SmartBadges: a wearable computer and communication system

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Outline

- Making appliances and other computing clients interface to the human, rather than the other way around
- Environment Awareness
- How the Smart Badge hardware and software evolved, and what it is now
- Courses - as a driving function
- How the sites interacted

Solving An Old Problem

- Our industrial partners make products that exploit technology
  - Computer
  - Peripherals
  - Consumer devices
- The “use” model continues to be an issue
  - Has an impact on what people buy
  - Has an impact on revenue
- What will people buy???

What does the consumer want?

"I'll buy anything if it saves me time and it's easy to use."

-- A member of the consumer market
(with 4 kids)

KISS

Date: Fri, 20 Feb 1998 19:14:53

To: Mark Smith <msmith@bender.hpl.hp.com>

From: albert mahood <delljo@jps.net>

Subject: thought

Computers are like Swiss Army Tools. They can do a whole bunch of things but nothing specific. I never have found those multiple tools worth a damn and that goes for computers. Just give me something that does a specific job and is simple. I don't want to point or calculate or make macros. Macros drive me nuts. How about dreamingup a voice activated simple machine to do "writing" or one to do simple accounting. How about saying "go to L15 R2 - $45.60" instead of all that pointing and moving and macroing. Keep it simple! I guess that KISS is the real answer. Dell

Traditional Approach

- Address Ease of Use
  - Make technology "easy to use", if we can define it.
  - Reduce to a "most common user" model.
- Provide human interfaces to technology, i.e.,:
  - Front panels on appliances.
  - GUI based operating systems.
  - Web Browsers

What is New

- Make ancillary technology **transparent**
  - ♦ It doesn't go away,
  - ♦ But, parts not central to perceived device purpose are hidden.
- Provide new interfaces
  - ♦ Technology interface to technology
  - ♦ Technology interface to people

Instead of a person trying to figure out what the technology wants,
can technology figure out what the person wants?

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
- Make the human the focus of the computer's interaction ($\Rightarrow$ human-centric)

Human Centered Applications and Interfaces

- Environment sensors are placed on devices and people
- Sensor information is available to applications and Agents
- Privacy and security are assured
- Human centered applications and interfaces can be developed

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 collate and 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,
  - ♦ 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

Enabling Technology

- Badges
  - tag for each object whose location or environment is important.
  - low power, low cost
  - communicative
  - reprogrammable
- Badge is a platform for sensor control and communication.
- Sensors
  - low power
  - small
  - highly integrated
  - diverse
  - common interface (i.e., I^2C bus)

Current Sensors

- Sensors are currently available for:
  - Temperature, Humidity, Pressure
  - Sound, Light
  - Strain, Electrostatic voltage
  - Gas composition, Airborne contaminants
  - Gas flow, Fluid flow
  - Acceleration, Magnetic flux
  - Radiation, Reaction chambers
- Tend to be single sensor chips.
  - Multi- sensors are needed
  - Common interfaces to outside world
    - I ^{2}C bus, others
    - High levels of integration needed
    - Sensor + ADC + Processor + Memory

Situational awareness and Adaptability

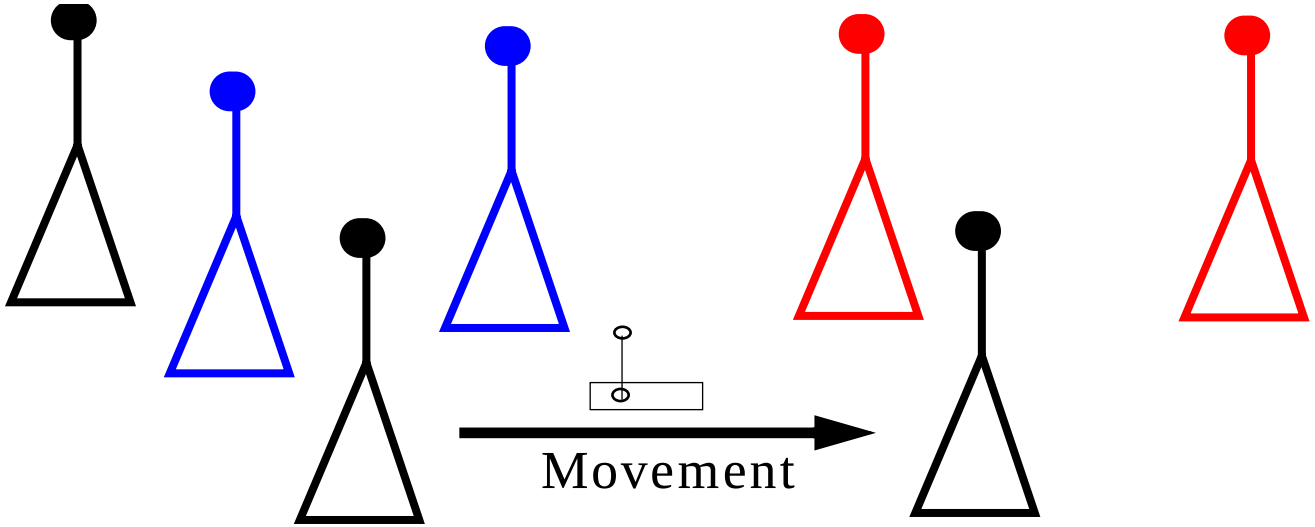


Figure 1: Where am I? What am I? Who am I?
Where am I going? When will I be there? What should I become? Who should I become?

- 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 [of order 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
  (complete with highlighted time table entry - since the system also knows the time)
- ♦ 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, …)

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

Example Applications

- Doors
- Telephones and Pagers
- HVAC and Lighting
- Appliances
- Education
- Many more:
  - games
  - vehicle tracking
  - shipping environment monitoring
  - patient monitoring...

Telephones and Pagers

- Wide area communications devices
  - ♦ know nothing of their location
- Combined with location sensing
  - ♦ GPS, next- generation triangulation
  - ♦ badge technology
- Result is a location and environment aware communications and control device:
  - ♦ single device
  - ♦ provide a badge like sensor platform and authentication
  - ♦ mechanism
  - ♦ wide area voice and data communications links
  - ♦ interface to telephony
    - ◆ already PC- Card GSM transceivers are available
  - ♦ interface to other peripheral devices encountered in the field

Heating, Ventilation, Air-conditioning, & Lighting

- Person enters a room: transceiver detects badge and sends badge ID to location server
- Room's agent notices: turns on the lighting and adjusts the air handling system
- Agent knows how many people are in the room.
  - ♦ tailor the room environment to the group preferences
- Smart Badge
  - ♦ agent also knows the temperature, humidity, and ambient light level seen by of each persons
  - ♦ much finer environment control
  - ♦ suit the people not the wall mounted sensor
- Agent can look for spatio- temporal correlation
  - ♦ predict the normal patterns of a person
  - ♦ anticipate their arrival, departure, and routine movements
- Apply technology to all buildings
  - ♦ power company's agent
  - ♦ predict load fluctuations
  - ♦ micromanage generators and grid
- Intelligent Badge
  - ♦ actively interact with the building system

Appliances

- To use an appliance (photocopier, dishwasher, set- top box, CD):
  - move to the appliance
  - transceiver sends ID to the location server
  - appliance's agent notices
    - loads appliance user interface into the Intelligent Badge
  - perhaps an alternate communications link: GSM, DECT, ATM, …
- Interface appears on Intelligent Badge.
  - appropriate language
  - customized to individual preferences
  - consistent for all appliances
    - it's **your** personal interface
  - interaction mediated by location server and agent
    - security, integrity, cost recovery

Education Space

- Students use an electronic note book replacement (PAD).
  - hand held, pen and keyboard input, docking station
  - local document storage, disconnected operation
  - wireless access, multimedia capability
  - Smart Badge
  - autonomously or wireless operation at home or in the field
  - cheap
  - e.g., Apple eMate 300
- PAD brought near an interactive CATV set- top.
  - agent detects the new peripheral and expands the PAD's capability to use it
  - audio and video material can be viewed and edited via the TV
- PAD placed near workstation.
  - agent detects new peripherals
  - mouse, keyboard and display are used with or in place of those in the PAD
- Student can access multimedia information.
  - from any location
  - delivered media stream tailored to available resources
- Support constructivist, situated and contextual learning environments

Your Own Personal User Interface

- Intelligent Badge allows each user to have their own appliance interface.
  - interface can be consistent across all appliances
    - not because each appliance supports the interface
    - but because the user's own interface provides consistency
  - e. g., an automatic teller machine
    - ATM no longer needs a human centered interface
    - all commands via the network as EDI requests
    - user's device provides necessary interface for the user
- Badge as a smart card.
    - provide higher levels of security
    - biometric signature of the person currently using the badge
    - the badge ensures that only you can use it

Smart Badge Local Mode

Camera Reconfigured To Wearer's Use Model.

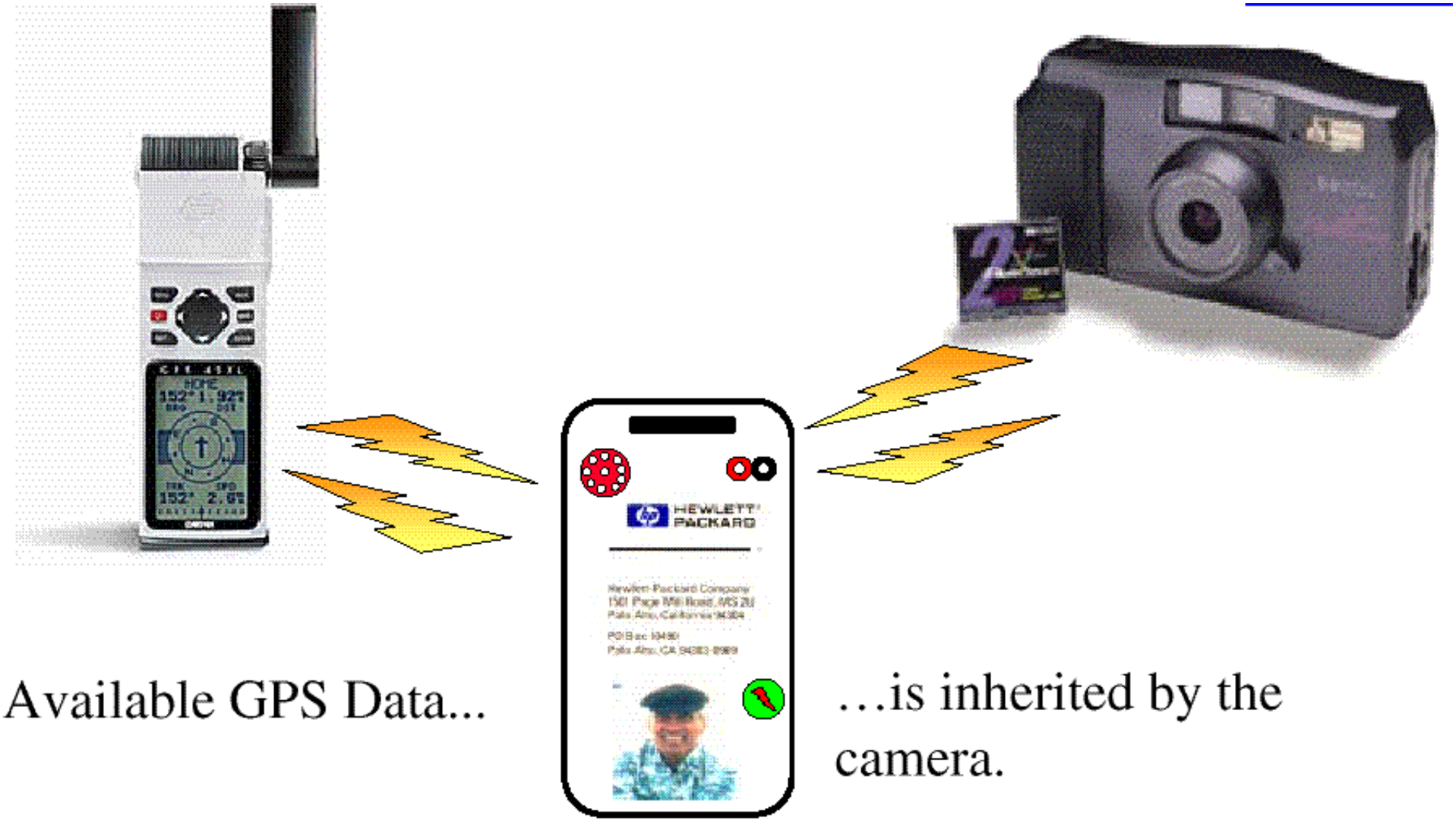
Device Inheritance

- A typical high-value customer might have:
  - Watch, mobile telephone, pager, PDA/Organiser, laptop computer, mobile printer, mobile scanner, digital camera, GPS locator, car, SmartBadge
- All these devices should be able to talk to each other and inherit each others functionality

Inheritance Example

- Customer takes a photo with their digital camera.
- Timestamp is added from watch
- Location is added from GPS
- Caption is added from SmartBadge data about people in the shot
- Image is transmitted back to customers home-server via GSM

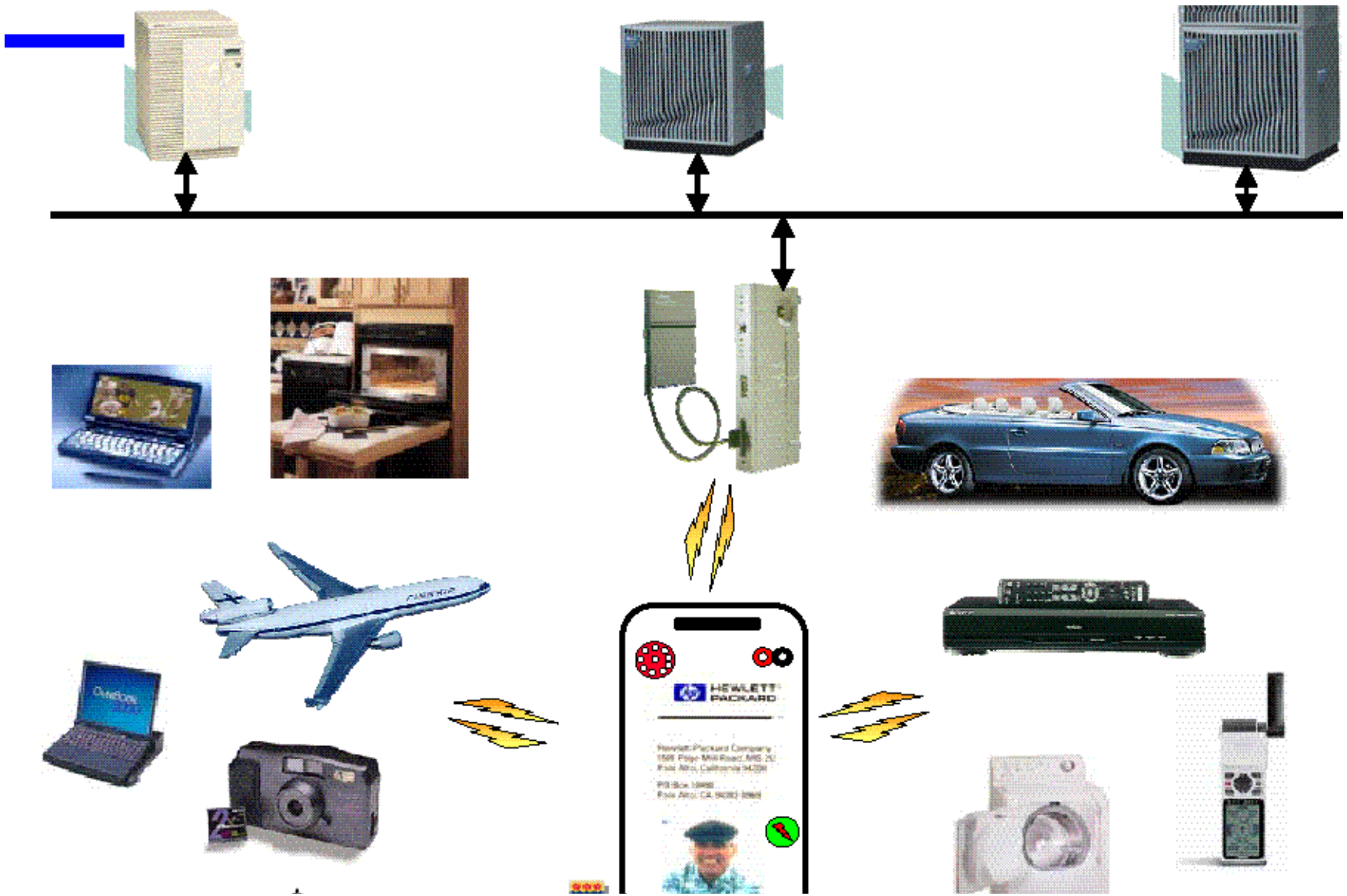
I/ O Inheritance



Available GPS Data...

…is inherited by the camera.

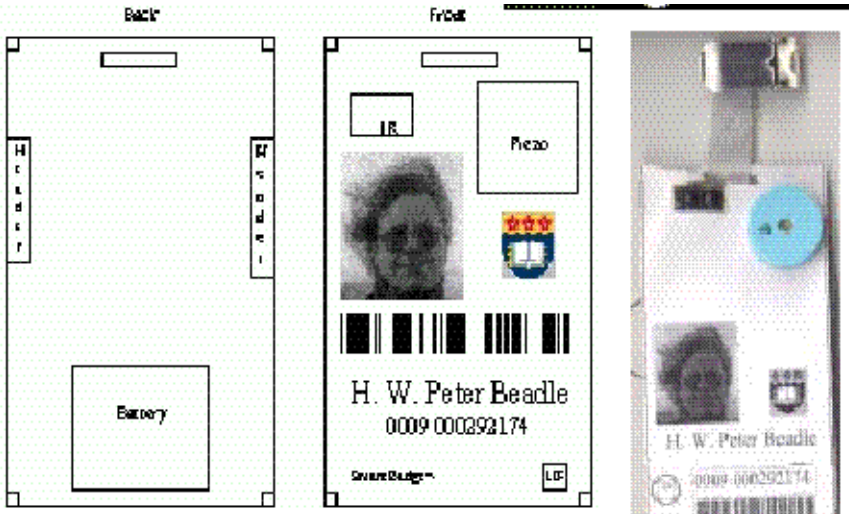
Server Based Infrastructure



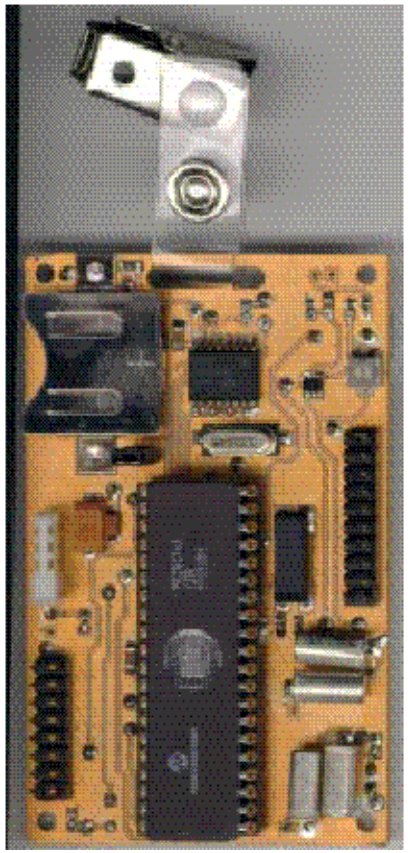
Inheritence Problems

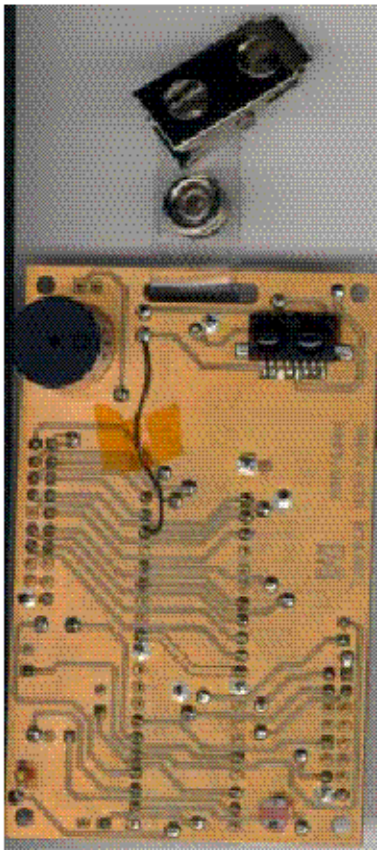
- Describing device capabilities
- Networking is not personal enough
  - IR is line of site
  - Radio potentially sends your data to near-by people
  - Intra-body
    - conductive effects of human body
    - low bandwidth
    - MIT, IBM prototypes

Badge Prototype and Badge 1

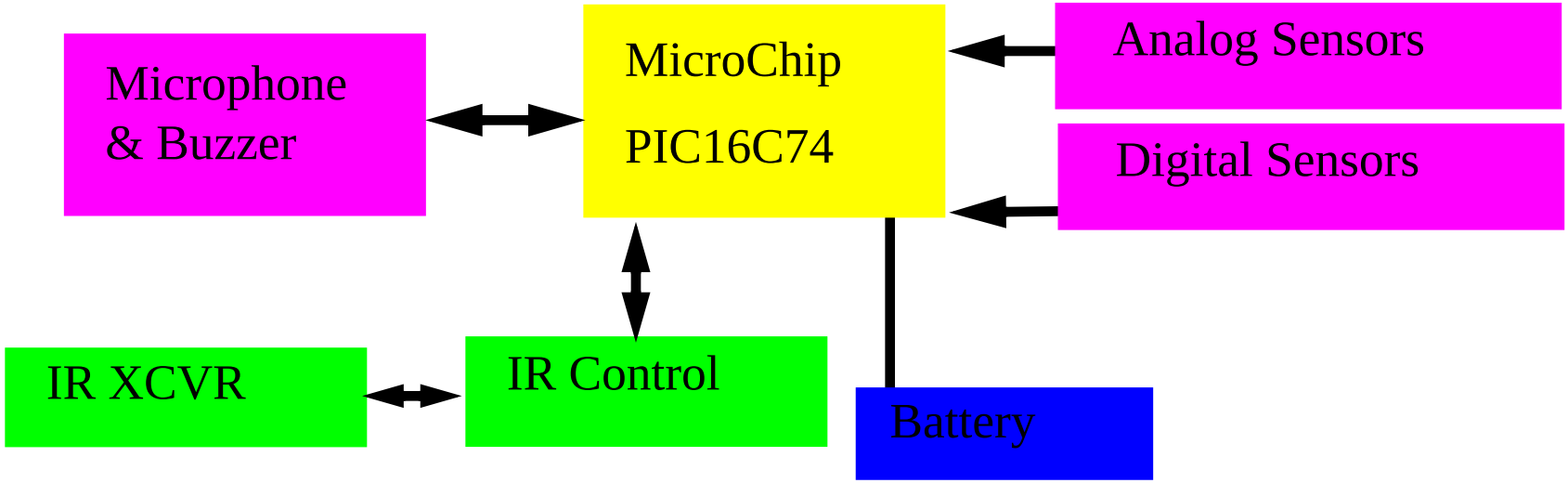


- Sound, Light, Temperature, Humidity, Orientation, Adjacency
- Beeps
- PIC 16C74A-jw based
- 5 MIPS
- 4m range
- 98mA average power





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

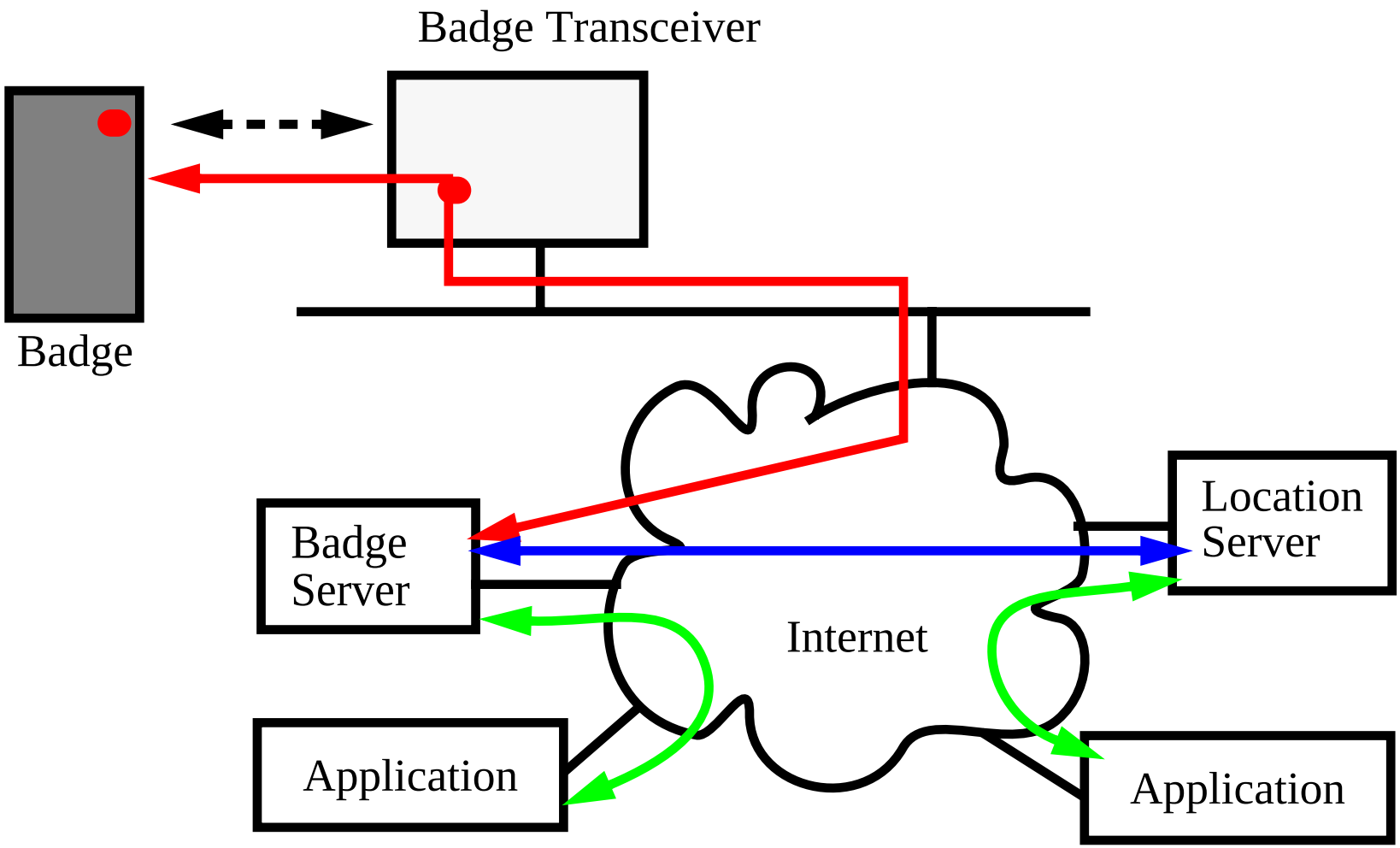
85x55mm $\Rightarrow$ 46.75 mm^2 - component cost ~US$30

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.



Badge Frame Format

Badge frame

- Encapsulated in an IrDA unit- data frame
- Extensible format
  - ♦ streaming sound to/ from badge
  - ♦ all environmental sensors

From badge

length (8 bits)
protocol (8 bits)
id (32 bit IPv4)
status (8 bits)
x, y, x (32 bits each)
roll, pitch, yaw (8 bits each)
temperature, humidity, light (8 bits each)
sound power (8 bits)

To badge (Remote Procedure Call model)

length(8 bits)
protocol (8 bits)
id (32 bit IPv4)
command (8 bits)
data

Symmetrically Encrypted Content

Goals

- authentication & privacy
- immunity to snooping/ spoofing attack

Symmetric encryption between:

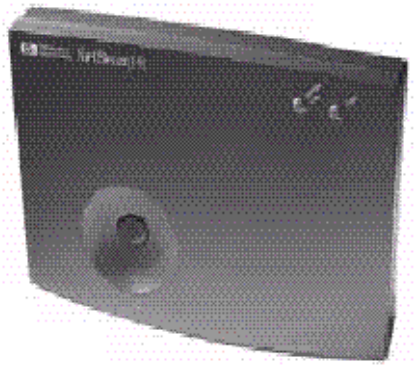
Badge to location server	Transceiver to location server	Agents to location server
Tiny Encryption Algorithm ♦ Oxford University, 128 bit DES strength ♦ Trades time against space	DES or similar	DES or similar

Badge can

- change ID and key dynamically
- change persona dynamically

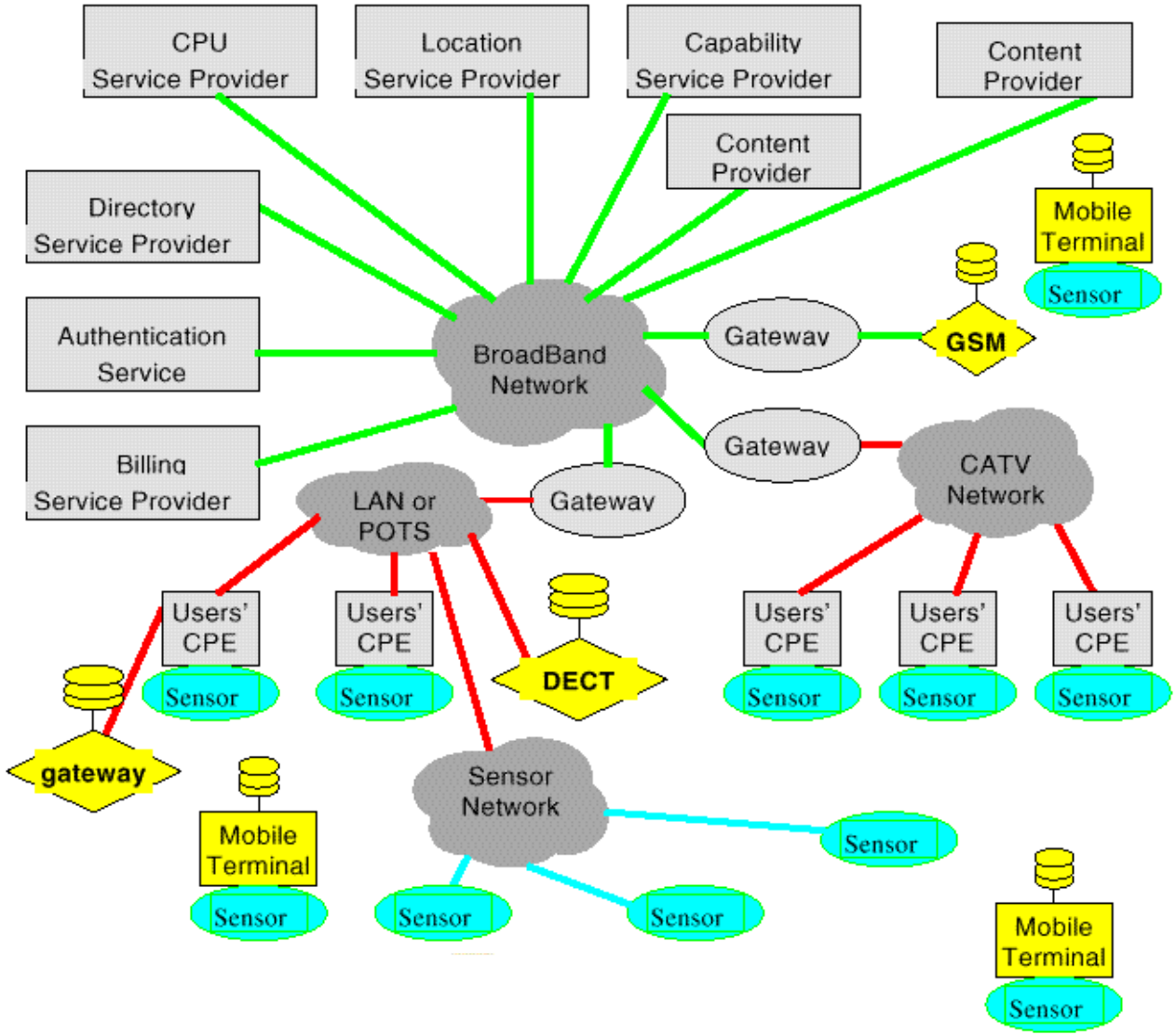
Fixed Badge Transceivers

- IrDA network technology
  - HP NetBeamIR as wall sensor

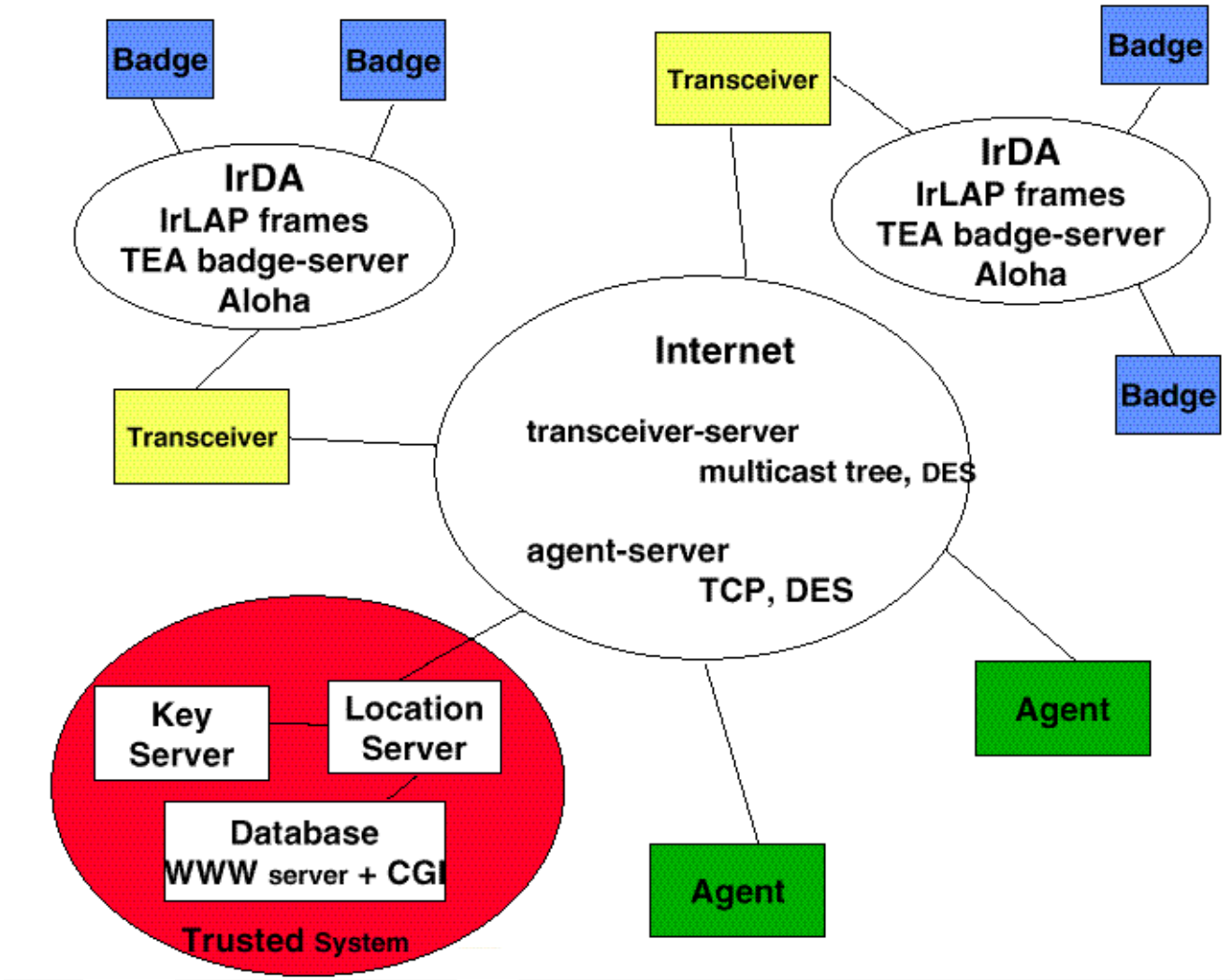


  - Required full IrLAP and IrLMP protocol stack in badge
  - Problems: IrLAP negotiation and setup times (abotu 3 sec) and unable to support multiple badges on one access point. The protocol is too heavy weight for highly mobile devices, doesn't support co-located devices and leads to a design that is power hungry.
- Daughter card
  - Use badge as fixed sensor -- relay data from IrDA to:
    - RS232
    - Ethernet
    - DECT
- Use Internet for wide area data carriage

Network Architecture



Software Architecture



WWW based Location Server

- WWW server + CGI prototype
  - Query primitives
    - where, near, distance
  - Location update primitives
    - position, adjacent
  - Callbacks (no Agents yet)
  - Need 3D Geographical Information System (GIS) style database and geometric reasoning
- Agents
  - Interrogate database looking for correlation
  - Agents for things (doors)
  - Agents for people
  - Agents that learn
  - Non- personal queries
    - Agents are not trusted systems
    - Query on user capabilities rather than identities

Students in the 1997 class (and others) built lots of applications using this server.

Problems with IRDA LAN for Badges

The IrDA LAN protocol builds upon their protocol stack[1].

IrLAP

- Connection establishment produces a connection id
  - ♦ autobaud negociation
  - ♦ negotiate the frame size
  - ♦ …
- Using the connection id we can re-start quickley if the IR device moves out of line of site
- If connection in-active for 12 s (timout period) without being re-activated, then it is dropped.

Problems:

- It take ~3 seconds to initially establish the link; ~1s to re-establish between the same IR devices.
- The NetBeamIR is a secondary device and the badge has to be the primary and initiate and control the link negotiation (it can force the baud rate and frame size, but it still takes time and power).

Implementing IRDA Lite - a give-away IrDA-lite stack by mid-year.

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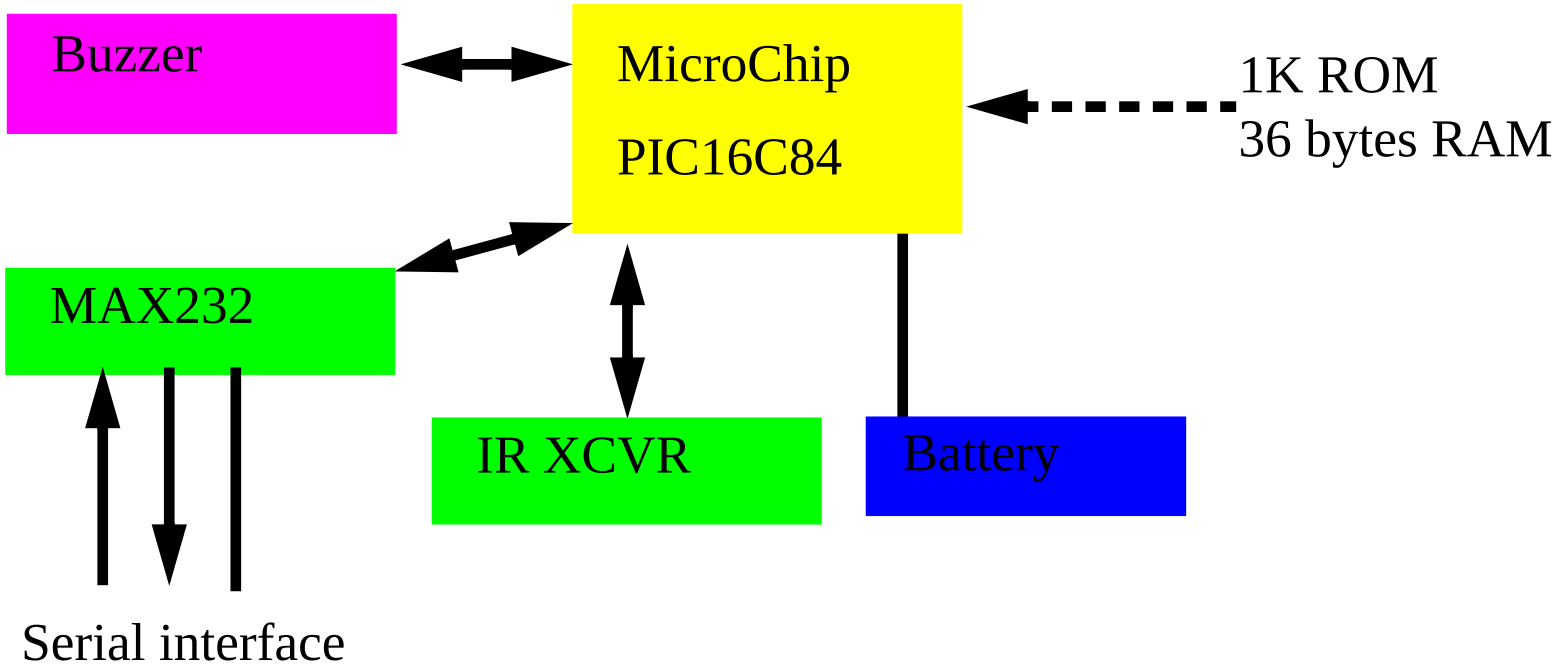
1. IrDA standards are available from http://www.irda.org/

Badge2A

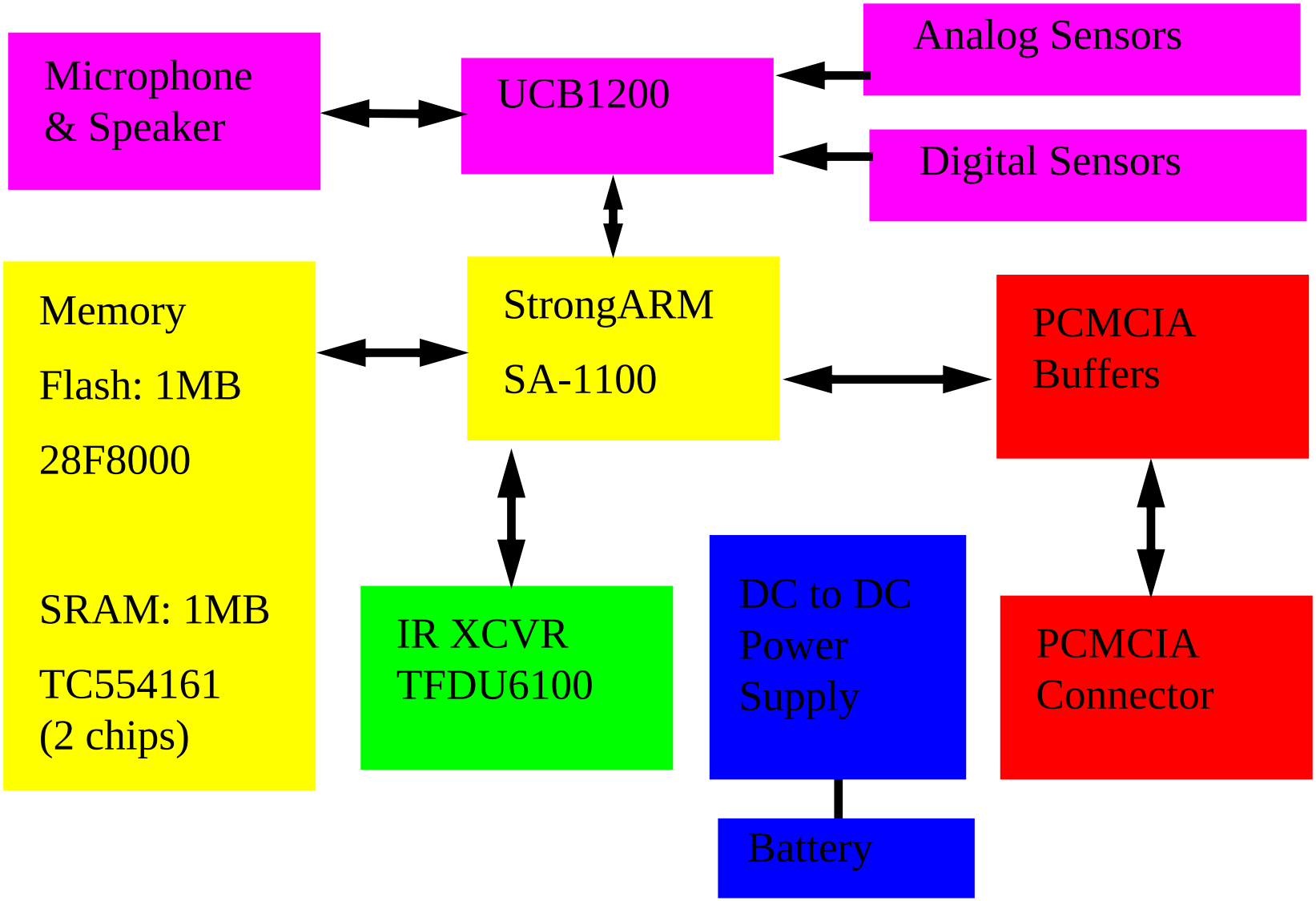


30mm^2 square board - component cost ~US$12

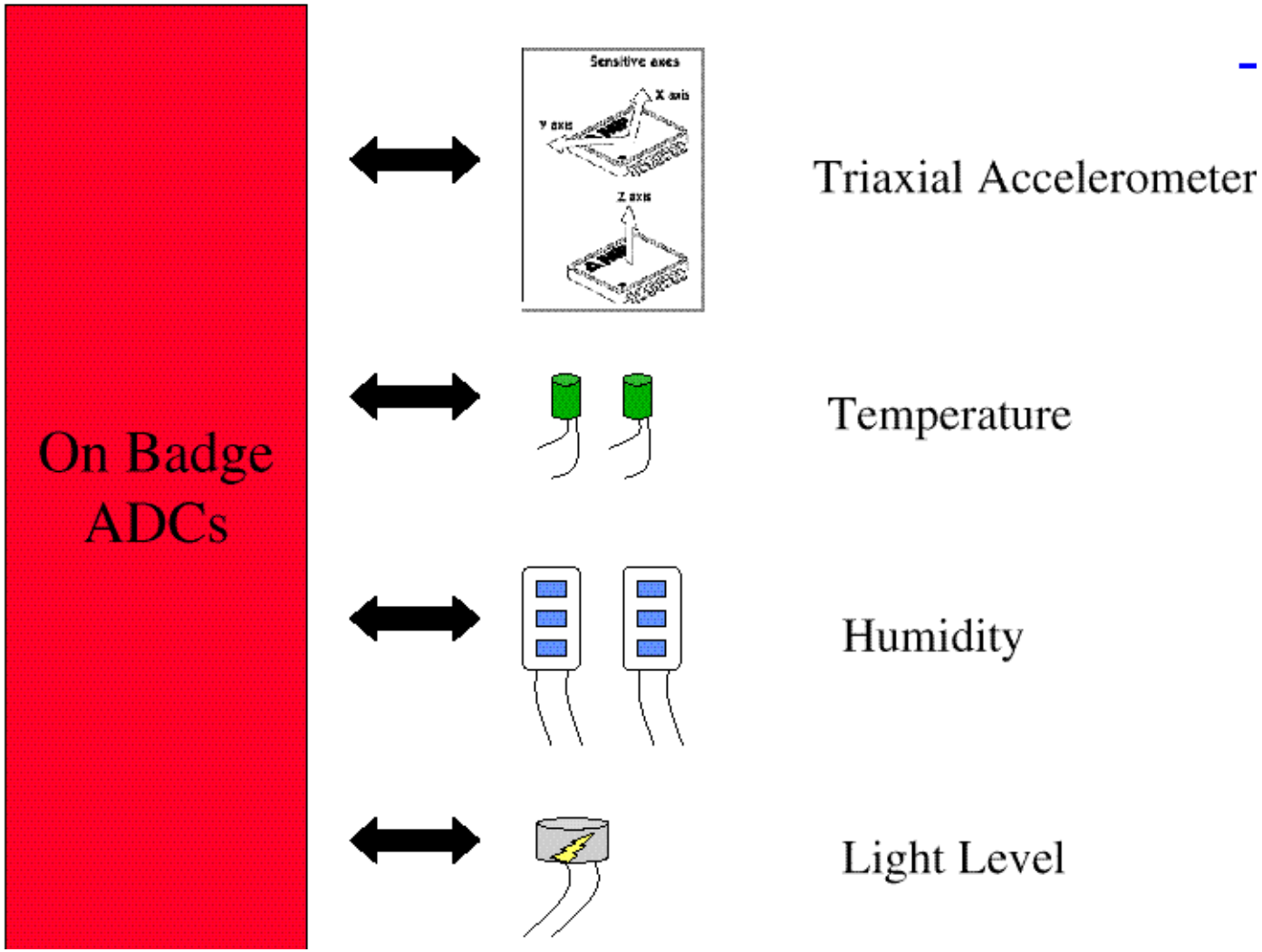
Make the access point the active device to get battery life >>100 hours. Badge responds when it receives a beacon, like slotted aloha with the access point generating the slots. Use the same protocol for Badge-3.

Transmitting and receiving at 9600 baud in software on a 4MHz PIC.

Smart Badge 3



Smart Badge Sensors



Badge 3

Number	Site
30	Ellemtel
	Ericsson Eurolab
50	Ericsson Media lab
10	Ericsson Radio
	HP
64-80	KTH
	Univ. of Wollongong
30	KTH use at Stanford Univ.
300	Total

Attaching base stations to LANs

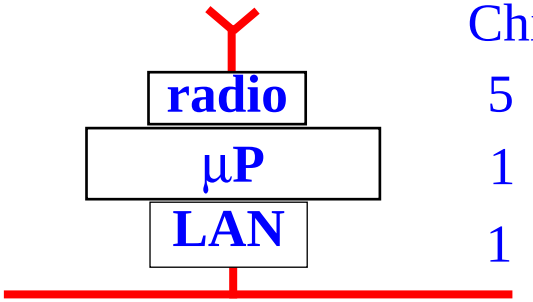
Key elements are:

- high enough bandwidth to support multimedia demands
  - Lucent Technologies Inc. - 10 Mbit/sec wireless LAN:
    The details are in the patent by Israel Bar-David and Rajeev Krishnamoorthy
    can be found at: http://patent.womplex.ibm.com/details?patent_number=5623511
- Digital radios (perhaps soft or virtual radios)
  - Wideband receiver followed by DSP: http://www.aircom.com/southcom.html
  - provide multistandard, multiband communication with one radio
    avoid the problems of the current cellular, cordless, … market
- reconfigurable electronics
  - support changing protocols
  - support much of the protocol processing in hardware

MEDIA

High integration (goal of MEDIA project)

Before



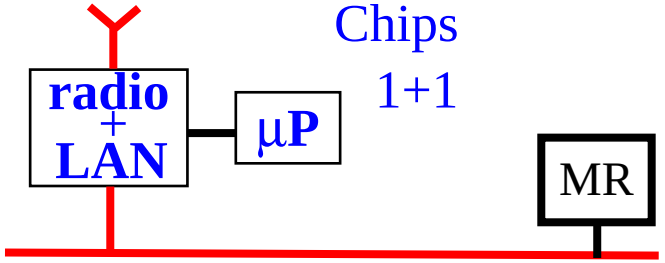
Chips

5

1

1

After



Chips

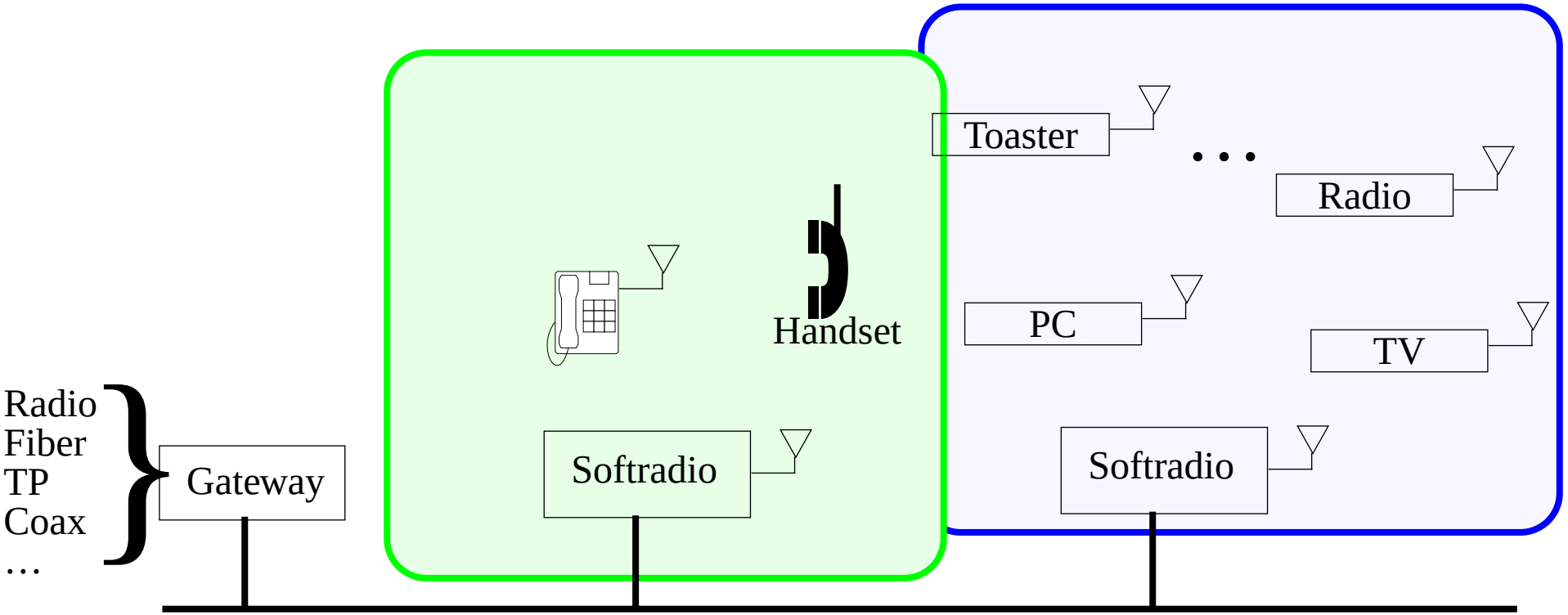
1+1

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

R&D areas under investigation

- Situational Awareness and Adaptability
- Device Inheritance
  - Intrabody Networking
  - Network attached appliances
- Personal User Interfaces
  - Speech based
  - Personalized appliances/devices/…
- Subconscious Authentication
  - Biometrics
- Low cost infrastructures to enable high bandwidth and low power portable devices
  - adding low power radios to badges
  - Low power radio access points

Future home/office/… network accesspoints



Upcoming courses - Spring 1998

KTH

2G1303 Telekommunikationssystem: Mobile Personal Communication

- http://www.it.kth.se/edu/gru/Fingerinfo/telesys.finger/Mobile.VT98/mobile.vt98.html
- 72 students

2G5541 Location/Context Aware Personal Communication

- http://www.it.kth.se/edu/Ph.D/LocationAware/aware.vt98.html
- 16 students

2G5535 Mobile Personal Communication: Access Points

- http://www.it.kth.se/edu/Ph.D/AccessPoint/accesspoint.vt98.html

Conclusions

- Smart Badge is a vehicle for ideas.
- It exploits Hardware and Software complexity by hiding it.
- Enables a large number of location and environment aware applications, most of which are service consuming.
- Explores allowing devices and services to use each other in an extemporaneous way.
- Distributed research - means that the project never sleeps.

The Technology is Here

All that is required to realize a universal authentication, communications, and interaction peripheral is to integrate the available components and provide the conceptual framework of an environment aware computer system to allow applications to be developed.

For more information see:

http://www.elec.uow.edu.au/people/staff/beadle/badge/location_aware.html