RFID: Technology and Applications

Internet-of-Things (IoT) COCSC20

Effect on Manufacturing

- Need to ensure error-free, custom assembly
- Need inventory of components for the various customization options

- Critical Issues
  - Assembly process control
  - Inventory management
  - Supply chain integration
  - Customer insight

- One solution: RFID

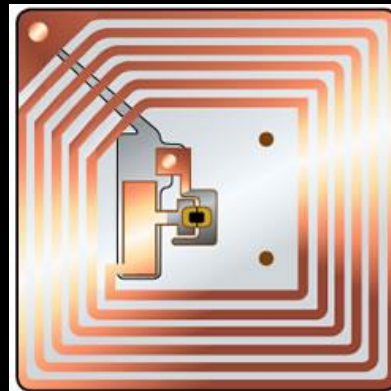# What is RFID?

Who Are You?

I am Product X

What is RFID?

- RFID = Radio Frequency IDentification

- An ADC (Automated Data Collection) technology that:

  - Uses radio-frequency waves to transfer data between a reader and a movable item to identify, categorize, track

  - Is fast and does not require physical sight or contact between reader/scanner and the tagged item

  - Performs the operation using low cost components

  - Attempts to provide unique identification and backend integration that allows for wide range of applications

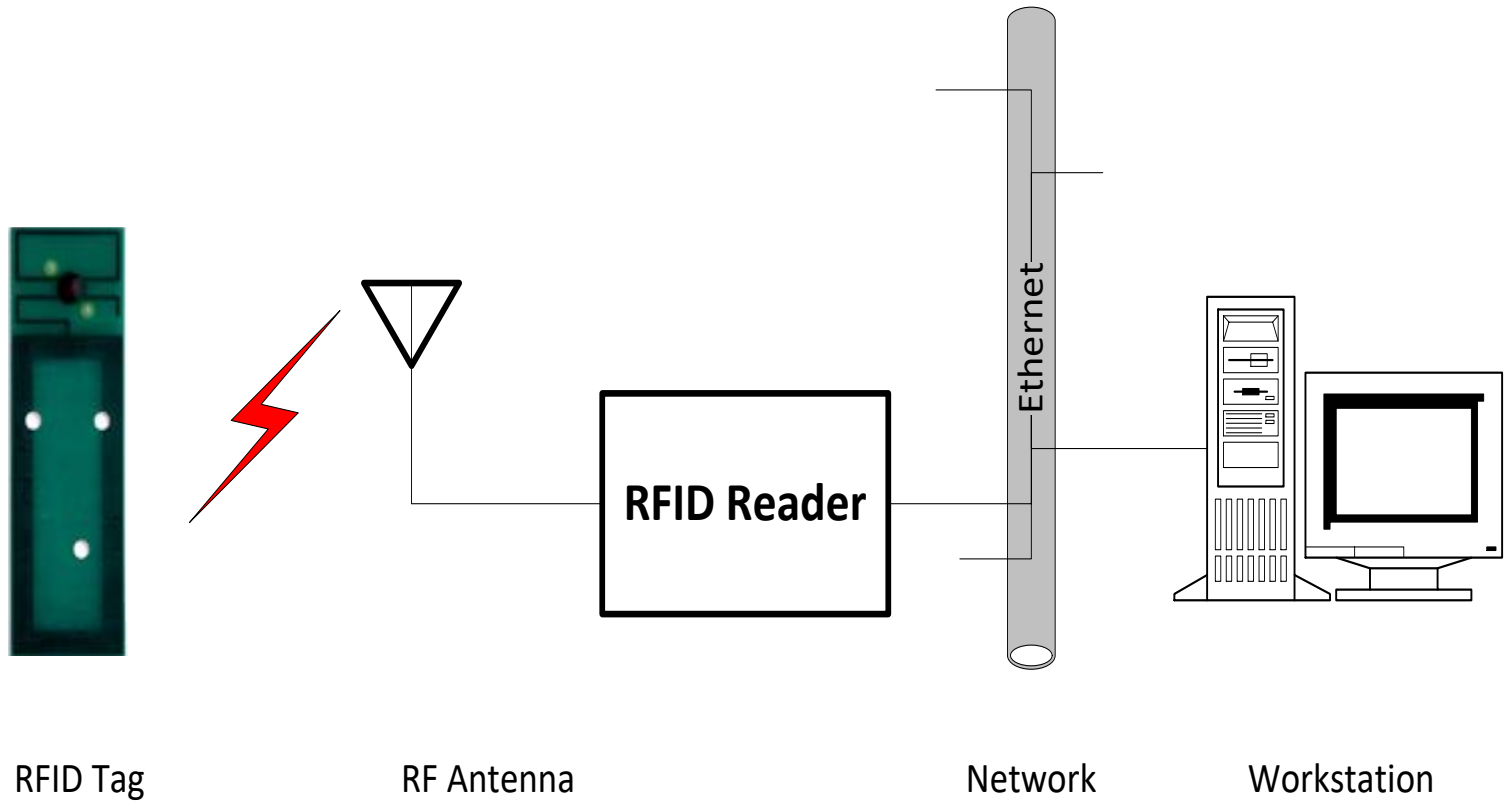- Other ADC technologies: Bar codes, OCR
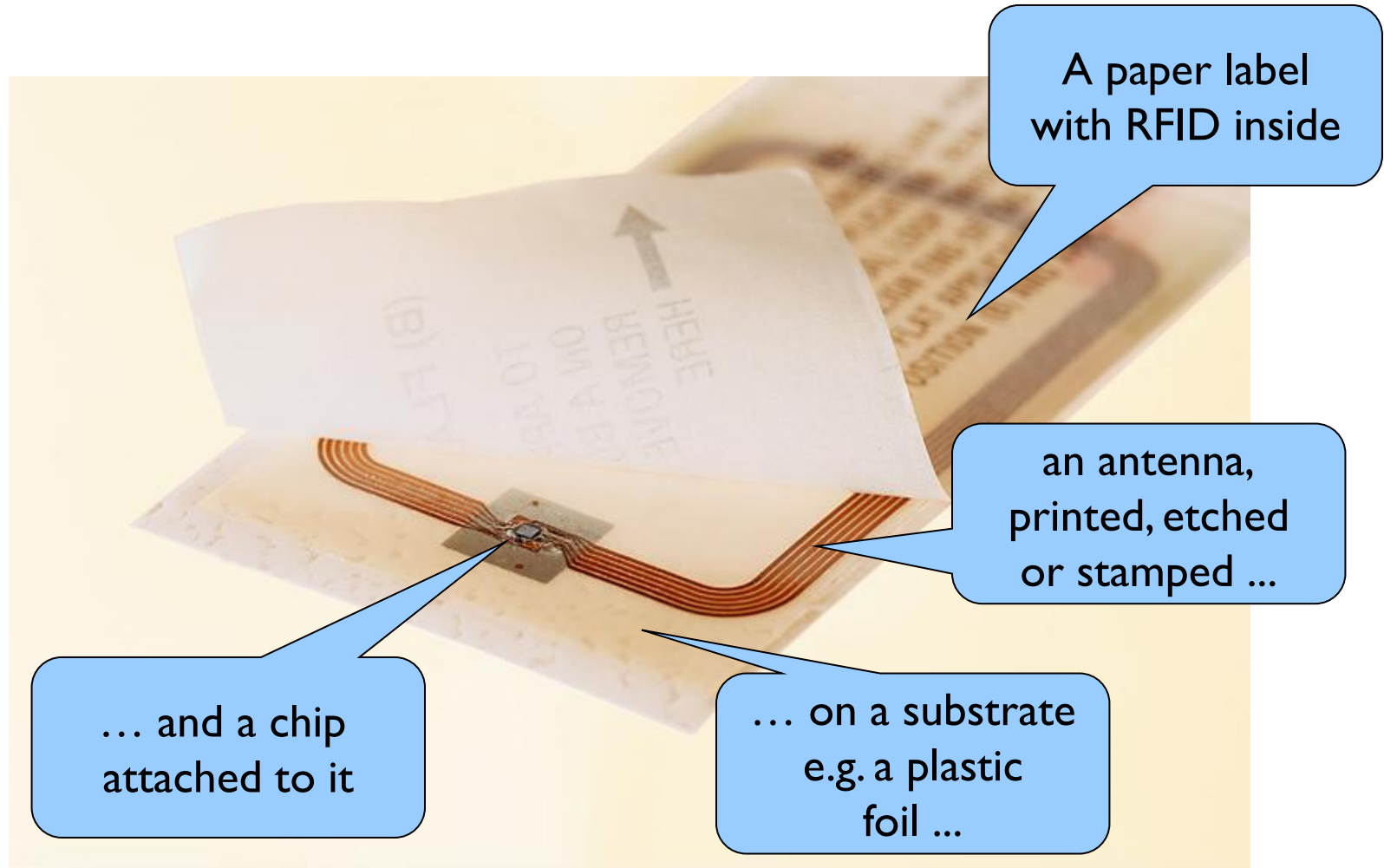
RFID Systems

Main components:

- **Tags** (transponders)
    - Microchip & antenna

- **Tag reader**
    - Decoder & antenna
    - RFID reader sends pulse of energy and waits for response
    - Can be on all the time or activate only in response to external event

RFID System Connectivity

RFID Tag   RF Antenna   Network   Workstation

RFID Reader

Ethernet

RFID Tags: Smart Labels

A paper label with RFID inside

an antenna, printed, etched or stamped ...

… and a chip attached to it
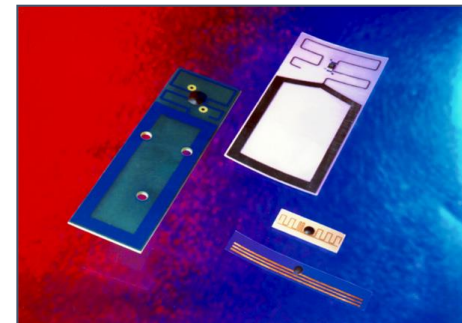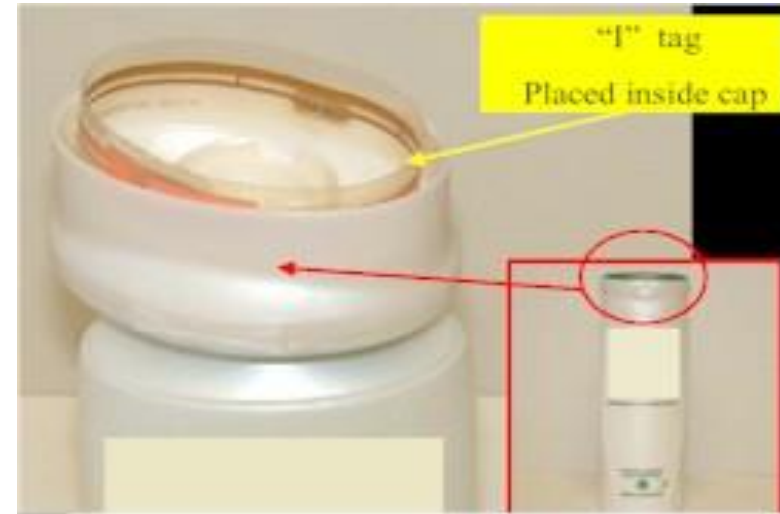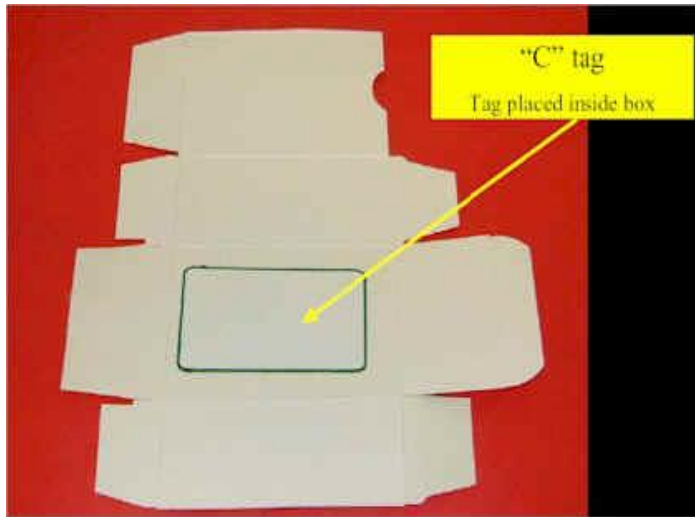
… on a substrate e.g. a plastic foil …

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Tags

Variations:

- **Memory**
  - Size (16 bits - 512 Kbytes)
  - Read-Only, Read/Write, or WORM
- **Arbitration (Anti-collision)**
  - Ability to read/write one or many tags at a time
- **Frequency**
  - 125KHz - 5.8 GHz
- **Price**
  - $0.10 to $250
- **Physical Dimensions**
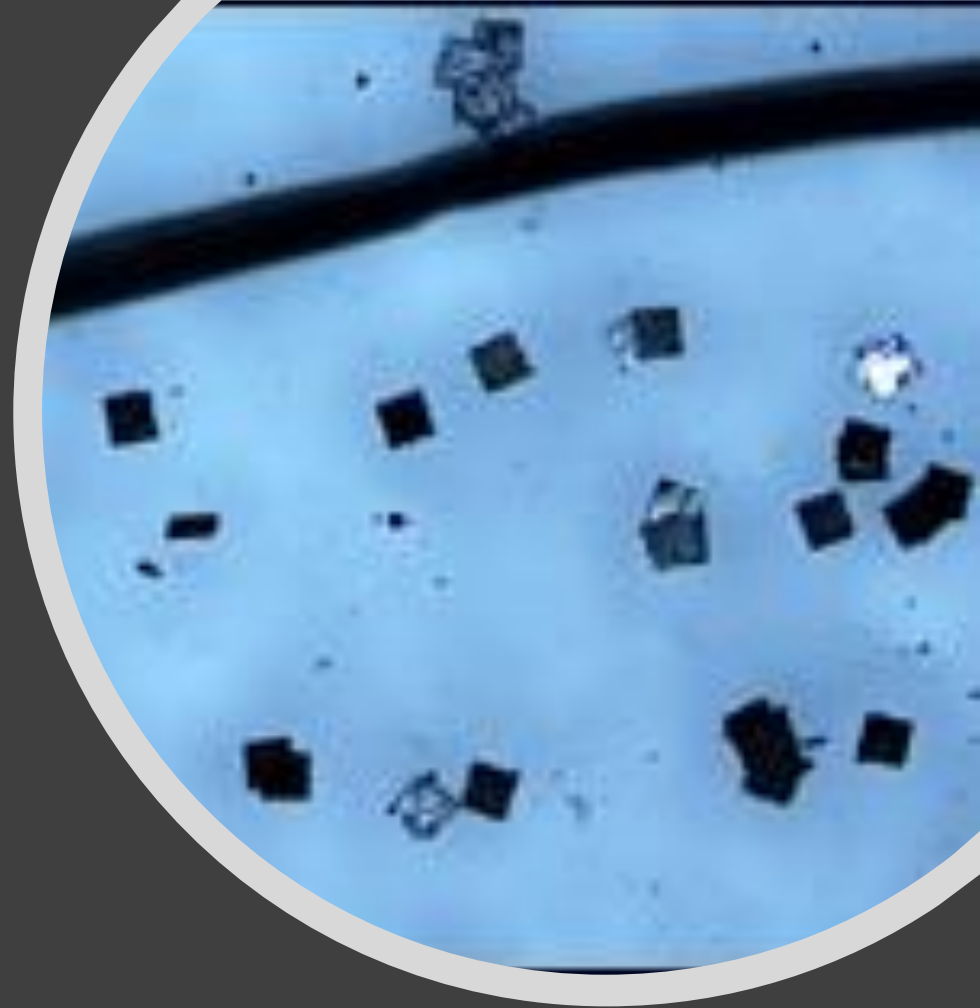 - Thumbnail to Brick sizes

Some RFID Tags

"Mission Impossible"

Tiny Tags

- 2007 Hitachi produced RFID device measuring 0.05×0.05 mm, and thin enough to be embedded in a sheet of paper. The data contained on them can be extracted from as far away as a few hundred meters.

Active v/s Passive

- Tags can be attached to almost anything:
  - Items, cases or pallets of products, high value goods
 - Vehicles, assets, livestock or personnel

	Active RFID	Passive RFID
Tag Power Source	**Internal to tag**	**Energy transferred using RF from reader**
Tag Battery	Yes	No
Required signal strength	Very Low	Very High
Range	Up to 100m	Up to 3-5m, usually less
Multi-tag reading	1000's of tags recognized – up to 100mph	Few hundred within 3m of reader, about 3 sec per read => at most 3 mph.
Data Storage	Up to 512 KB	16 bits – 1 KB
Cost	3000 to 10000 INR	Upto 1000 INR
Tag Memory	Typically can be re-written by RF Interrogators	Usually Write-Once-Read-Many or Read-Only tags
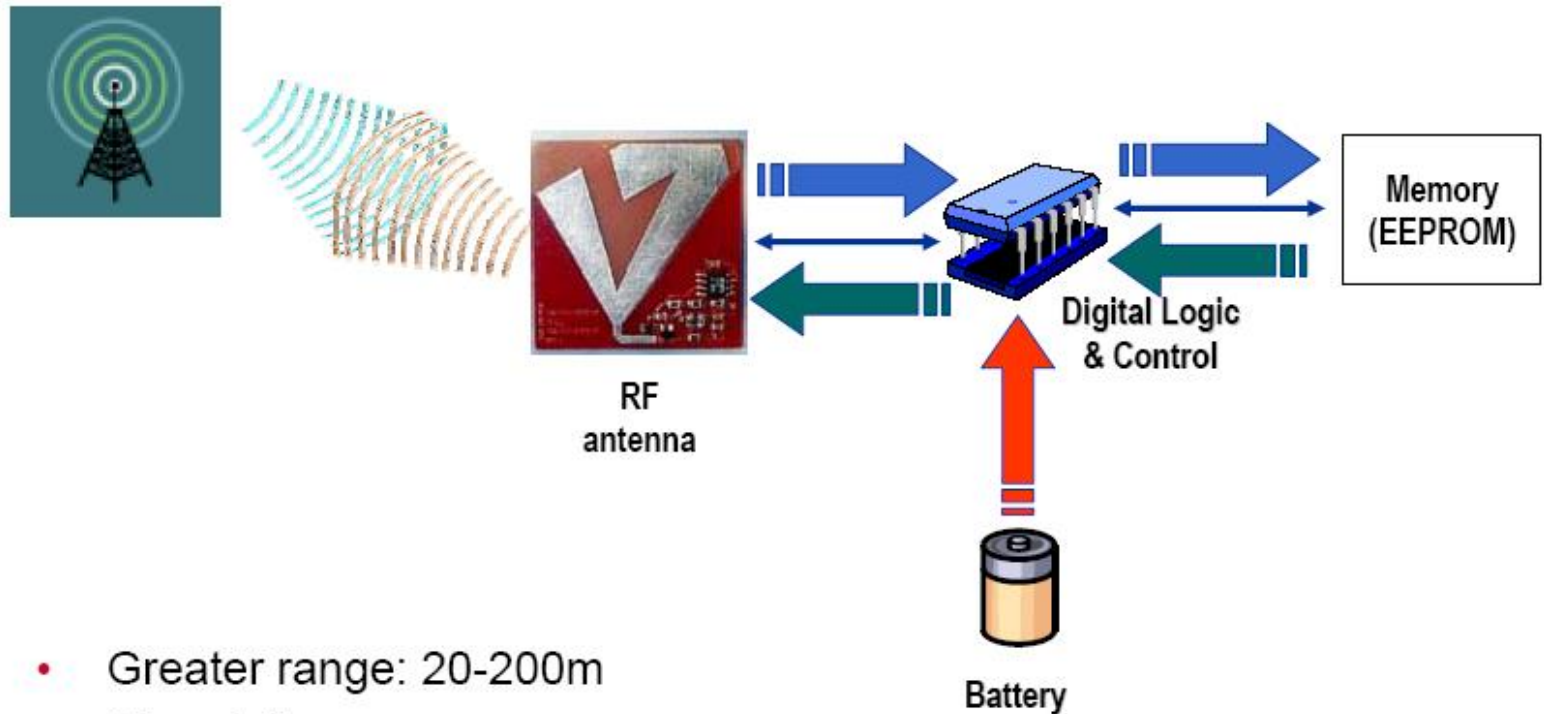
- Greater range: 20-200m
- 10 yr. Life
- Limited sensor capabilities
- "Self-powered" uses interrogator RF beam for wake-up and communication

Passive Tag

RF antenna

Memory (EEPROM)

Digital Logic & Control
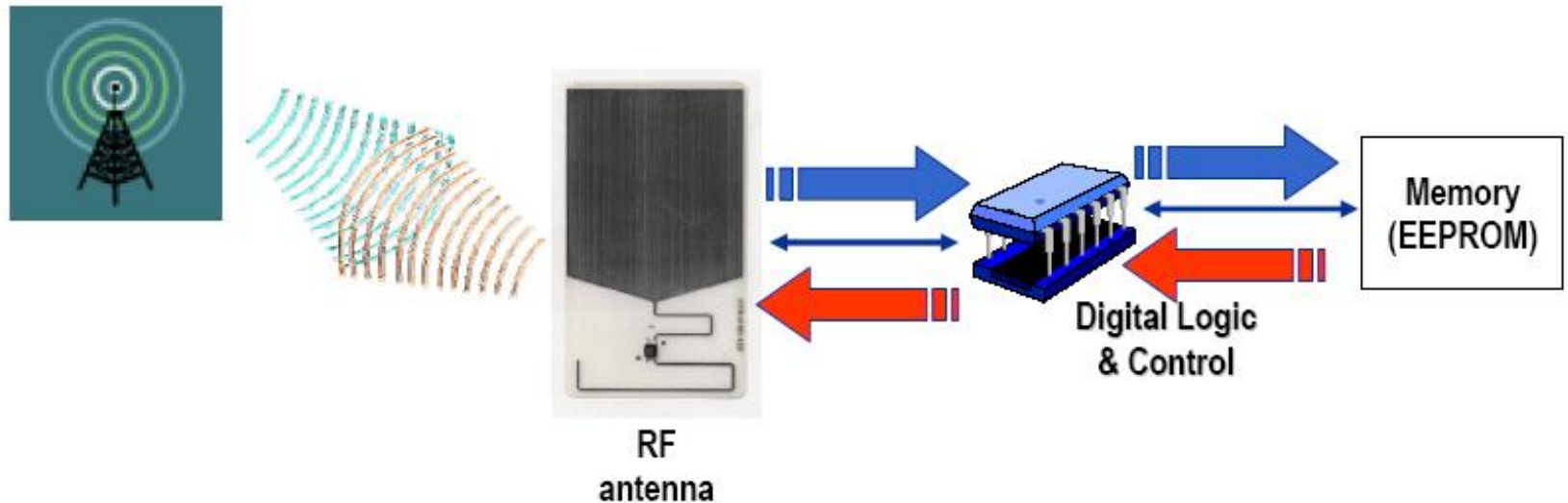
- Limited range: <10m (frequency dependent)
- Communication & power from interrogator RF beam

RFID Tag Memory

Read-only tags

- Tag ID is assigned at the factory during manufacturing
  - Can never be changed
  - No additional data can be assigned to the tag

Write once, read many (WORM) tags

- Data written once, e.g., during packing or manufacturing
  - Tag is locked once data is written
  - Similar to a compact disc or DVD

Read/Write

- Tag data can be changed over time
  - Part or all of the data section can be locked

RFID Readers

- Reader functions:
    - Remotely power tags
    - Establish a bidirectional data link
    - Inventory tags, filter results
    - Communicate with networked server(s)
    - Can read 100-300 tags per second
- Readers (interrogators) can be at a fixed point such as
    - Entrance/exit
    - Point of sale
- Readers can also be mobile/hand-held.

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Some RFID Readers

RFID Advantages over Bar-Codes

- No line of sight required for reading
- Multiple items can be read with a single scan

- Each tag can carry a lot of data (read/write)
- Individual items identified and not just the category

- Passive tags have a virtually unlimited lifetime
- Active tags can be read from great distances

- Can be combined with barcode technology

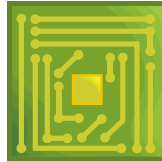# "Smart labels": EPC (Electronic Product Code) tags

Barcode

EPC tag

Line-of-sight

Radio contact

Fast, automated scanning

Specifies object type

Uniquely specifies object

Provides pointer to database entry for every object, i.e., unique, detailed history

RFID Vs Barcode

| Barcode	RFID
Optical technology	Radio technology
Barcode uses UPC (Universal Product Code)	RFID uses EPC (electronic product code)
Bar codes are larger than the smallest tag	Tags range in size from a postage stamp to a book
Barcodes have unlimited shelf life but are subject to degradation with handling.	Tags have no moving parts and have multi-year lifespan
Bar Codes can be easily duplicated and reattached to products and are, therefore, easily counterfeited	Tags have a unique identity code embedded on the microchip. Its difficult to duplicated tags so products can not be counterfeited

RFID Application Points
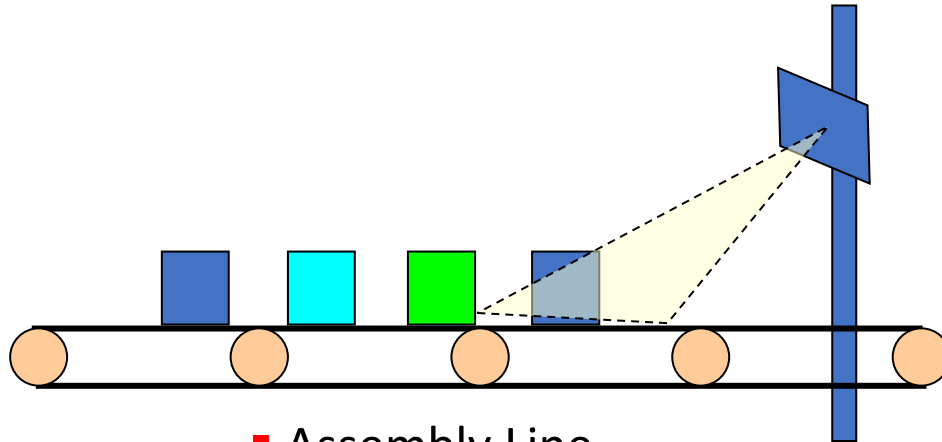
- Assembly Line
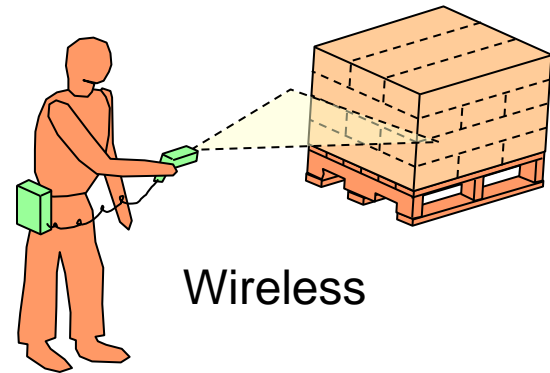
Wireless

- Handheld Applications
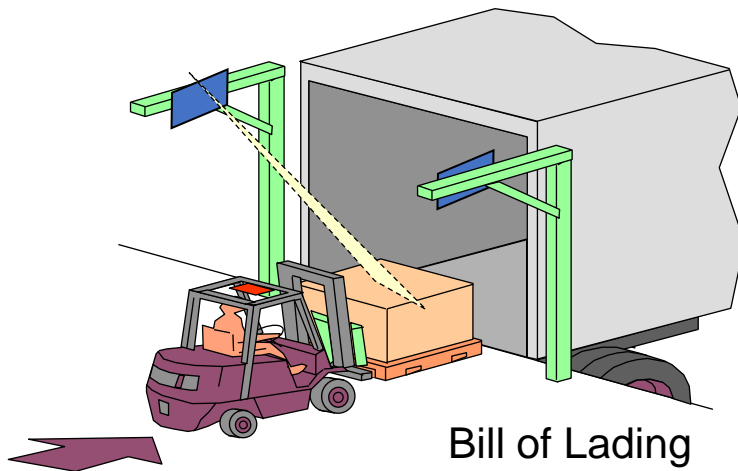
Bill of Lading
Material Tracking

- Shipping Portals

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RFID Applications

- Manufacturing and Processing
  - Inventory and production process monitoring
  - Warehouse order fulfillment
- Supply Chain Management
  - Inventory tracking systems
  - Logistics management
- Retail
  - Inventory control and customer insight
  - Auto checkout with reverse logistics
- Security
  - Access control
  - Counterfeiting and Theft control/prevention
- Location Tracking
  - Traffic movement control and parking management
  - Wildlife/Livestock monitoring and tracking
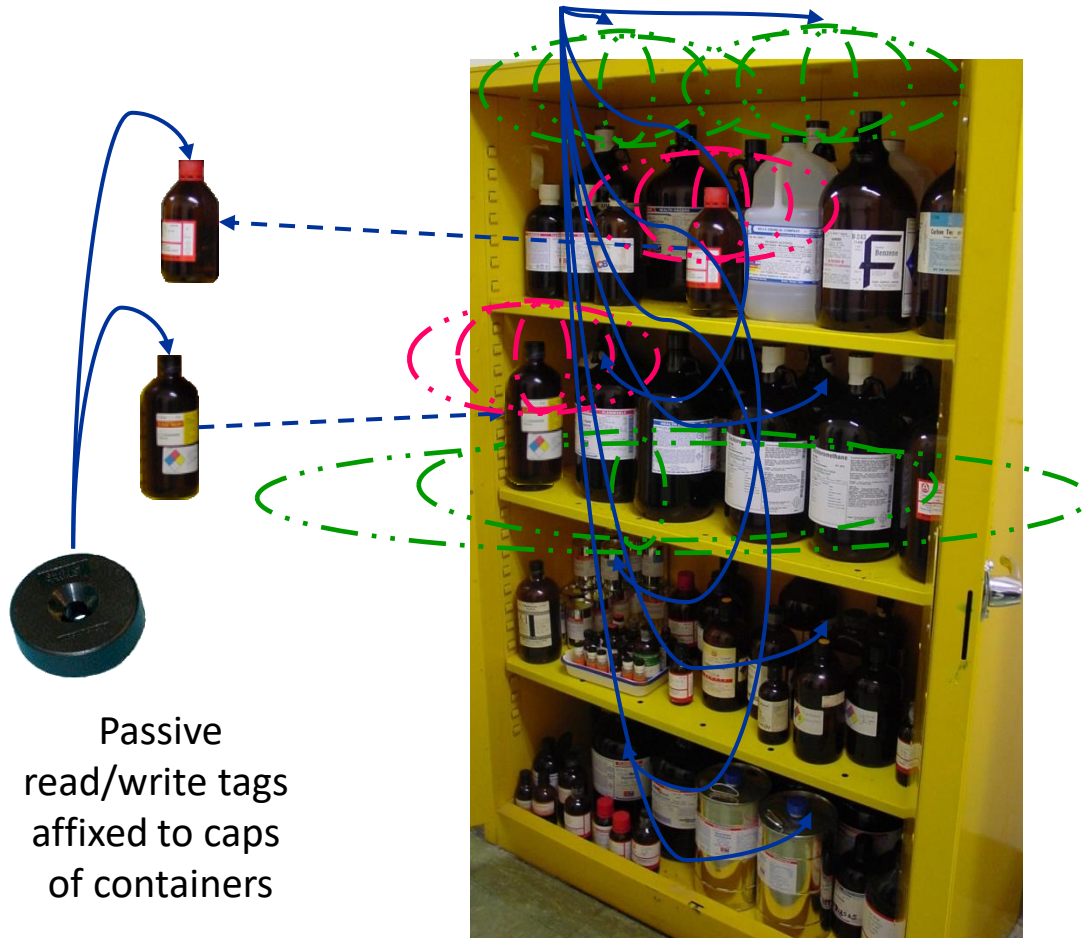
Smart Groceries

- Add an RFID tag to all items in the grocery

- As the cart leaves the store, it passes through an RFID transceiver

- The cart is rung up in seconds

Smart Cabinet

Reader antennas placed under each shelf

Passive read/write tags affixed to caps of containers

1. Tagged item is removed from or placed in "Smart Cabinet"

2. "Smart Cabinet" periodically interrogates to assess inventory

3. Server/Database is updated to reflect item's disposition

4. Designated individuals are notified regarding items that need attention (cabinet and shelf location, action required)
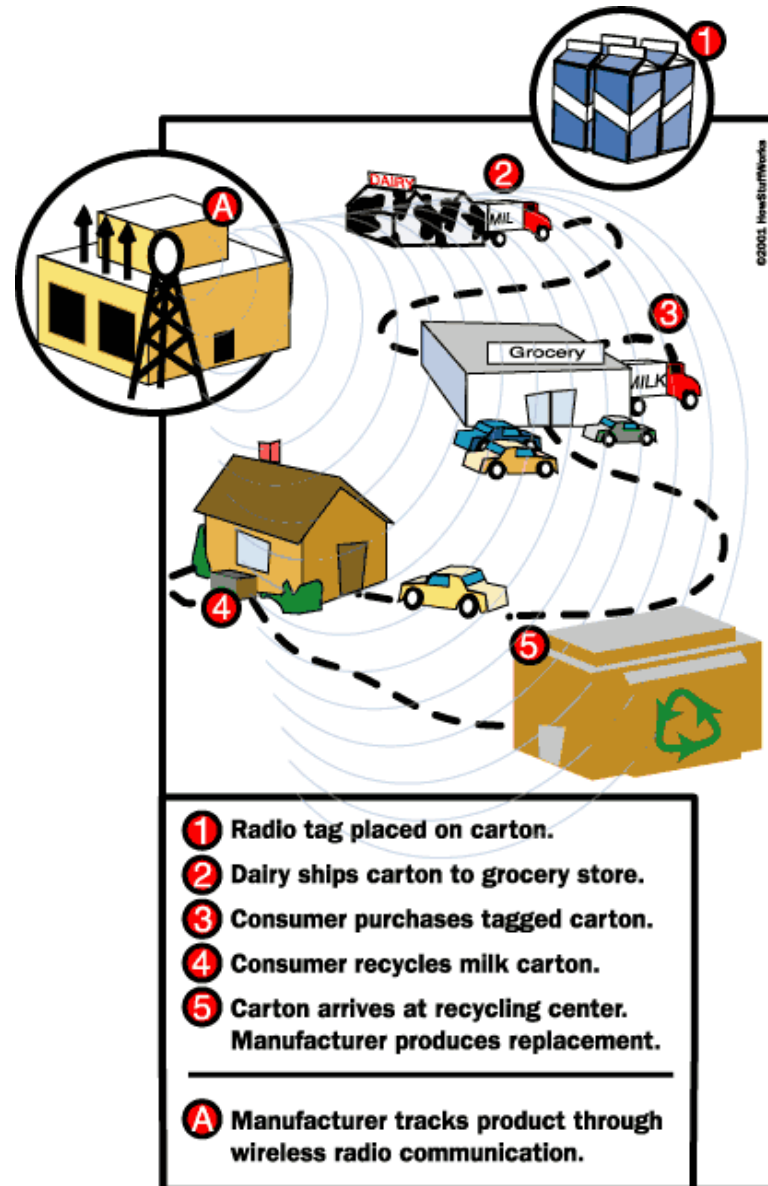
Smart Fridge

- Recognizes what's been put in it
- Recognizes when things are removed
- Creates automatic shopping lists
- Notifies you when things are past their expiration

- Shows you the recipes that most closely match what is available

Smart Groceries Enhanced

- Track products through their entire lifetime

1. Radio tag placed on carton.
2. Dairy ships carton to grocery store.
3. Consumer purchases tagged carton.
4. Consumer recycles milk carton.
5. Carton arrives at recycling center. Manufacturer produces replacement.

A. Manufacturer tracks product through wireless radio communication.

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Some More Smart Applications

- "Smart" appliances:
  - Closets that advice on style depending on clothes available
  - Ovens that know recipes to cook pre-packaged food

- "Smart" products:
  - Clothing, appliances, CDs, etc. tagged for store returns

- "Smart" paper:
  - Airline tickets that indicate your location in the airport

- "Smart" currency:
  - Anti-counterfeiting and tracking

- "Smart" people ??

Implants

- It is the most controversial application
- Small glass cylinders approximately 2 or 3mm wide and between 1 and 1.5cm long
- Consists of a microchip, a coiled antenna, and a capacitor
- Implanted typically under the skin of arm or the back of the neck

https://www.youtube.com/watch?v=HkKhlLzoGR8
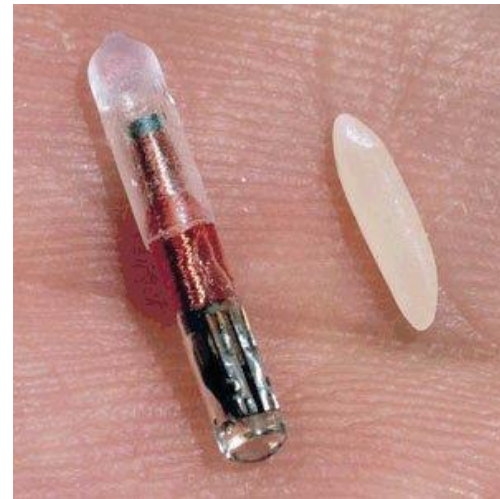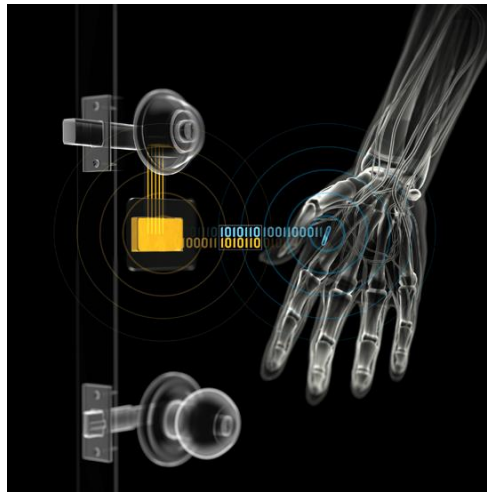
Security/Privacy Issues and Solutions

- **Unauthorized Reading:**
  - Scan closed boxes and find out what is inside
  - Read RFID enabled credit card or ID (metal foil in passports)
- **Unauthorized Writing:**
  - Can change UPC/price of an item
  - Can kill a tag

- **RFID Zapper:**
  - Can burn a tag using overcurrent
- **RSA Blocker Tag:**
  - Placed near another RFID; prevents its reading
- **Put Tag to Sleep:**
  - Can wake up later; reuse tags
- **Re-label Tag and Dual-Use Tag:**
  - Customer sees differed info or can over-write tag with useful information
- **Authentication:**
  - Reader has to know PIN

Near-Field Communication (NFC)

- **NFC** is one of the latest wireless communication technologies. As a short-range wireless connectivity technology, NFC offers safe yet simple communication between electronic devices

- It enables exchange of data between devices over a distance of 4 cm or less

- NFC operates at 13.56 MHz and rates ranging from 106 kbit/s to 848 kbit/s

How NFC Works

- NFC is based on **RFID technology** that uses magnetic field induction between electronic devices in close proximity

- For two devices to communicate using NFC, one device must have an **NFC reader/writer** and one must have an **NFC tag**. The tag is essentially an integrated circuit containing data, connected to an antenna, that can be read or written by the reader

How NFC Works

- The technology is a simple extension of the ISO/IEC14443 proximity-card standard (contactless card, RFID) that **combines the interface of a smartcard and a reader into a single device**

- An NFC device can **communicate with both existing ISO/IEC14443 smartcards and readers, as well as with other NFC devices**, and is thereby compatible with contactless infrastructure already in use for public transportation and payment

- NFC is primarily aimed at usage in **mobile phones**

- 2015: ~600 million NFC-equipped phones in use (estimate that 5% are used at least once a month)

NFC Applications

There are currently three main uses of NFC:

- **Card emulation:** The NFC device behaves like an existing contactless card

- **Reader mode:** The NFC device is active and reads a passive RFID tag, for example for interactive advertising

- **P2P mode:** Two NFC devices communicating together and exchanging information

NFC Applications

- **Mobile payment**
- **Mobile/electronic ticketing**
- **Smart objects**
- **Electronic keys**
- **P2P data transfers**
- NFC can be used to configure and initiate other wireless network connections such as Bluetooth or Wi-Fi
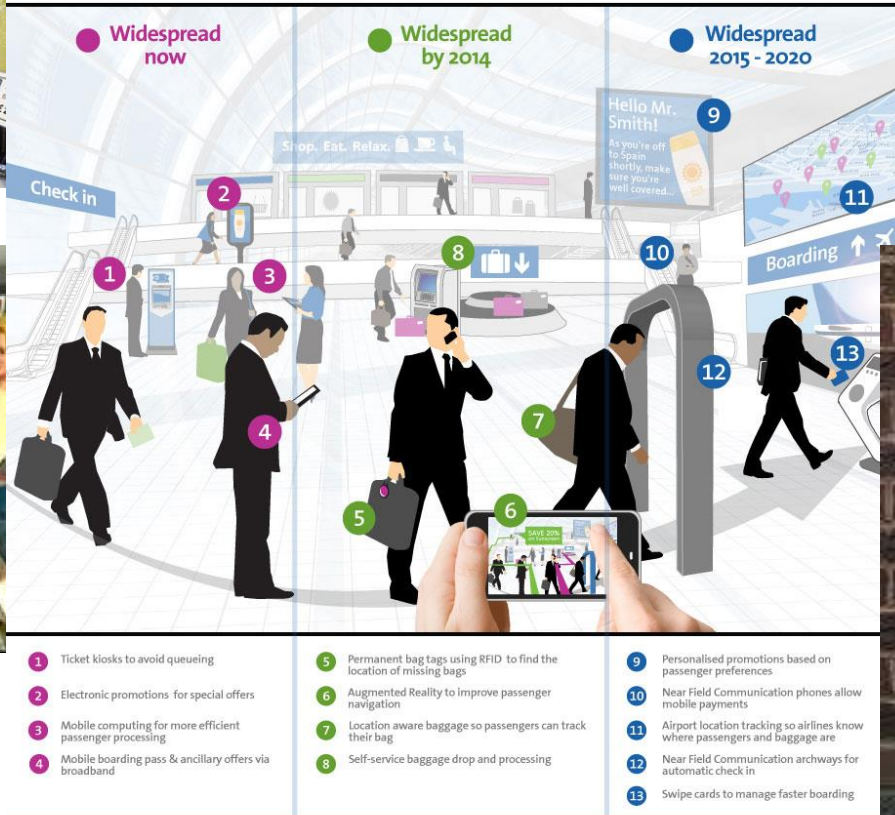
Future of RFID and NFC

2030: Week in the Life of a Milk Carton


- 30 April: RFID-tagged cow 'Bessie' produces milk

  - 30 April: Milk transferred to RFID-tagged tank
    - Cow identity and milking time recorded in tank-tag database

  - 1 May: RFID portal on truck records loading of refrigeration tanks
    - (Truck also has active RFID (+GPS) to track geographical location and RFID transponder to pay tolls)

  - 2 May: Chemical-treatment record written to database record for milk barrel
    - Bessie's herd recorded to have consumed bitter grass; compensatory sugars added

  - 3 May: Milk packaged in RFID-tagged carton; milk pedigree recorded in database associated with carton tag

  - 4 May: RFID portal at supermarket loading dock records arrival of carton
  - 5 May: 'Smart' shelf records arrival of carton in customer area
  - 5 May 0930h: 'Smart' shelf records removal of milk
  - 5 May 0953h: Point-of-sale terminal records sale of milk (to Alice)

2030: Week in the Life of a Milk Carton
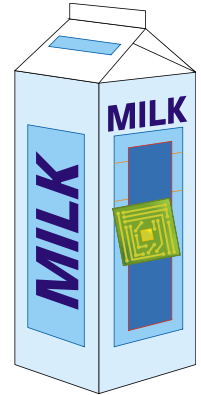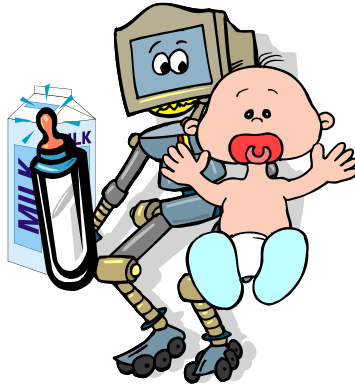
- 6 May 0953h: Supermarket transfers tag ownership to Alice's smart home

- 6 May 1103h: Alice's refrigerator records arrival of milk

- 6 May 1405h: Alice's refrigerator records removal of milk; refrigerator looks up database-recorded pedigree and displays: "*Woodstock, Vermont, Grade A, light pasturization, artisanal, USDA organic, breed: Jersey, genetic design #81726*"

- 6 May 1807h: Alice's 'smart' home warns domestic robot that milk has been left out of refrigerator for more than four hours

- 6 May 1809h: Alice's refrigerator records replacement of milk

- 7 May 0530h: Domestic robot uses RFID tag to locate milk in refrigerator; refills baby bottle

2030: Week in the Life of a Milk Carton
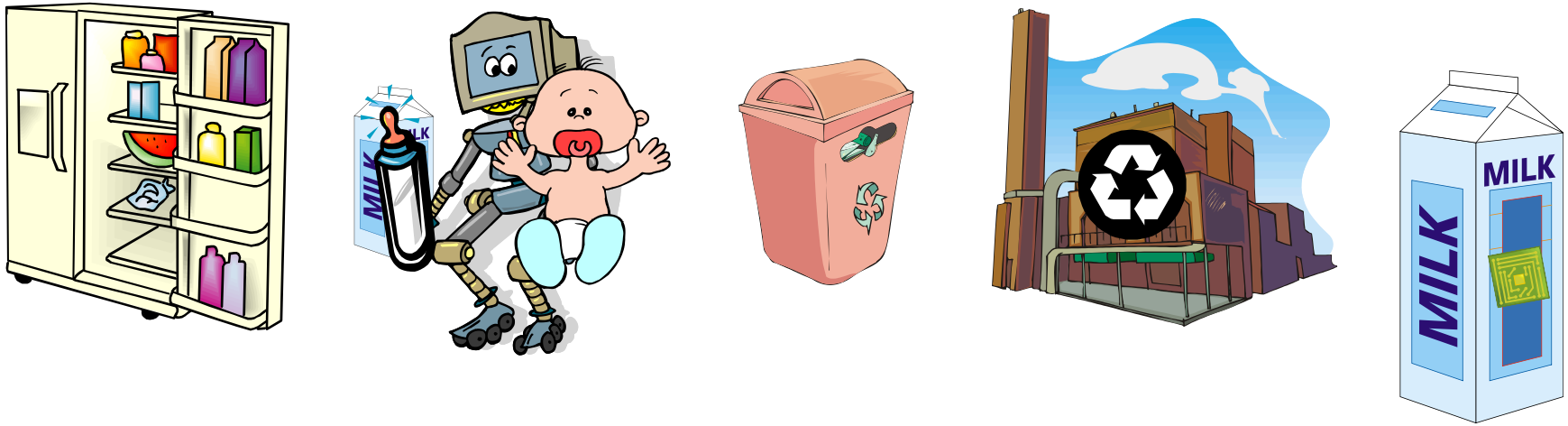
- 7 May 0530h: Domestic robot uses RFID tag to locate milk in refrigerator; refills baby bottle

- 7 May 0531h: Robot discards carton; 'Smart' refrigerator notes absence of milk; transfers order to Alice's PDA/phone/portable server grocery list

- 7 May 2357h: Recycling center scans RFID tag on carton; directs carton to paper-brick recycling substation

Thank You

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