Personal Computing and Communication: the Near Future[1]

“Hacia donde vamos”

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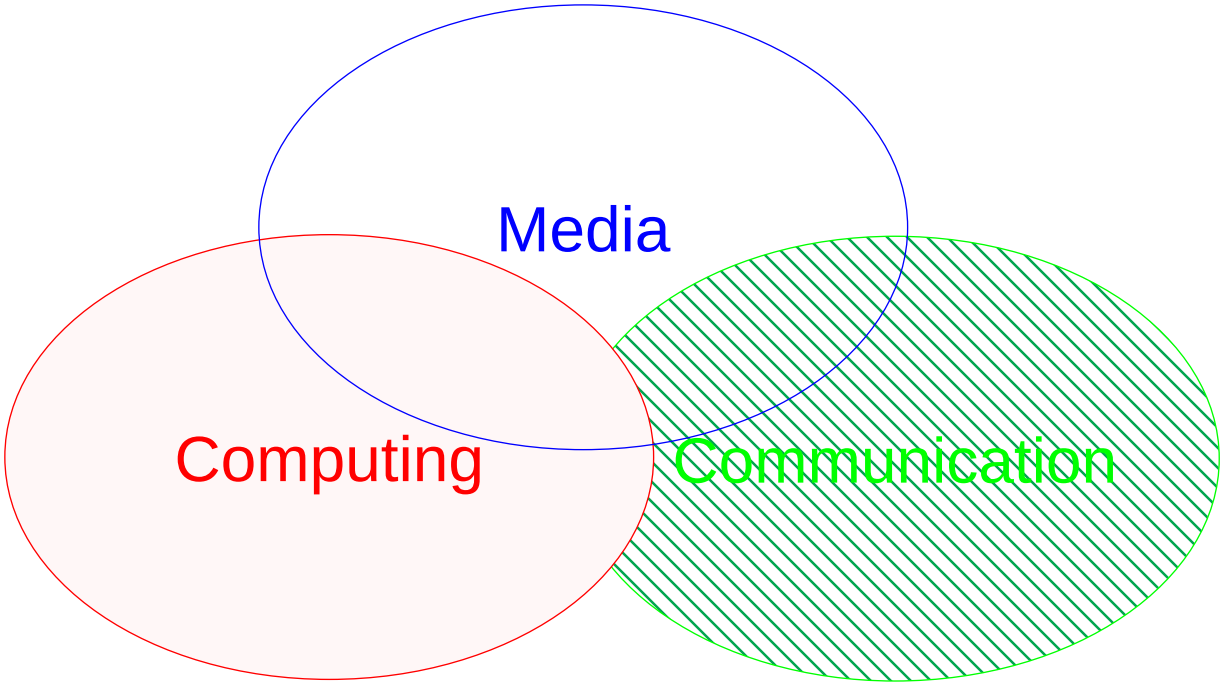
Las telecomunicaciones y la nueva era económica, 1 September 1998, Santander, Spain

1. Translation by http://babelfish.altavista.digital.com/ Español: El computar personal y comunicación: cercano el futuro

Convergence



Telecommunications

A long history:

- Siemens, AT&T, Ericsson > 100 years
- Nomadic communications has existed since at least 1910, when Hilda Ericsson persuaded Lars Magnus Ericsson to buy a car and they made calls via the overhead telephone wires!

Two infrastructures

- Public
  - Regulated monopolies, PTTs, …
  - 15 to 30 year amortization periods
  - high prices and low performance
  - Mobile telephone as the hottest growth area
- Customer owed
  - LANs moving to 100s Mbit/s and on to Gbit/s speeds
  - interfaces on the motherboard - since an additional connector would be more expensive!
  - very low cost and high performance
  - Internet/Intranet/… as the hottest growth area

Computing

A much shorter history:

- The 50th anniversary of the programmable computer was a relatively recent event
- The Association for Computing Machinery (ACM) celebrated its 50th anniversary in March 1997

Characteristics:

Moore's law:

- For 30 years semiconductor performance has been doubling following Moore's law.
- The time constant for doubling just changed from 18 months to 9 months!

Mobile Communication

It used to be paging, voice (NMT, AMPS, …, GSM), and Mobitex,
but it is becoming **much** more data oriented.

Mobile links

- GSM voice and data ⟹ GPRS and HSCSD
- Cellular Digital Packet Data (CDPD), multihop (Ricochet) networks, … {symmetric?}
- DSS based IP service (one-way 21 Mbit/s - other way via other links), DAB, … {asymmetric?}
- Wireless LANs - multiple Mbit/s
  - ♦ IrDA - up to 4 Mbit/s over IR links
  - ♦ IEEE 802.11 standard defines 1 and 2 Mbit/s radio and IR
  - ♦ 10 Mbit/s RF systems (starting to appear)
  - ♦ Bluetooth - and other low power radios starting to appear

Mobile-IP

- A mobile version of the IP protocol first shown in 1989
- Mobile-IP defined by RFCs 2002 .. RFC 2006 (Fall 1996)
- "Mobile IP: Design Principles and Practices" by Charles Perkins or
  "Mobile IP: The Internet Unplugged" by James D. Solomon.

What is the short term time line?

1996: 40% of the telecom budget of the Fortune 500 companies is FAX traffic

⇒ distributed “printing”, Internet FAXing, …

How much can this reduce traditional FAXing? perhaps to 2%

1996: public introduced to Internet Telephony

- multimedia PCs - built-in support for stereo audio

⇒ what will be the usage curve for Internet Telephony

1997: Internet Videoconferencing

- using $150 digital color cameras attached to multimedia PC

1998 is the year of mobile internet multimedia computers

- especially in local area settings - using wireless LANs, DECT, …
- perhaps in urban and campus settings - this could challenge cellular telephone systems
- new scanner technology to hit the market
- ADSL (VDSL, …) ==> new use of telephone access net to build new fixed and mobile infrastructure
- NorWeb Direct Power Link technology - using power distribution lines for Mb/s access.

¿Question?

"Which would you rather have twice as fast:
your computer's processor or modem?

After 30 years of semiconductor doublings under Moore's Law, processor speed are measured in megahertz. On the other hand, after 60 years of telco's snoozing under monopoly law, modem speeds are measure in kilobits. Modems are way too slow for Internet access, but you knew that."[1]

-- Bob Metcalfe,

inventor of Ethernet (May 22, 1973)

1. "From the Ether: Moving intelligence and Java Packets into the Net will conserve bandwidth", by Bob Metcalfe, Inforworld, Oct. 6, 1997, pg. 171.

IP traffic growing exponentially!

Traffic increasing (but not due to voice)

- IP traffic between US and Sweden much greater than 10 times the total voice+FAX traffic
- 5% of all US radio stations simulcast on the internet; additionally new **internet only** "stations"
- WWW servers (URLs featured in most print and broadcast ads)
- search/translation/… engines
- internet cameras, …

Fixed Links - arbitrarily fast:

- LANs: 10 Mbit/s, 100 Mbit/s, 1 Gbit/s, …
- Backbones: 45 Mbit/s or 34 Mbit/s ⟹ 155 Mbit/s, 662 Mbit/s, and Gigabit/s
  Transoceanic fibers between continents ⟹ xx Gbit/s
- Major site's links to backbones: T1 (1.5 Mbit/s) or E1 rate links (2 Mbit/s)
  ⟹ increasingly 34 Mbit/s or 45 Mbit/s - even 155 Mbit/s in some metropolitan areas
- Individual users links: 28.8 Kbit/s and ISDN (128Kbit/s)
  ⟹ xSDL (Mbit/s .. ~51 Mbit/s in the fast direction)

Points of Presence (PoPs) + CIX and GIX ⟹ GigaPoPs

Infinite Bandwidth

Guilder's Law states that network speeds will triple every year for the next 25 years.
This dwarfs Moore's law that predicts CPU processor speed will double every 18 months.

- More than 4,000 miles of fibre optic cable installed **each day** in the USA
  (with less than 40% of that fibre optic cable capacity being used)
- Dense Wavelength Division Multiplexing, …

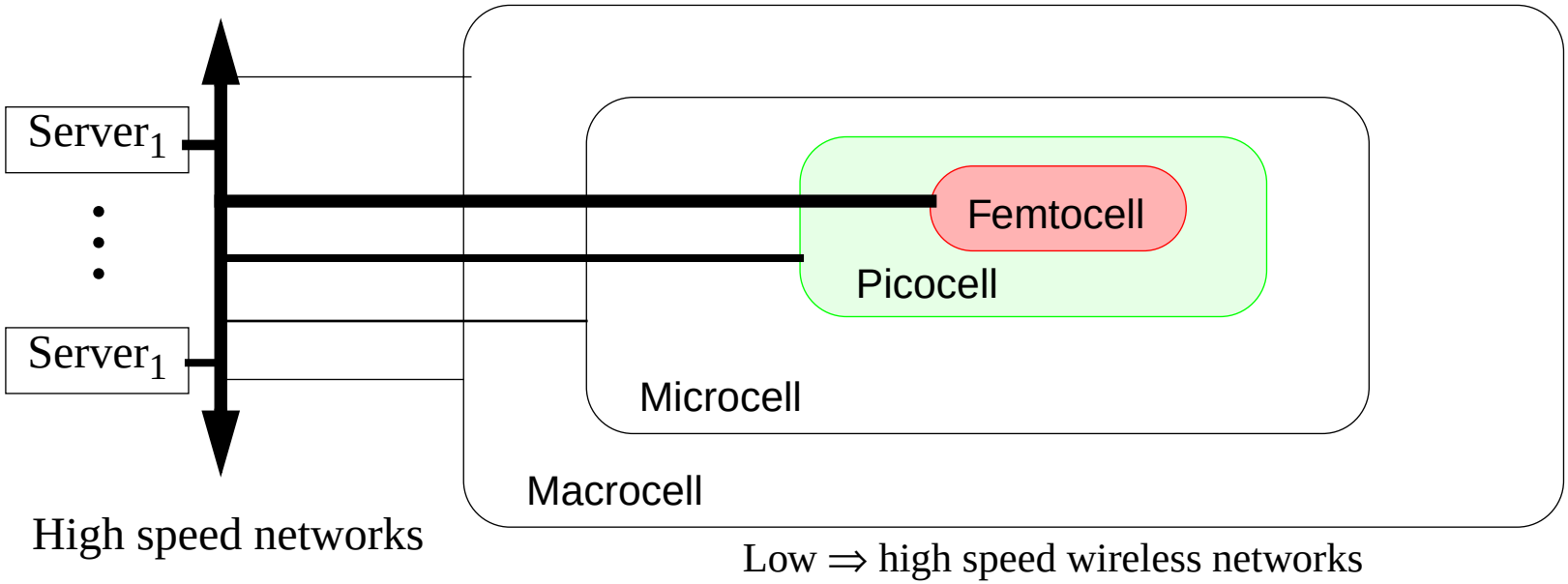
MCI network backbone:

- 1995 capable of moving 45 Mb/s
- 1996 already 1.2 Gb/s
- by 1999 at or above 40 Gb/s
- by 2000 who knows?

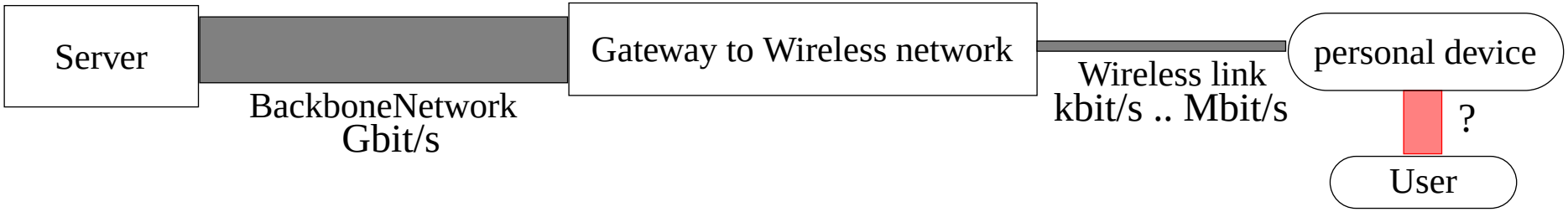
Telia installing a 60 Gbps transatlantic fiber

Bottlenecks

- Server and Network Bandwidth and latency



- User Bandwidth and latency



- Power and Energy ⇒ need a computational theory of O(energy)
- Imagination!

Wearables

"… It will be possible to put a 100+ MIPS CPU and a 0.5 GFLOP DSP in a $200 Nintendo Game Boy within 2 years, for less than $25 bucks of Si cost. With this kind of cheap, available cycle time, how hard would it be to add a communications cartridge/dongle into a game slot? …"

-- John Novitsky
of MicroModule Systems,
and of Microprocessor Report[1]

Who are the competitors?

Ericsson, Lucent, Nokia, Siemens, … or Nintendo

1. From Wearables mailing list Wed, 17 Sep 1997 19:22:17 -0700.

Near Future systems

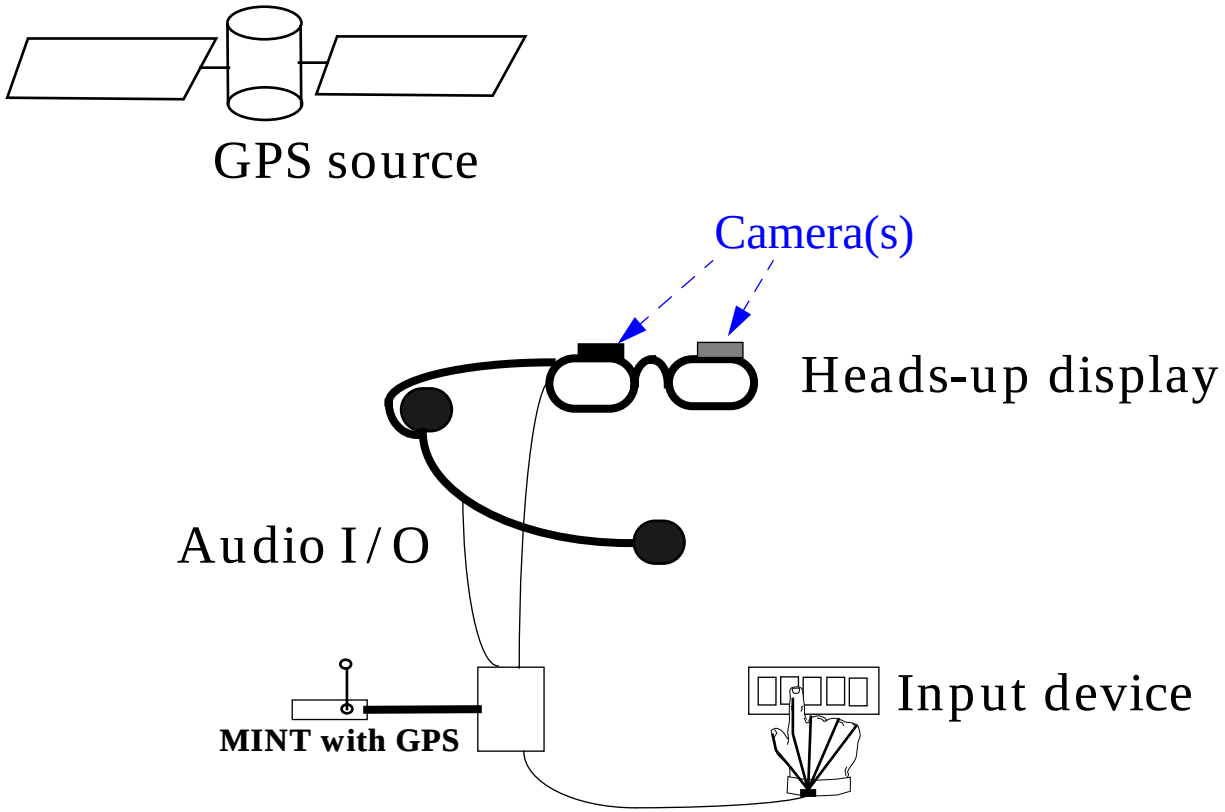


Figure 1: Vision-2, 2000 - high level of integration

Evolution of new varieties of networks

Already we have: WANs (Wide Area), MANs (Metropolitan Area), LANs (Local Area Networks)

VANs Vehicle Area Networks

Very local networks

DANs Desk Area Networks

The computer/printer/telephone/… will all be part of a very local area network on your desk.

- wireless links ⇒ No longer will you have to plug your printer into your computer (PDA/…) into your computer
- active badges⇒ No longer will you have to sign in/out of areas, write down peoples names at meetings, … the system can provide this data based on the active badges

Olivetti and Xerox are exploring “Teleporting” your windows environment to the workstation nearest you, on command, if there are multiple choices probe each one (currently a “beep” is emitted to tell the user which).

BANs Body Area Networks

Users will be carrying multiple devices which wish to communicate:

- thus there will be a need for a network between these devices which you carry around; and
- personal devices will wish to interact with fixed devices (such as Bankomat machines, vehicle control systems, diagnostic consoles (for a “mechanic” or repairman), …) and other peripherals.

Situational awareness and Adaptability

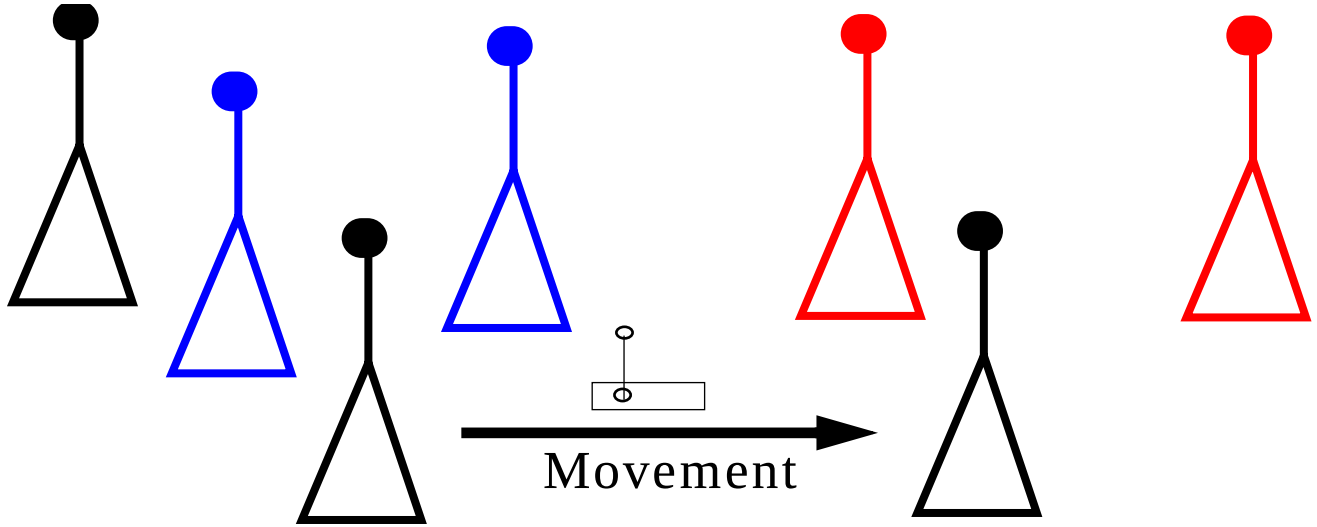


Figure 2: Where am I? What am I? Who am I?
Where am I going? When will I be there? What should I become? Who should I become?

- Location dependent services
- Predicting location to reduce latency, reduce power, hide position, …
- Adapting the radio to the available mode(s), purposely changing mode, …
- Reconfigure the electronics to adapt, for upgrades, for fault tolerance, …; Reconfiguration vs. powering up and down fixed modules (what are the “right” modules, what is the “right” means of interconnect, what is the “right” packaging/connectors/…, needed speed of adaptation)
- “right” level of independence; spectrum from Highly Independent ⇒ Very Dumb

Location Dependent service(s)

How do I know where I am?

- Outdoors: GPS or from the network operators knowledge [resolution: 100m to sub-centimeter]
- Indoor: IR and RF beacons, triangulation, knowing what you can **see** or **hear**

What can I do with this knowledge?

KTH students built a JAVA Applet which gets data from GPS unit and dynamically displays a list of the information available - as a function of where you are:

- if near bus, subway, train stop - you get transit information - potentially with real-time schedule - since the system knows current location of vehicles
- list of restaurants, shops, etc. where you are and in the direction you are headed
  - the scope is based on your velocity vector - so if you move quickly it reduces detail, but increases the scope
- map information with updated position

How do I know who I'm with or what I'm near?

- Olivetti, Xerox, and MIT - using IR emitters as "ID" tags
  - Olivetti put them on people, equipment, …
  - Xerox put them on electronic notepads, rooms, …
  - MIT Media Lab is putting them on people + lots of inanimate objects (clock, fish tank, …)

Human centered

- Computer - human interaction is currently focused on the computer (computer-centric)
  - Currently computers know little about their environment
    - Where are we?
    - Who is using me?
    - Is the user still there?
- Evolving Environment awareness
  - Give computers senses via sensors
    - Environment
    - User identity and presence
- Badge as a smart card replacement
    - biometric signature of the person currently using the badge
    - the badge ensures that only you can use it
- You wear your own personal user interface
  - interface can be consistent across all appliances
    - not because each appliance supports the interface, but because the user's own interface provides consistency
- Make the human the focus of the computer's interaction ($\Rightarrow$ human-centric)

Requirements

- Systems with which humans wish to interact:
  - ♦ traditional computers, desktop workspaces, domestic appliances, building and automotive systems, doors, elevators (lifts), environmental control, seats and mirrors, etc.
- Systems to provide sensor data:
    - ◆ location, orientation, light, heat, humidity, temperature, gas analysis, biomedical, …
- Systems to correlate the sensor information and provide it in a useful way to the computer systems:
  - ♦ Spatial and temporal sensor fusion,
  - ♦ 3D and 4D databases,
  - ♦ Machine Learning, and
  - ♦ Prediction (based on pattern extraction)
- Agents and actuators to provide intelligent control of the environment
- wireless/wired/mobile communications infrastructures to link it all together
  - ♦ must assure privacy and security

Dumb Badge, Smart Badge, and Intelligent Badge

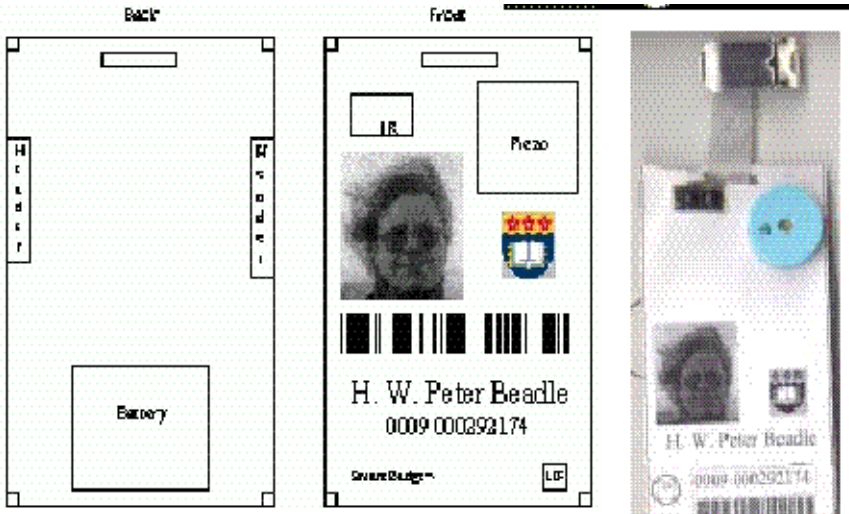
- Dumb Badge just emits its ID periodically
- Smart Badge - [an IP device] Location and Context Aware (i.e., a sensor platform)
- Intelligent Badge - add local processing for local interaction by the user

Acknowledgment:

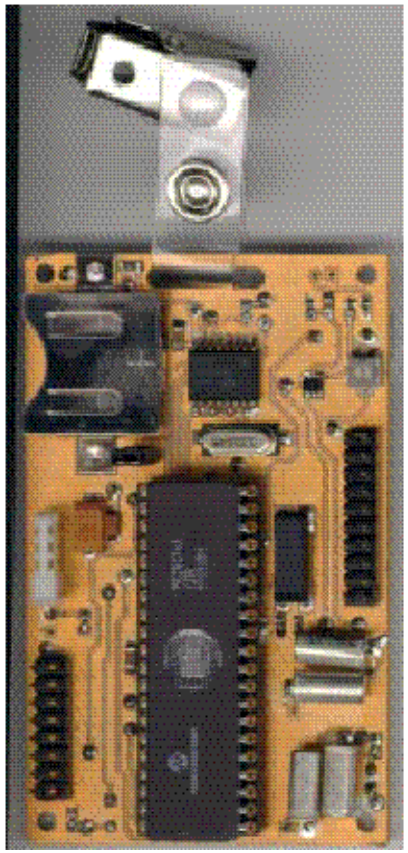
All of the badge work is done in cooperation with:

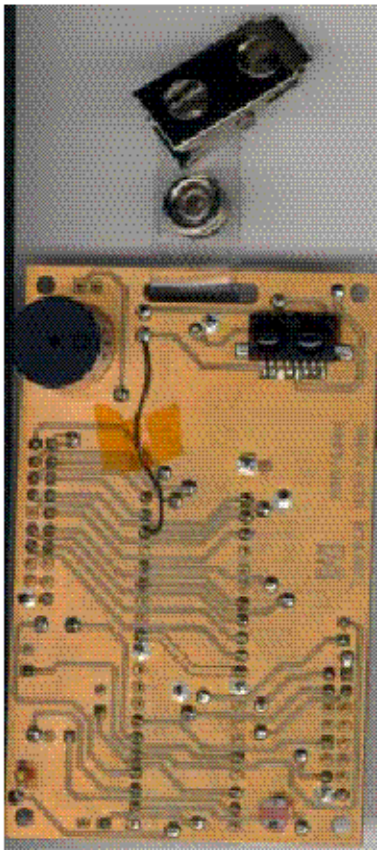
- Dr. Mark T. Smith - Hewlett-Packard Research Laboratories, Palo Alto, California, USA
- Dr. H. W. Peter Beadle
  - ♦ Formerly: University of Wollongong, Wollongong, Australia
  - ♦ Currently: Assistant Director, Motorola Australian Research Centre, Botany, NSW, Australia

Badge Prototype and Badge 1

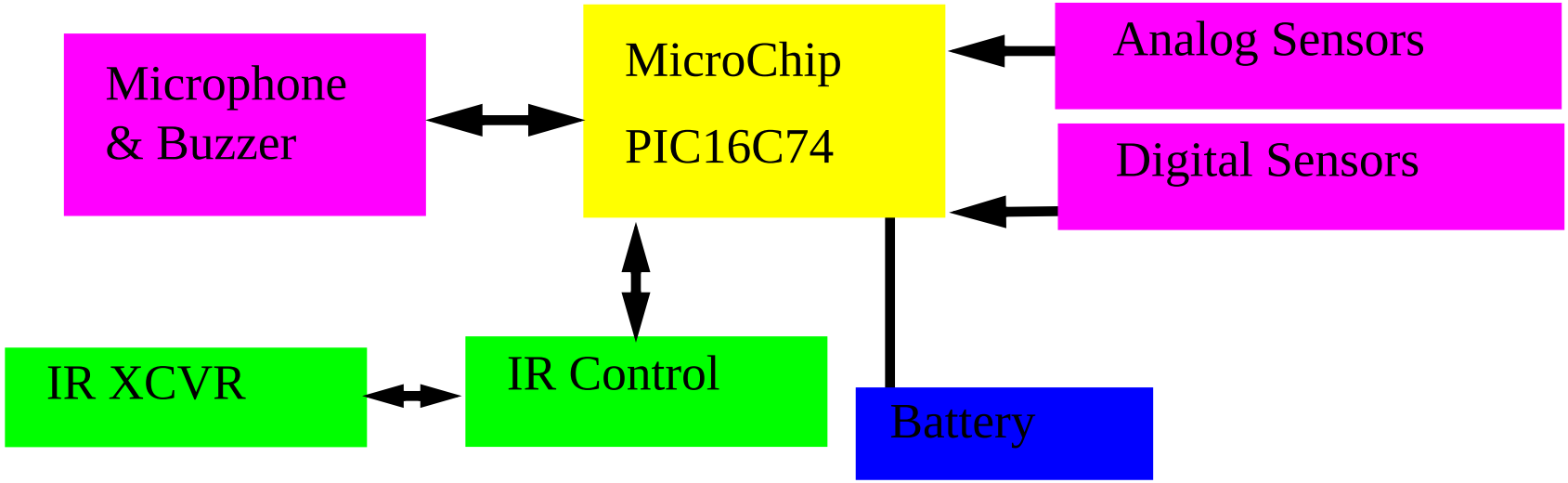


- Sound, Light, Temperature, Humidity, Orientation, Adjacency
- Beeps
- PIC 16C74A-jw based
- 5 MIPS
- 4m range
- 98mA average power





Smart Badge 1



Conceived in January 1997; Used in the “finger” course in May 1997

URL: http://www.it.kth.se/edu/gru/Fingerinfo/telesys.finger/Mobile.VT97/mobile.vt97.html

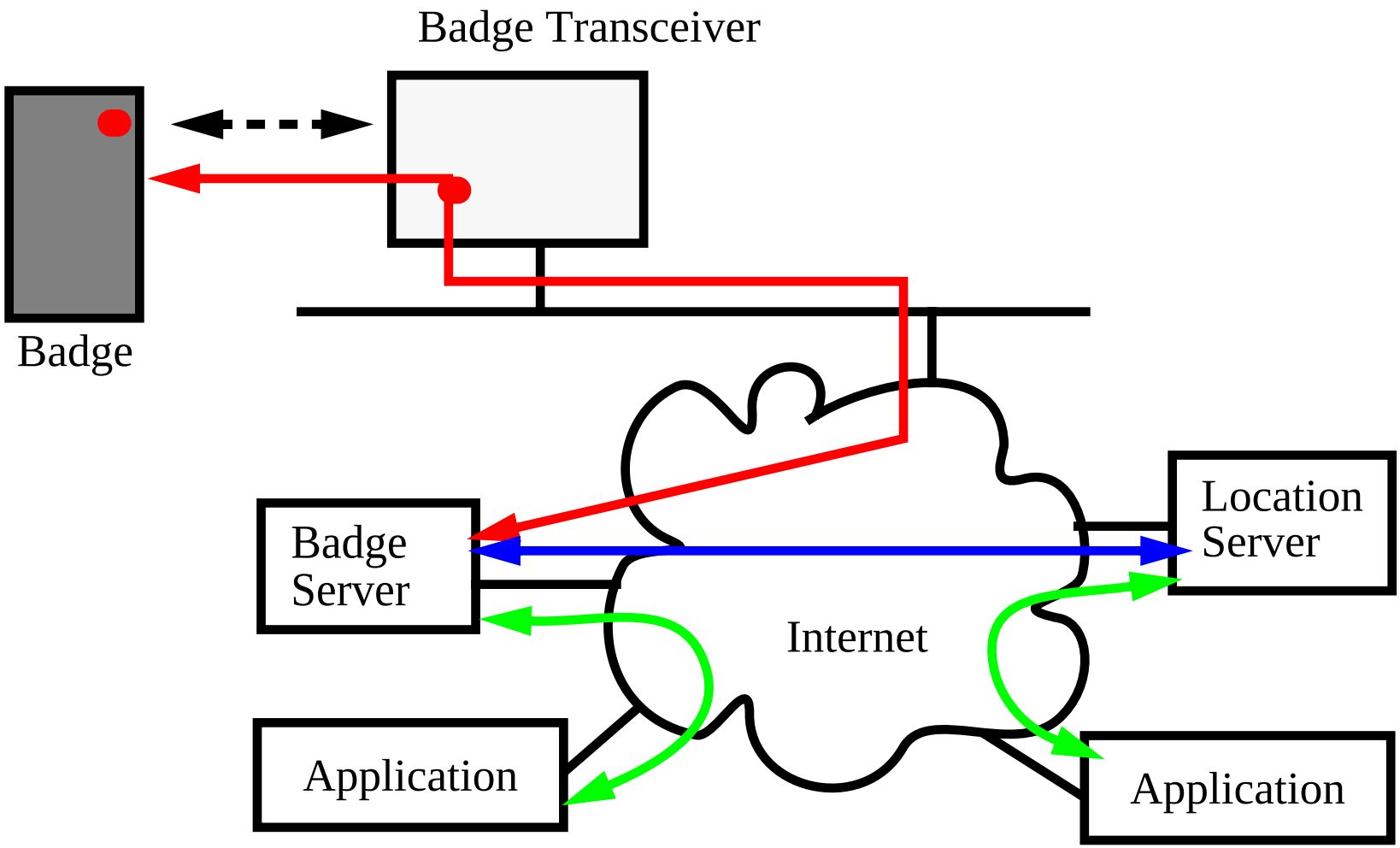
85x55mm $\Rightarrow$ 46.75 mm^2 - component cost ~US$30

24 systems made using milling machine and hand assembly

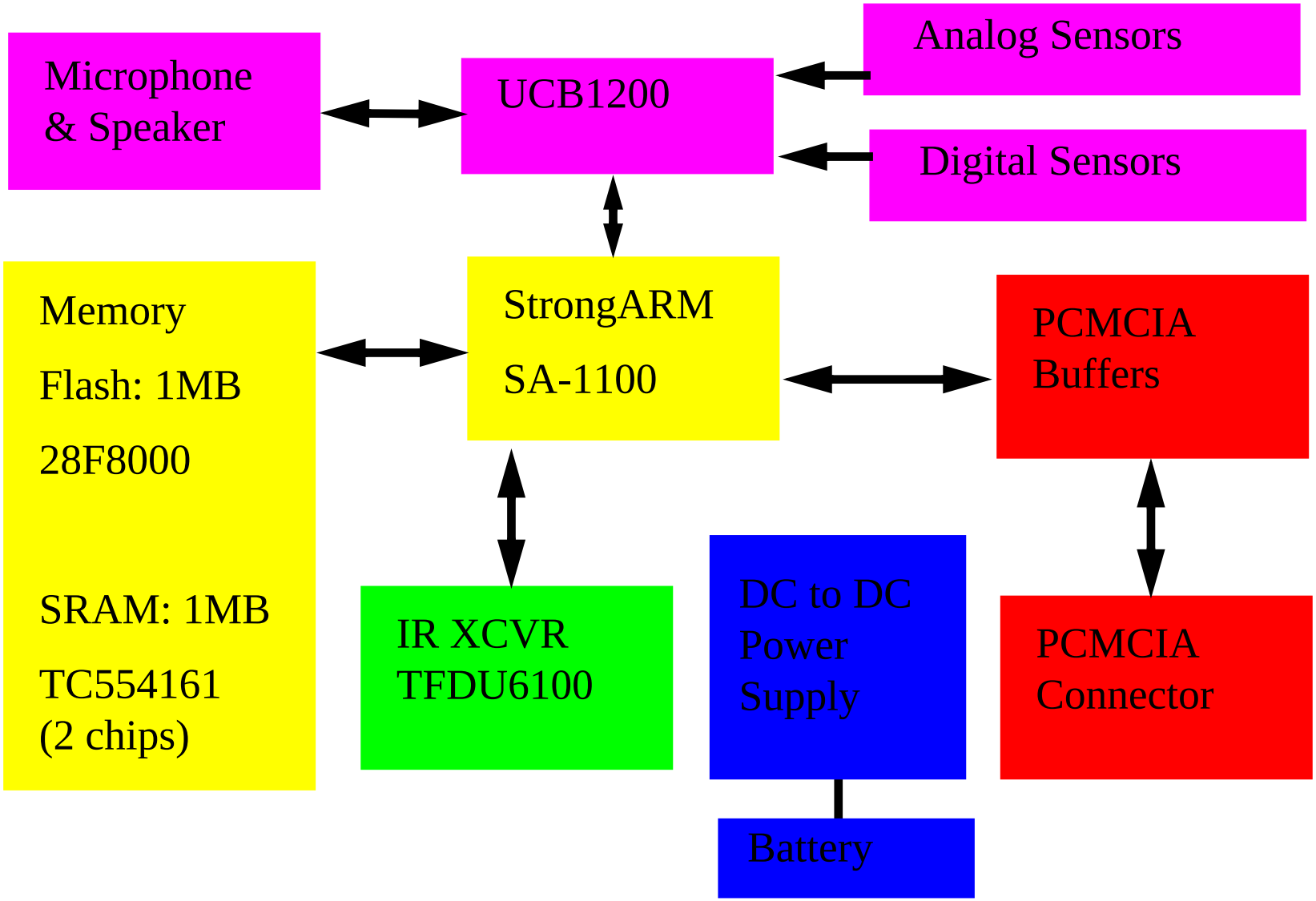
Subsequently used for course at Univ. of Wollongong and thesis projects at: KTH, Wollongong, Ellemtel, Ericsson Radio, …

Badge Communications Model

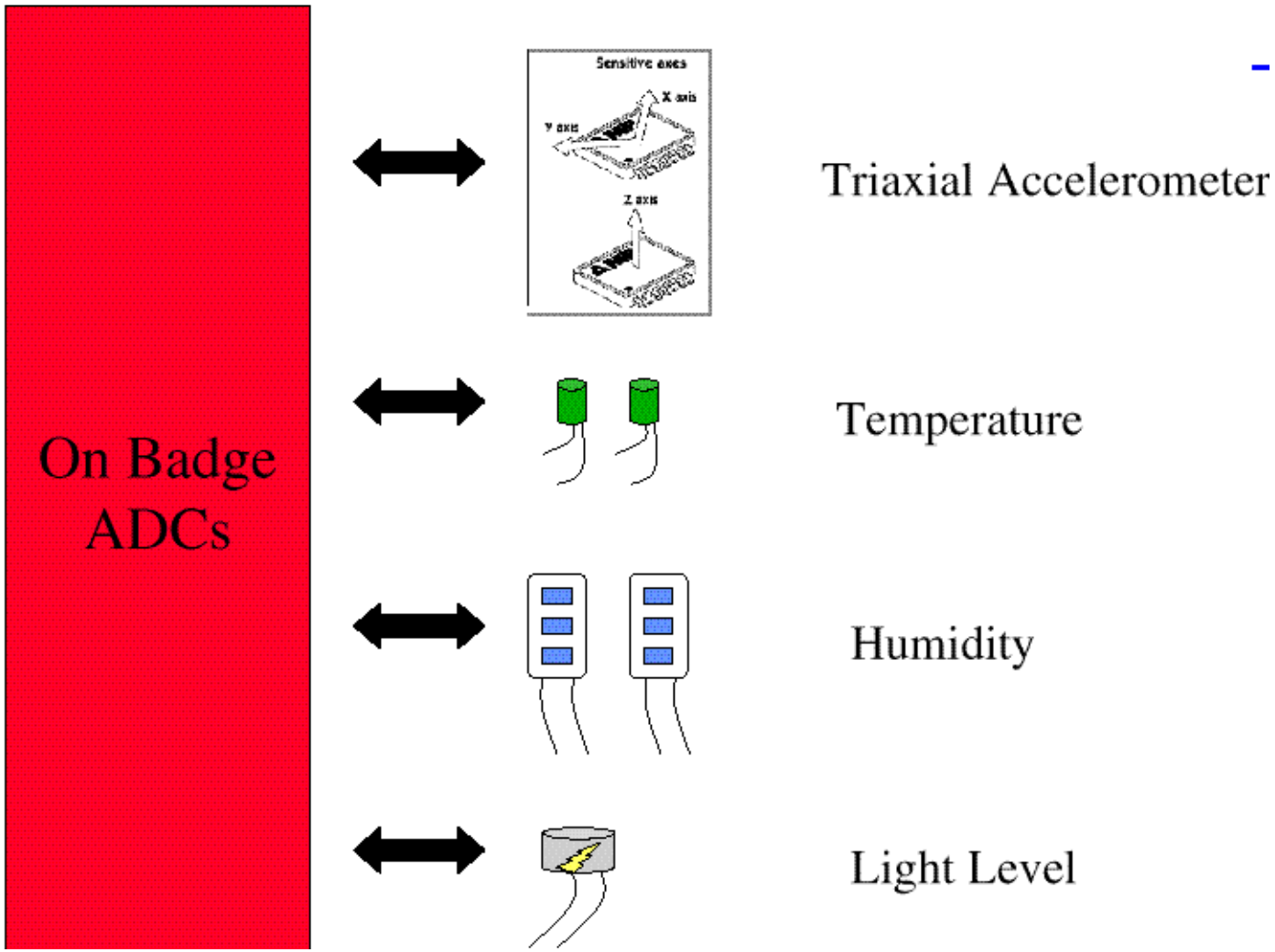
Badges are IP devices (or should be), they communicate via network attached access points.



Smart Badge 3

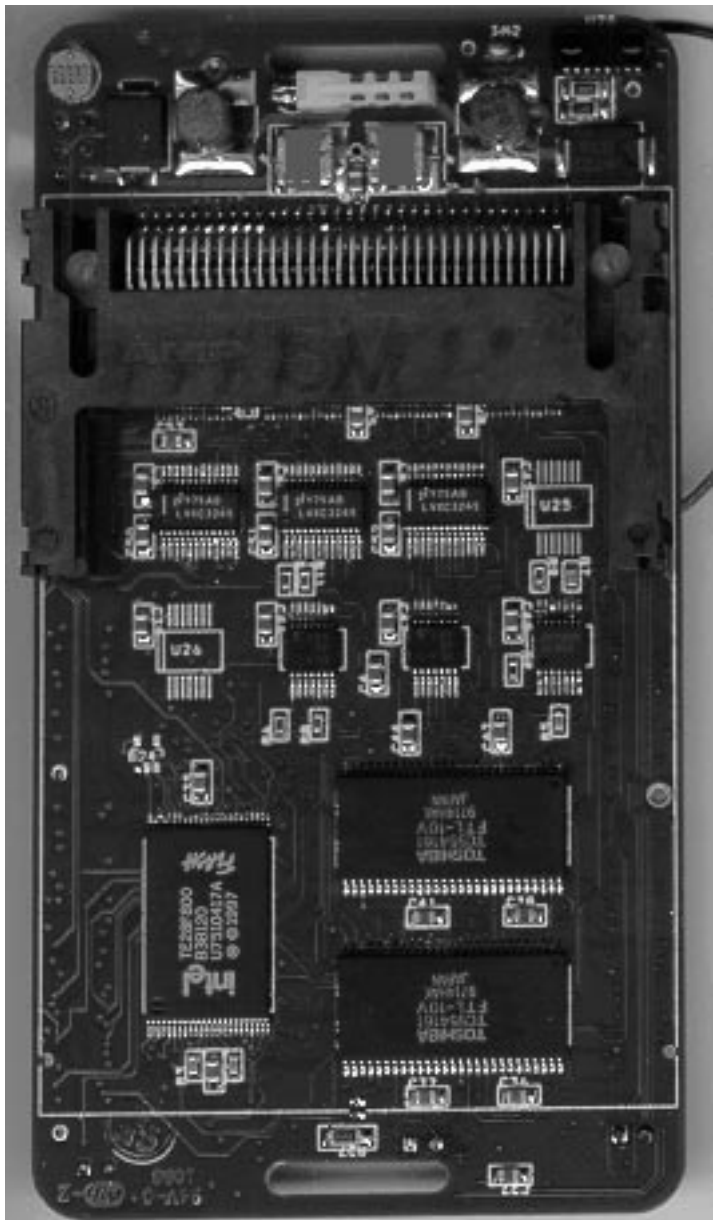


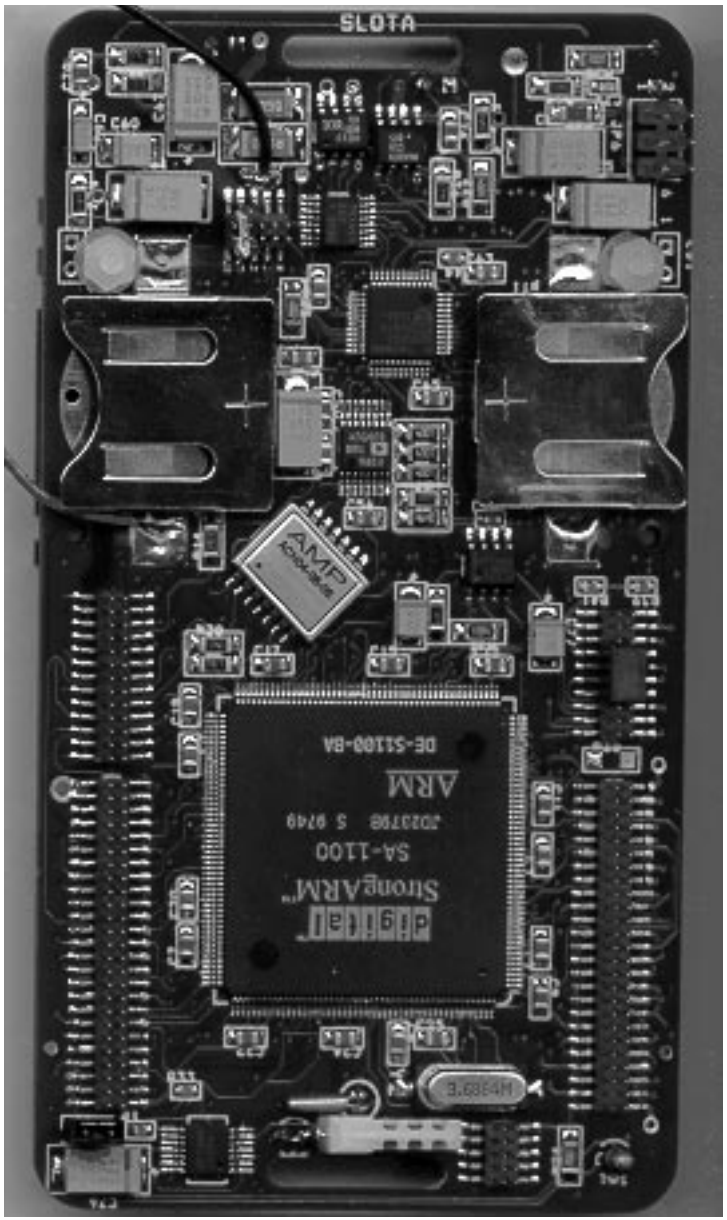
Smart Badge Sensors



Details of the 3rd version:
http://www.it.kth.se/edu/gru/Fingerinfo/telesys.finger/Mobile.VT98/badge3.html

Badge 3





How to field a new telecom infrastructure

Telecommunication operators and others need to address how they are going to introduce a new infrastructure which supports **low cost mobile** access to new services.

Let us start with the vision of wireless in the local loop. What is it and how do we get there?

- Forget spectrum availability as **the** problem
- Forget limited bandwidth as **the** problem
- Forget error rate as **the** problem

Problem: Finding the trade off between available high quality bandwidth and the cost of the infrastructure,
i.e., if cells shrink (thus increasing capacity, available bandwidth, decreasing error rate, …),
then infrastructure cost increases, or is there another way?

Coupling PSTN and Internet telephony worlds

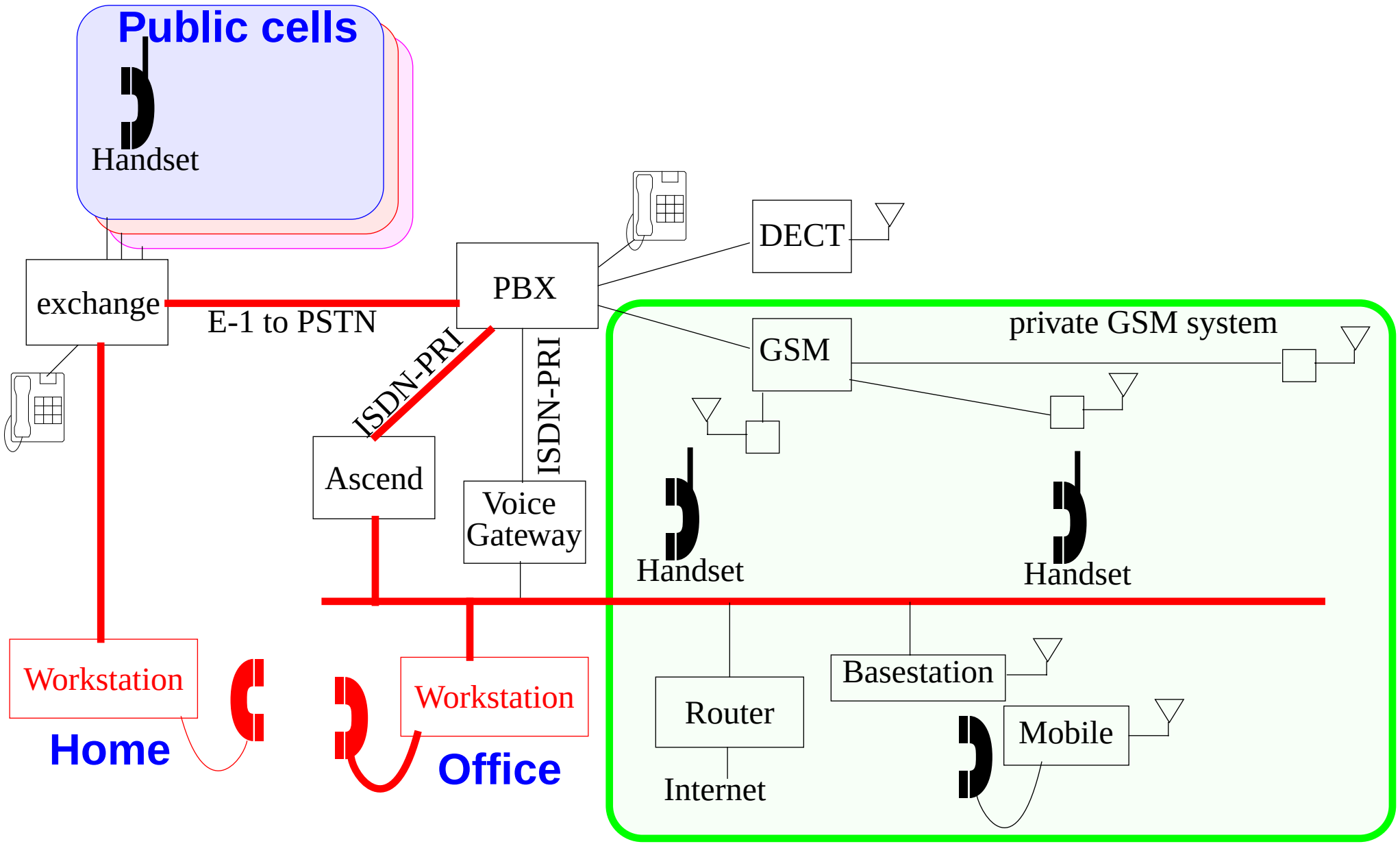
Coupling of voice and data communication systems (perhaps unification of these formerly separate worlds).

Driven by a number of features:

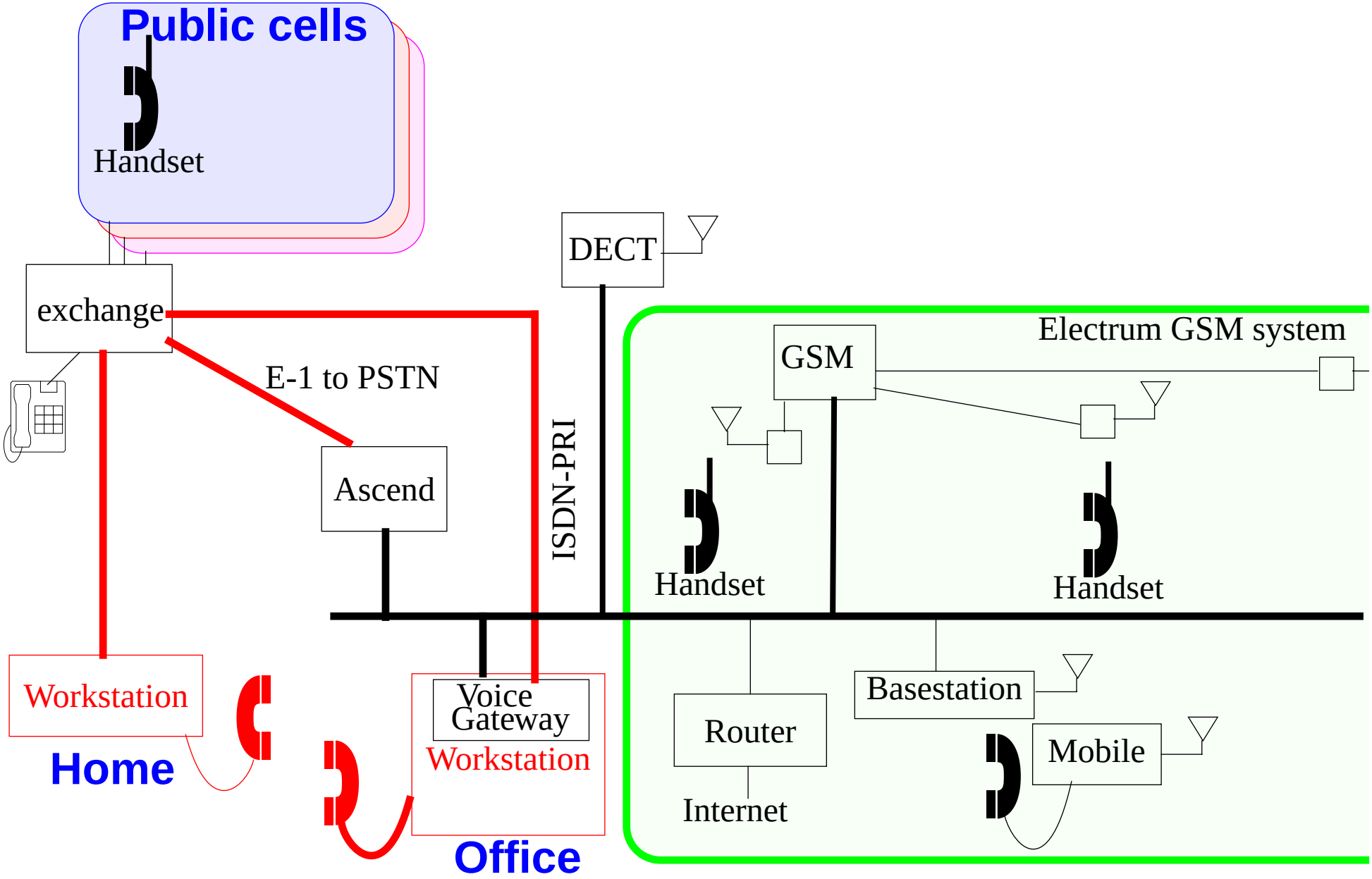
- emergence of high speed digital paths (ISDN, xDSL, …)
- emergence of integrated traffic (Does this imply B-ISDN? perhaps not)
- “phone” programs for placing long distance calls across the internet, loss of traditional income sources
- exploding Multimedia computing market
  - therefore, nearly all new PCs have audio input and output (high-end ones even have video input and output)
  - OS and other support for audio is becoming standard
  - more and more multimedia information being broadcast, pointcast, …

LAN(s) provide the local interconnections between the various types of networks
$\Rightarrow$ no more PBXs and perhaps no more traditional telecom interfaces!

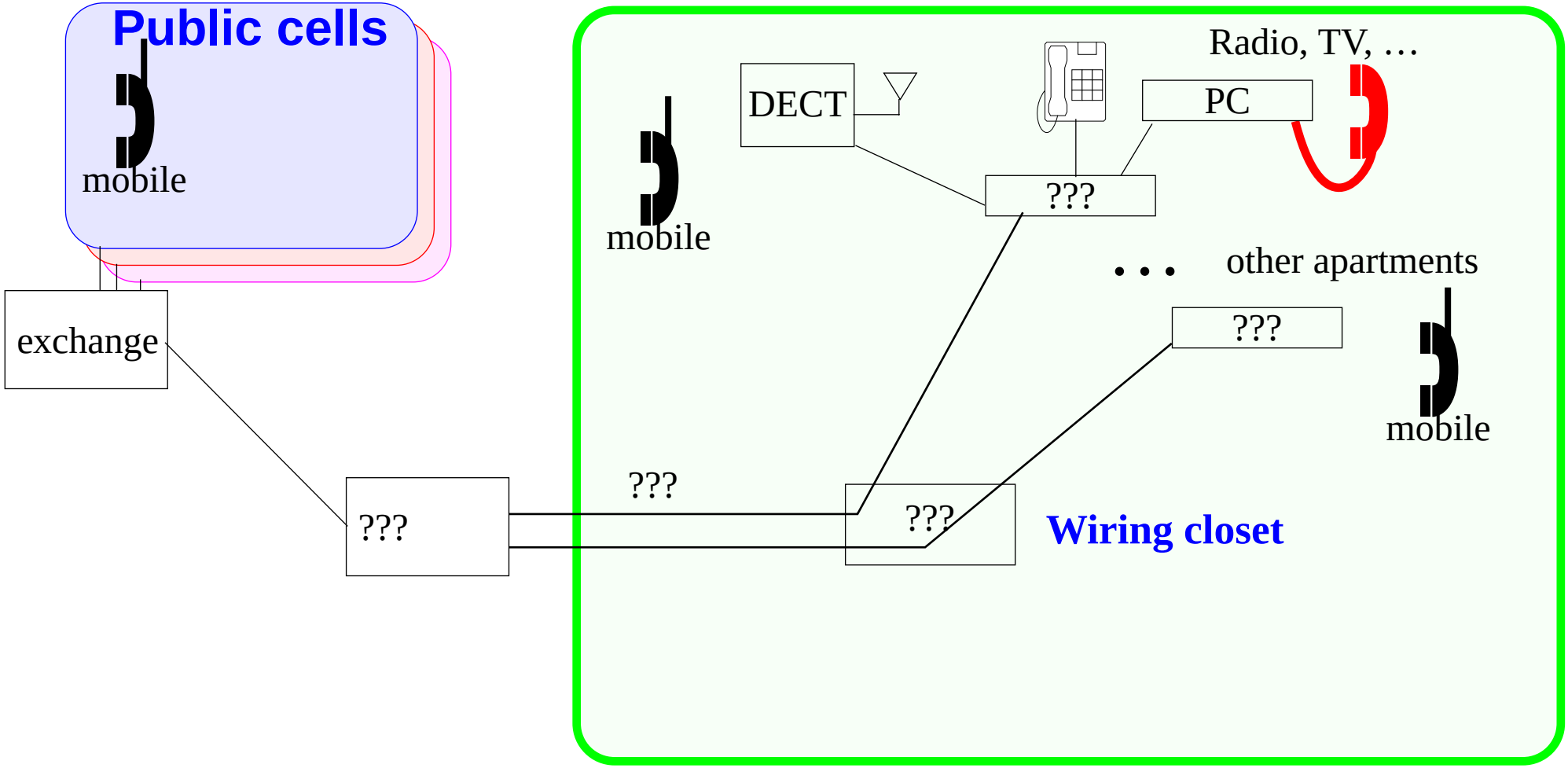
A new data+voice infrastructure



Future data+voice infrastructure

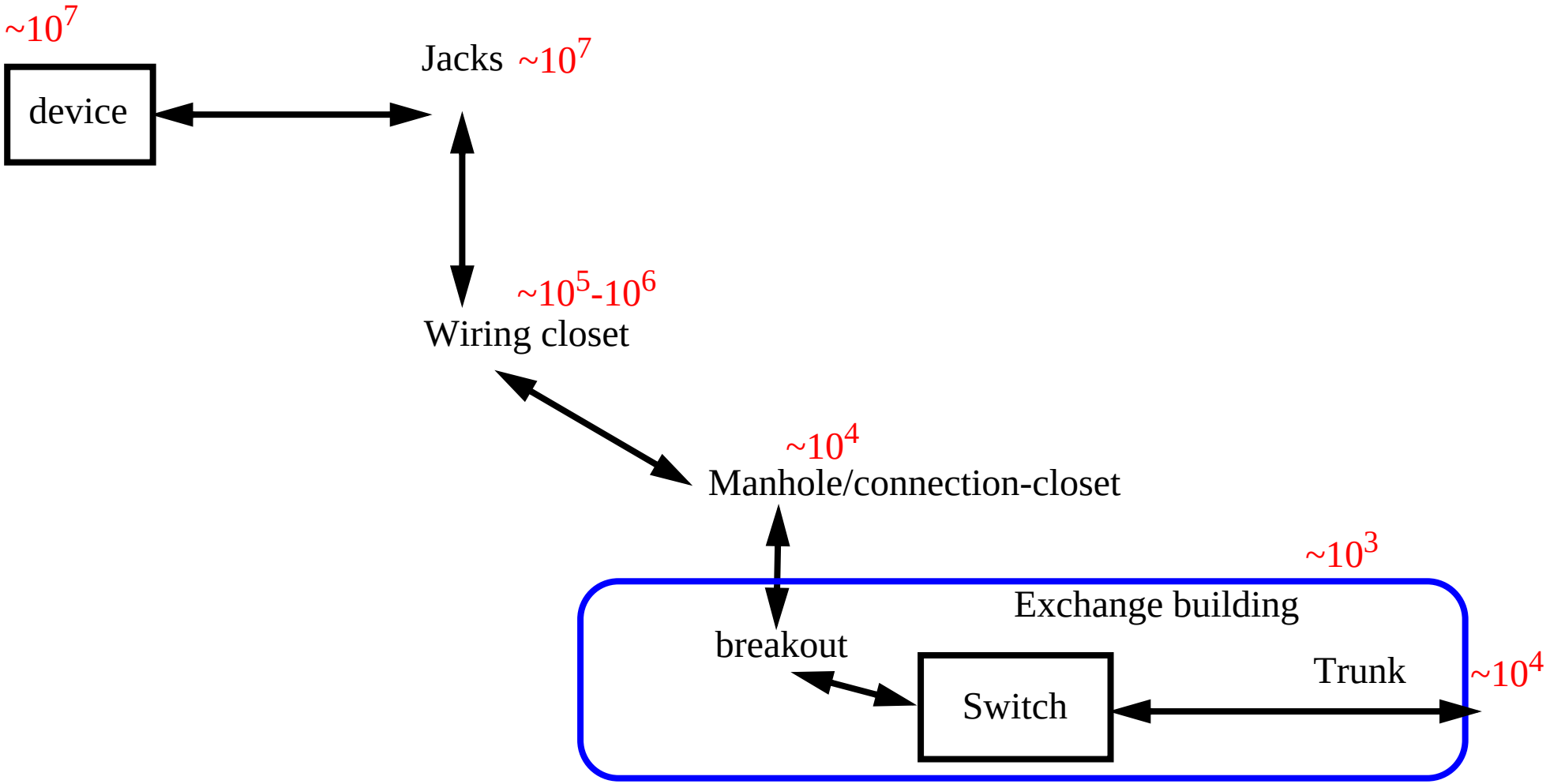


New fixed infrastructure

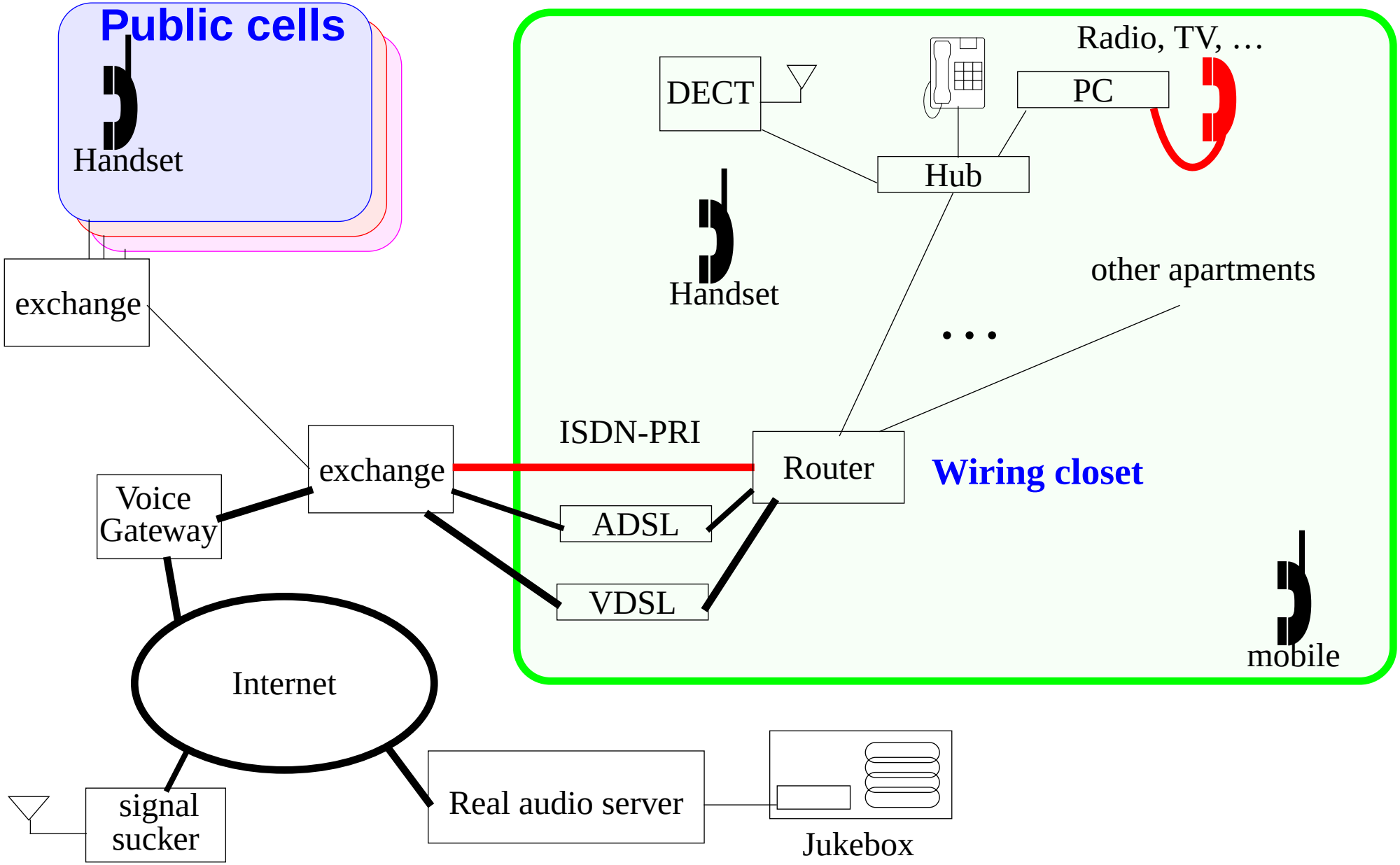


Orders of magnitude

Numbers shown below are my approximation of the actual numbers Sweden

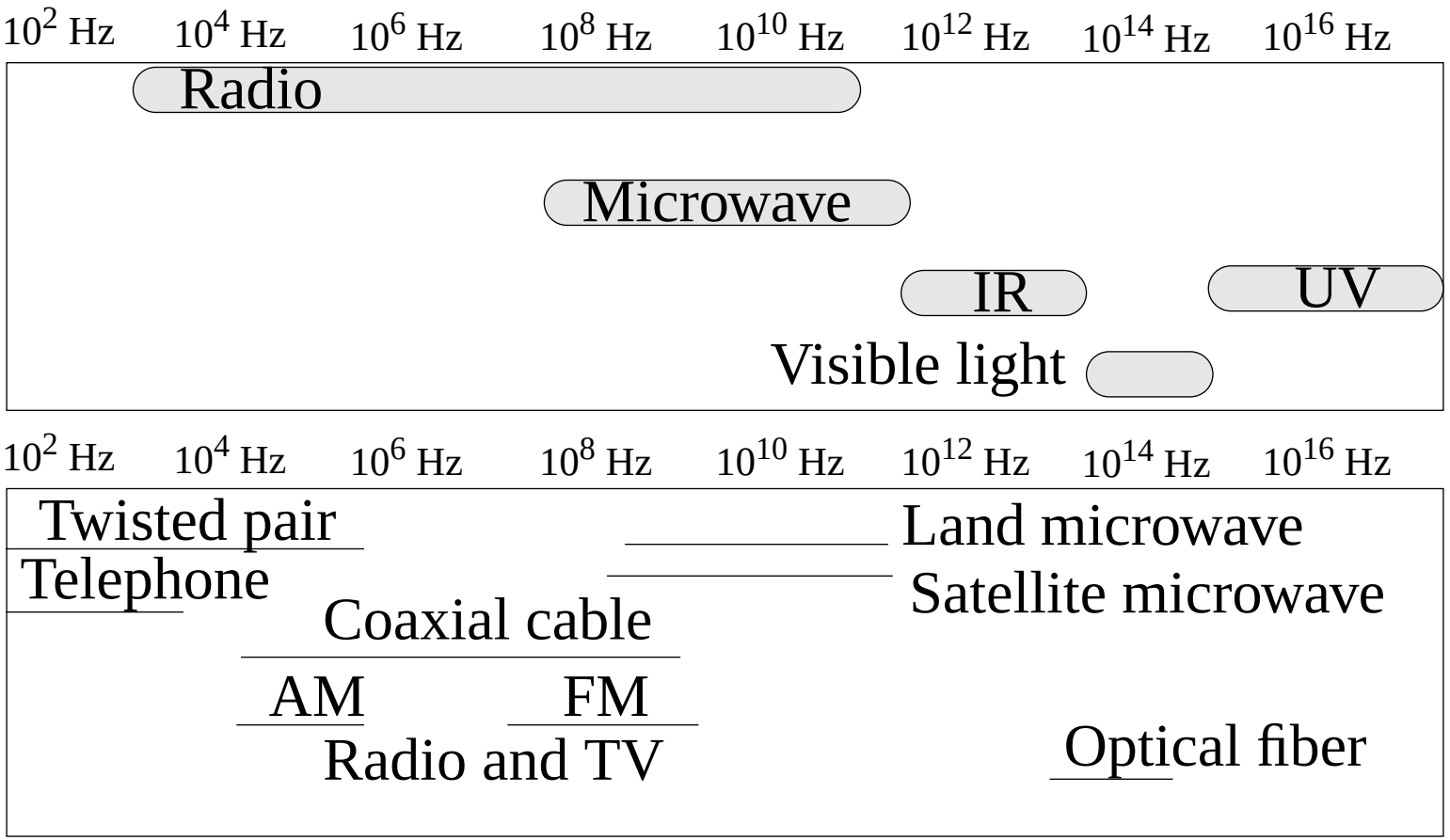


A new infrastructure- How do we implement it and pay for it?



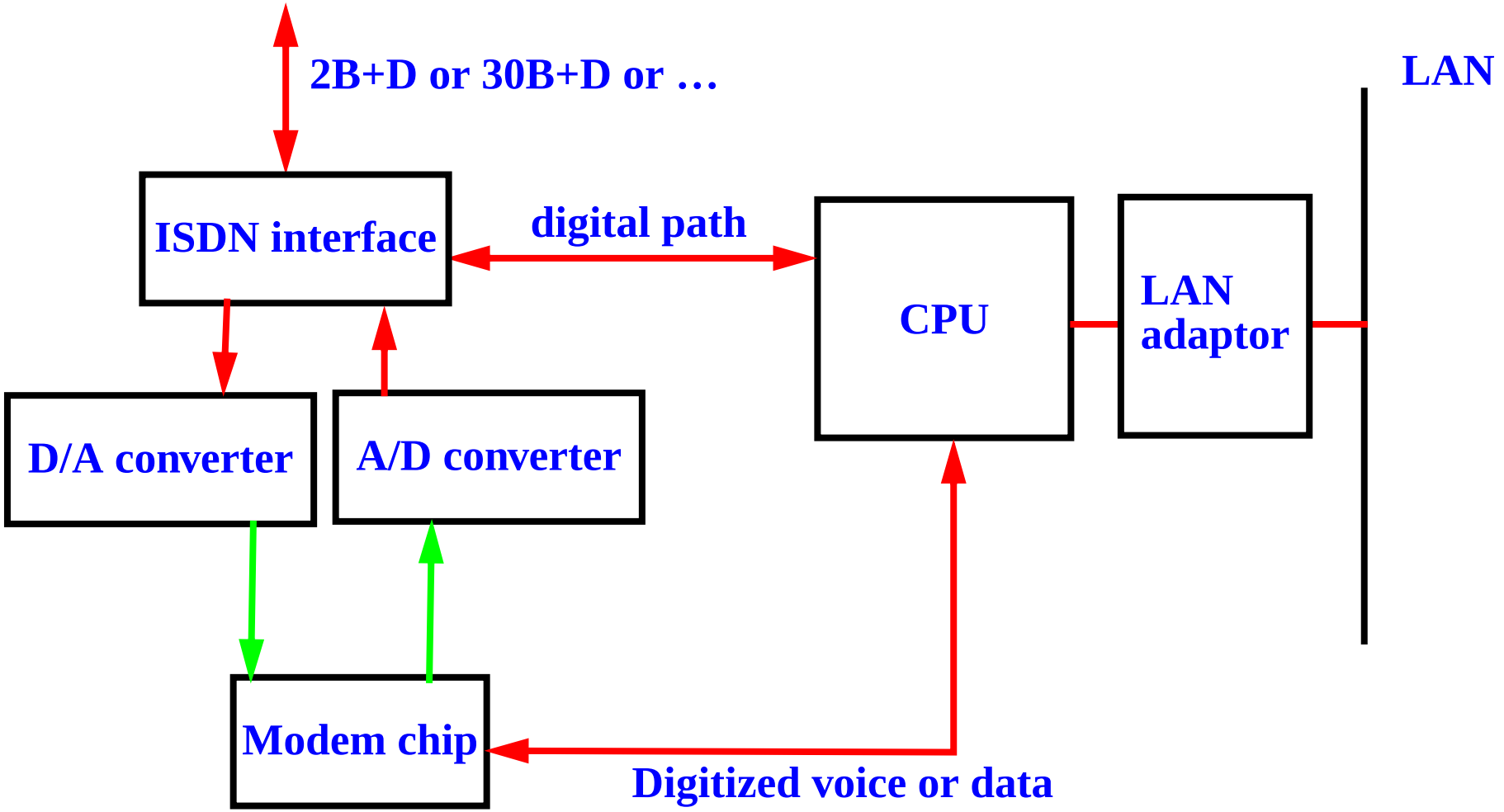
Free space (air, vacuum, …) vs. Guided (wires, cable, fiber, ...)

Electromagnetic spectrum:



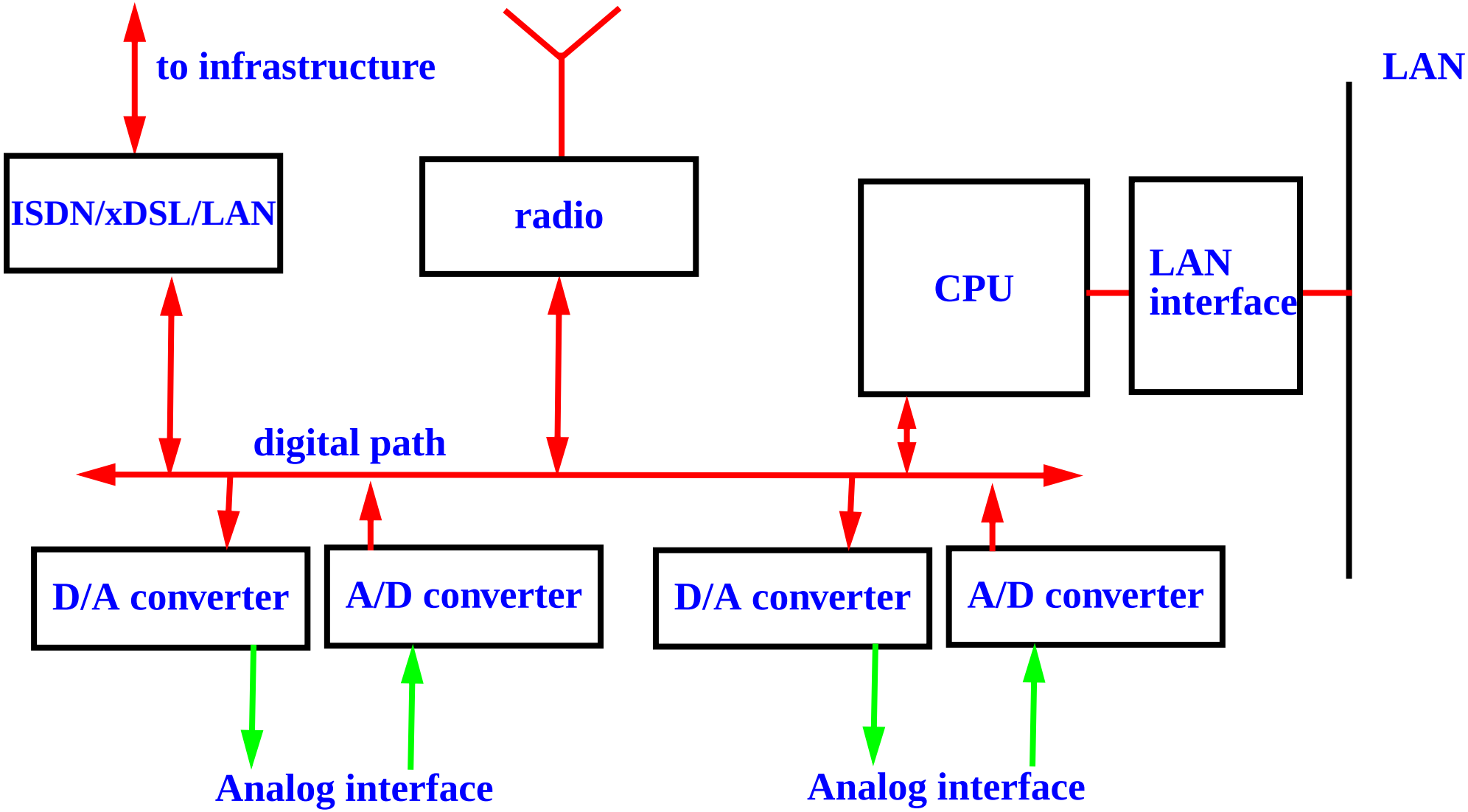
Note the scale is **logarithmic** ⇒ there is more bandwidth available in fiber than all of the 100 Hz through microwave range!

Voice Gateway



Use access servers such as Ascend Communications MAX, filled with digital modems (currently used for current analog modem pools) as voice gateways [see Ascend's MultiVoice Application for the MAX]

Local access point



All but the radio are current inside an Ascend Communications Pipeline 25 or 75.

Access Point Architecture

In order for future picocellular environments to support both high user data rate and high capacity, a lot of base stations will be needed for a picocellular system. Unless the cost of base stations is low, this would increase the cost of such an infrastructure to a unreasonable level.

There are a number of possible ways to decrease the cost of picocellular system infrastructure:

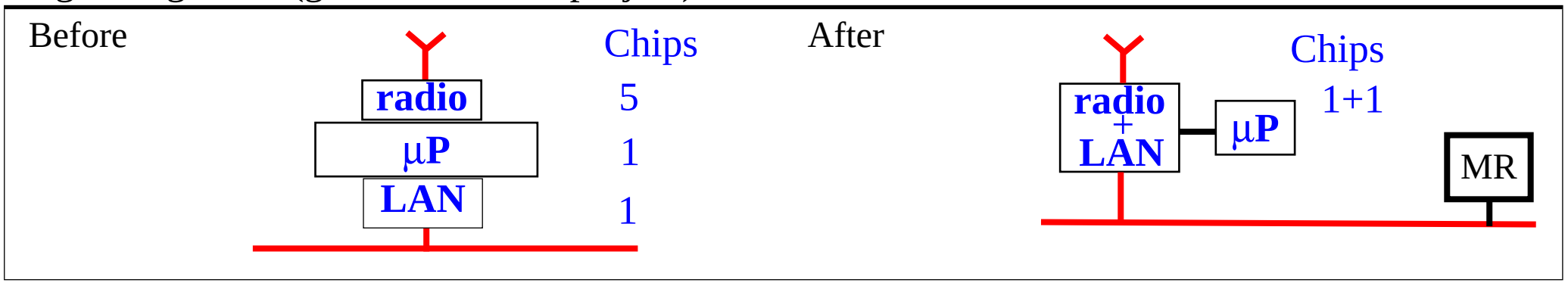
- use soft or reconfigurable radios - so that we can make one kind radio, therefore increasing manufacturing volume;
- simplify base station structure, by making them look like mobiles, but with a connection to the wired/fibered/… infrastructure;
- it all has to fit on one chip which is made in high volume, i.e., to ride the VSLI price-performance curve; and
- leverage something you already have (recycling of bandwidth, wires, content, …), to the greatest possible extent, thus re-use the already existing facilities:
  - ♦ attach base stations to LANs
  - ♦ attach base stations in place of telephones

Except the soft radio (which is a technology that is still in its early developing phase), all these imply that we need to simplify the access point's structure as much as possible.

$\Longrightarrow$ How to simplify the BS architecture, while at the same time do not decreasing performance.

MEDIA

High integration (goal of MEDIA project)

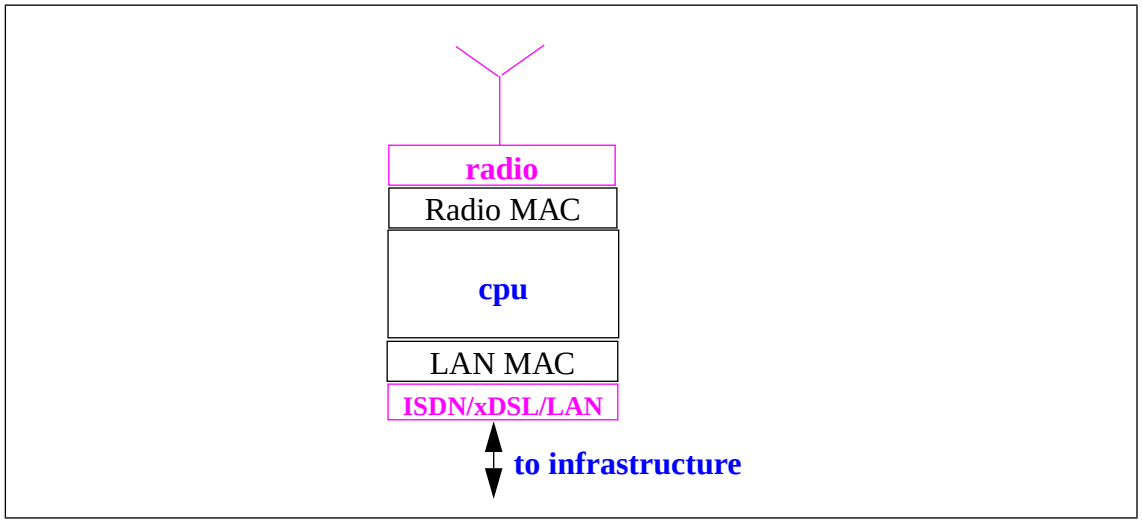


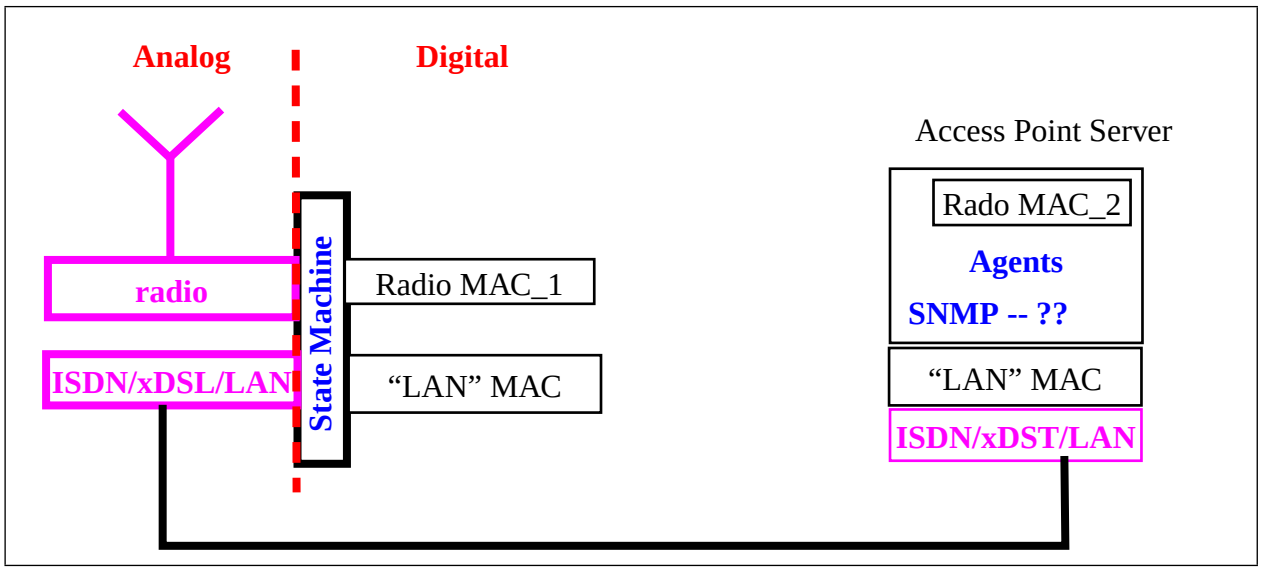
Partners:

- Kungl Tekniska Högskolan (KTH/ELE/ESDlab and KTH/IT/CCSlab)
- Tampere University of Technology (TUT)
- GMD FOKUS (GMD)
- Technische Universität Braunschweig (UBR)
- Interuniversity Microelectronics Centre (IMEC)
- Ericsson Radio Systems AB (ERA)

See http://www.ele.kth.se/ESD/MEDIA for more information

Split the functions between access point and access point server





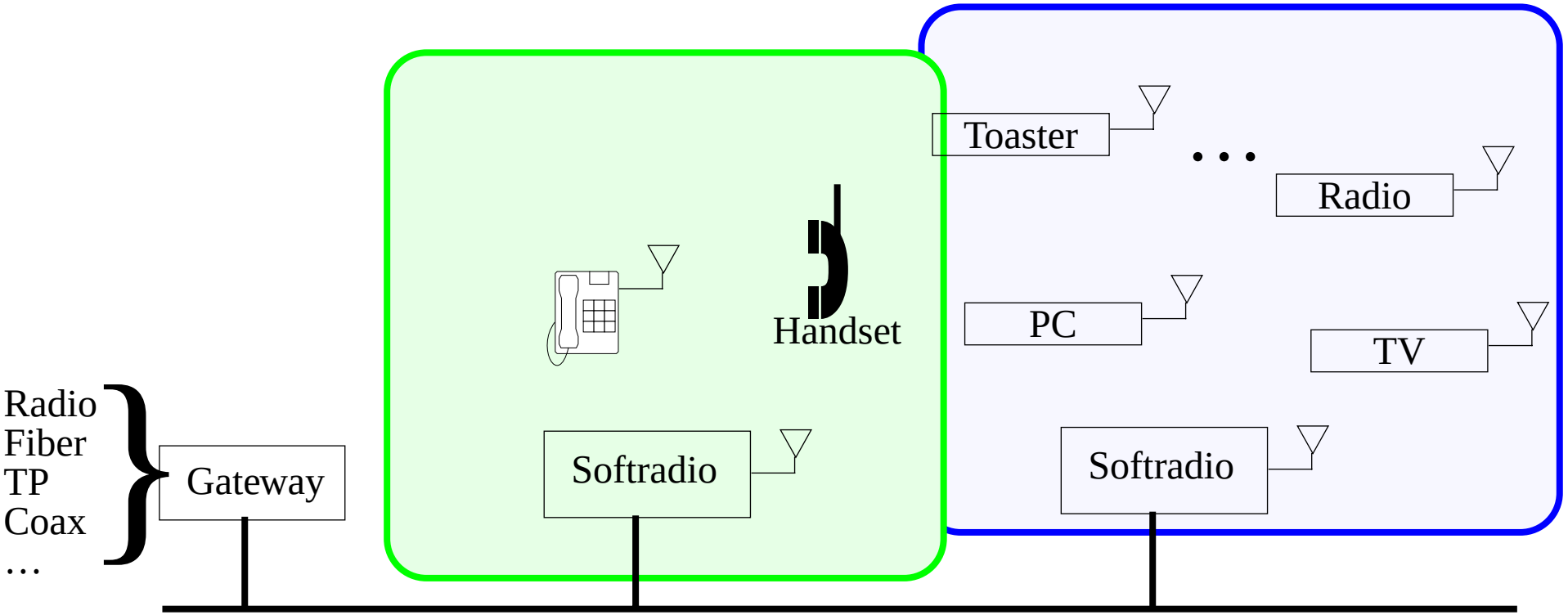
Radio Part MAC

Open questions:

- How many radio we need?
- What is the right number of receivers that a typical mobile user would want to have?
- What is the relationship between the number of radios and: the data rates that a user can source and sink? a user's context switching time?
- We think that its best to have two radios. One is used as the current communication channel and the second is time-multiplexed:
  - to look for other access points,
  - when bursts of extra bandwidth are needed,
  - to acquire information which is used to determine your location and heading,
  - as a secondary channel to listen to (and perhaps transmit) contents which is not available via the main communication channel,
  - listen to non-traditional communication emissions in your environment, etc.

It is also important to note that the authentication and privacy features were defined to provide "wire-line" features. However, these features are *optional* and need *not be implemented* in a given device.

Future home/office/… network accesspoints



Looking forward

Turning a transistor on/off - number of electrons:

1997: 10^3 2010: 8-9 2020: < 1

We already have DNA based computing, the beginning of Quantum Computing, …

50 years: Auxiliary brain

- a single chip storing $2x10^{16}$ bits of data, ~storage capacity of 10^5 human brains.
- volume of 1 cubic centimeter, about the size of a sugar cube.
- with power of 500 million Pentium Pros
- able to record life's experiences and replay them

"We should not be shy about our predictions."

-- Joel Birnbaum, Senior VP R&D and Director of HP Labs[1]

1. from ACM'97:The Next 50 Years of Computing (http://www.acm.org/acm97/home.html) and http://www.research.microsoft.com/acm97/

Personal Computing and Communication (PCC)

Upper limit of bandwidth: saturate the senses: sight, sound, touch, smell, taste

$\Rightarrow$ ~1 Gbit/sec/user

Current workstations shipping with 1 Gbit/sec interfaces for LAN!

Telepresense for work is the long-term “killer” application

-- Gordon Bell and James N. Gray[1]

1. “The Revolution Yet to Happen” in Beyond Calculation: The Next Fifty Years of Computing, Eds. Denning and Metcalfe, Copernicus, 1997.

The Future is Now

The easiest way to predict the future is to make it.

- Alan Kay

Español: La manera más fácil de predecir el futuro es hacerlo.[1]

1. Translation by http://babelfish.altavista.digital.com/

Conclusions

- Now is the time for operators to reinvent themselves and their infrastructures
- Low cost access points which exploit existing or easily installed infrastructure are key to creating a ubiquitous mobile infrastructure with effectively infinite bandwidth.
- Smart Badge is a vehicle for exploring our ideas
  - ♦ Exploits hardware and software complexity by hiding it.
  - ♦ Explores allowing devices and services to use each other in an extemporaneous way.
  - ♦ Enables a large number of location and environment aware applications, most of which are service consuming.
  - ♦ Service is where the money is!
- Distributed research - means that the project never sleeps; global operations will be part of the key to success.

Don’t waste! Help stamp out analog phones

No pierda! Ayude a eliminar los teléfonos analogicos.[1]

Use each jack as a place to put an access point, thus making it possible to have lots of picocells, so that **everything** can be on the net.

1. Translation by http://babelfish.altavista.digital.com/