Networking Trends

- Networking in the past:

- Networking today:

- Networking tomorrow?
The Qualitative Growth of the Internet

- **Mobility** (users, devices, programs) becomes an important paradigm
  - E-commerce --> mobile commerce

- Networked **embedded** systems
  - smart devices
  - machines talking to machines

---

**Internet time line**

© F.Ma. 3
Ubiquitous Networking

- **Today**, the Internet connects all *computers*

- **Tomorrow** everyday *objects* will become smart and they will all be interconnected
  - Ubiquitous Computing
Outline

- Smart Objects
- 5 Reasons for Ubiquitous Computing
- Information Appliances
- Connecting Atoms and Bits
- Consequences

I’m smart

hello!
Smart Objects

- **Embedded processors**
  - in everyday objects
  - small
  - cheap
  - lightweight

- **Wireless communication**
  - spontaneous networks

- **Sensors**

- Real world objects are enriched with **information processing capabilities**
An Example of a Smart Object

- MediaCup from TeCo, University of Karlsruhe
Smart Objects

- May find their place **everywhere**
  - work, home, entertainment, ...

- Can **remember** pertinent events
  - they have a memory

- Show **context-sensitive behavior**
  - they may have sensors

- Are **responsive**
  - communicate with their environment
  - require new **user interfaces**
    - touching, moving, using them; speaking to them; ...?
  - **networked** with other smart objects

- e.g., *location awareness*
- or *situation awareness*
Networked with Other Smart Objects?

ANOTHER BEER, PLEASE, HAL...

I'M SORRY, DAVE. I CAN'T DO THAT.
THE BATHROOM SCALE AND THE HALL MIRROR ARE REPORTING DISTURBING FLAB ANOMALIES
Computers Everywhere

- **Clear trend:**
  - 1 computer (mainframe) for many -->
  - 1 computer (PC) for everyone -->
  - many computers for everyone

- Small, lightweight, cheap, mobile processors
  - in almost all *everyday objects*
  - *embedded* in the environment
  - everywhere

what sensible applications are possible?
Ubiquitous Computing

„In the 21st century the technology revolution will move into the everyday, the small and the invisible...“

- Mark Weiser
  - 1952 - 1999
  - XEROX PARC
Invisible Computing

- Information processing moves to the **background**
  - **human centered**: concentrate on the **task**, not the **tool**
  - the notion „computer as a tool“ does no longer hold

- **New picture of computing** as an invisible, ubiquitous background assistance
  - specialized, invisible computers will become an integral part of the natural human environment
  - „computing without computers“
The Disappearing Computer

- Computer **merges** with physical objects
The Disappearing Computer

- Mark Weiser

„The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”
Outline

- Smart Objects
- 5 Reasons for Ubiquitous Computing
- Information Appliances
- Connecting Atoms and Bits
- Consequences
Five Reasons for Ubicomp
First Reason for Ubiquitous Computing: Moore’s Law (1965)

- Processing speed and storage capacity **double every 18 months**
  - „cheaper, smaller, faster“

- **Exponential increase**
  - will probably go on for the next 10 years at same rate
Example:
CMOS Performance Increase

Source: IBM
Generalized Moore’s Law

- Most important technology parameters double every 1 – 3 years ("Generalized Moore’s Law"):
  - computation cycles
  - memory, magnetic disks
  - bandwidth

- Consequence: **scaling down**

- But Moore’s Law **doesn’t apply** to
  - batteries
  - user mind-share
Barriers

Exponential increase of aircraft speed?

Speed [km/h]

10

10^2

10^3

1900 1920 1940 1960 1980 2000

Wright brothers

Concorde

747

Sound barrier

© F.Ma. 23
Quantum Leap or Evolution?

- Thesis: **further progress** in
  - computing speed
  - energy usage
  - battery technique
  - communication speed
  - miniaturization
  - display technologies
  - sensor techniques
  - price
  - computer science concepts
  - ...

enables (once again) completely new applications

--> „post-PC era“
Five Reasons for Ubicomp
2nd Reason: New Materials

- Materials are important
  - whole eras named after materials (e.g., „Stone Age“)
  - more recently: semiconductors, fibers (--> information and communication technologies)

- New materials for information technologies:
  - e.g., small capacitors with high capacity
  - better means to conserve energy
  - higher density of information storage
    - holographic, biological, molecular storages?
  - plastic laser
    - applications: opto electronics, flexible displays,...
Example: Light Emitting Polymer

- Organic semiconductors
- Plastic displays (~1 mm thick)
- Applications soon (e.g., curved or flexible displays)
Flexible Displays: The PC of the Future?

...of course with wireless Internet access!

But what about its energy source? (Fuel cells?)
A Flexible „PC“ Concept

image source: Toshiba
Another Example: Smart Paper, Electronic Ink

- **Electronic ink**
  - micro capsules, *white* on one side and *black* on the other
  - oriented by electrical field
  - substrate could be an array of plastic transistors

- Potentially high contrast, low energy, **flexible**

- **Interactive**: writable with magnetic pen
Smart Paper, Electronic Ink

An electronically charged pencil rotates the "pixels"

Detailed view of the micro capsules

© F.Ma. 31
Smart Paper: Applications

This foldable and rollable interactive map ("you are here") is still science fiction, unfortunately.
Five Reasons for Ubicomp

3
3rd Reason: Progress in Communication Technologies

- Bandwidth of single fibers $\sim 10$ Gb/s
  - 2002: $\sim 20$ Tb/s with wavelength multiplex (often at no cost for laying new cable!)

- Powerline technique
  - coffee maker "automatically" connected to the Internet

- Wireless
  - mobile phone: GSM, UMTS
  - wireless LAN ($> 10$ Mb/s)

- Room networks, body area networks
Body Area Networks

- **Very low current** (some nA), some kb/s through the human body

- Possible applications:
  - **car** recognizes driver
  - **phone** configures itself when it is touched
  - **micro payment**: pay when touching the door of the bus
  - **toaster** and **TV** identify user

Note: Images of a hand interacting with a computer screen and a business card scanning device with text: "650 Harry Road
San Jose, CA 95120

tzim@almaden.ibm.com"
Five Reasons for Ubicomp

4
4th Reason: Better Sensors

- Miniaturized **cameras**, microphones,...
  - **pattern recognition**, assisted by heuristics
  - **speaker recognition**, **speech controlled** devices

- **Fingerprint** sensor on mobile objects

- **Autonomous perception**
  - establishing **contextual relations**
  - recognition of objects
Example: Standalone Radio Sensors

- No external power supply
  - energy from the actuation process
  - piezoelectric and pyroelectric materials transform changes in pressure or temperature into energy
- RF signal is transmitted via an antenna (20 m distance)
- Applications: mobile devices, temperature surveillance, remote control (e.g., wireless light switch),...
Another Example: Location Sensors

- Geographic location of increasing interest for mobile devices
- Various techniques
  - GPS receivers are becoming smaller and cheaper
    - accuracy ~5 m (improvements with differential GPS)
    - new civilian European Galileo-System by 2008?
  - GSM and other mobile phone protocols
    - infrastructure soon available, accuracy > 100 m
  - inertial sensors to measure acceleration
  - measuring signal propagation delay and phase shift (infrared, microwave, ultrasonic) for indoor use
GPS Receiver

Example: „Pathfinder“ (Casio)
- accuracy: 30 m
  - variance reduction in continuous mode
- 66 x 66 x 30 mm
- 140 g
- ~ 700 measurements with one battery

- Current development goal: credit card form factor
  - integration in PCMCIA card and in smart cards
Five Reasons for Ubicomp
5th Reason: New Concepts

- E.g., spontaneous networking
  - objects in an open, distributed, dynamic world find each other and form a transitory community
  - devices recognize that they "belong together"

I'm a smart home gateway, let's all work together!

that's my local text-to-speech server!

may I help you?

not with me this time!
Outline

- Smart Objects
- 5 Reasons for Ubiquitous Computing
- Information Appliances
- Connecting Atoms and Bits
- Consequences
Information Appliances

- Networked (possibly mobile) specialized devices
  - adapt to individual users and their customs
- Some applications will leave the PC
  - instant-on devices for calendar, weather forecast,…
  - example: e-book (new flat or flexible panels, e-ink)
Information Appliances
Information Appliances: Specialization and Simplicity

„Today's desktops and palmtops are multi-purpose tools - electronic Swiss Army knives. But how many of us would use a Swiss Army knife for preparing a dinner at home? It may be fine on a camping trip, but not for more routine activities where efficiency and quality are more highly valued.“

From: „Portolano: An Expedition into Invisible Computing“
Wearable?
Wearables Today
Future Wearables

- Headsets of mobile phones as jewelry?
Retina Eyeglass Display?
Smart Clothing

- **Conductive textiles** that are also soft and warm to touch
  - integrate conductive fibers into woven materials
  - move audio, **data**, and **power** around a garment

- **Conductive inks**
  - print electrically active patterns directly onto fabrics

- Challenge: design **fashionable** clothes that people want to wear
Soft Fabric User Interfaces

e.g., textiles that change conductivity when stretched
Smart Clothing

- **Sensors** based on fabric
  - e.g., monitor pulse, blood pressure, body temperature
- Invisible **collar microphones**
- **Kidswear**
  - integrated **GPS**-driven locators
  - integrated small **cameras** (to keep the parents calm)
  - **game console** on the sleeve?
Outline

- Smart Objects
- 5 Reasons for Ubiquitous Computing
- Information Appliances
- Connecting Atoms and Bits
- Consequences
Real World and Virtual Worlds: How to Bridge the Gap?
Narrowing the Gap

Virtual world

files
data bases

manual data entry

bar code labels

Real world

time

© F.Ma. 59
Narrowing the Gap

Why not attribute every object a unique representation in cyberspace?

- „virtual counterpart“
Making Things Smart with Virtual Counterparts

Virtual world
(Internet, Cyberspace)

Real world

virtual counterparts

pure virt. object (e.g. email)
Virtual Counterparts as Artifact Memories

1) Aug. 3rd, 2001: ...
2) Aug. 5th, 2001, 10:34 ..... 
3) Aug. 5th, 2001 10:37 ...
4) ...

Counterparts act as memories for their artifacts

Updates triggered by events

Queries from the real world return memory content

Sensors generate events

- **Label** = Internet-URL (pointing to the bag’s „home page“)
  - e.g., recipe „on“ food for microwave oven
  - label could be an RFID (i.e „smart label“)

Bought on 20 Aug 2001; last travel: to London Sep 2003; contained shirt no. 1342 and 1349; was on 17 Nov 2002 in Hotel Atlantic, room 317 ...
RFID:
„Radio Frequency Identification“

- **Identify** objects from **distance**
  - small IC with RF-transponder
- **Wireless energy supply**
  - ~ 1 m
  - magnetic field (induction)
- **ROM or EEPROM** (writeable)
  - ~ 100 Byte
- **Price** ~ $0.1 ... $1
  - consumable and disposable

image source: Portolano project
RFIDs as „Smart Labels“

- **Flexible tags**
  - laminated with paper
  - self-adhesive
  - printable (e.g., barcode)

(image source: Portolano project)
Smart Labels

- **Chip** (without antenna):
  ~ 2 mm x 2 mm x 10 µm
  - fits into 80 µm thick paper!

- **Antenna:**
  - copper, or
  - printed with conductive ink, or
  - on CMOS wafer (micro galvanic „coil on chip“)
Components of an RFID System

RFID "reader"

antenna

energy

data

RFID tag

application

~ 1 m

2 x 2 mm

~ 3 cm

© F.Ma. 68
Radio frequency identification tag having a printed antenna and method
Motorola Inc, issued 01/25/2000

„A radio frequency identification tag includes a radio frequency identification tag circuit chip coupled to an antenna including a conductive pattern printed onto a substrate. The substrate may form a portion of an article, a package, a package container, a ticket, a waybill, a label and/or an identification badge...“
Application Domains for RFIDs

- Electronic article surveillance
  - „EAS“ - anti-theft functionality
- Inventory control
  - shops or mini bar in hotel rooms
- Libraries, video rental
- Baggage labels
Application Domains for RFIDs

- **Access** token (e.g., ski pass)
- Ear clips for **animals**
- Transport of mail and **parcels**
- Tracking of **goods**
- „Radio signature“ of **documents**
- ...
Commercial Interest in Linking „Atoms to Bits“

- Connect the **real world** to the **digital world**
  - e.g., by using bar code readers or RFID readers

- Number is transformed to an URL, associated **Web page** is returned
- Identify **object instance**, not object type (e.g., UPC)
Application Scenarios

- Get information about real objects
  What is contained in this medicine? Listen to music found in an ad.
- Smart assistant
  What parts need maintenance? What is the layout of this machine?
- Context awareness
  Is this tool available here?
- Smart home, car, office, ...
  Adapt to people's preferences
- ...
Clicking on Real-World Objects?

- PDAs, mobile phones, and wireless internet appliances become request devices for information
  - find information
  - order products
  - ...

- Bar code reader connected to a mobile phone
  - send codes via SMS to bar-mail server
  - server may also send back an e-mail
“Cross Convergence“
Scanner and Pen

- Mobile scanner and pen, $89.90
- Allows to link from a printed page directly to the Web
  - scans barcodes on printed material
CueCat

- **Bar code scanner** (shape of a cat)
  - LED based; attaches to the computer via the keyboard port

- **10 million free** scanners distributed in the US by the end of year 2000
  - 50 millions planned in 2001
  - estimated cost of $ 5 - $ 10 per CueCat
  - someone spends at least $ 500 000 000

- Sends the **Web browser** directly to the „right“ location when scanning the bar code of an **ad in a magazine**
  - „our **revenue model** is being the gate keeper between codes and their destination online“

© F.Ma. 79
Patent US5978773

„System and method for using an ordinary article of commerce to access a remote computer.“

NeoMedia Technologies, Inc., Fort Myers, FL
Issued / Filed Dates: Nov. 2, 1999 / Oct. 3, 1995
A system and method for using identification codes found on ordinary articles of commerce to access remote computers on a network. In accordance with one embodiment of the invention, a computer is provided having a database that relates Uniform Product Code ("UPC") numbers to Internet network addresses (or "URLs"). To access an Internet resource relating to a particular product, a user enters the product's UPC symbol manually, by swiping a bar code reader over the UPC symbol, or via other suitable input means. The database retrieves the URL corresponding to the UPC code. This location information is then used to access the desired resource.
Outline

- Smart Objects
- 5 Reasons for Ubiquitous Computing
- Information Appliances
- Connecting Atoms and Bits
- Consequences
Infrastructure for Smart Objects

“A Dancing Toaster” (Rich Gold, XEROX PARC)
Why Infrastructure for Smart Objects?

- **Guarantee**
  - security
  - privacy
  - availability
  - reliability

- **Provide services**
  - location (“where am I?”)
  - context (“are we in a meeting?”)
  - event delivery (“tell me when... happens”)
  - brokering (“find a something that...”)
  - directory
  - registry
  - ...

How do we organize billions of mobile smart objects that are highly dynamic, short living,…?

for applications built with smart objects

for smart objects
More Infrastructure Tasks

- Enable
  - spontaneous networking
  - cooperation among smart objects
  - communication
  - mobility
  - service creation
  - service discovery ("is a service available that ...?")
  - ...

- Facilitate linking the real world to the virtual world

Challenge for practical computer science research!
The European „Disappearing Computer“ Initiative

- New information artifacts
  - possibly with sensors, micro mechanical systems, wireless connections,...

- Emerging new functionality from collections of interacting artifacts
  - awareness of other artifacts in the environment

- Emphasis: new people-friendly environments
  - design of new user interfaces

- 16 trans-European projects started in 2001
  - more will follow
Ubicomp - Applications?

- **Travel**, mobility
  - travel planning, navigation, traffic guidance
  - spontaneous networks for traffic signalization
  - replacement of classical traffic signals
- **Health**
  - sensors for health monitoring
- **Entertainment**, leisure, fun
- **Work**, office
- **E-commerce**
- ...

“We are always very bad at predicting how a given technology will be used and for what reasons”

-- Bran Ferren, Chief Disney Imagineer
Impact: Evolution vs. Revolution

- Technique and science have a major impact on our society and the world we live
  - historically: industrialization, electricity, trains and automobiles, electronic mass media
  - implies therefore eventually also ethical questions
  - social adaptation to technical impacts needs some time since this is an evolutionary process (willingness to learn, generational aspects,...)
Privacy in a Ubicomp World?

- Privacy is already a concern with the WWW
  - what do they do with my personal data?
  - are my page visits and mouse clicks analyzed?
- Much more dramatic in a ubicomp world!
  - many events of very elementary actions are registered
  - could be assembled to perfect profiles

How do we address this privacy issue?
- technical solutions, laws, social processes,...?
Two Worlds that Collide?

- If there is **tight interaction** between the physical and the virtual world – what happens?
  - what is gained?
  - what is lost
Two Worlds that Collide?

- If there is **tight interaction** between the physical and the virtual world – what happens?
  - what is gained?
  - what is lost?

- Can we make a **better world**, or just **better business**?
- Which **techniques** are needed? Which are suitable?
- What are the **limits**?
Conclusions

- Technical progress (Moore’s Law...) goes on
  - cooperating smart objects become reality
- Consequences yet unclear
  - applications?
  - privacy?
- Economy
  - whole new industry to build and manage an intelligent infrastructure (e.g., “e-utilities”)

As we approach 2001, we are in the Information Age, not in the Space Age!

Randy Katz, UC Berkeley

www.inf.ethz.ch/vs
mattern@inf.ethz.ch