Telecooperation Lab
Prof. Dr. Max Mühlhäuser

TK3: Ubiquitous Computing

Chapter 1: Devices & Sensing

Part 1: Tagging

Lecturer: Dr. Immanuel Schweizer

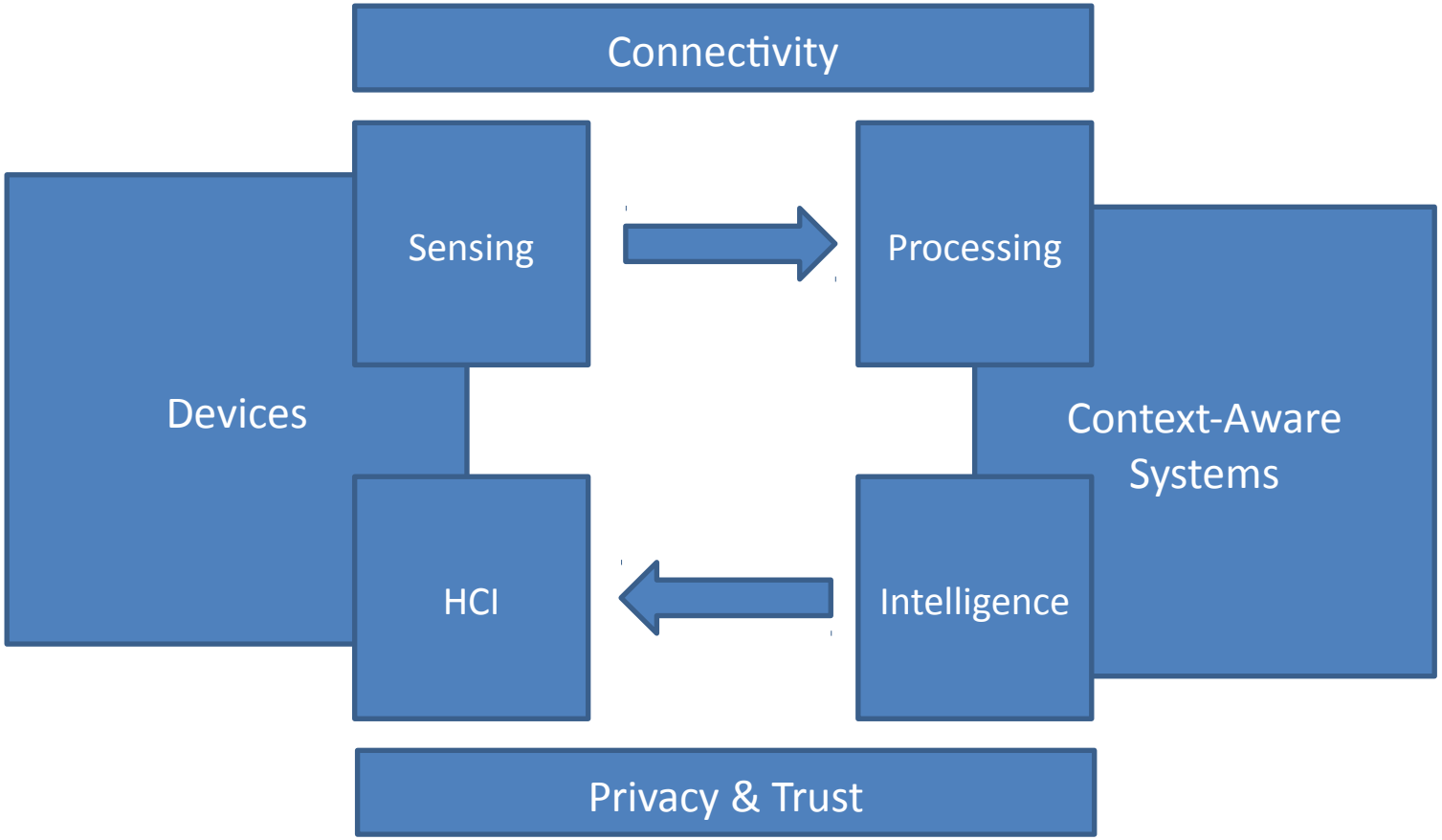
Recap

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

Recap

1. Computers need to be networked, *distributed* and transparently accessible
2. Computer *Interaction* with Humans needs to be more *hidden*
3. Computers need to be *aware* of *environment context*
4. Computers can operate autonomously, without human intervention, be self-governed
5. Computers can handle a multiplicity of dynamic actions and interactions, governed by intelligent decision-making and intelligent organisational interaction. This entails some form of artificial intelligence.

Simple Architecture



Tagging: Definitions

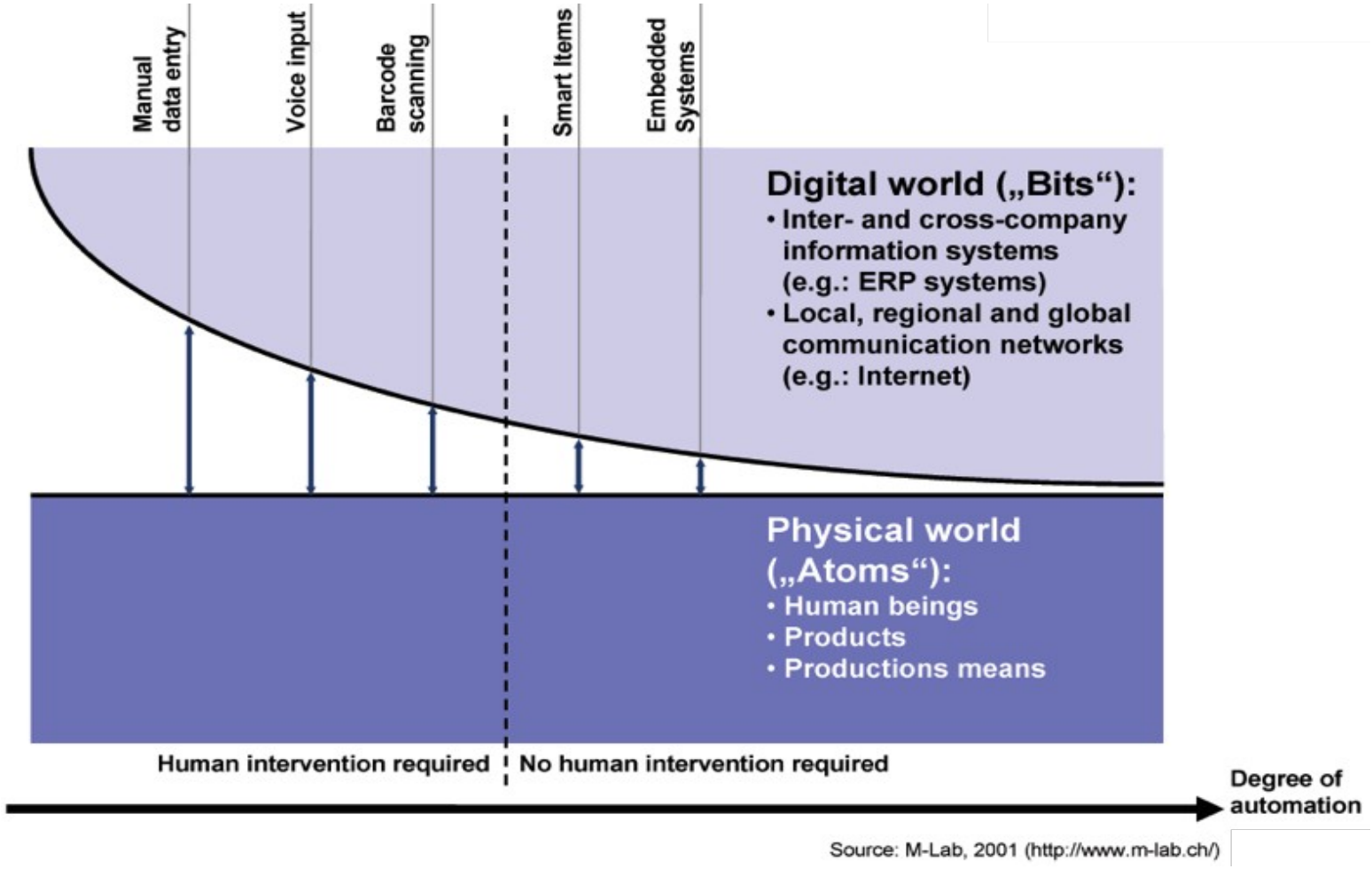
- Augment a physical object or the environment with digital information

- Smart Item = [physical node] + digital node
  - The mapping from *physical* to *digital* node is automated!

- Physical nodes in the Internet-of-Things
  - **Passive:** machine-readable identifier (→ e.g., RFID)
  - **Active:** things have an IP connection

- Digital nodes in the Internet-of-Things
  - **Passive:** data about a physical node
  - **Active:** data + methods for a physical node (e.g., generates events, changes data)

Tagging: Idea



Design issues for Tagging Physical environment

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- Tags read outdoors in noisy, wet, dark or bright environments.
- Annotation data storage, distribution & integration with data
- Data management must start as soon as the data is captured (readers).
- Multiple tags & readers per unit Vol..
- Challenges?
  - Redundant annotations: similar items are captured, many times over.
- Solutions?
  - Applications and businesses need to define the level of aggregation, reporting, analysis

Tagging: Technologies

- Radio Frequency Identification (RFID)
- NFC
- iBeacons

Radio Frequency IDentification (RFID)

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- RFID: Radio Frequency IDentification
  - Wireless and non-contact use of radio-frequency electromagnetic fields to transmit data
    - Between a reader and a tag
  - Identifying and tracking tags attached to objects

RFID: Applications

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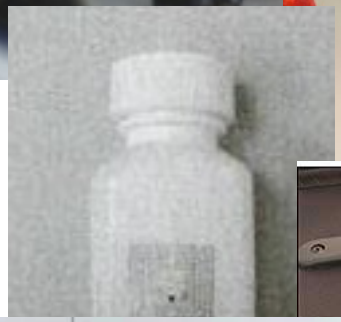
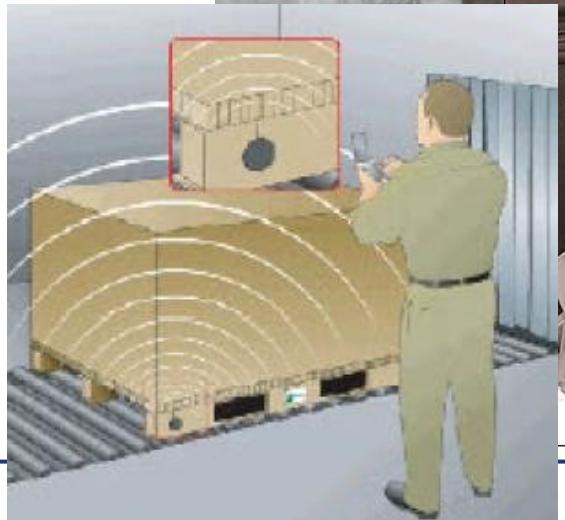
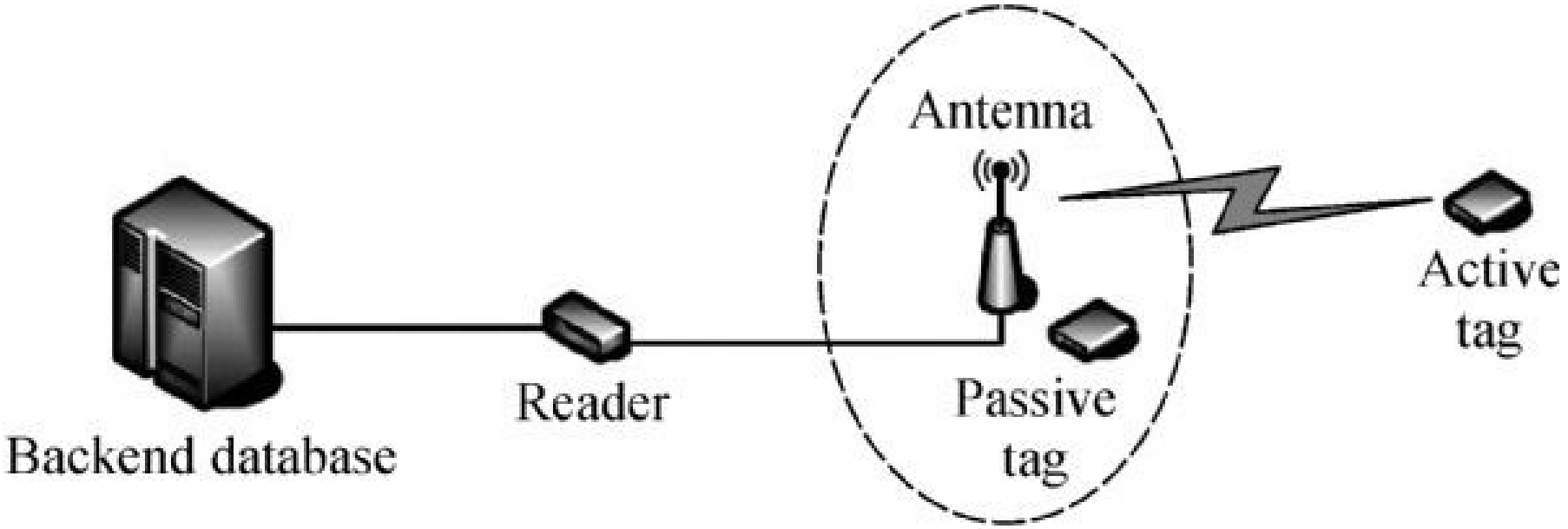
- Retail
- Security
- Supply Chain Management
- Manufacturing and Processing
- Location Tracking





RFID: System Components

- RFID System
  - RFID Reader
  - RFID Transponder
  - Backend

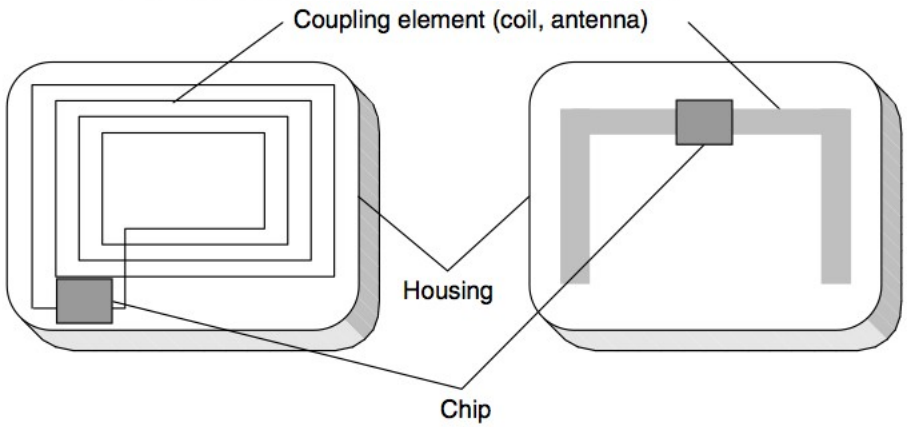


RFID Reader

- RFID Reader
  - Gateway between tag and backend
  - Powers tags
  - Location
    - Mobile / Hand-held
    - Fixed, e.g., PoS, Entrance, etc.

RFID Tags

- RFID Transponder (= Tag)
  - Chip / Antenna / Housing
- Stored information
  - Unique ID
  - Optional data
- Type
  - Passive RFID Tags
    - Powered from the reader only
  - Active RFID Tags
    - Includes power source (battery, ...)
  - Semi-active RFID Tags
    - Uses battery to power chip



History: The Thing

- Developed in the ‘40s by Leon Theremin
- No power supply
  - Capacitive membrane connected to antenna
- First bug
  - External radio signal was modulated by sound waves
  - Receiver demodulated the signal to decode sound

RFID: Foundations

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Technologies:

- Electromagnetic Induction (19th century)
- Identify friend or Foe (IFF) Transponder (1939/40)
- Communication by Means of Reflected Power (Stockman, 1948)

Commercial:

- First patents 1972
- Electronic article surveillance (EAS) – 1 bit tag
- 1975: Electronic identification system
- Standardization in the 80s
  - Transportation, Road tolls, etc.
- Auto-ID (MIT, 1999)
  - EPC Global
- Walmart, 2003

RFID: Technology

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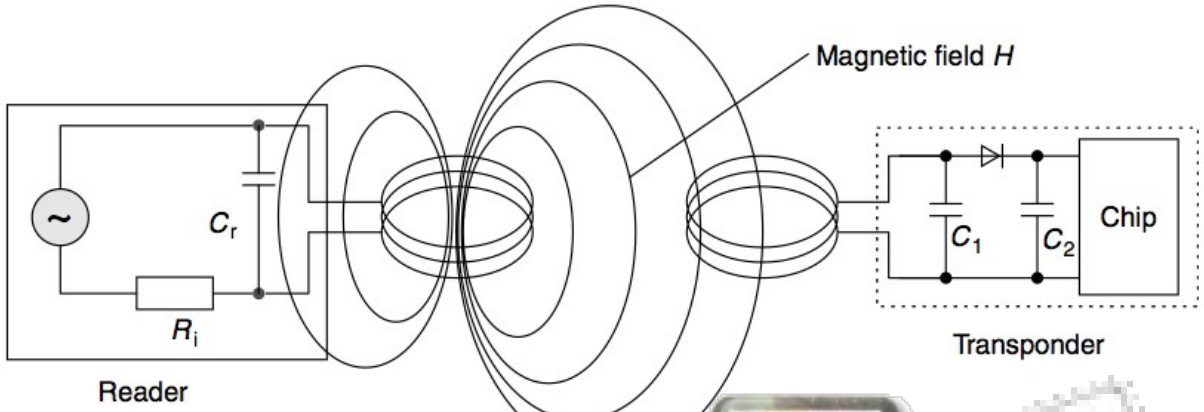
- Close coupling systems
  - Use very small ranges (<= 1cm)
  - Transponder must be inserted into reader or positioned on surface
  - Greater amount of power can be provided
- Remote coupling systems
  - Read ranges of up to 1m
  - Almost always based on **Inductive Coupling**
  - Have 90% market share
- Long-range systems
  - Typical read ranges: 3m with passive tags, 15m with active tags
  - **Electromagnetic Backscatter Coupling** or **SAW-Transponders**

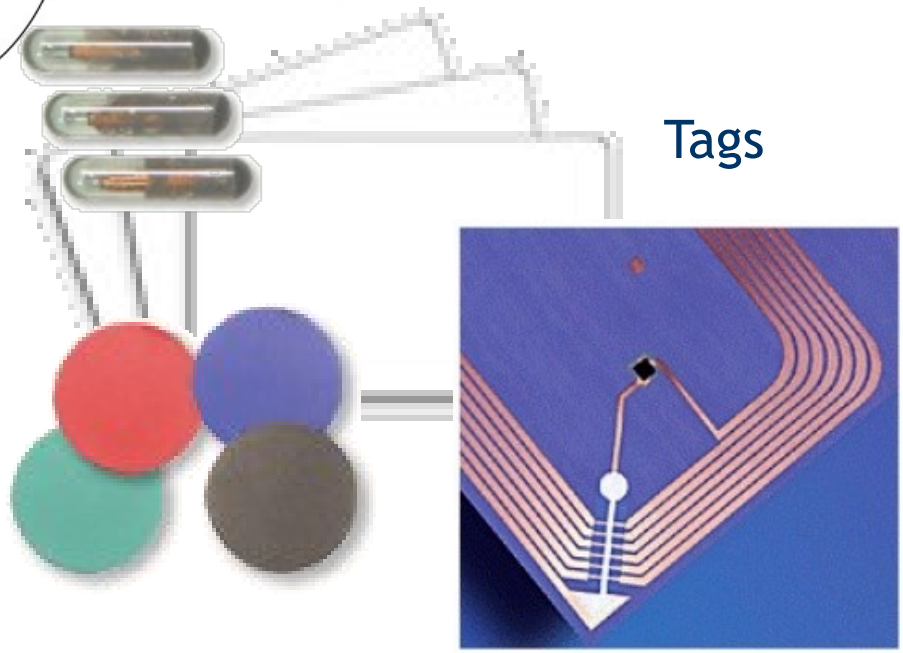
	LF	HF	UHF	Microwave
Freq. Range	125 - 134KHz	13.56 MHz	866 - 915MHz	2.45 - 5.8 GHz
Read Range	10 cm	1M	2-7 M	1M
Application	Smart Card, Ticketing, animal tagging, Access, Laundry	Small item management, supply chain, Anti-theft, library, transportation	Transportation vehicle ID, Access/Security, large item management, supply chain	Transportation vehicle ID (road toll), Access/ Security, large item management, supply chain

RFID: Inductive Coupling



Reader

Tags

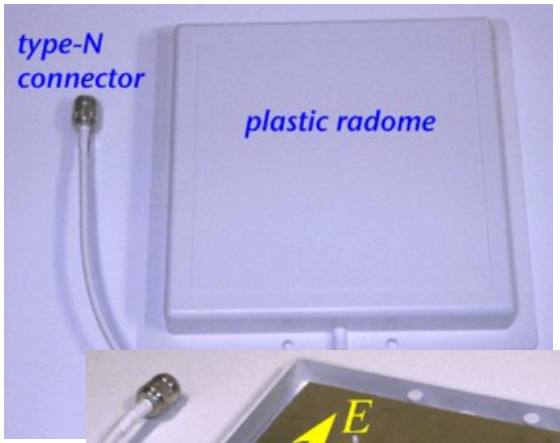


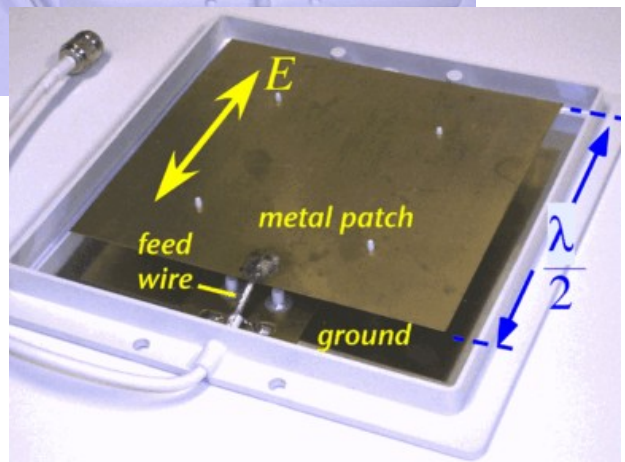
RFID: Inductive Coupling

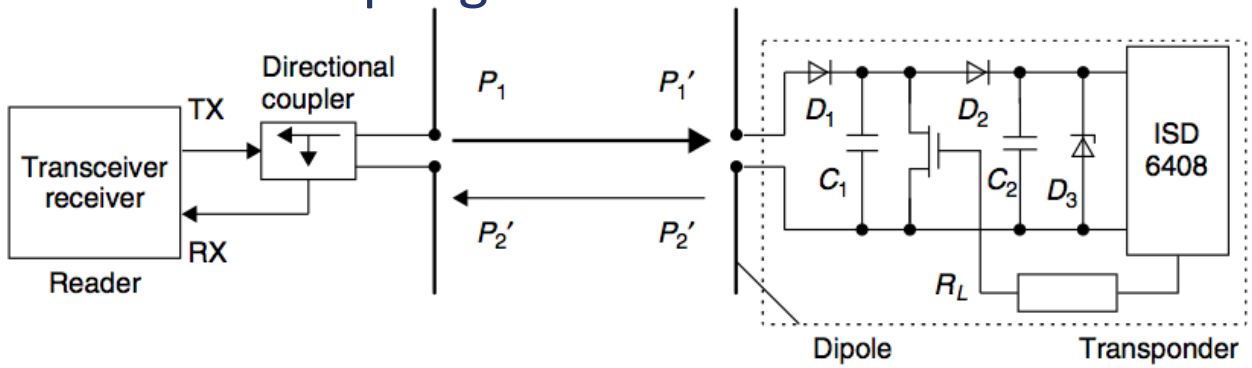
- Typical frequencies: <135kHz (λ=2400m), 13.56MHz (λ=22.1m)
- Distance reader-tag << λ:
  - Operates in the near field of antenna
  - EM-field may be treated as simple magnetic alternating field
  - „transformer-type coupling“ btw. reader and transponder antennas
- Transponders comprise of
  - Microchip
  - Large area coil antenna
- Power supply to passive transponders
  - Reader (continuously) sends a strong carrier signal
  - Transponder‘s self resonant frequency = read frequency
  - Transponder draws energy from magnetic field
  - Near field -> Power drops with 60dB/decade
  - Range limited to ~1m

RFID: EM Backscatter Coupling

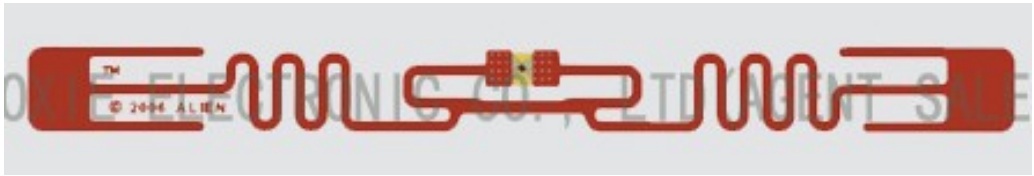
- Electromagnetic Backscatter Coupling

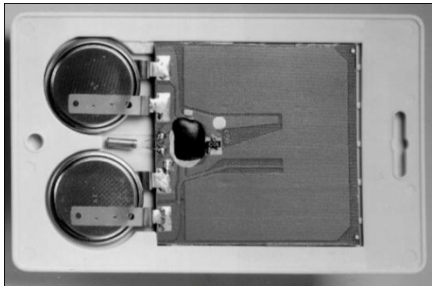






Passive Tag





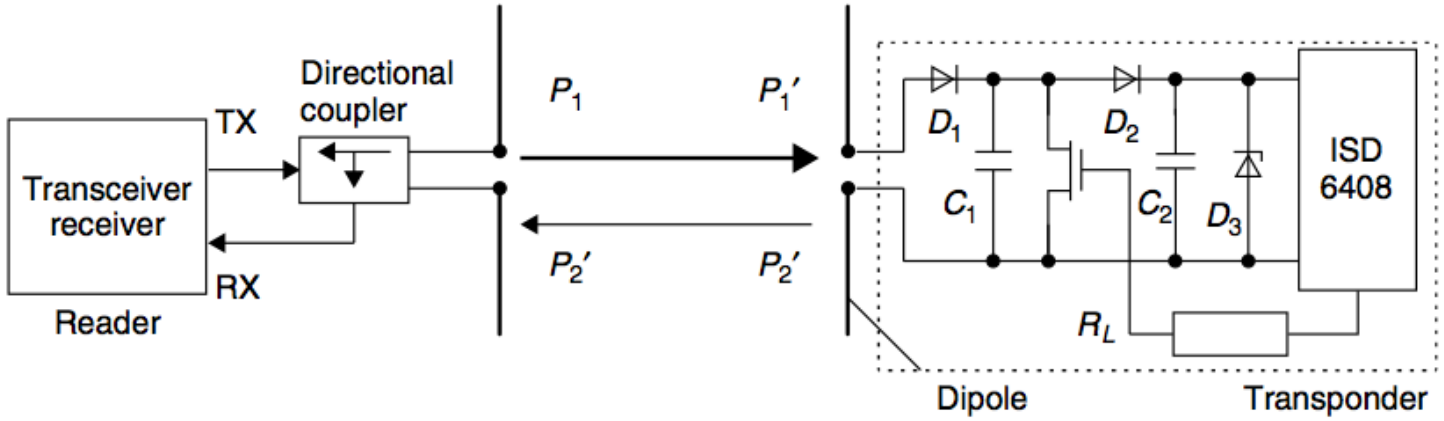
Active Tag

RFID: EM Backscatter Coupling

- Typical frequencies:
  - UHF: 868, 915 MHz
  - Microwave: 2.5, 5.8 GHz
- Allows construction of antennas with far smaller dimensions and greater efficiency
- Power supply to transponder
  - Estimated with free space path loss
  - Need ~50µW to operate chip on transponder
  - If reader‘s transmission power = 0.5W, then path loss must be <=40dB

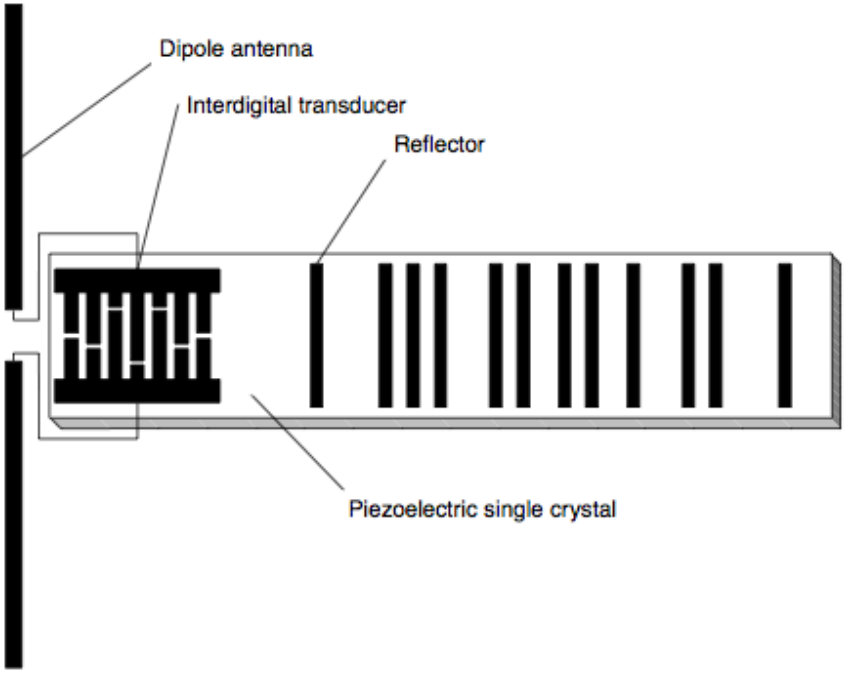
Distance *r*	868 MHz	915 MHz	2.45 GHz
0.3 m	18.6 dB	19.0 dB	27.6 dB
1 m	29.0 dB	29.5 dB	38.0 dB
3 m	38.6 dB	39.0 dB	47.6 dB
10 m	49.0 dB	49.5 dB	58.0 dB

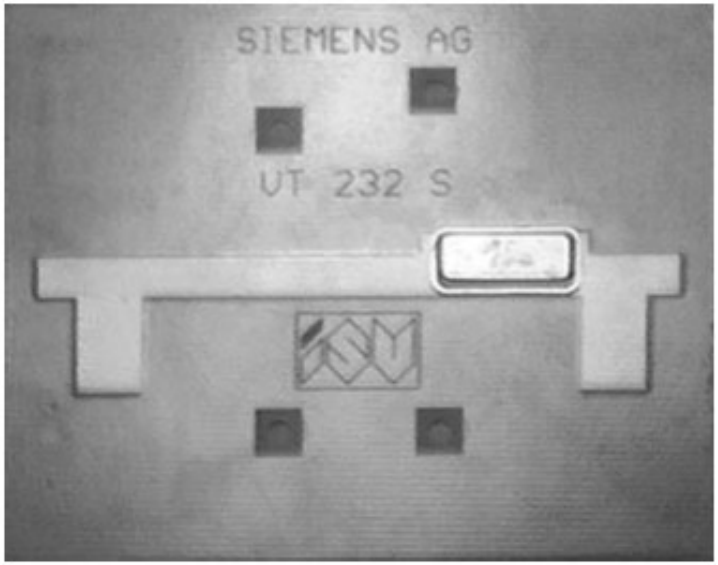
RFID: EM Backscatter Coupling



- Electromagnetic Backscatter Coupling
  - EM waves are reflected by objects greater than λ/2
    - most prominently, the radar utilizes this principle
  - In particular, objects in resonance with the reader signal reflect well
  - The reflection characteristic can be influenced by altering the load connected to the antenna

RFID: SAW-Transponder

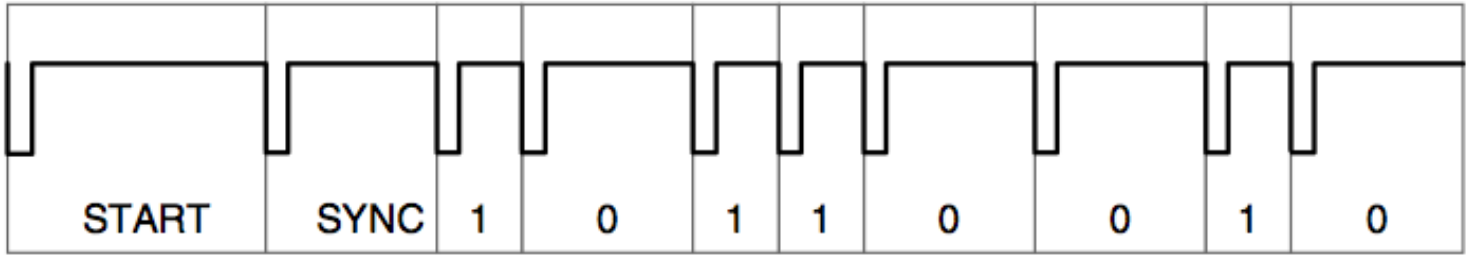




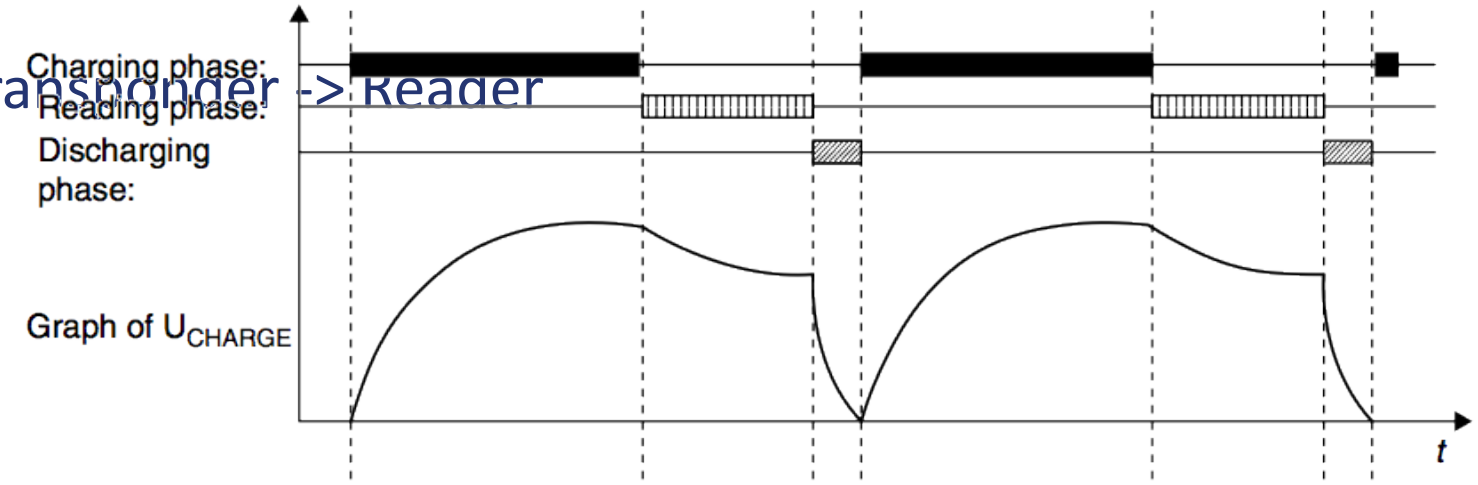
- Surface acoustic wave (SAW) transponder
  - Uses piezoelectic effect (and has no chip)
  - Interdigital Transducer converts voltage to surface wave and vice versa
  - Transponder ID (16-32 bit) determined by placement of reflectors
  - Typical frequency: 2.45 GHz
  - Reading range: 1-2m (at permitted transmission powers)

RFID: Data Transmission

- Reader -> Transponder
  - Often uses Pulse-Pause Coding: bits encoded in pulse lengths
  - Well-suited for passive tags, because only short power interruptions



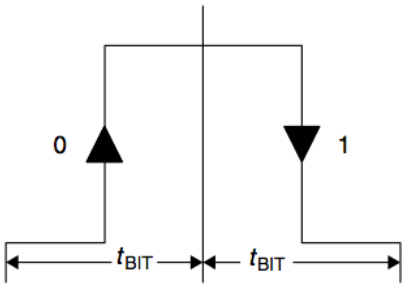
- Transponder -> Reader



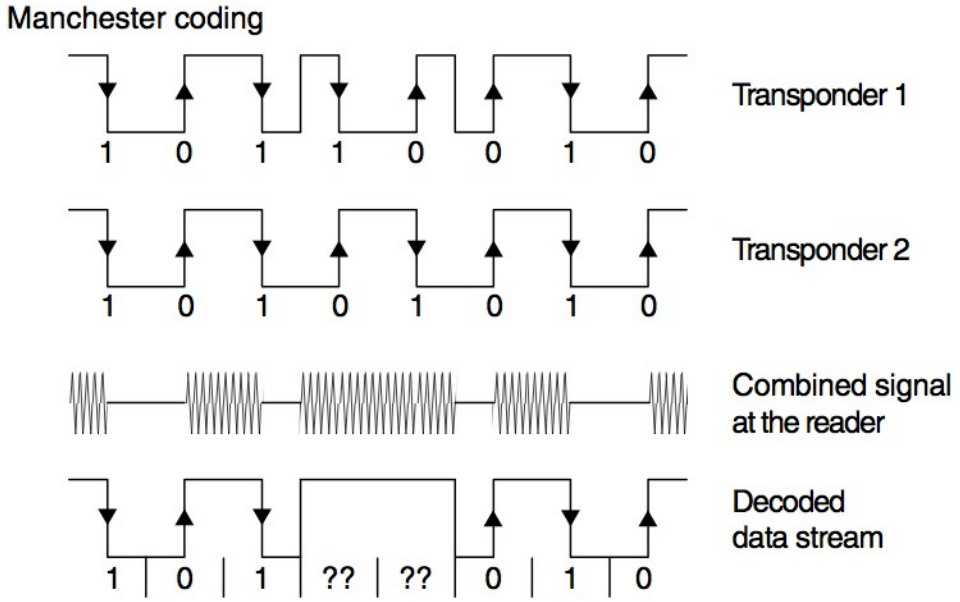
RFID: Anticollision

- Anticollision / Multiple Access
- When the reader polls, all transponders answer -> collision
  - Problems very similar to that in Wireless Networks
  - Short-range readers usually do not support anticollision at all
- RFID anticollision methods (examples)
  - **Transponder-driven**
    - ALOHA, Slotted ALOHA
      - Transponders send at a random time, repetition time differs slightly
      - Assumption: not many tags, short duration of transmission
        -> low collision probability
  - **Reader-driven**
    - Binary search algorithm
      - Uses binary search to identify one transponder after the other
    - Dynamic binary search algorithm
      - More efficient for multibyte IDs
      - Allows to limit the number of bytes transmitted

RFID Anticollision: Binary Search



Manchester Code



- Assumptions
  - All transponders send in sync
  - The precise bit positions of collisions are recognizable by reader
  - Further, this example assumes load modulation with subcarrier
- Manchester code allows to detect collisions
  - Rising edge indicates 0, falling edge indicates 1
  - Missing edge indicates collision

RFID Anticollision: Binary Search

- Transponder commands sent to the transponders:
  - **REQUEST(searchId)**
    - If the transponderId <= searchId, then the transponder replies with its transponderId
  - **SELECT(id)**
    - The transponder with the specified id becomes active for the following read/write requests
  - **UNSELECT**
    - Removes the selection and mutes the selected transponder. It will not even respond to further REQUEST commands
  - **READ/WRITE**

RFID Anticollision: Binary Search

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- Example: 4 Transponders

Command	Reply
REQUEST(11111111)	1X1X001X

Transponder	ID
1	10110010
2	10100011
3	10110011
4	11100011

- yields 8 possibilities:

Bit number:	**7**	**6**	**5**	**4**	**3 2 1**	**0**
Received data in the reader	1	**X**	1	**X**	001	**X**
Possible serial number A	1	**0**	1	**0**	001	**0**
Possible serial number B*	1	**0**	1	**0**	001	**1**
Possible serial number C*	1	**0**	1	**1**	001	**0**
Possible serial number D*	1	**0**	1	**1**	001	**1**
Possible serial number E	1	**1**	1	**0**	001	**0**
Possible serial number F*	1	**1**	1	**0**	001	**1**
Possible serial number G	1	**1**	1	**1**	001	**0**
Possible serial number H	1	**1**	1	**1**	001	**1**

*) transponder actually exists

RFID Anticollision: Binary Search

- Algorithm to identify all transponders:

```
while true:
send REQUEST(maxId)
receive(id)
while id contains ‘X‘:
        replace highest ‘X‘ with ‘0‘ and set all lower bits ‘1‘
        send REQUEST(id)
        receive(id)
foundTag(id)
send SELECT(id) ...
send UNSELECT
```

- 1st iteration:

Command	Reply
REQUEST(11111111)	1X1X001X
REQUEST(10111111)	101X001X
REQUEST(10101111)	10100011
SELECT(10100011)	
READ	
UNSELECT	

AutoID / EPC

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step 1:
read ID# → ask, e.g. ONS server for URL

"Service Discovery", e.g., ONS Server (cf. Internet-DNS)

step 2:
use URL to access product data "somewhere"

Electronic Product Code EPC: "EAN/UPC + serial no."

Header: 8 Bit	Manufacturer: 28	Product: 24	Serial Number: 36

Reader

Internet

Server: XML-Data in Product Markup Language PML

1.

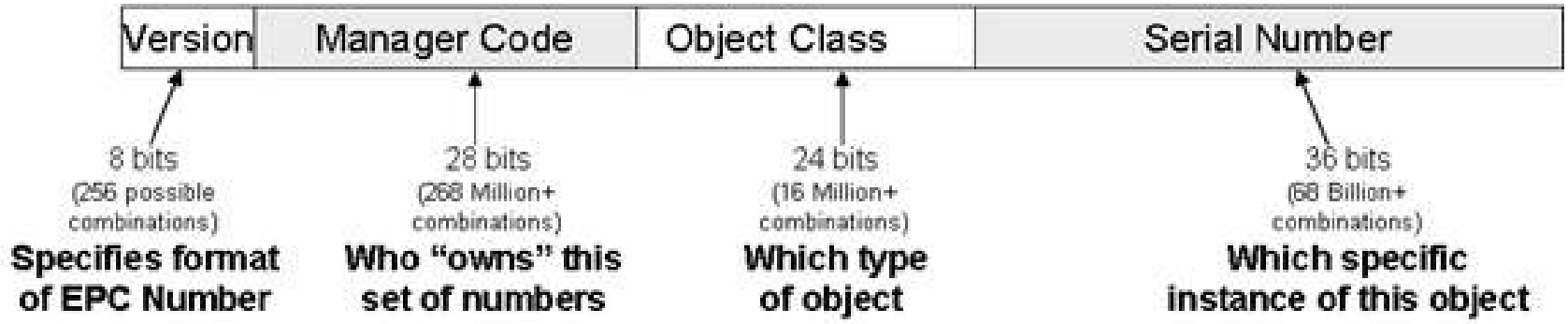
2.

3.

three „tiny changes":
1. serial no.
2. reading efficiency (d, %, Σ)
3. distributed system = Internet

➡ „big effect"!!!

Electronic Product Code (EPC) standard



EPCIS architecture

- Process of getting product information
  - Send EPC to Object Naming Service (ONS) to obtain address of PML server
    - ONS works similar to DNS
  - Send EPC to PML server to obtain PML document with product description
- Physical Markup Language (PML)
  - Proposed as a standard for describing physical objects and environments for industrial, commercial and consumer applications
  - Example: A batch of "Red Delicious" apples is harvested and assigned an EPC code 01.081958.0094FE.008ED81C. This code references a PML file describing the batch and identifies it with a number of classes
- Also: Store events related to EPC numbers
  - Adding events when RFID is scanned / Item is processed

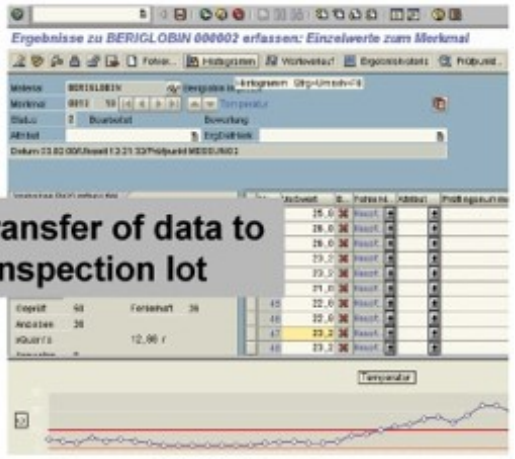
```
<class>
  <system>Scientific</system>
  <type>Variety</type>
  <name>Malus S. Red Delicious
Group</name>
</class>
<class>
  <system>Internal</system>
  <type>Produce</type>
  <name>Apple <code>A2-
L109A</code></name>
</class>
<class>
  <system>Apple Growers
Group</system>
  <type>Produce Class</type>
  <name>Red Delicious
    <code>USAGG-0010198</code>
  </name>
</class>
```

End-to-End Quality Management

1. Supplier: start measurement

2. Carrier: Transportation

3. Customer: Goods Receipt



4. Transfer of data to Inspection lot

5. Usage decision

6. Preconfigure Logger

Issues?


GOOD AFTERNOON, MR. HENFENNEL! HEMORRHOID CREAM AISLE SIX!
BEEP!
TOO MUCH INFORMATION IN MY MEDICAL I.D. CHIP.
DON'T FORGET MOUTHWASH. I FIGURED THAT ONE OUT BY MYSELF.
TOLES
©2004 THE WASHINGTON POST
10-17-04

Near Field Communication (NFC)

- Two way interaction
- Based on High Frequency (HF), 13.56 MHz
  - RFID Technology
  - Distance: Up to 10cm
  - Data rates: 106, 212 or 425kbits/s

NFC Modes of Operation

- Two terminals
  - Initiator / Target
- Initiator starts communication
  - Sense radio & send signal
  - Target can only send after receive
- Three modes of operation
  - Reader / Writer
  - Card Emulation (Optional)
  - Peer-to-Peer

NFC Reader / Writer Mode

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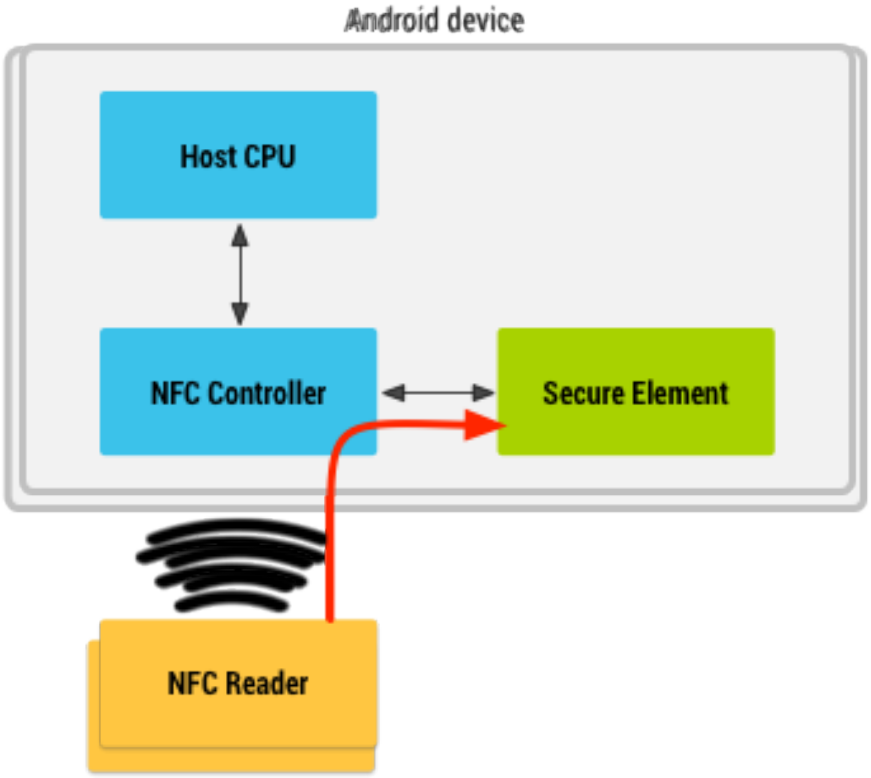
- NFC device acts as Reader
  - Can read or write NFC tags
- Proximity Coupling Device (PCD)
  - Exchange data format NDEF (NFC Data Exchange Format)
  - Multiple records per tag are possible
- Applications
  - Posters, Advertisements
  - Launch Applications

NFC Card Emulation Mode

- NFC devices acts as smart card
  - ISO 14443 smart card
  - Can store multiple types of cards
- Example: Android Host-based Card Emulation
  - Secure Element
  - Software
- Applications
  - Contactless Payment
  - Ticketing
  - Access Control
  - Virtual Key



NFC Peer-to-Peer Mode

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- Enables two NFC devices to exchange data
  - Before: One-way
  - Based on ISO 18092

- Applications
  - Setup Bluetooth / Wi-Fi
  - Transfer data
  - Money transfer

NFC Data Exchange Format

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- NDEF defines the message format for NFC

NDEF Message			
Record 1 MB=1, ME=0	**Record 2** MB=0, ME=0	...	**Record *N*** MB=0, ME=1

- Format
  - Payload length
  - Payload type
  - Optional payload identifier

- http://nfcpy.readthedocs.org/en/latest/topics/ndef.html

NFC Use Cases

Get information by touching smart posters!

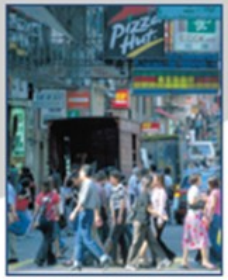
Your NFC device is your ticket!

Your NFC device is your travel card!

TOUCH

Buy goods from vending machines with your phone!

Get information about your current job or task!



Your NFC device is your credit card!

NFC Adoption

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- Always meant for phones
  - Java ME tutorial from SUN / Oracle
- First mainstream adoption: Android
  - Support since Android 4.0
  - http://developer.android.com/guide/topics/connectivity/nfc/nfc.html
- Now: Support in all major mobile OSs
  - Android, iOS, Windows Phone, Blackberry, etc.
- Why: Google Wallet, Apple Pay

Close Range Technologies

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	NFC	RFID	IrDa	Bluetooth
Set –up time	<0.1ms	<0.1ms	~O.5s	~6 sec
Range	Up to 10cm	Up to 3m	Up to 5m	Up to 30m
Usability	Human centric Easy, intuitive, fast	Item centric Easy	Data centric Easy	Data centric Medium
Selectivity	High, given, security	Partly given	Line of sight	Who are you?
Use cases	Pay, get access, share, initiate service, easy set up	Item tracking	Control & exchange data	Network for data exchange, headset
Consumer experience	Touch, wave, simply connect	Get information	Easy	Configuration needed

http://www.oracle.com/technetwork/articles/javame/nfc-140183.html

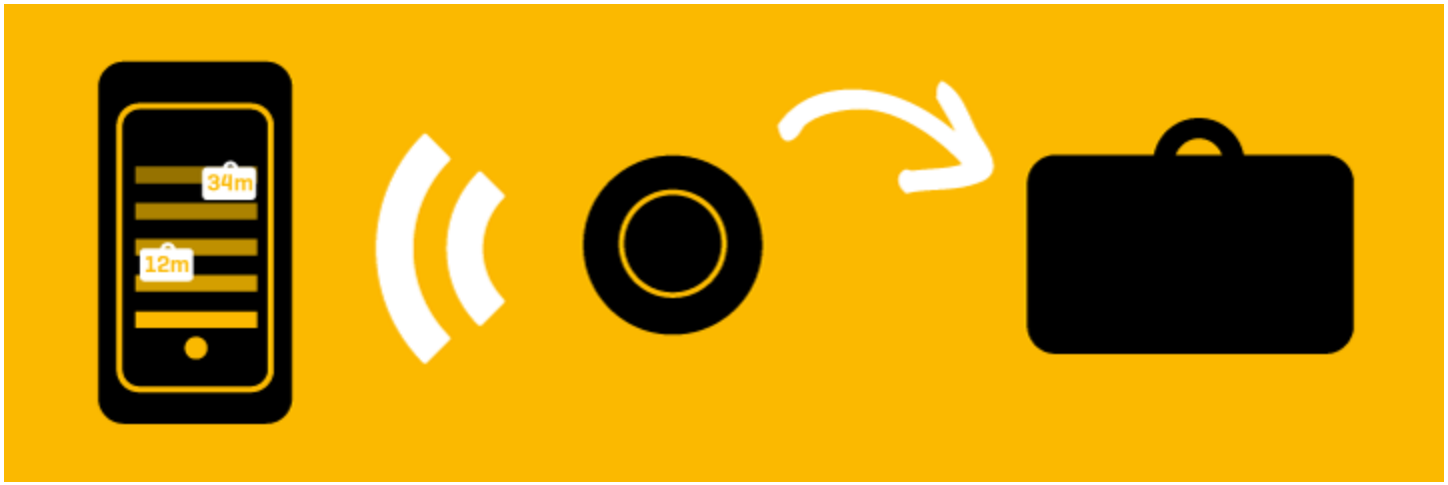
iBeacon

iBeacon: Idea

- Tagging of the environment
  - Distribute beacons in stores / airports
- Bluetooth LE
  - Years of operation
  - Longer Range (~60-350 meters)
- RSSI measurements
  - Measure distance
  - Additional sensor data
  - Location & Direction
- Use cases:
  - Indoor location
  - Proximity services (Ads…)

Use case I: KLM

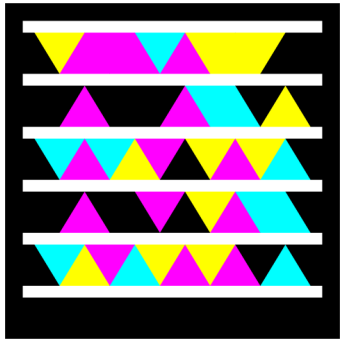
Use case II: Luggo



More tagging

- 2D barcodes
  - QR Code
  - Microsoft Tag
  - Data Matrix

- Advantages
  - Cheaper
  - Requires camera only



- Disadvantages
  - Read only
  - Detection accuracy

Summary: Tagging

- Tagging
  - Augmenting people, objects, and the environment with digital information
- Technologies
  - RFID
  - NFC
  - iBeacons
- Automatic interaction between virtual and real world