How the Internet will look like in a near future?

(De quoi sera fait l'Internet de demain?)

LIUPPA

January, 2006

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http://www.univ-pau.fr/~cpham

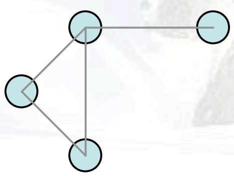
UPPA, France

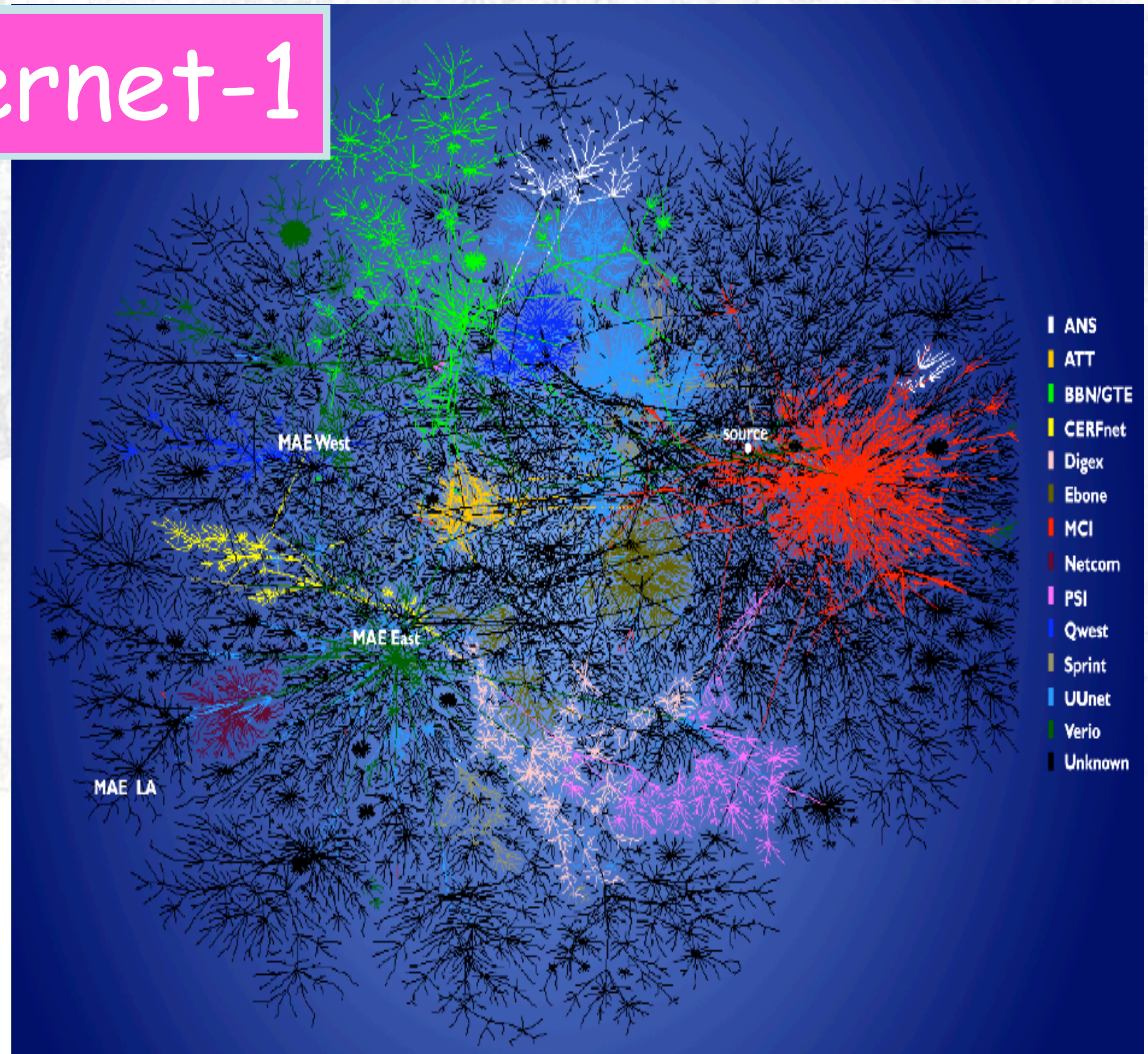
This talk is about…

It began with the need for communication…

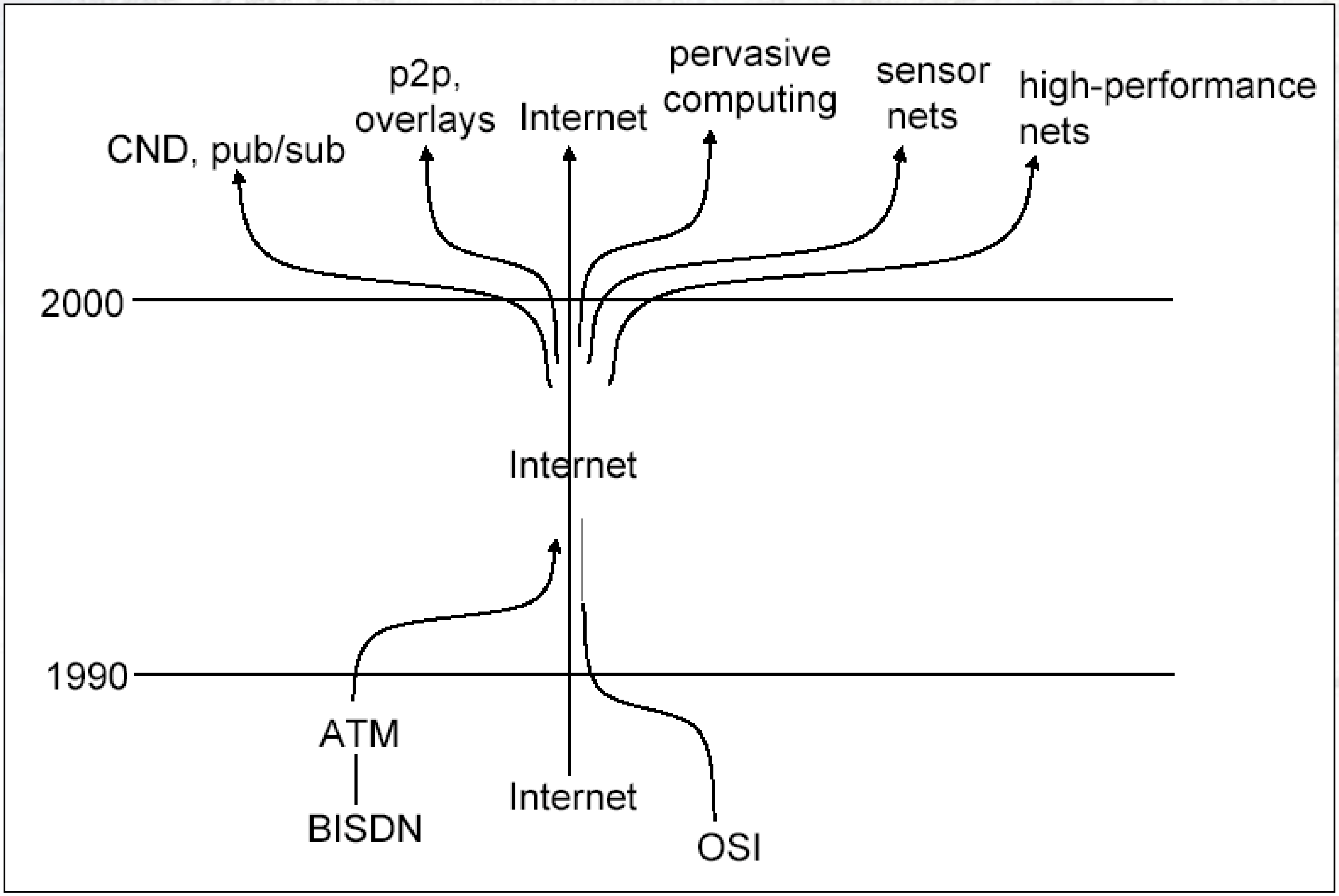
The big-bang of the Internet

Internet-1





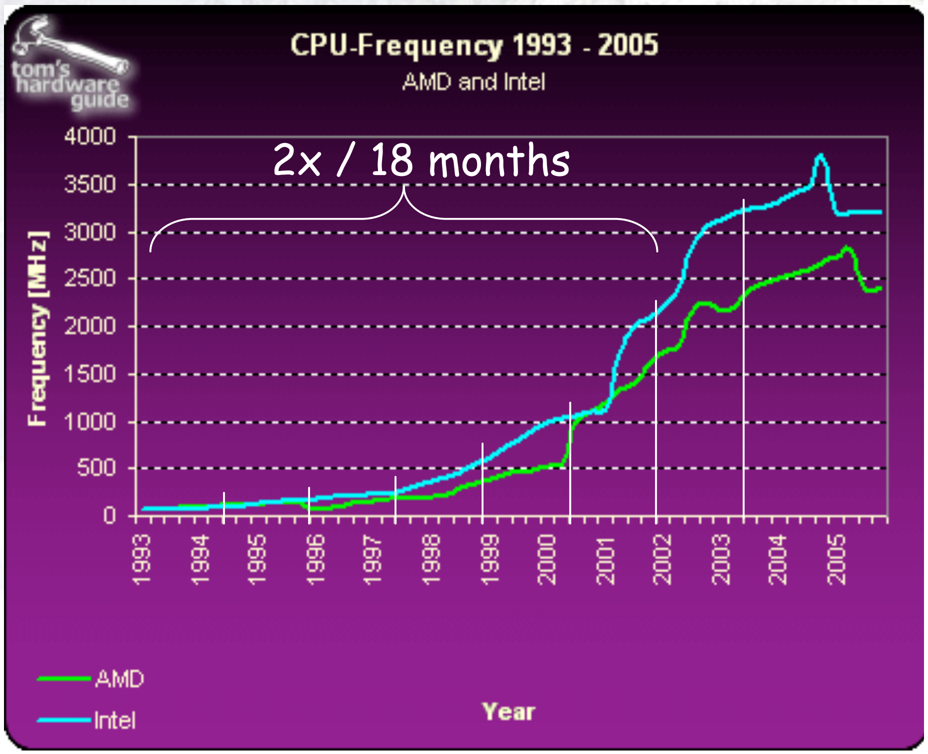
Towards all IP

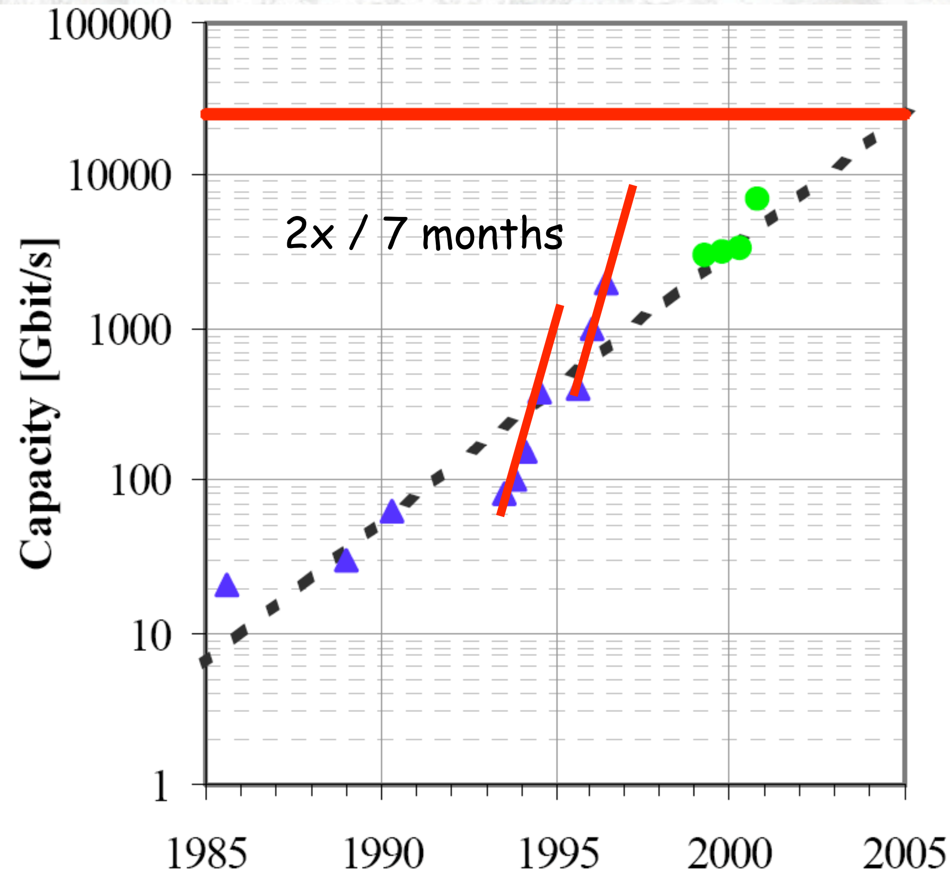


From Jim Kurose

A whole new world for IP

1st revolution: optical transmission

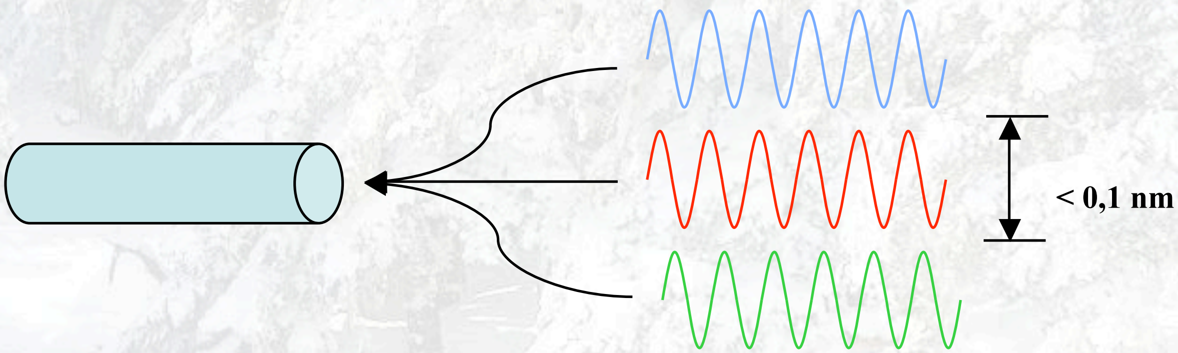


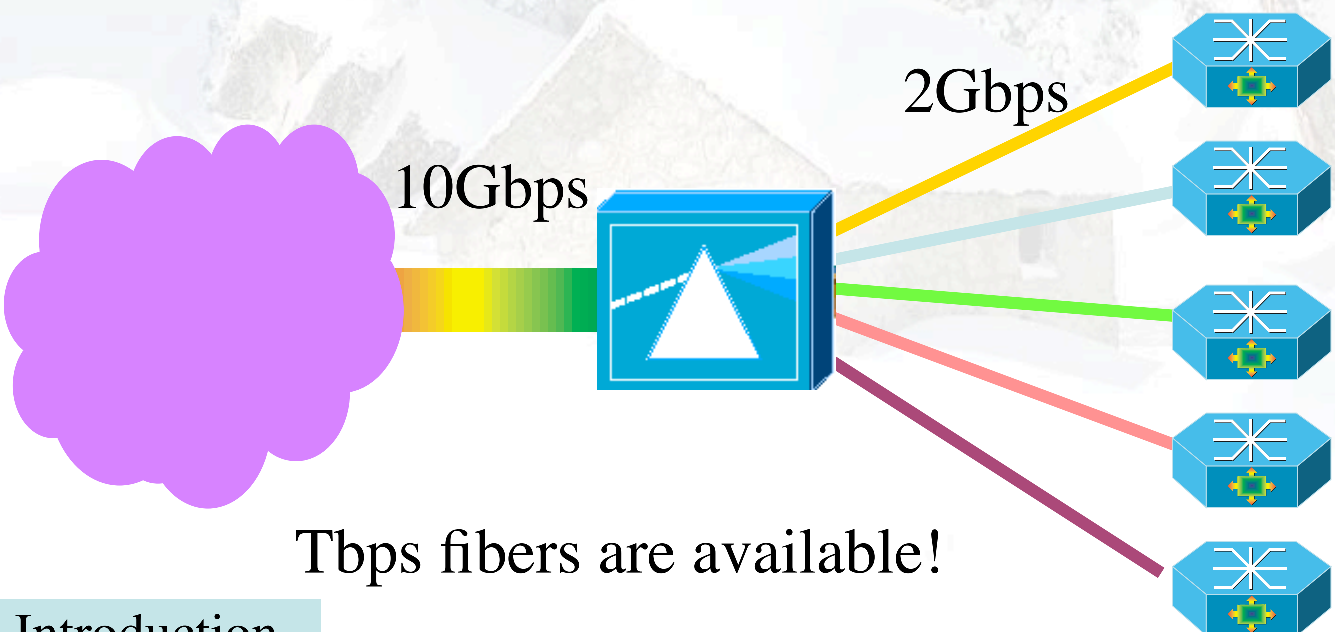


Source « Optical fibers for Ultra-Large Capacity Transmission » by J. Grochocinski

DWDM, bandwidth for free?

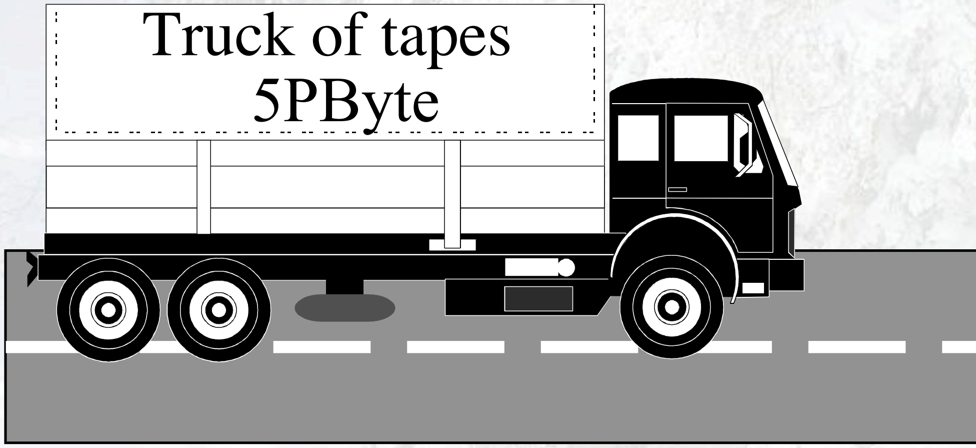
DWDM: Dense Wavelength Division Multiplexing





Tbps fibers are available!

The information highways



DWDM

NEWS of Dec 15th, 2004

3 A throughput of 1.28 Tbits/s has been achieved on a 430kms regular monomode fiber between France Telecom and Deutsch Telecom using 8 DWDM channels (EU project TOPRATE)

Revisiting the truck of tapes

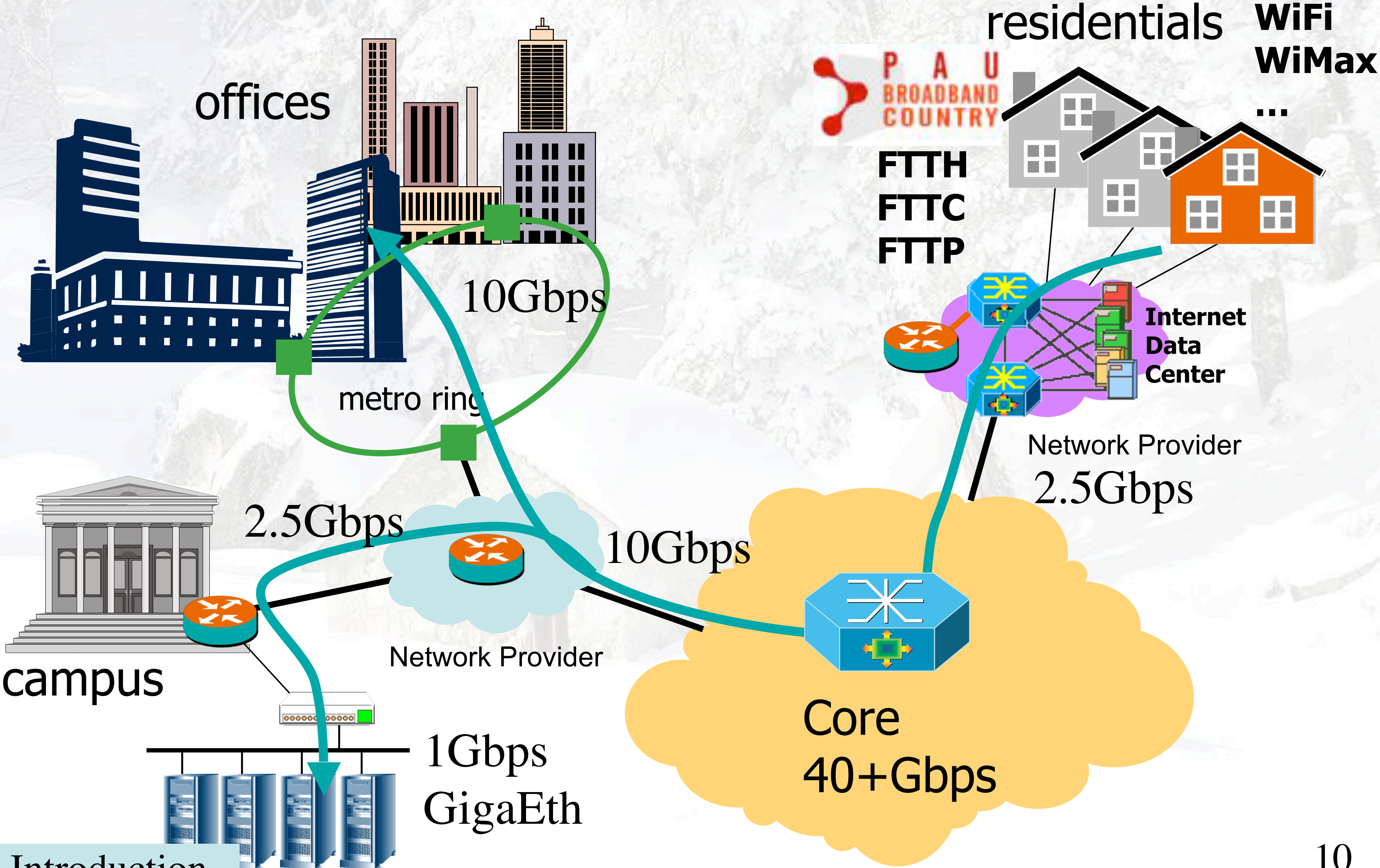
(18 of 18)

Consider one fiber

- Current technology allows for 320 λ in one of the frequency bands
- Each λ has a bandwidth of 40 Gbit/s
- Transport: $320 * 40*10^9 / 8 = 1600$ GByte/sec
- Take a 10 metric ton truck
- One tape contains 50 Gbyte, weights 100 gr
- Truck contains (10000 / 0.1) * 50 Gbyte = 5 PByte
- Truck / fiber = 5 PByte / 1600 GByte/sec = 3125 s ≈ one hour
- For distances further away than a truck drives in one hour (50 km) minus loading and handling 100000 tapes **the fiber wins!!!**

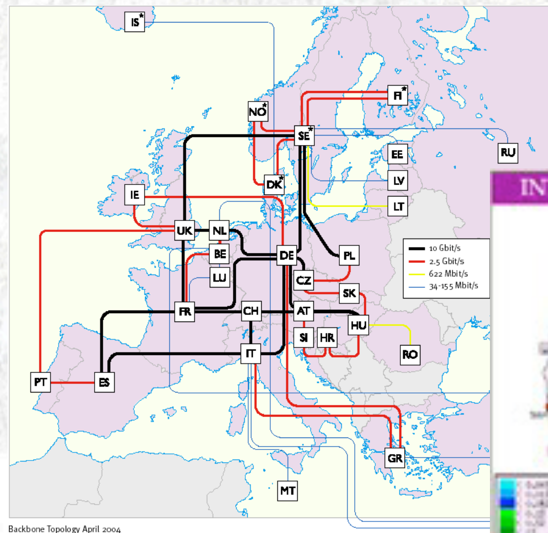
Example from A. Tanenbaum, slide from Cees De Laat

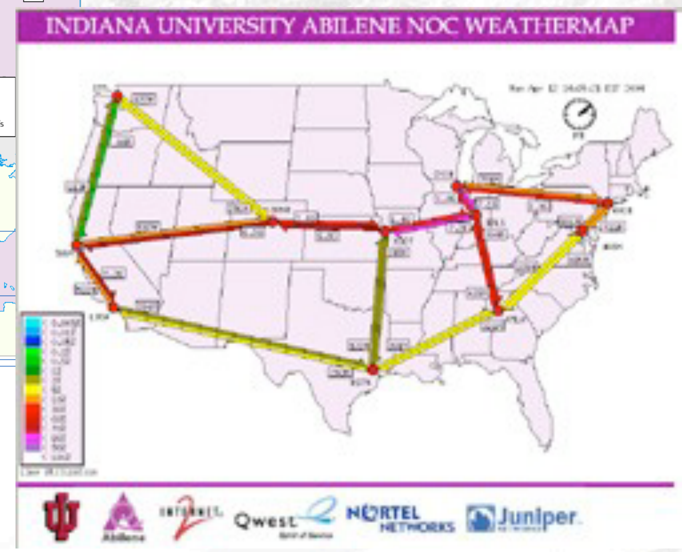
Fibers everywhere?



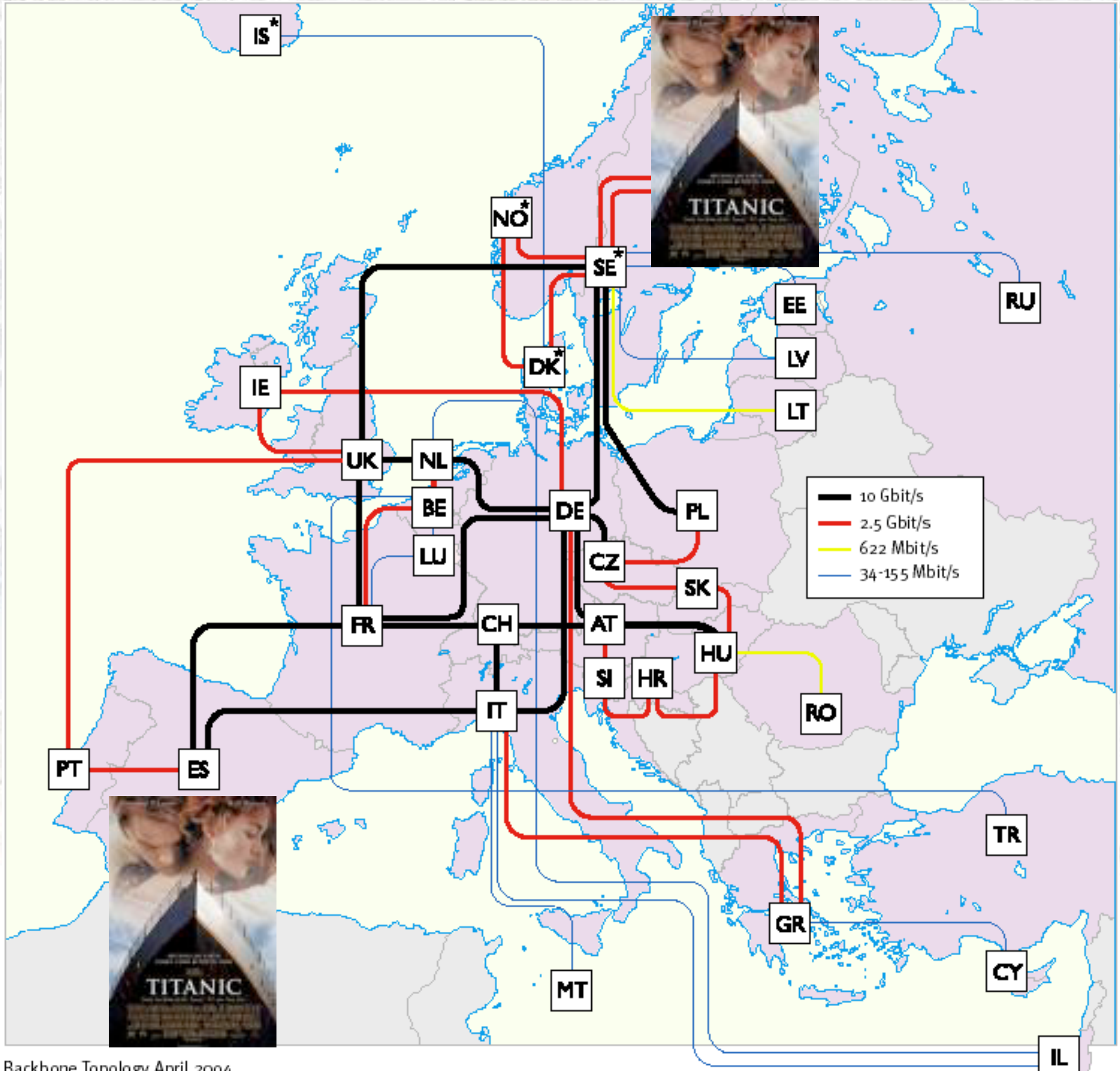
The new networks

- vBNS
- Abilene
- SUPERNET
- DREN
- CA*NET
- GEANT
- DATATAG
- ...much more to come!





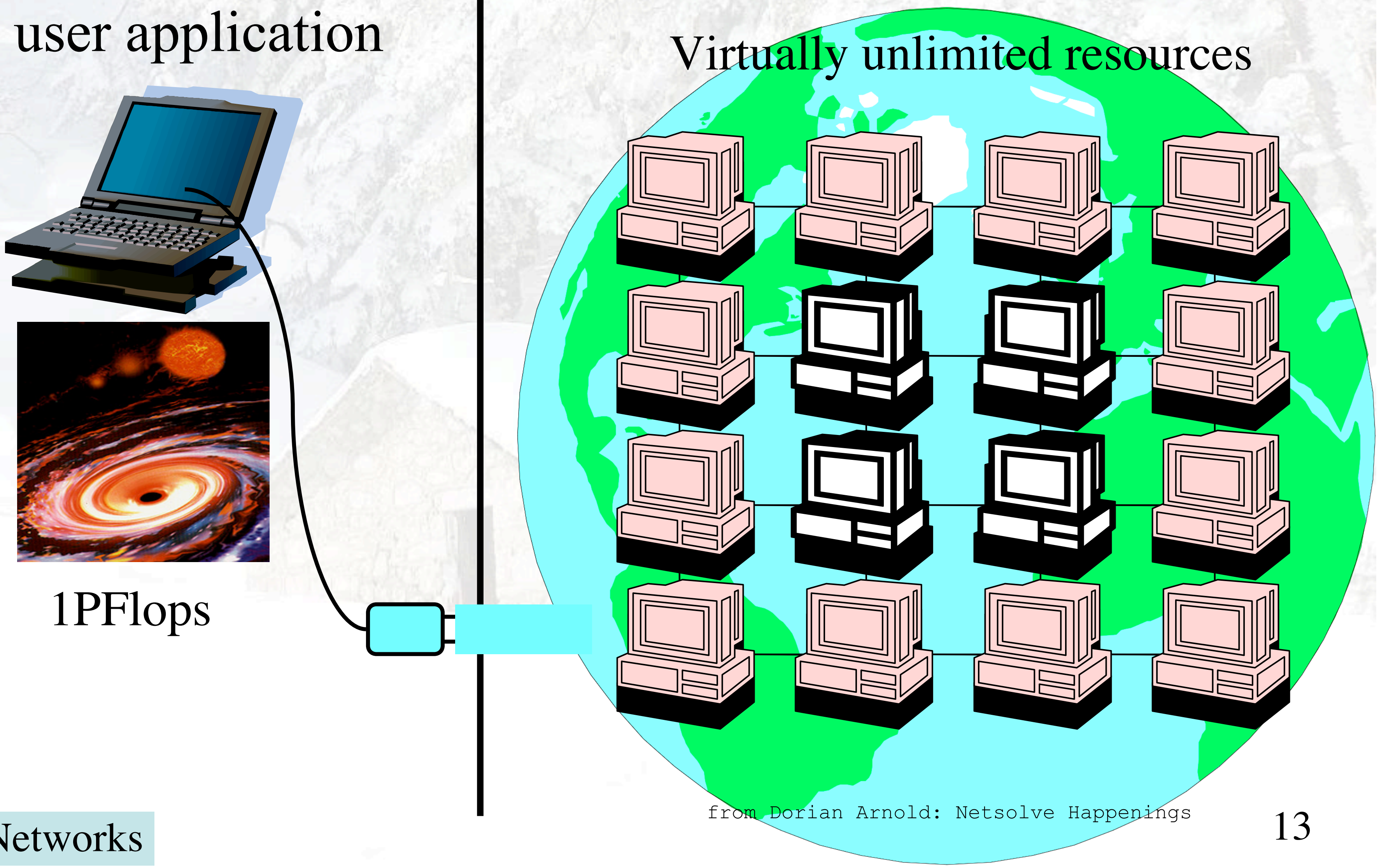
GEANT



Backbone Topology April 2004

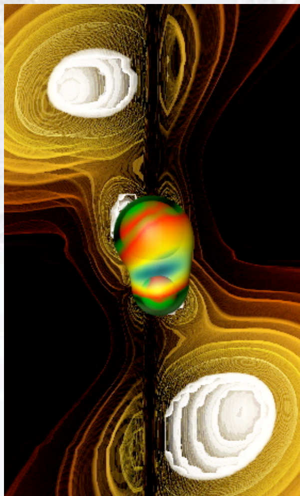
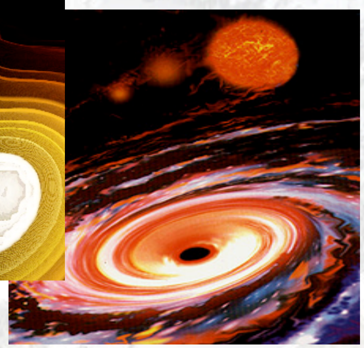
Computational grids

user application

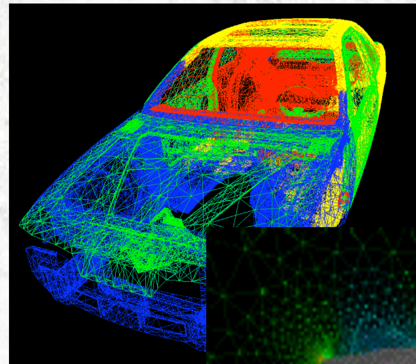
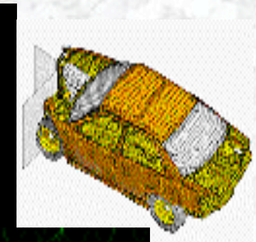
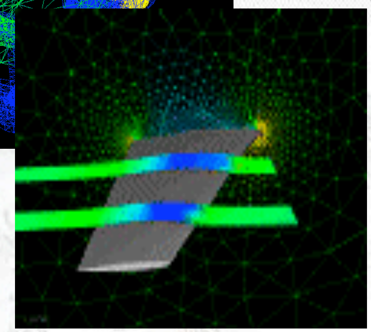


from Dorian Arnold: Netsolve Happenings

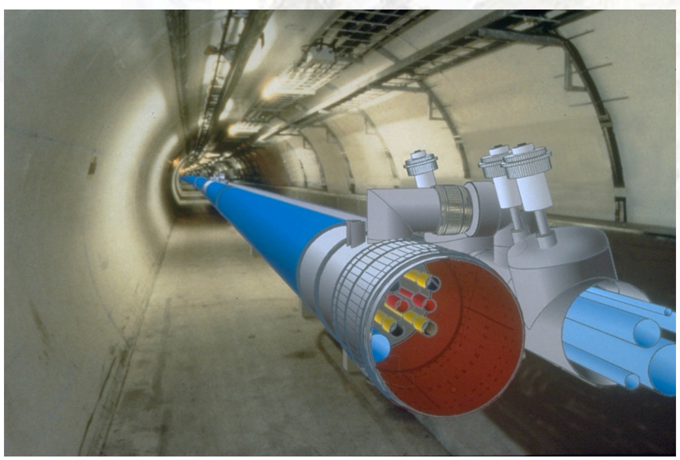
A large variety of applications

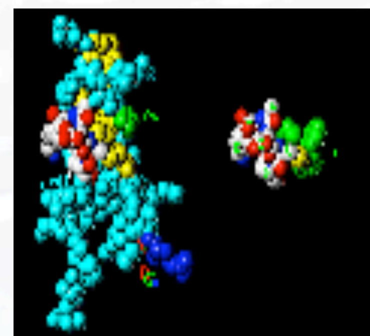
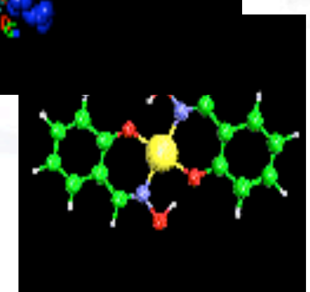
Astrophysics:
Black holes,
neutron stars,
Supernovae…

Mechanics:
Fluid dynamic,
CAD, simulation.

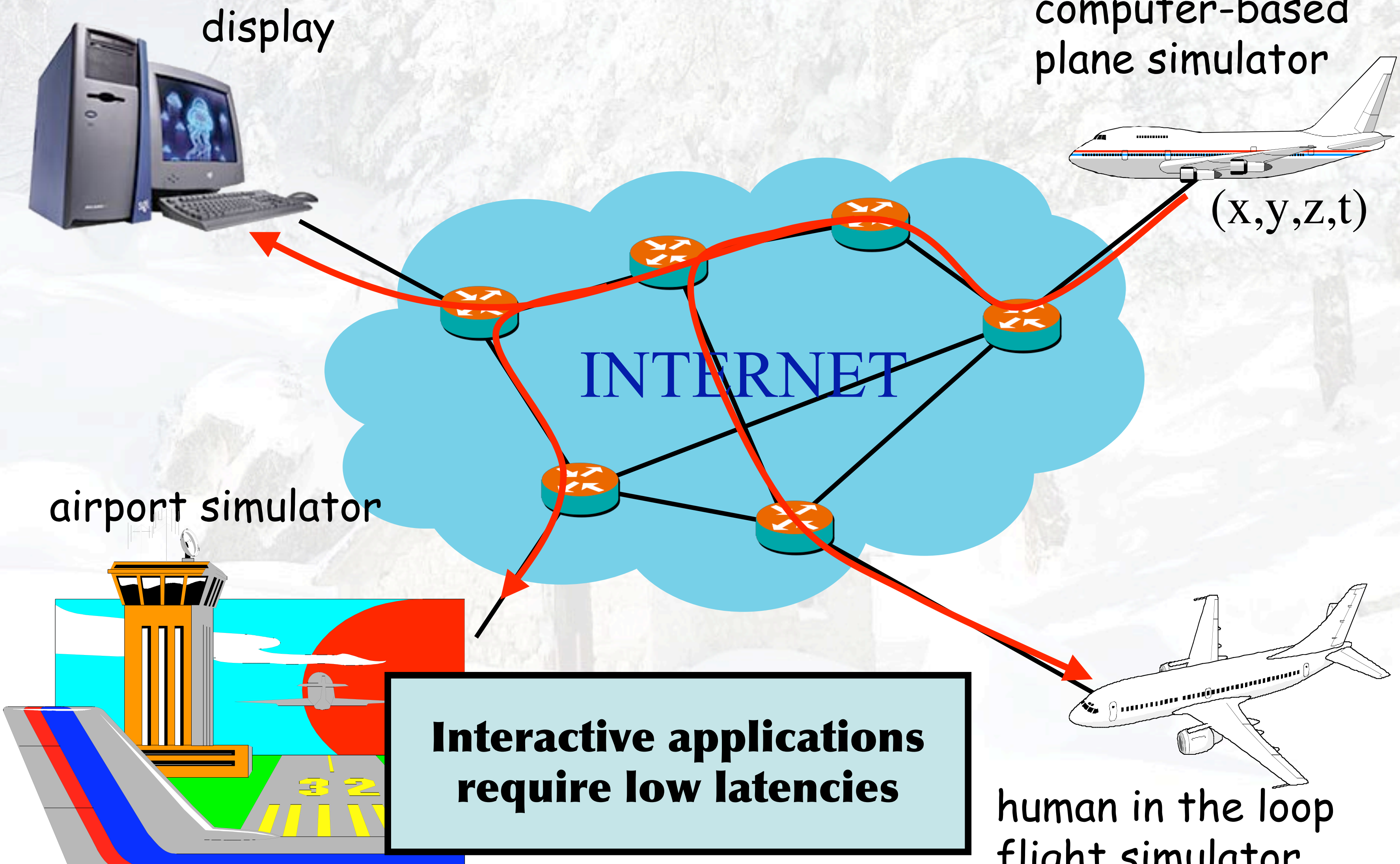


High-Energy Physics:
Fundamental particles of matter,
Mass studies…

Chemistry&biology:
Molecular simulations,
Genomic simulations…

Wide-area interactive simulations



Interactive applications require low latencies

Internet-1 & Internet-2

- The network is a transport network, only a transport network!
- Processing inside the network is limited to tasks for performing the transport itself
- End-to-end is the main way of operation
- Links are getting faster, host are getting more and more powerful

Hiding behind the Net!

- The Internet scales because IP assumes almost nothing!

Borrowed from N. Gershenfeld

ON THE INTERNET NOBODY KNOWS YOU'RE A DOG!

The outsider: active/programmable networks

- Opens hardware to users/operators
- Allows customized processing within network nodes
- Breaks the end-to-end paradigm of the Internet
- Have high potential for customization of services

- Router-assisted contributions
  - feedback aggregation
  - cache of data to allow local recoveries
  - subcast
  - early lost packet detection
  - …

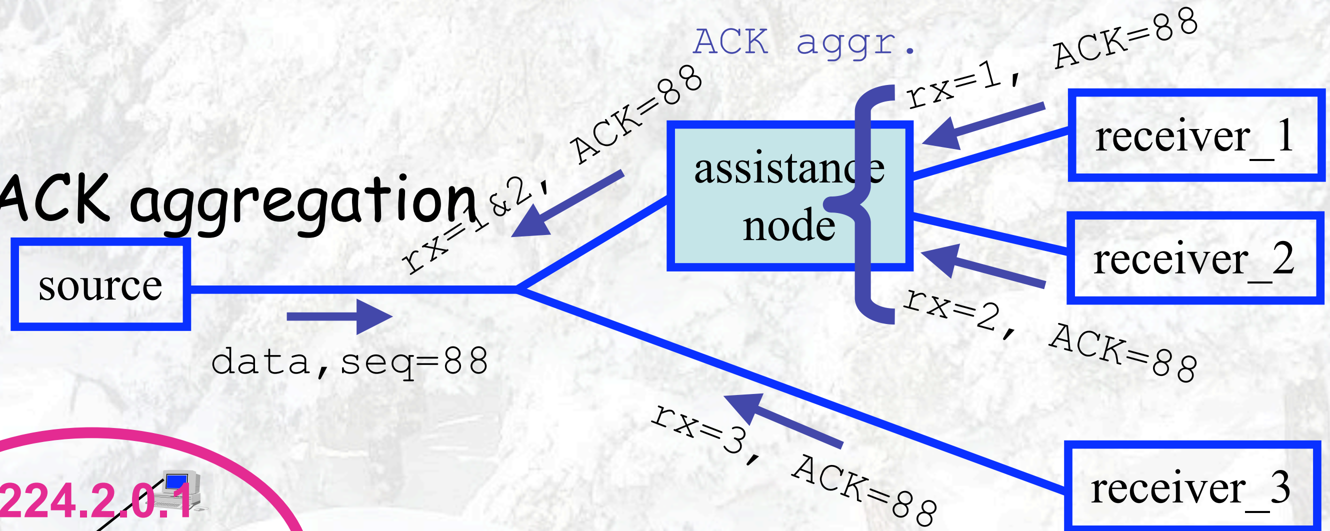
Leading applications

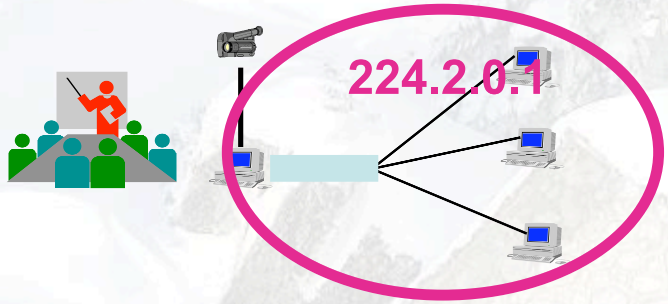
- Multimedia communication
  - On-the-fly adaptation of contents
  - New service deployment
- Multicast and group management
  - Topology management
  - Control feedbacks

Traditionally performed
with end-to-end mechanisms

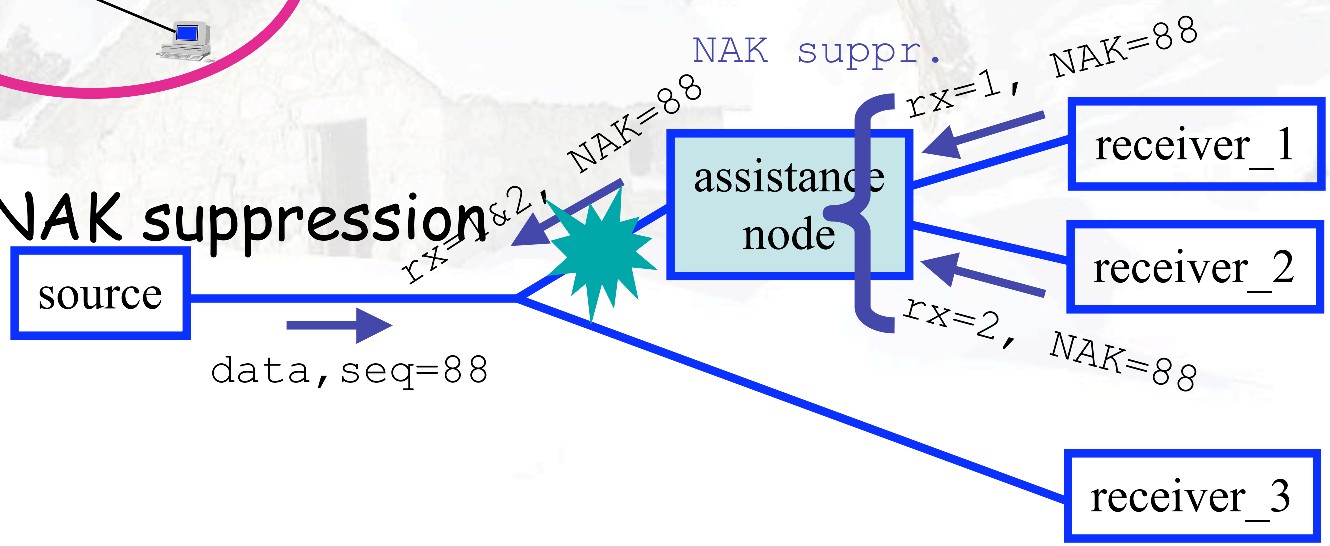
Ex: feedback aggregation

- ACK aggregation



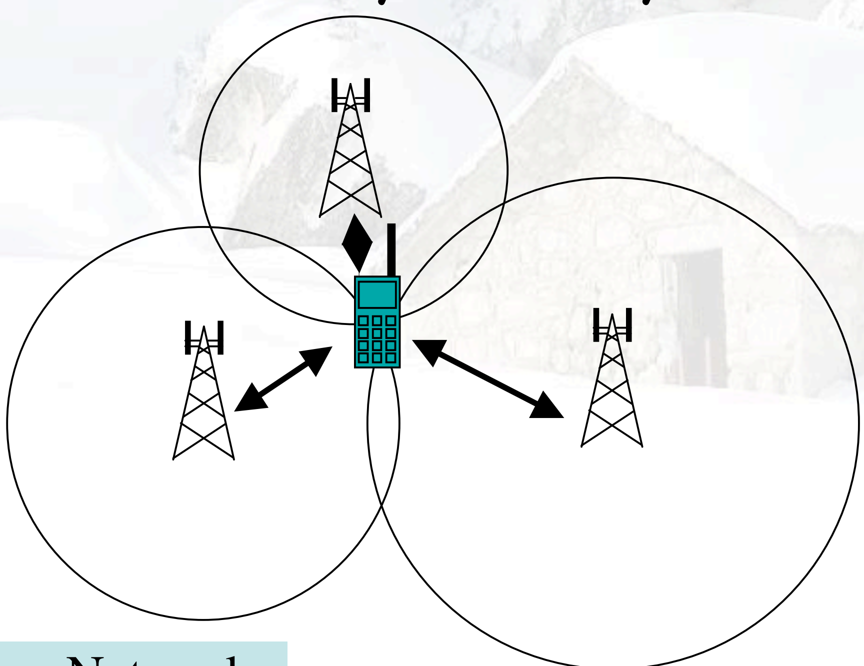


- NAK suppression



2^{nd} revolution: Wireless Networks

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



Ad-hoc (wireless) networks

- Mobile ad-hoc networks (MANETS) are networks built on-the-fly, no need for infrastructure

Future will be wireless!

- True for end-users!
- Wireless hot-spots provide ubiquitous access to the Internet
- Lots of high-value added services
  - E-mail and Internet surfing when travelling
  - High-quality multimedia streaming in hospitals, nomadic applications
  - Easy updates of advertising panels
  - Monitoring of elderly people
  - Much more to come!!!

Now, what's up?

Internet-1

Internet-2

Internet-~~3~~

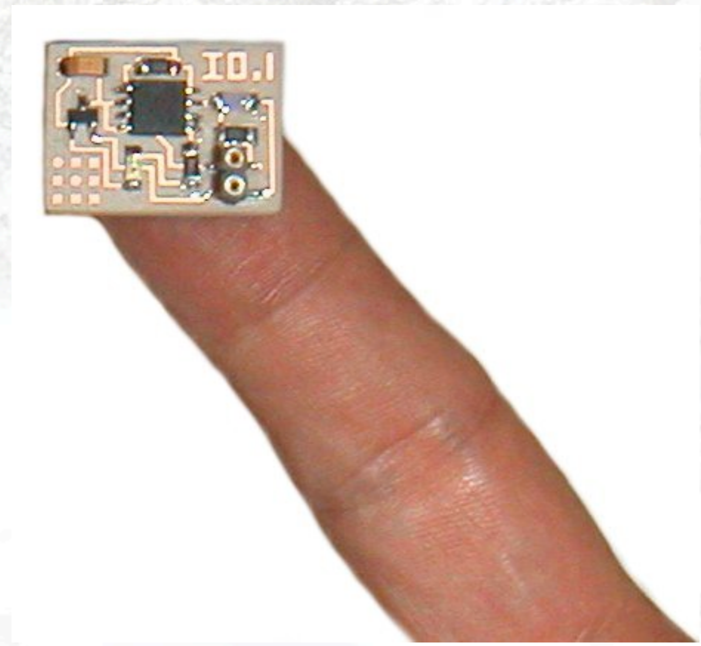
0

Internet-0: the Internet of Things

Borrowed from N. Gershenfeld

 ON THE INTERNET NOBODY KNOWS YOU'RE A LIGHT BULB!

Internet Hosts

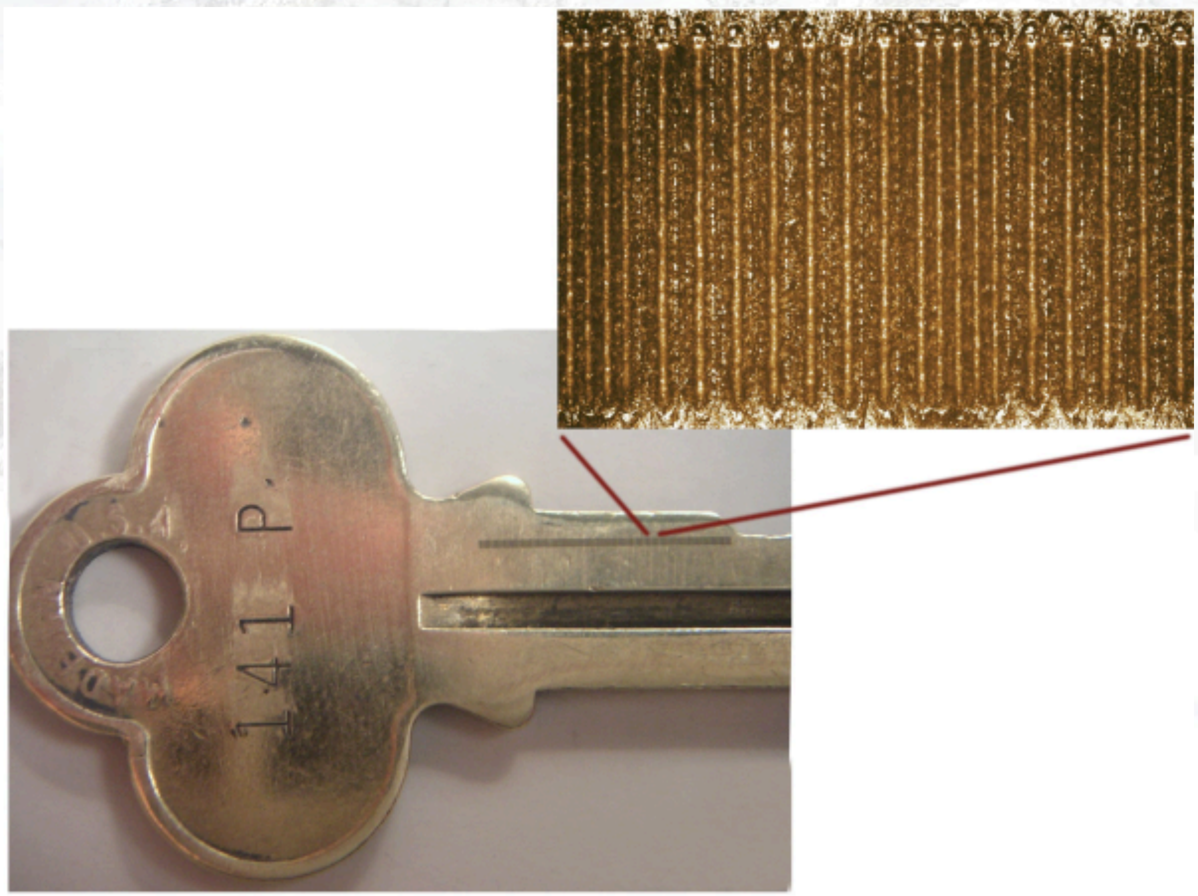


1974 **2004**

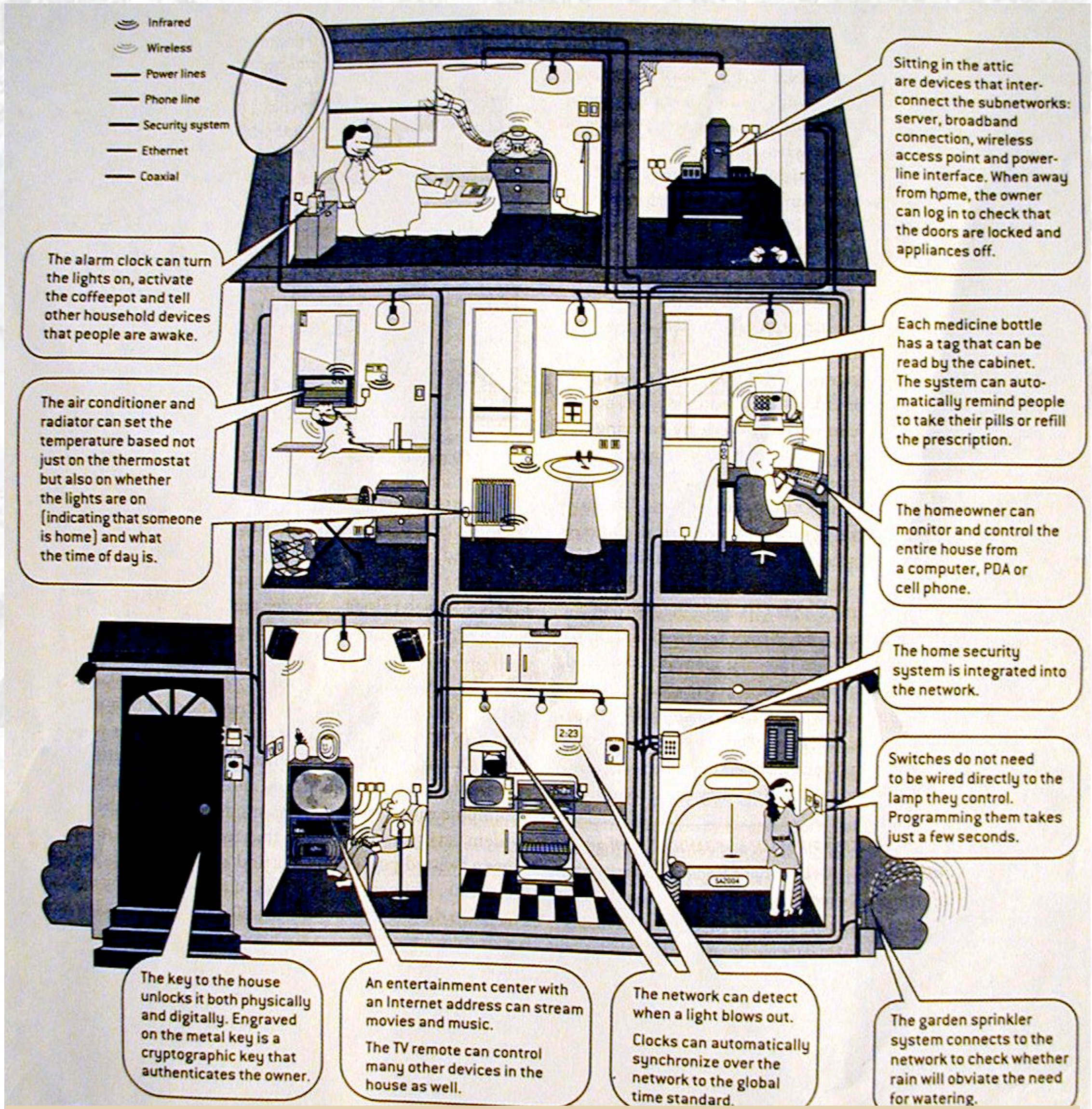
Borrowed from N. Gershenfeld

IP on a simple key?

UDP
Src 18.243.0.1
Dst 18.243.0.1
Port 80
IP header
UDP header



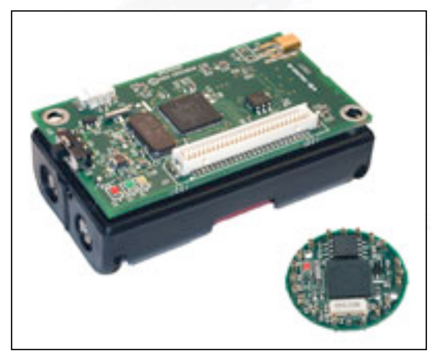
Ambient Networking



From « The Internet of Thing », Scientific American, Oct 2004

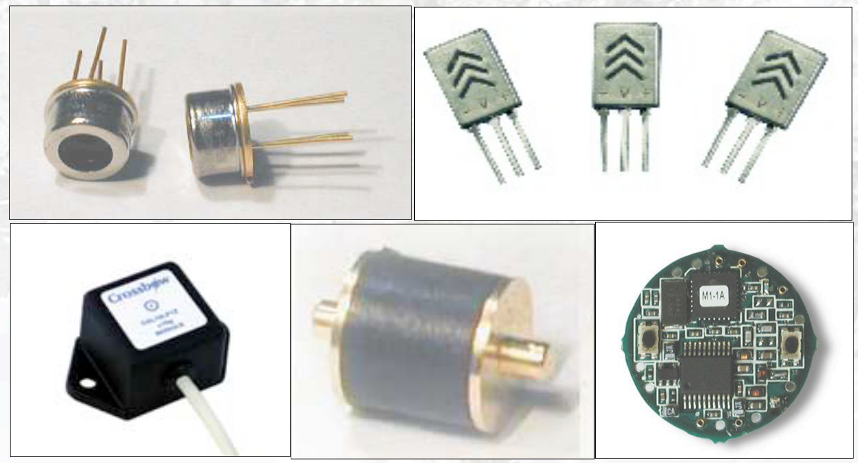
What's missing?

Between the PDA and the RFID tag of Internet-0, is the wireless autonomous sensor



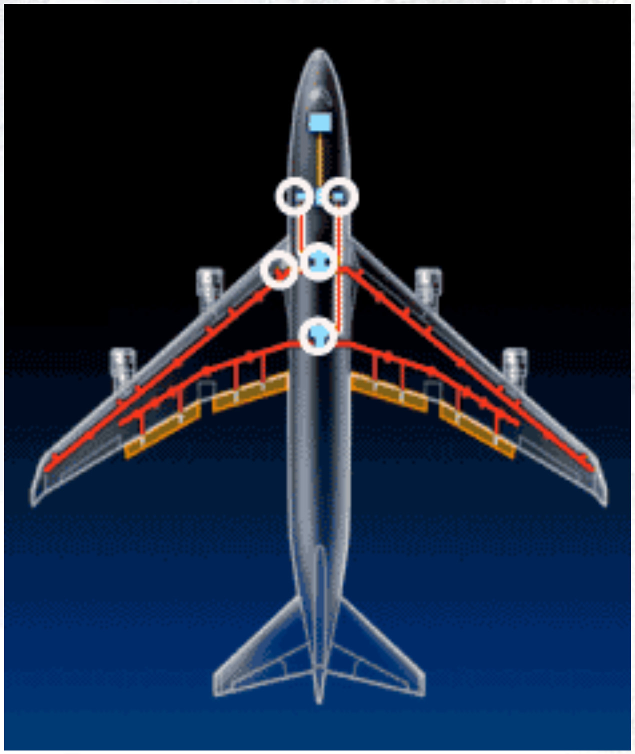
What Is A Sensor Node?

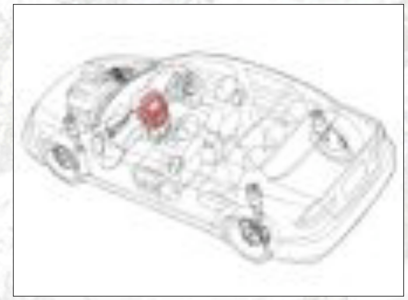
- Sensor nodes could monitor a wide variety of ambient conditions that include the following:
  - temperature,
  - humidity,
  - vehicular movement,
  - lightning condition,
  - pressure,
  - soil makeup,
  - noise levels,
  - the presence or absence of certain kinds of objects,
  - mechanical stress levels on attached objects, and
  - the current characteristics such as speed, direction, and size of an object.



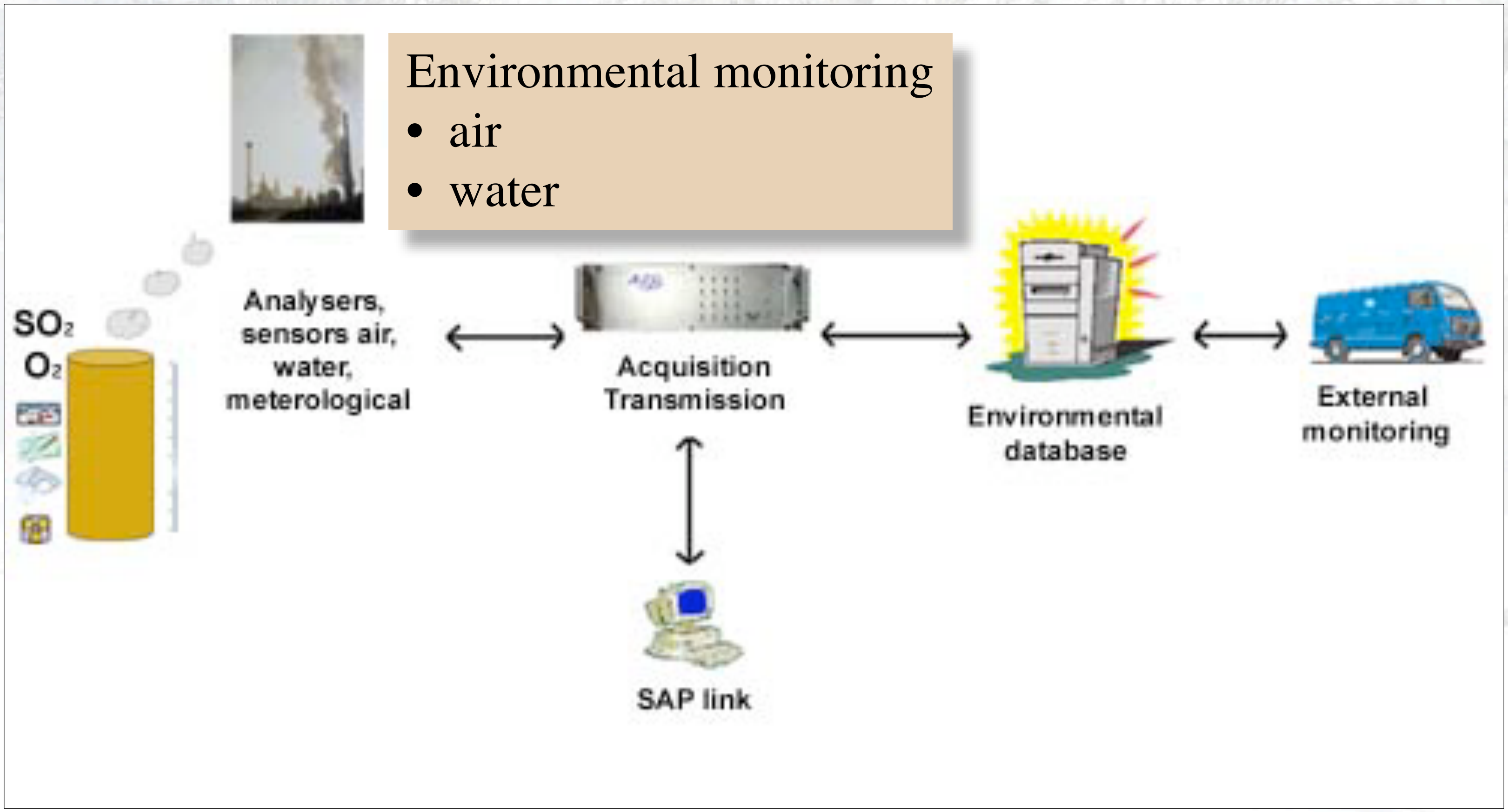
- Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing, etc.

Traditional sensing applications





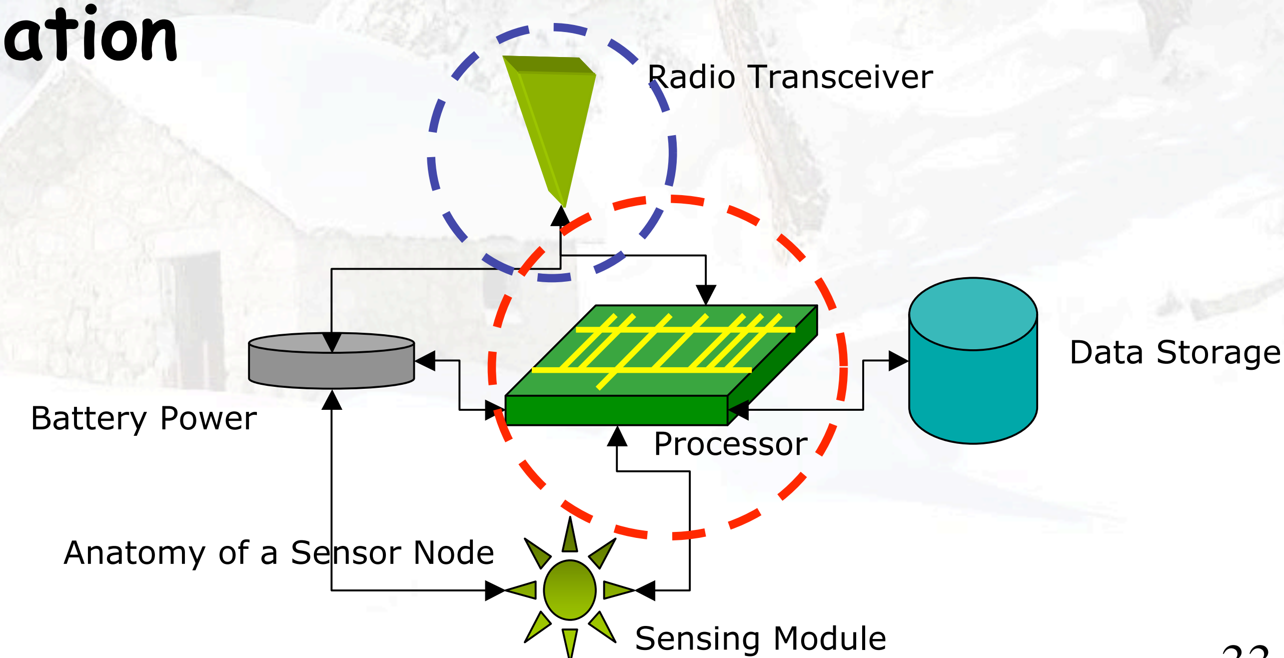
Traditional sensing applications (contd.)



Borrowed from www.iseo.fr

Wireless autonomous sensor

- In general: low cost, low power (the battery may not be replaceable), small size, prone to failure, possibly disposable
- Role: sensing, **data processing**, **communication**



Anatomy of a Sensor Node

Berkeley Motes

- Size: 4cm×4cm
- CPU: 4 MHz, 8bit
- 512 Bytes RAM, 8KB ROM
- Radio: 900 MHz, 19.2 Kbps, ½ duplex
- Serial communication
- Range: 10-100 ft.
- Sensors: Acceleration, temperature, magnetic field, pressure, humidity, light, and RF signal strength

MICA2DOT

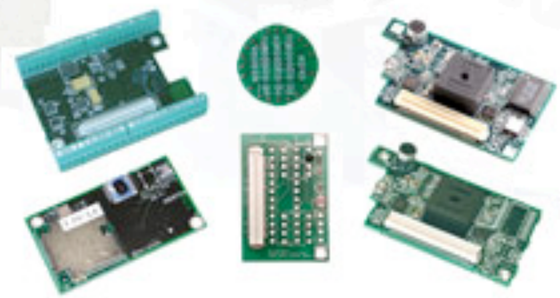
Battery
Panasonic
CR2354
560 mAh

Berkeley Motes (contd.)

- Each Mote has two separate boards
  - ✓ A main CPU board with radio communication circuitry
  - ✓ A secondary board with sensing circuitry
- Decouples sensing hardware from communication hardware
- Allows for customization since application specific sensor hardware can be *plugged-on* to the main board

MICA2

MICAz



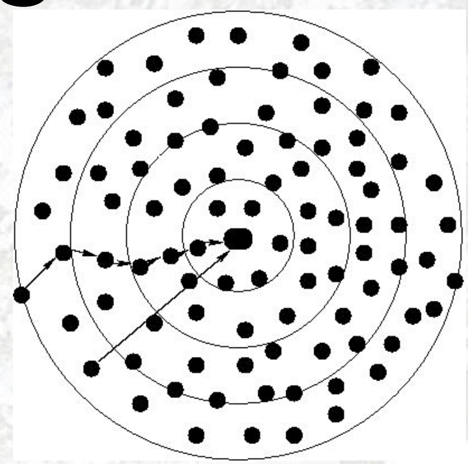
Sensing boards

Wireless Sensors Networks

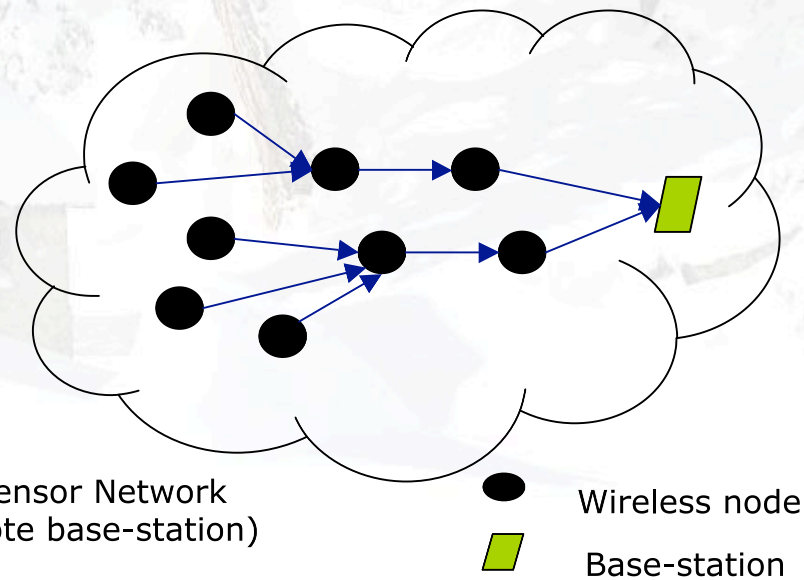
- 1 wireless sensor is better than none!
- 2 wireless sensors is better!!
- 3 wireless sensors is even better!!!
- 4 wireless sensors is much more better!!!!
- …
- 10000 wireless sensors is incredibly better!!!!!
- 10001 wireless sensor is much more incredibly better!!!!!!!!
- …

Salient Features

- Very dense network (spatial density): what level of addressing?
- Can monitor "up close" and with very tight time scale (temporal density: from µs to days)
- Possibly random deployment due to inaccessible terrain ➔ need for self-organizing capabilities
- Mobility is typically low, but topology could be dynamic



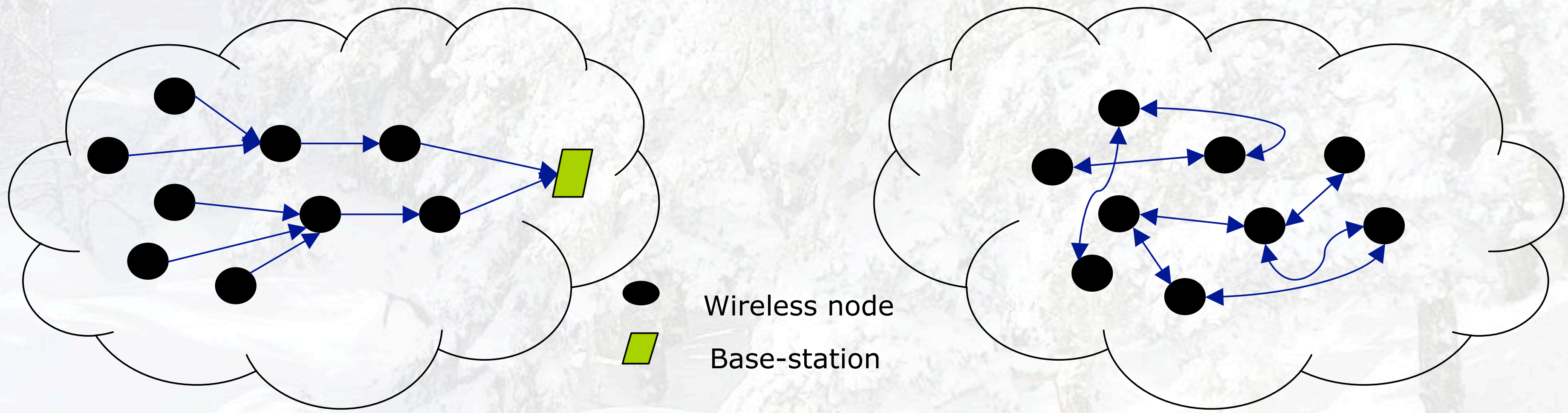
A Sensor Network
(base-station at center)



A Sensor Network
(remote base-station)

Borrowed from C. Rosenberg

Salient Features



Many-to-one data flow (Sensor Network)

Many-to-many data flow (Ad-hoc Network)

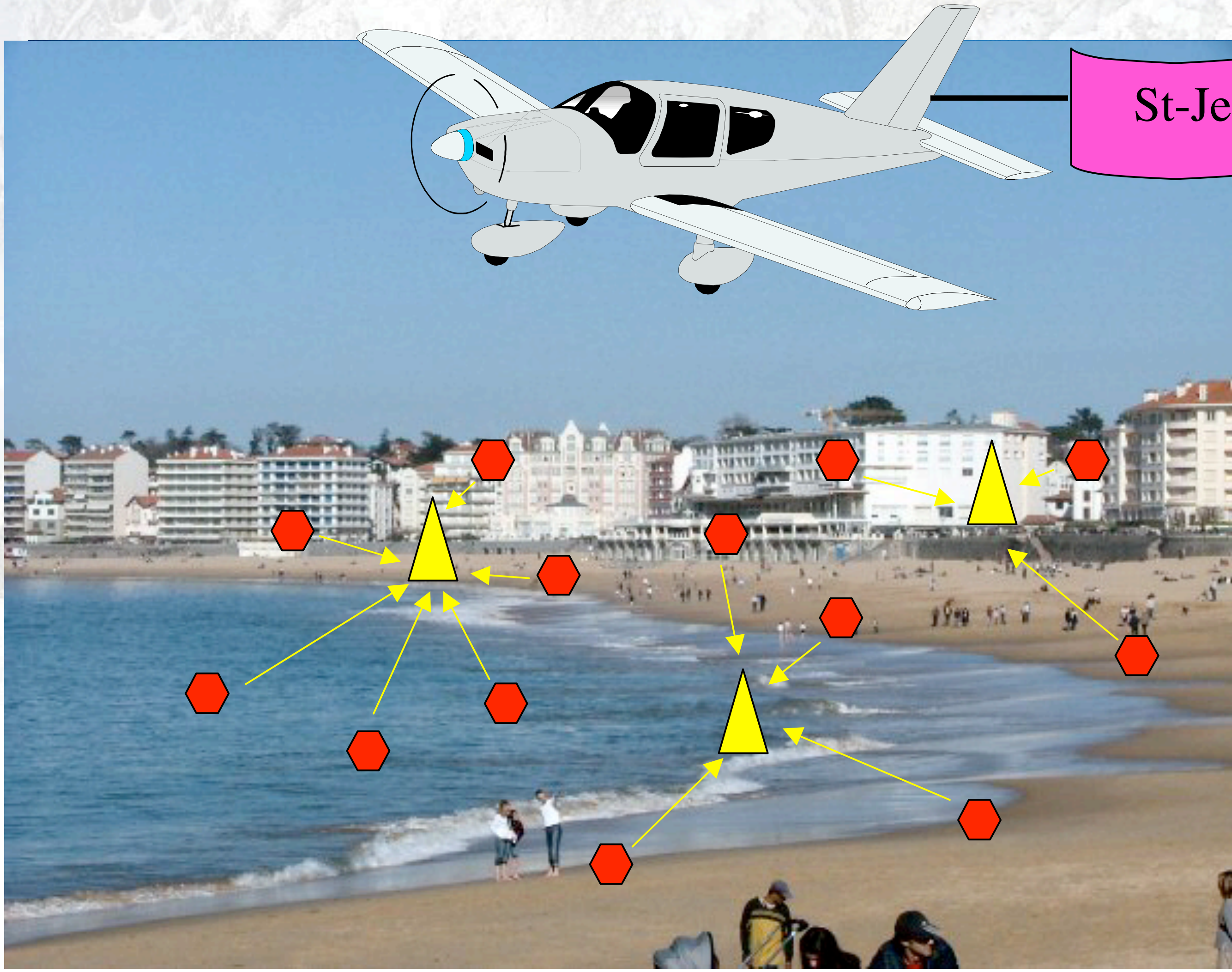
- Finite battery life: energy-efficiency is the prime issue
- Many-to-one communication rather than many-to-many
- Need to ensure sensing coverage of the area of interest, connectivity, and satisfy tolerance limits on latency

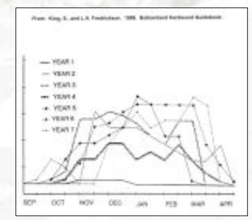
Sensor versus Ad-hoc

Sensor Network	Ad-hoc Network
1. A sensor network has an objective or a task	1. An ad-hoc network has no specific task except communication
2. Nodes collaborate to achieve the objective	2. Individual nodes have their own objectives
3. Many-to-one data flow	3. Any-to-any data flow
4. Very high number of nodes, so each node may not have an id	4. Fewer number of nodes, each with a unique identifier
5. Energy-efficiency is extremely important	5. Node throughput is of prime importance
6. Mainly use broadcast communications	6. Mainly use point-to-point communications

New sensor applications

environmental

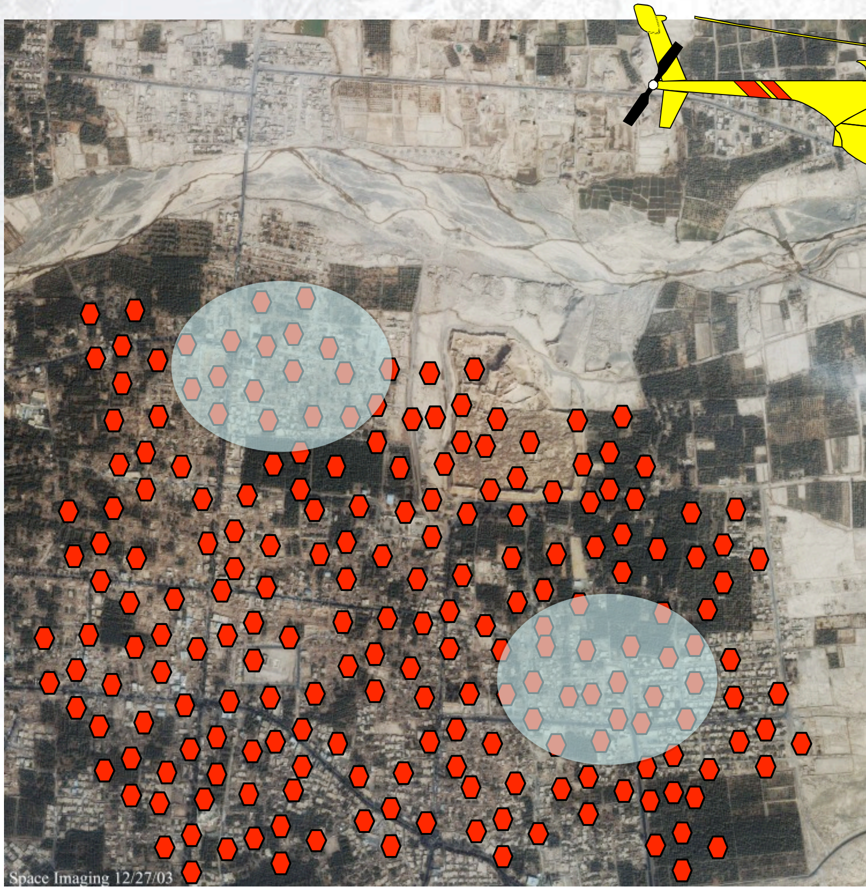


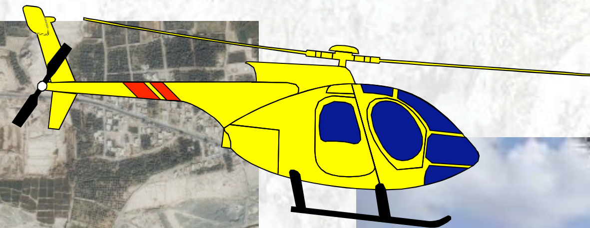


On-the-fly deployment of environmental monitoring's network

New sensor applications

disaster relief - security

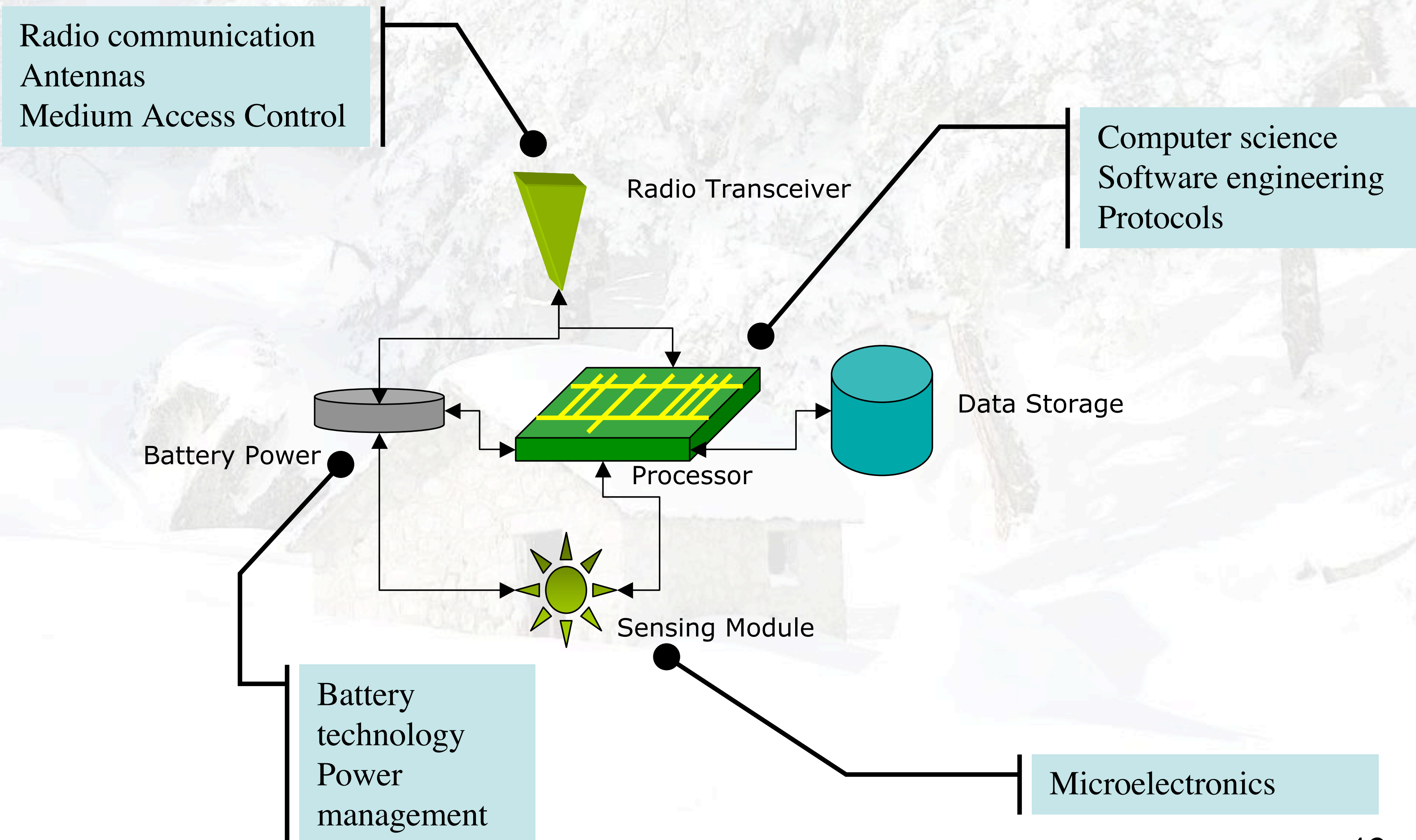




Real-time organization and optimization of rescue in large scale disasters

Rapid deployment of fire detection systems in high-risk places

Inter-disciplinary



For computer scientists

POWER MNGT

- Software & OS
  - Design of software architecture
  - Flexibility, adaptativity
- Communication
  - Addressing, Routing, Security
  - Reliability, congestion control
- Management & administration
  - Service deployment
  - Composability, reconfigurability

SCALABILITY

What can we address within the LIUPPA lab?

- Software engineering
  - New component-based OS
  - Automatic generation of customized components
- Networking
  - Optimized transport protocols
  - Multicast & broadcast
- Multimedia and adaptive applications
  - Quality of Service
  - Management & Service deployment
- Security
  - Intrusion detection, authentication, isolation

Software engineering

- Research have addressed
  - Operating Systems for constrained resources
  - Formal approaches to prove development
- Future research directions are
  - Specialized support to design WSN applications
    - Unified Model for Sensors & Software Components
    - Unified Data and flow Model
  - Middleware for very low resourced environment
    - High-level architecture (abstraction, agent, components)
    - Self-adaptation/reconfiguration capabilities

Networking

- Research have addressed
  - Medium access control protocols, broadcast, radio interface, power management
  - Routing, reachability, topology control, naming
- Future research directions are
  - Communication architecture design
  - High-level communication protocols
  - Reliability & Congestion control
  - Multicast protocols, data-aware protocols

Multimedia and adaptive applications

- QoS for MM applications is hardly correlated to the fluidity and synchronization of information and depends on the mobility.
- The use of sensors will
  - Help for previous items
  - Provide context informations for new applications
  - Applications will adapt their local context according to the external context (environment)

A day in the life of a computer scientist is 2012