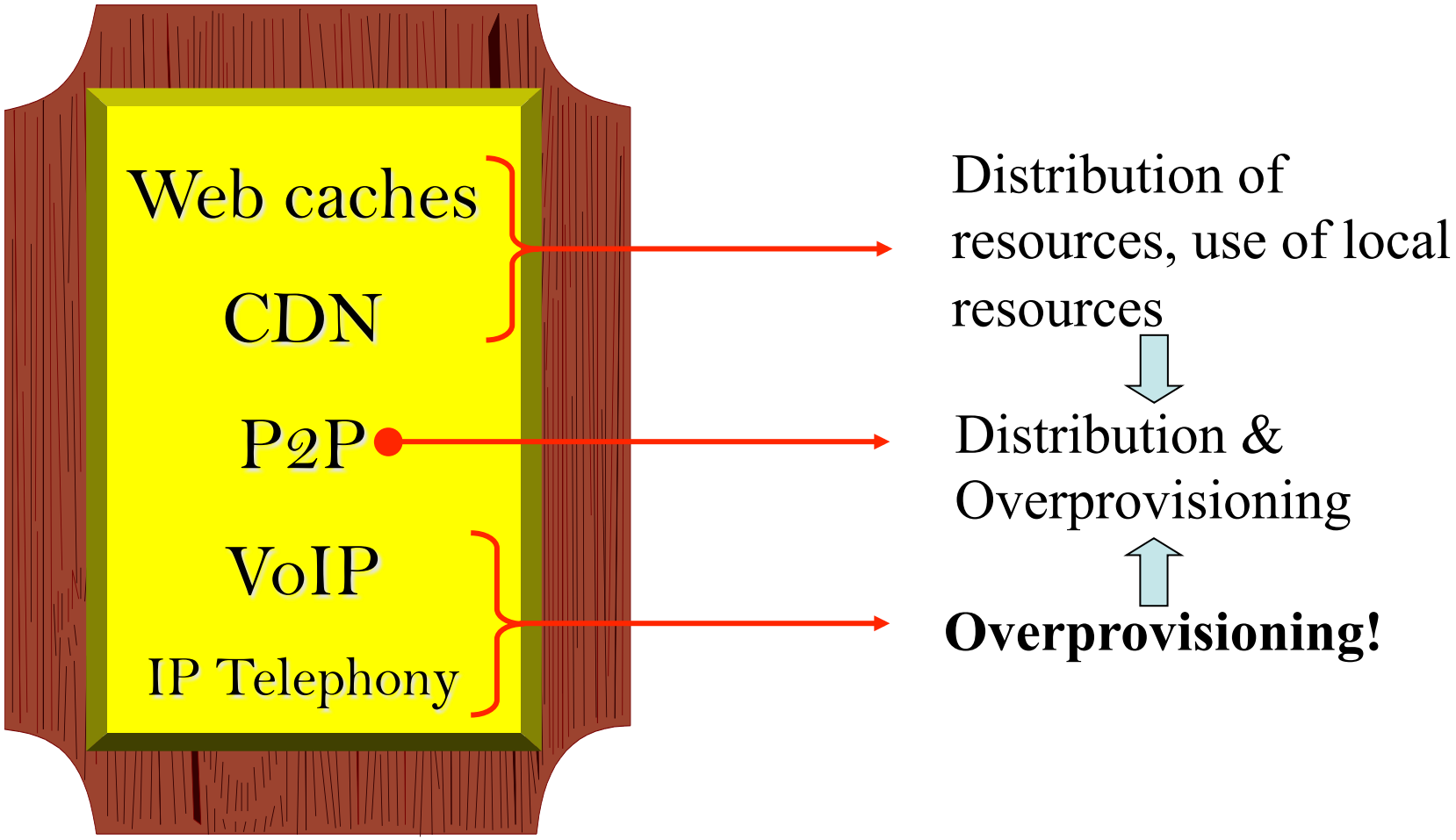
- Limit globalization
- Limit the pursuit of continued economic prosperity
- Redistribute labour, wages,…
- Promote the use of local resources
- Change mentality

Net Neutrality or Not?

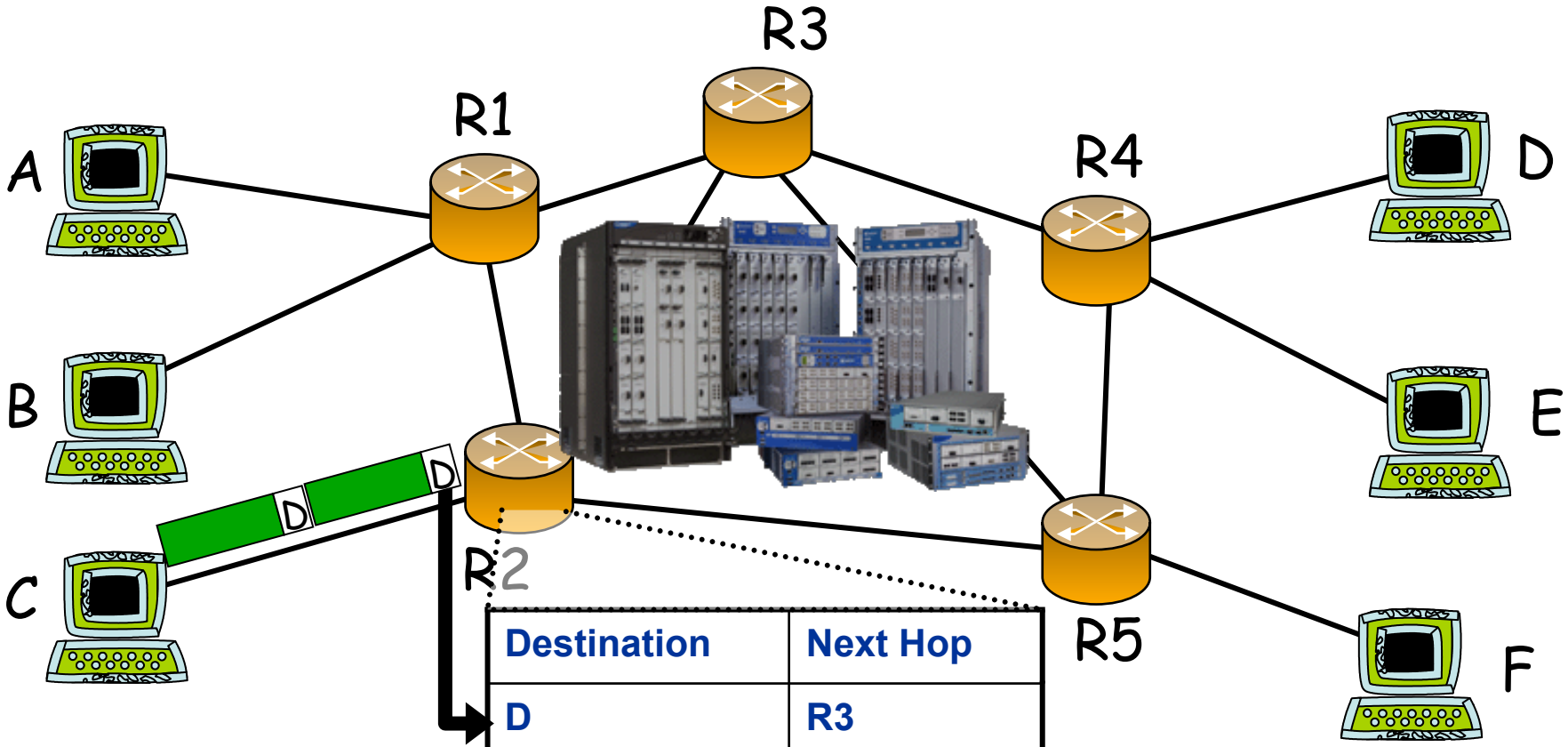
- NN or NNN? That's the question!
- NN = dumb network!
- Internet's success is in a large part debtful to what's called Net Neutrality (IP neutrality)
- So is the evolution of our society!

Can we afford to continue blind, unconcious development?

Some NN success stories

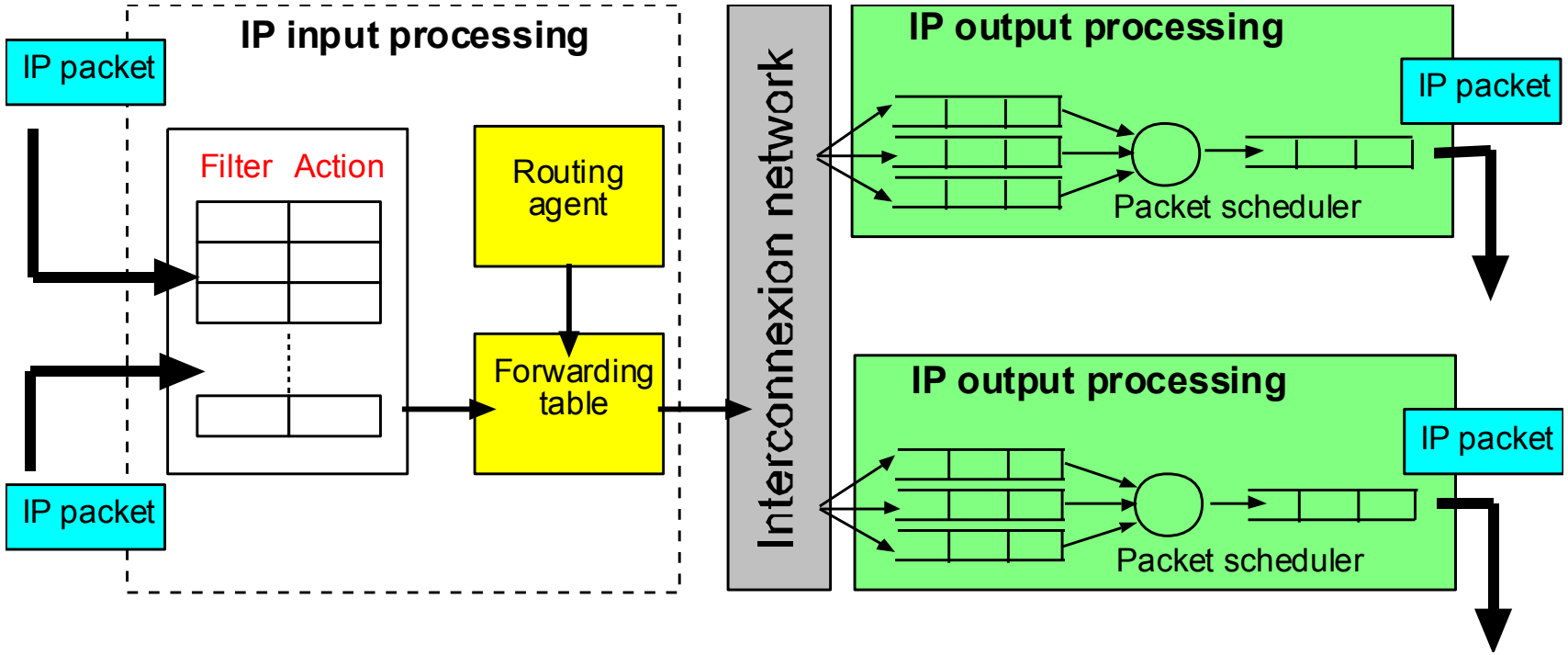


If no NN then give more power to routers!



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

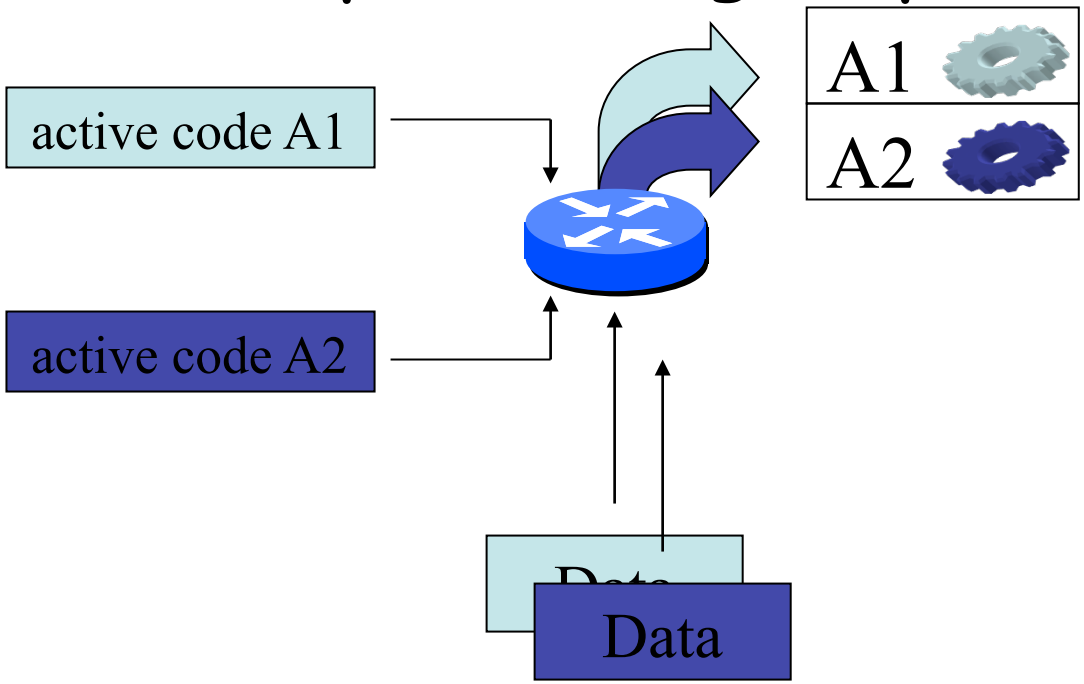
- From the user perspective
  - applications can specify, implement, and deploy (on-the-fly) customized services and protocols
- From the operator perspective
  - reduce the latency/cost for new services deployment/management
- From the network perspective
  - globally better performances by reducing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

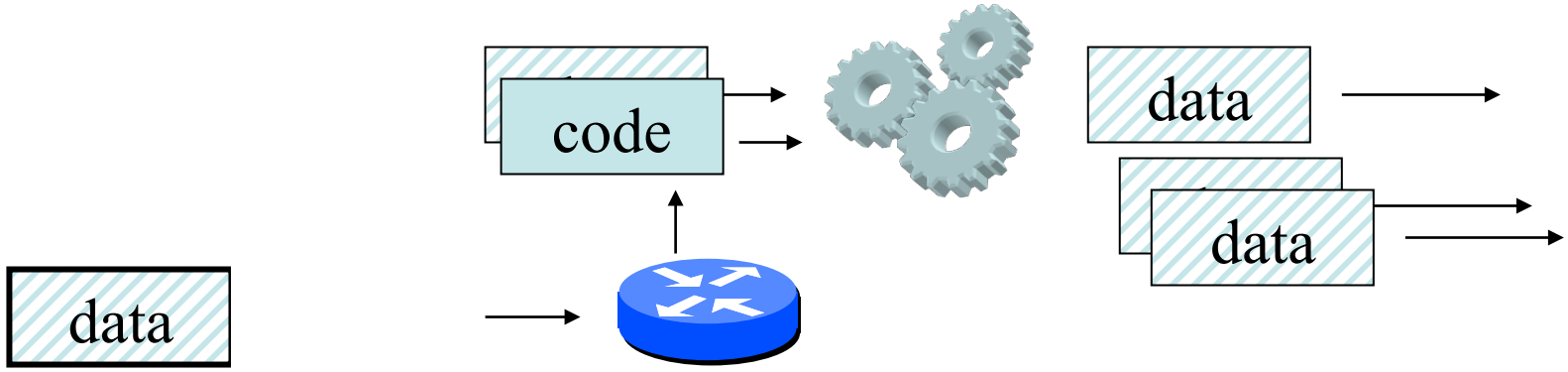
The discrete approach

- Separates the injection of programs from the processing of packets



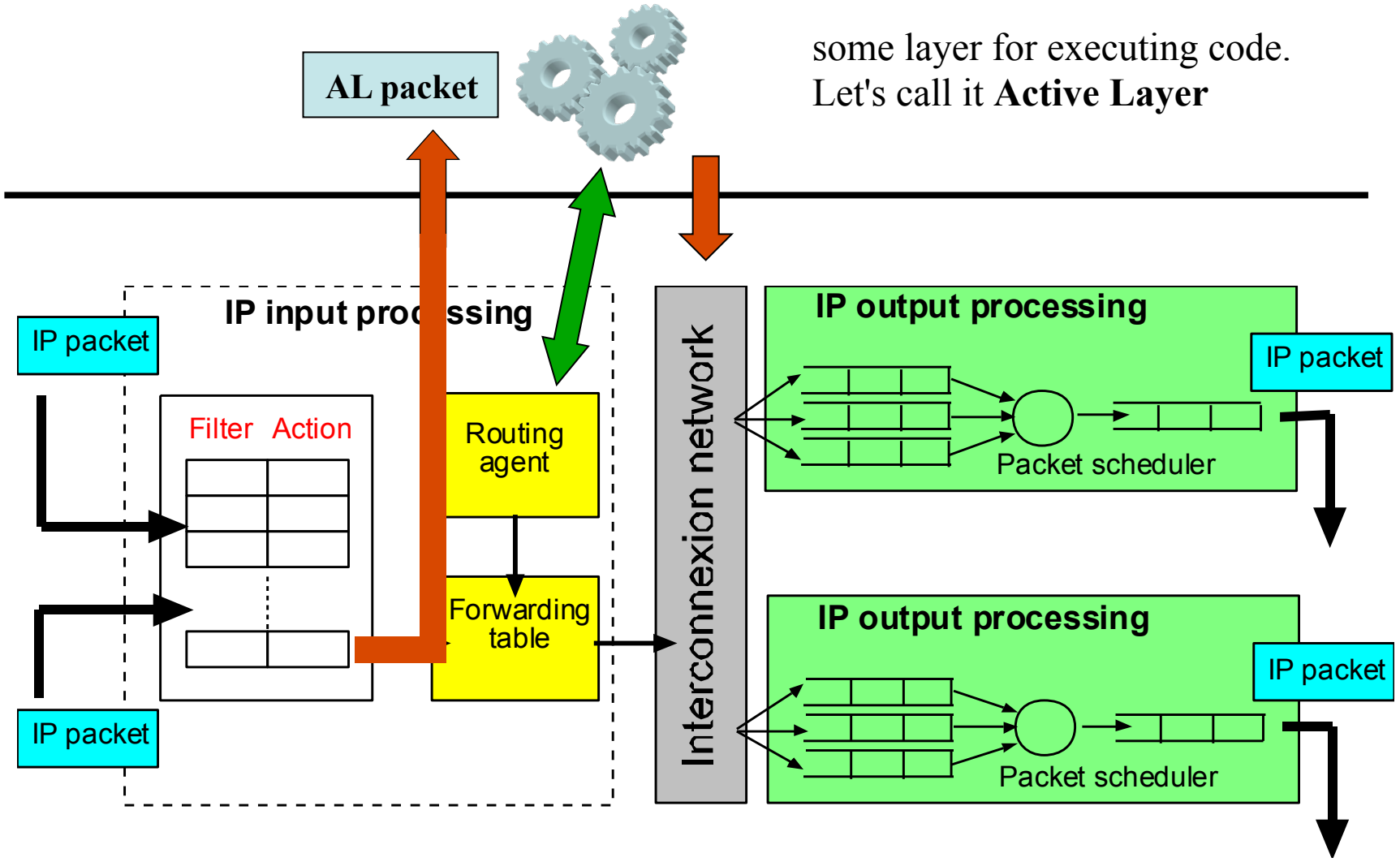
The integrated approach

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

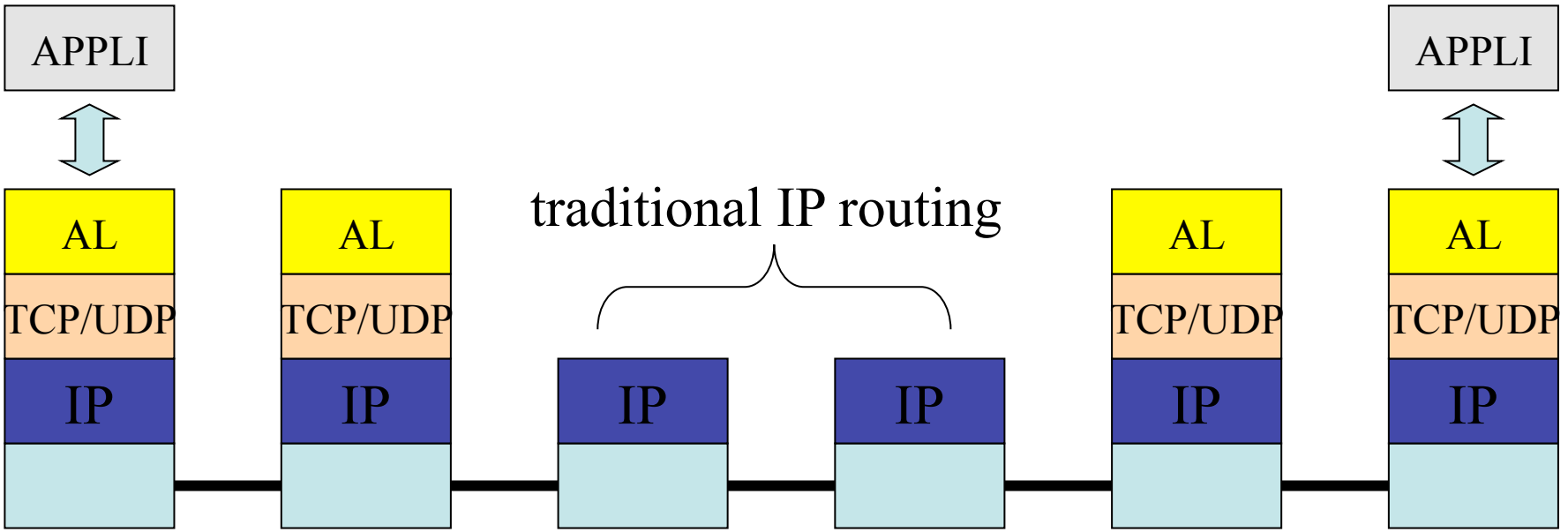


- High flexibility to define new services

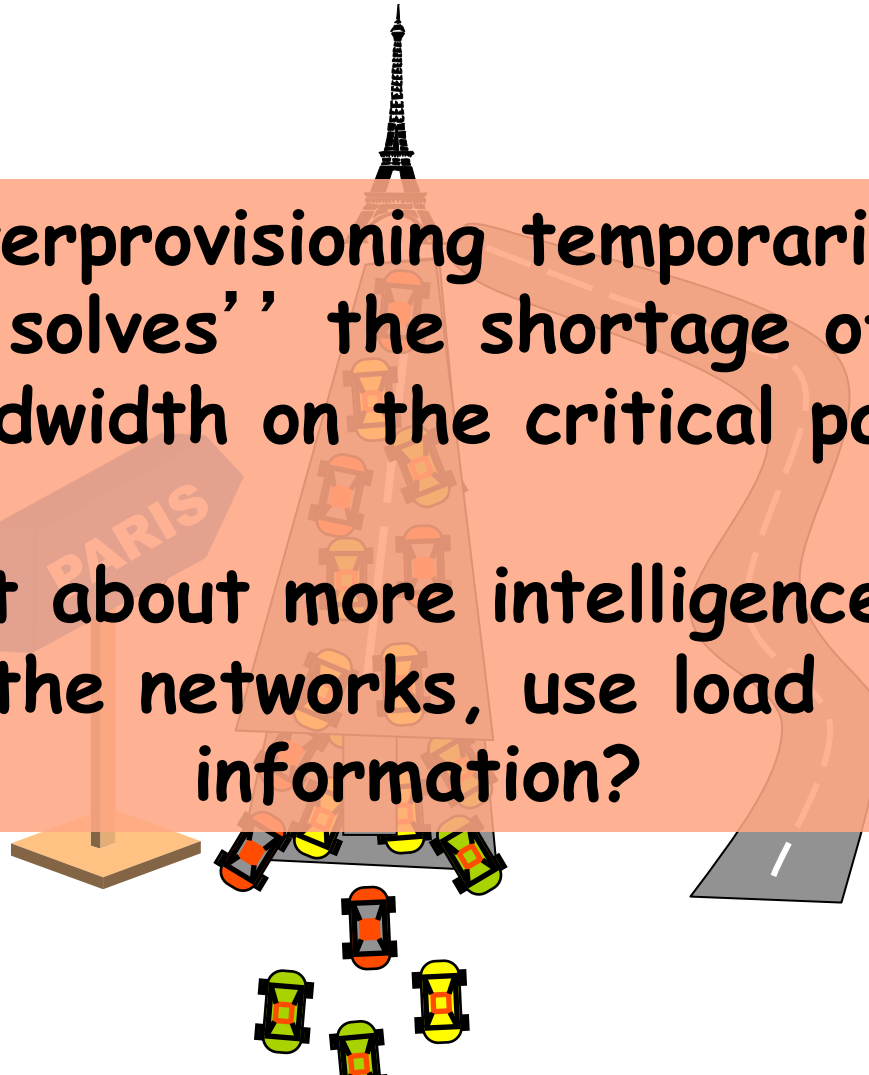
An active router



Interoperability with legacy routers



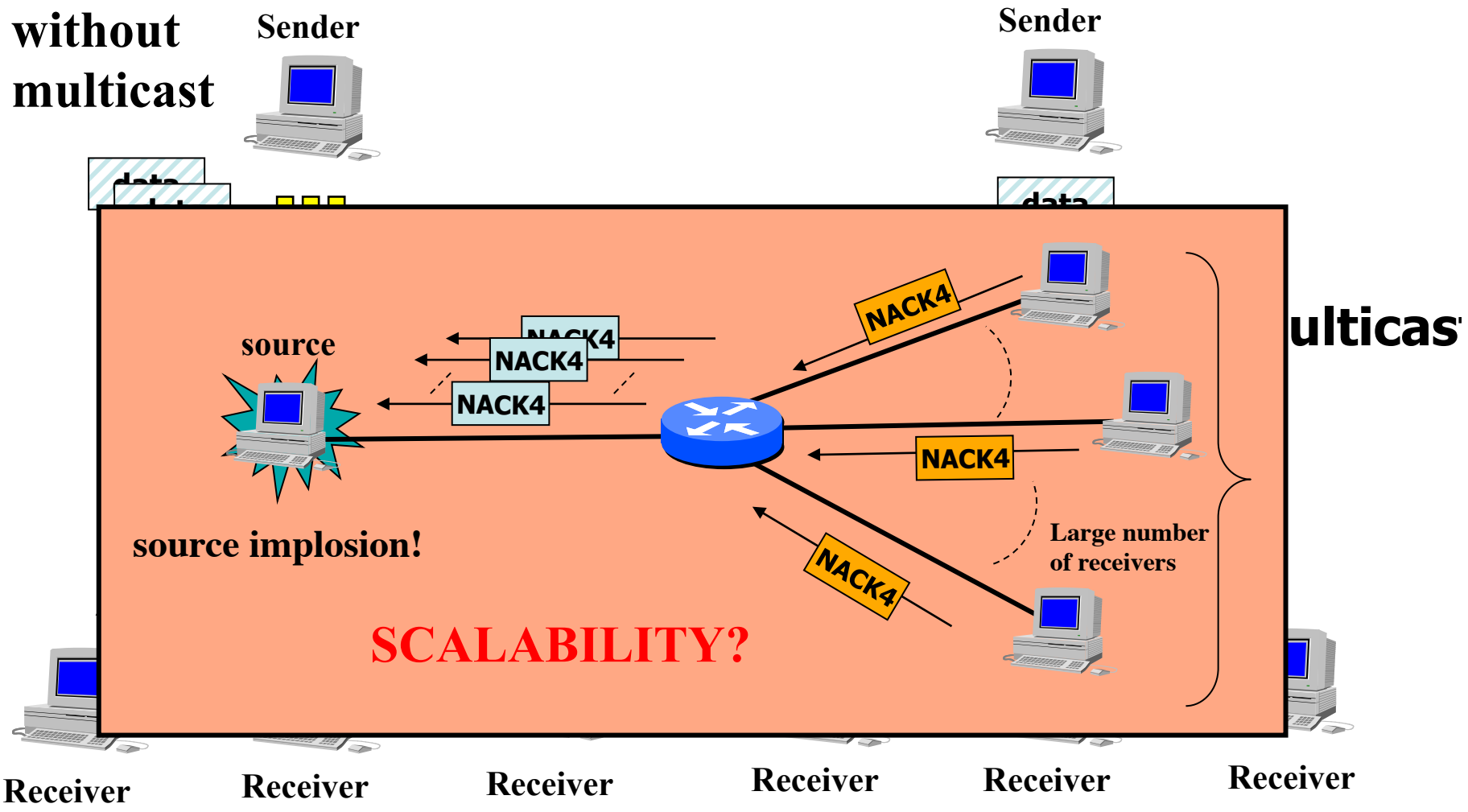
Example with routing



Overprovisioning temporarily ''solves'' the shortage of bandwidth on the critical path

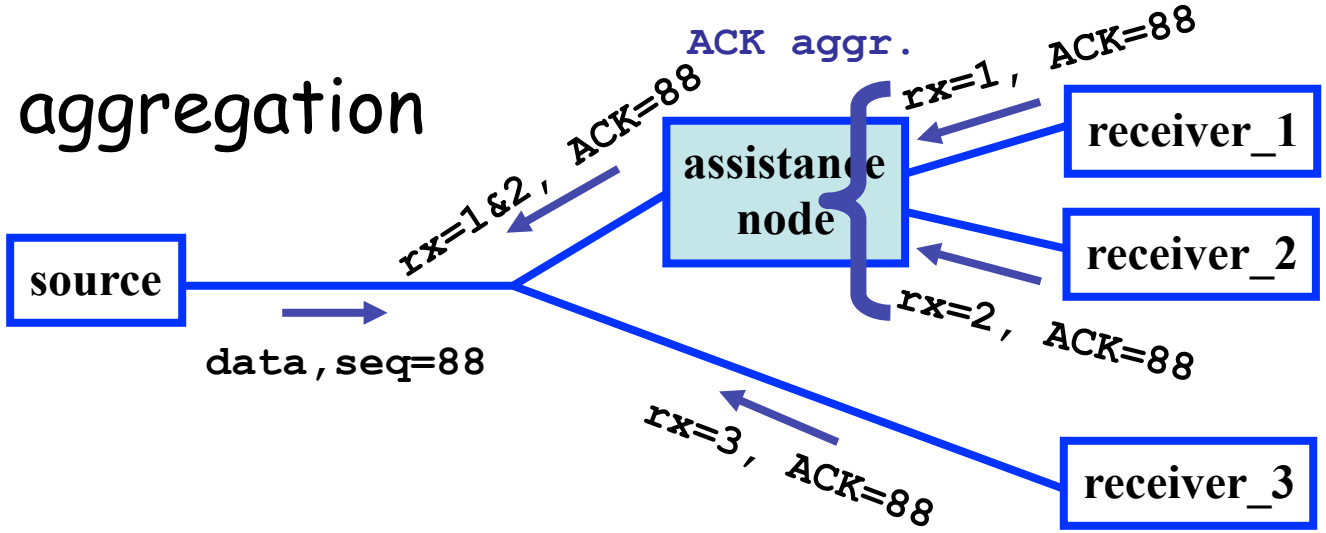
What about more intelligence in the networks, use load information?

Example with multicast

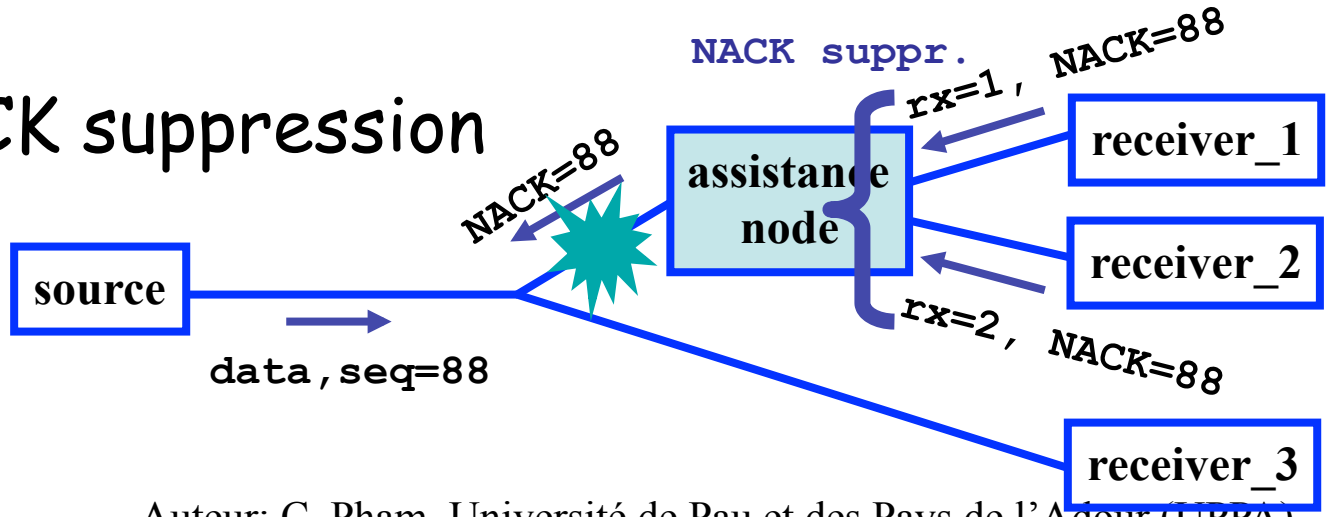


Feedback aggregation

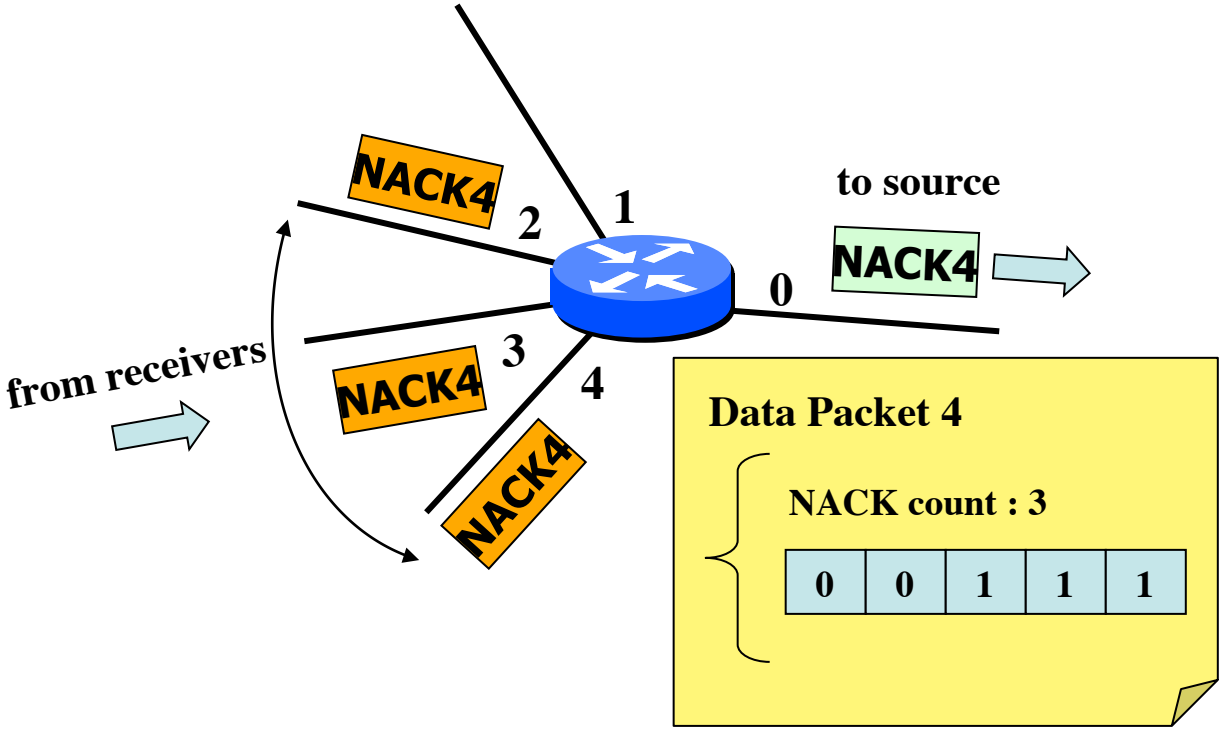
- ACK aggregation



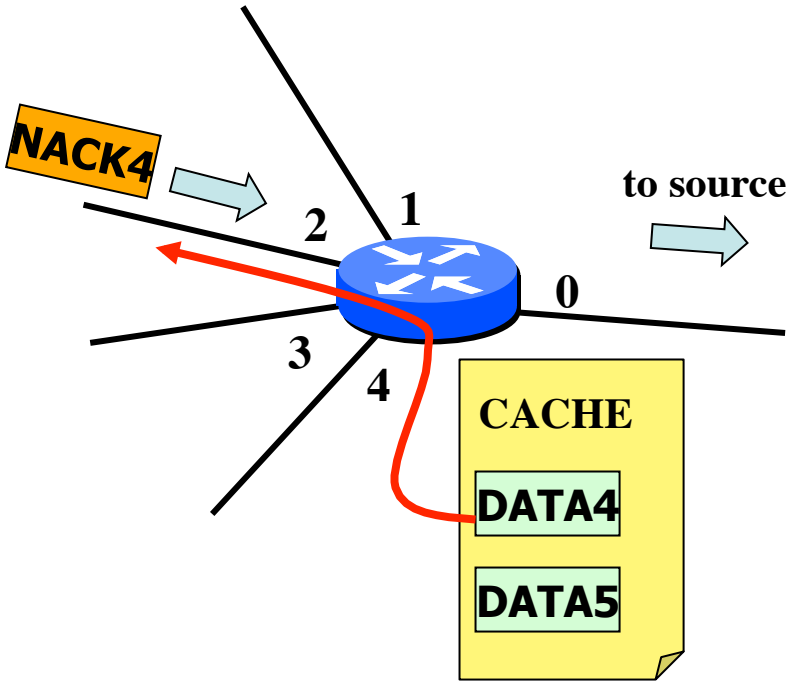
- NACK suppression



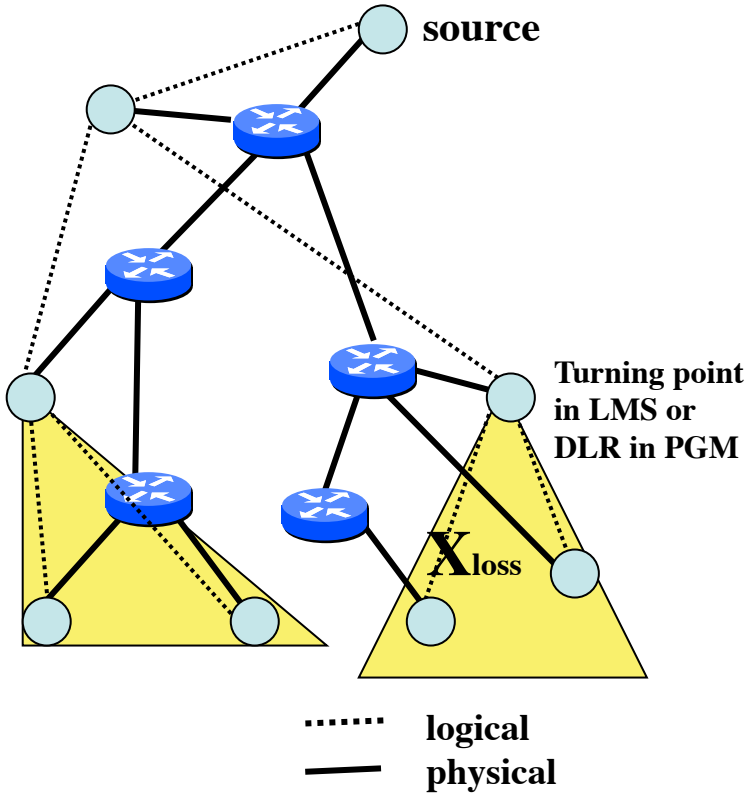
Implementing NACK aggregation



Advanced functionnalities

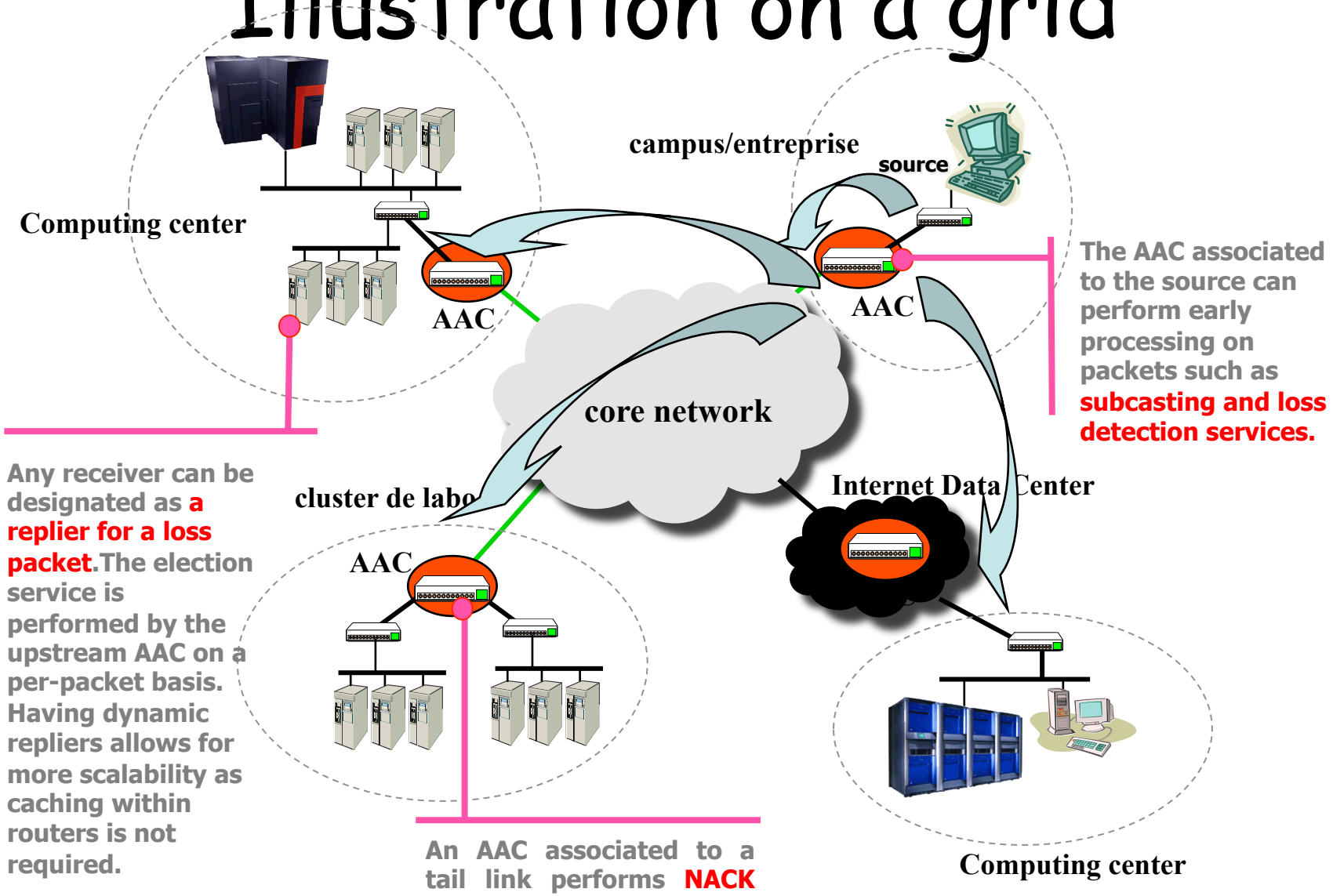


Data packet cache



Representative election

Illustration on a grid



The AAC associated to the source can perform early processing on packets such as **subcasting and loss detection services.**

Any receiver can be designated as **a replier for a loss packet**. The election service is performed by the upstream AAC on a per-packet basis. Having dynamic repliers allows for more scalability as caching within routers is not required.

An AAC associated to a tail link performs **NACK aggregation, subcasting and the election on a per-packet basis of the replier.**

AAC: ***application-aware component***