

# **ECE 5990**

## **Note 1**

# **Introduction of RFID Systems**

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# Outline

- Brief history
- System overview
- Main applications
- Relation of RFID to Internet and Internet of Things (IoT)
- RFID categories

# Quotable Quotes

“One cannot escape the feeling that these mathematical formulae (Mechanics and Electromagnetics) have an independent existence and an intelligence of their own, that they are wiser than we are, wiser even than their discoverers, that we get more out of them than was originally put into them.”

— Heinrich Hertz (1857 – 1894)



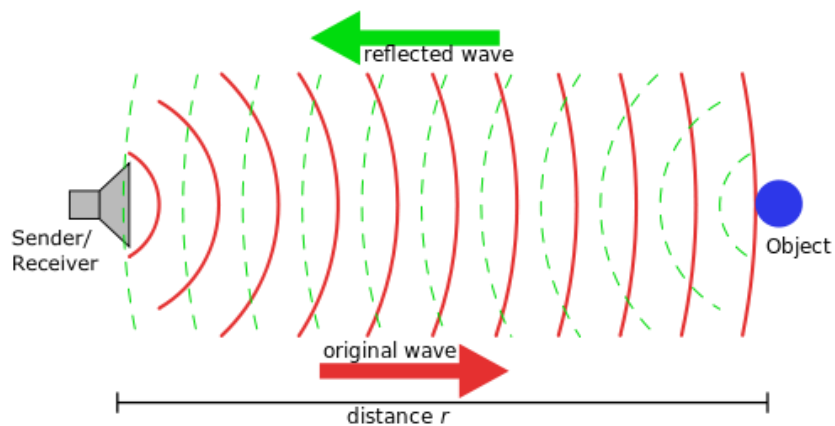
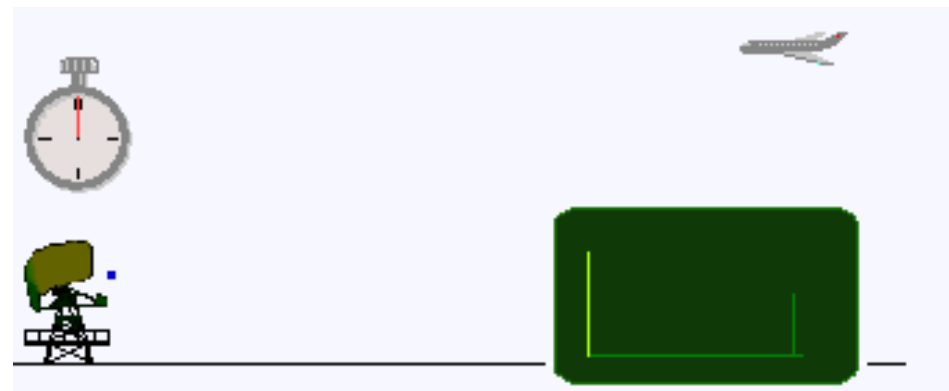
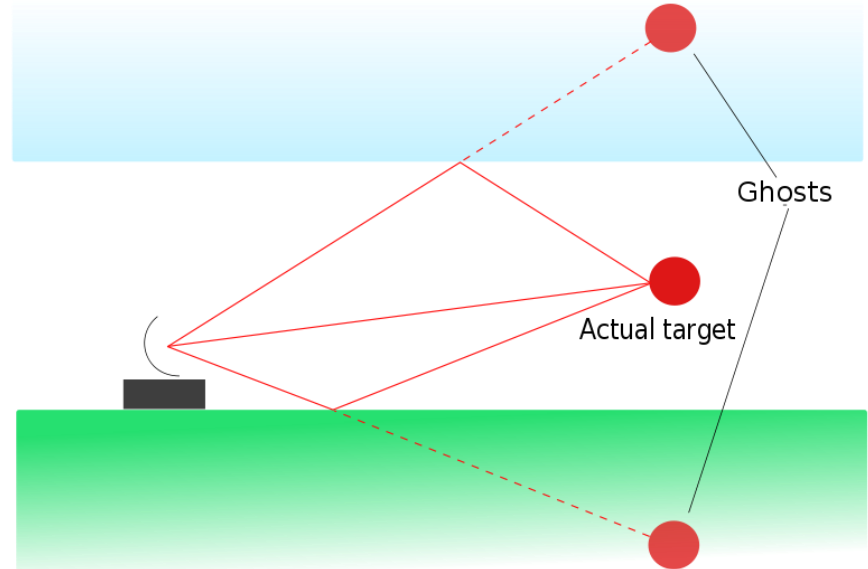
# How to Best Learn From This Course

- Your tuition is expensive. There are MOOC courses on line (although I will argue that the materials in this course are unique): PARTICIPATE!!
- I will try to make slides and notes ready for you to learn, but do ask questions.
- History helps you become a scholar, and also your conversation with other engineers and physicists.

# History of RF Backscattering

- Backscattering of radio waves for detection and ranging: Heinrich Hertz, 1886
- Hülsmeier (1904) and Tesla (1917): RADAR: **R**adio **D**etection and **R**anging
- World War II period: a race for radar technology
- Radar is VERY HARD for indoor even after 140 years of studies, mainly due to multi-path interference (ghost images)

# Indoor radar: A dream for more than 100 years



**Continuous Wave (CW) radar**

**Pulse (ToF) radar**

# History of RFID

- RFID: Information obtained remotely by radio inquires
- 1980: First generation of low-cost NFC RFIDs
- 1990: First generation of low-cost UHF RFIDs
- 2005: Walmart-led Electronic Product Code (EPC) of RFID for logistics
- 2010, 2014: Renewed logistic RFID efforts from Walmart and JCPenny
- Many forecasts on RFID as the last leaf nodes in local area network (LAN) or Internet of Things (IoT)

# Main Applications

Healthcare



Industrial



Retail/CPG



Government



Logistics

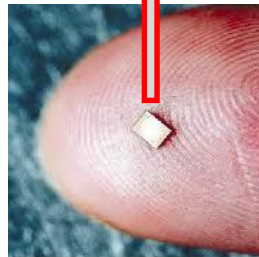
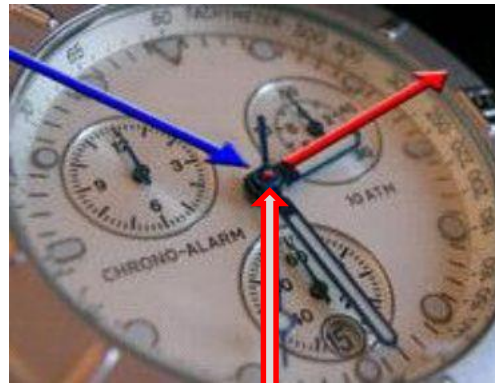


Field Service

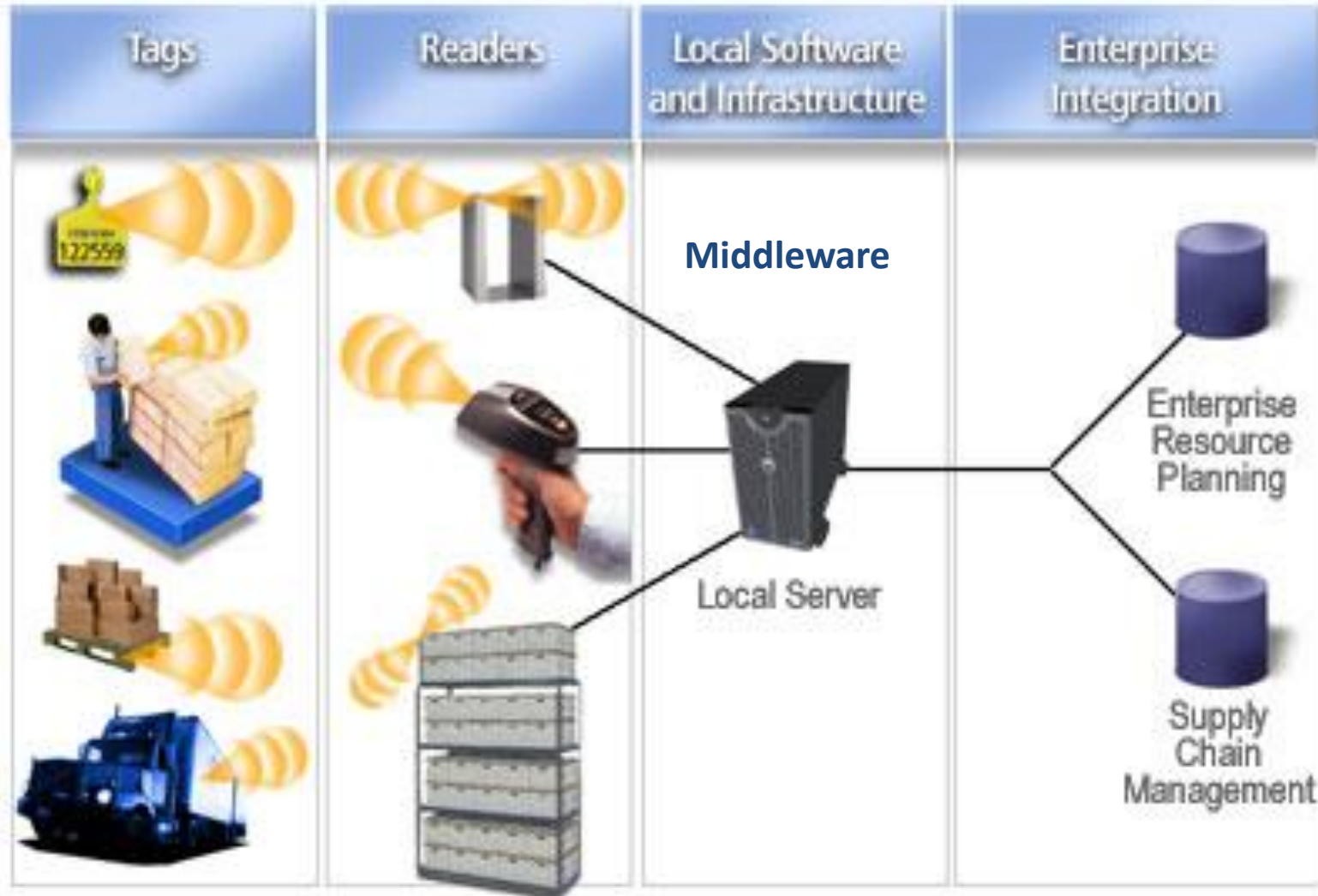


# Main RFID Application: Logistics

Digital ID Integration to enable product content and encryption to support shipping and distribution



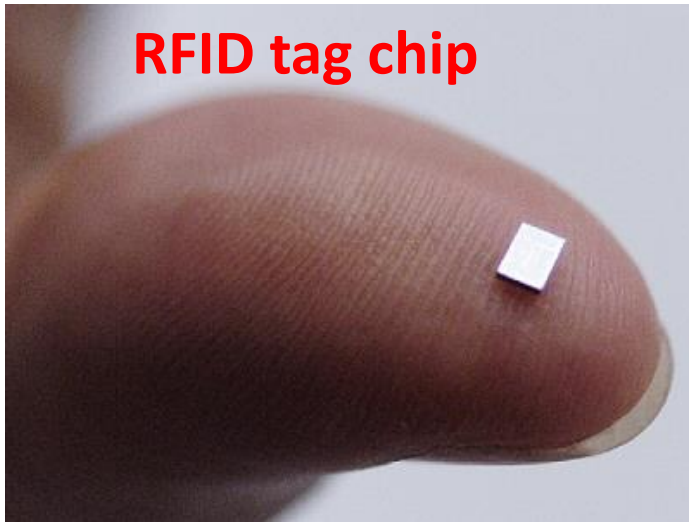
# RFID in Logistic Network



# Main RFID Application: Point of Sales (PoS)



# Commercial RFID System



# Main RFID Application: Infrastructure and Automobile Sensors

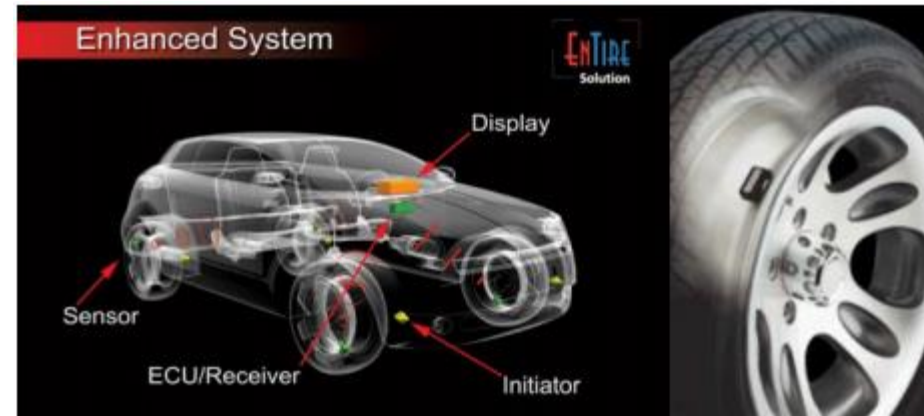
Small, flexible

Battery-free maintenance

Integrated, cheap (< \$0.10)



Infrastructure health monitoring

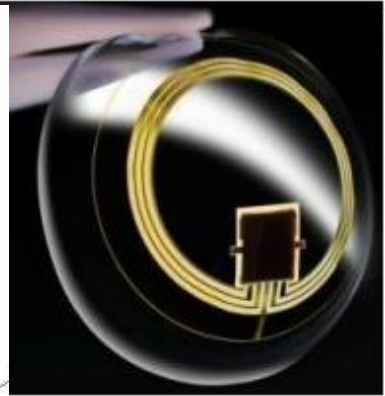
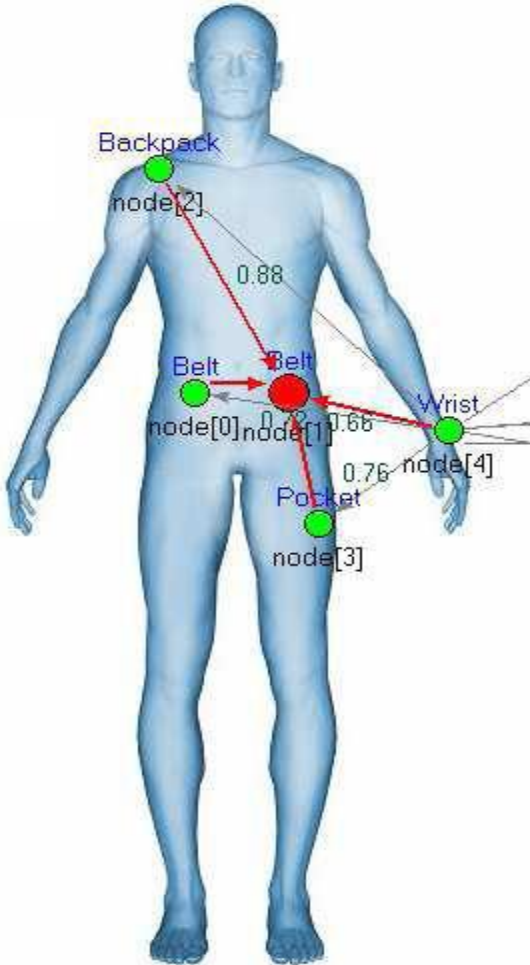
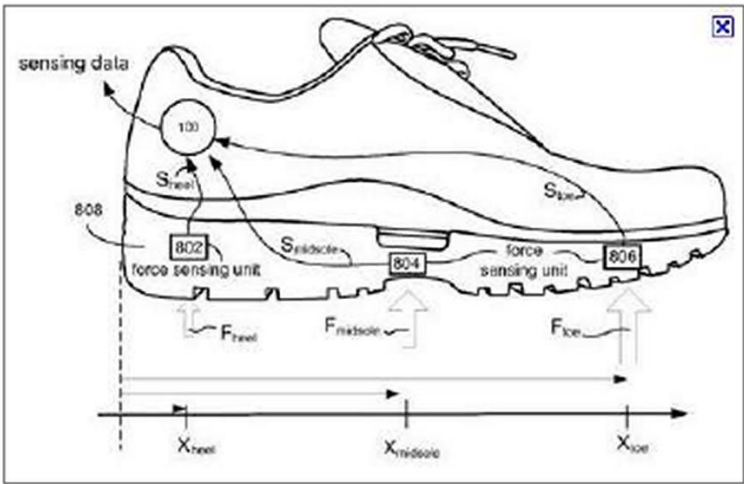


Pressure sensor inside the tire

# Main RFID Application: Body Area Network (BAN)



Nike+

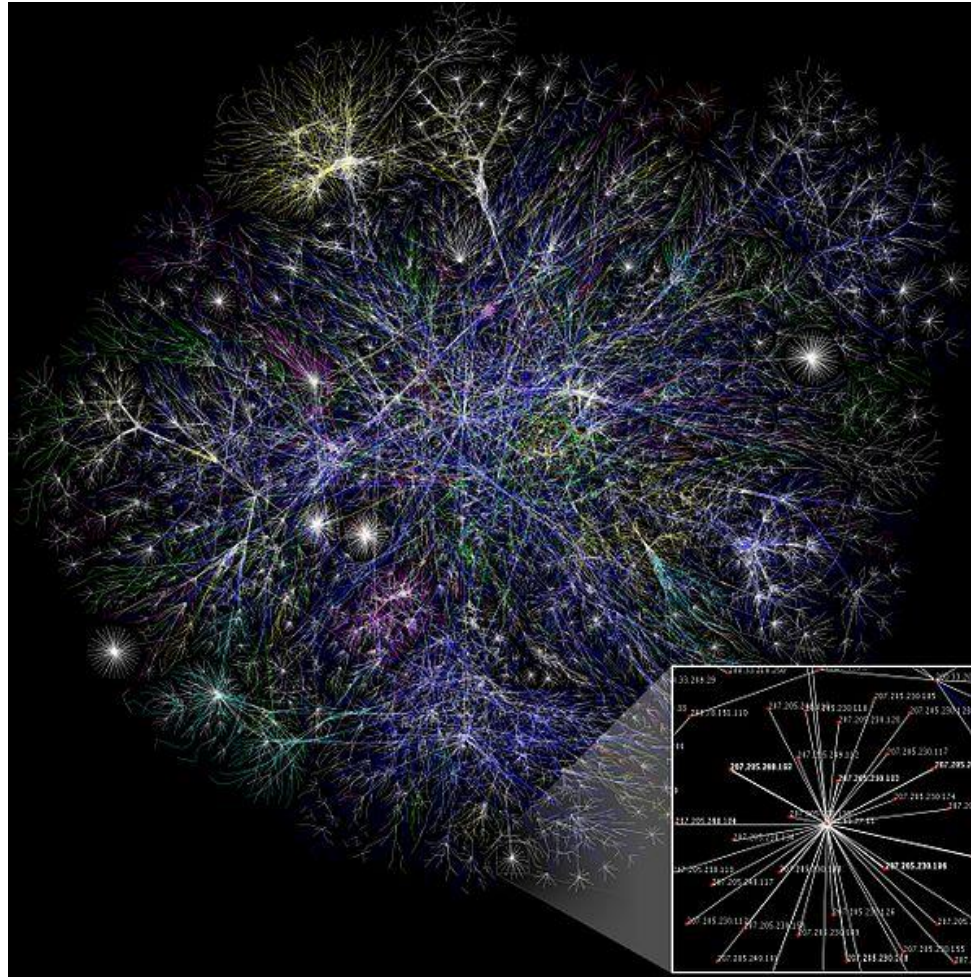


# Internet of Things (IoT)

IoT, smart buildings, smart cities, ubiquitous computing – all mean the same thing: “Digitally connect the whole real world!”



# The Power of Internet



**Internet doubles  
in size every 5  
years**

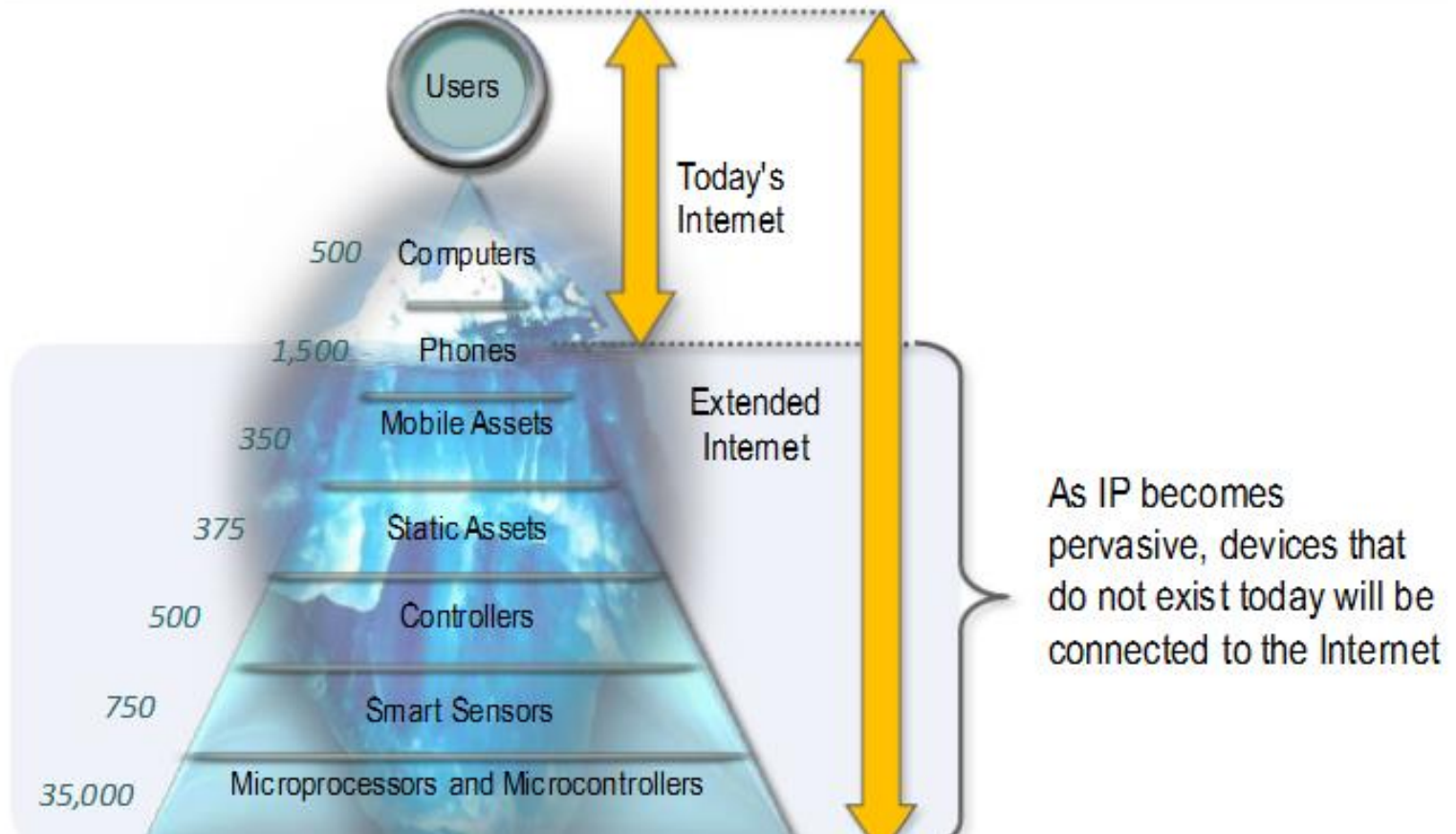
**– Cisco**

**Internet map as of 01/16/2009**



# Layer of Connectivity

The Internet Will Extend to Billions of New Devices



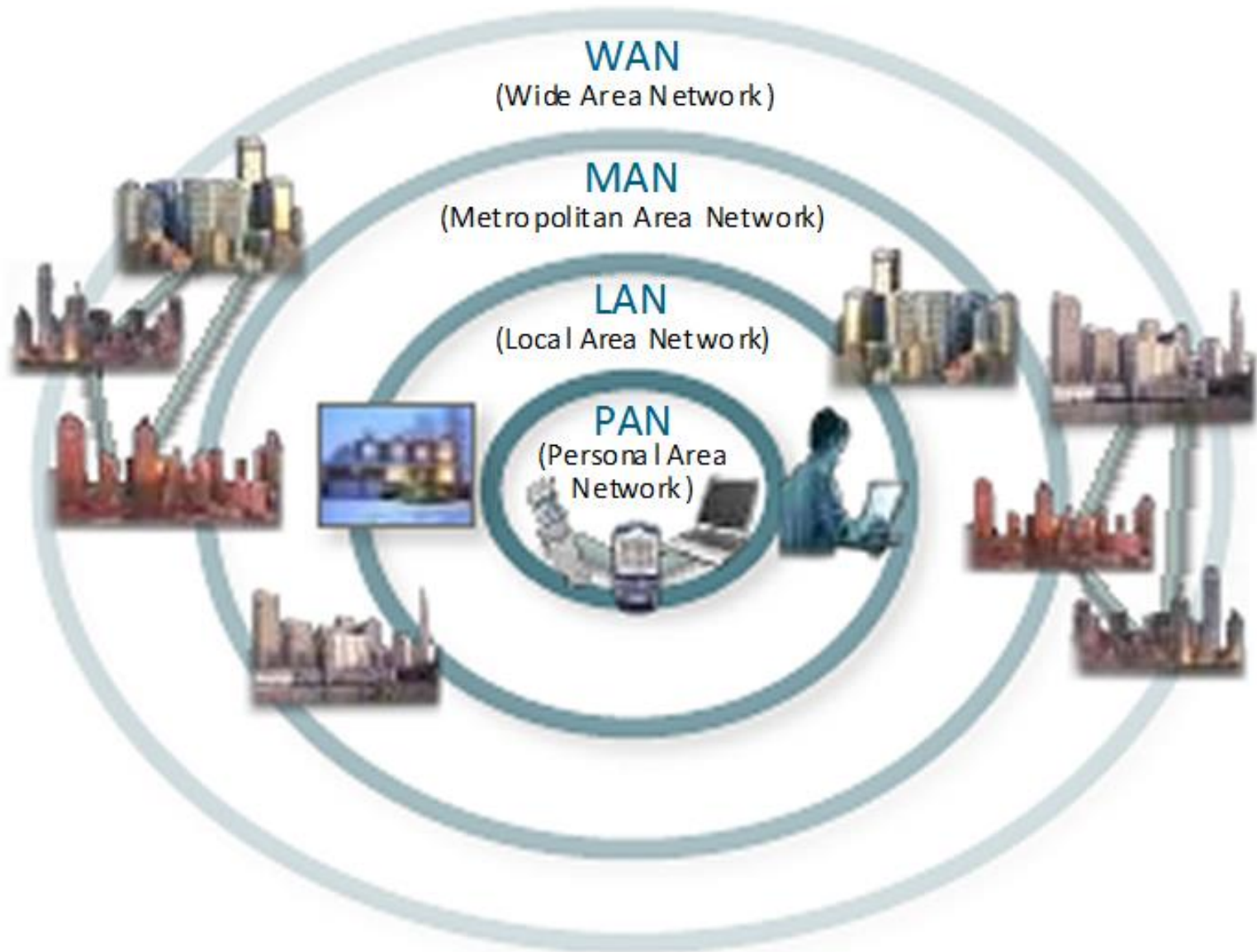
# RFID Future Progression

#	Stage	RFID development areas	Year
1	<b>SUPPLY-CHAIN HELPERS</b>	Inventory management RFID systems to maximise sales, efficiency and reduce losses, mainly in logistics. This first stage of RFID adoption is already completed, using RFID to track assets.	2010
2	<b>VERTICAL - MARKET APPLICATIONS</b>	This second wave of applications will include Security, Surveillance, Healthcare, Transport, Food Safety and Document Management (we are in this stage now). This stage includes reduced initial costs for RFID.	2015
3	<b>UBIQUITOUS POSITIONING</b>	RFID to locate people and objects. This will see devices able to receive geo-location signals. This stage aims for a cyber-space network mass-adoption hosting electronic environments known as 'ambient intelligence'.	2020
4	<b>PHYSICAL-WORLD WEB (I.O.T)</b>	Through <i>miniaturisation</i> and more power-efficient electronics RFID could and should bring 'Tele-operation' and 'telepresence' (the ability to monitor and control distant objects). This is the future for RFID. This stage could also see software agents and advanced software fusion.	2030

Source: UKRFID

**We may not want to wait that long....**

# Network Hierarchy

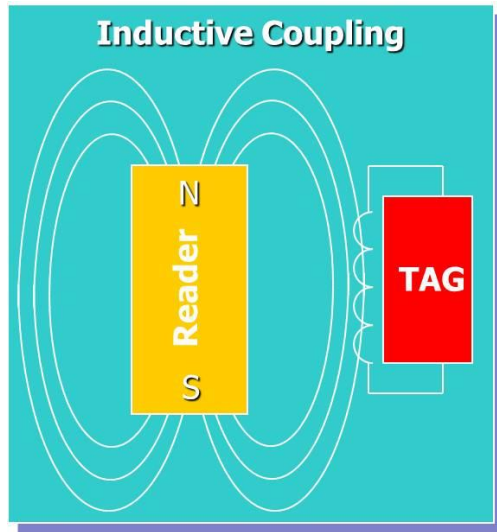


# **What RFID Applications Can Make the Most Money in the Future?**

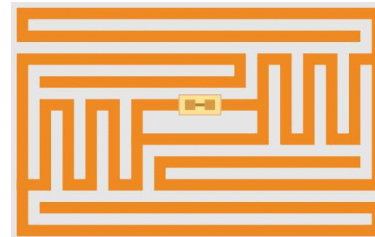
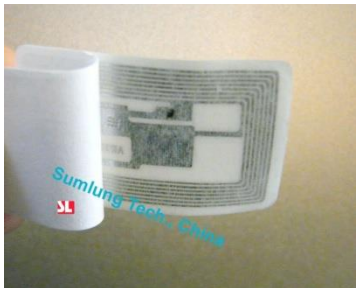
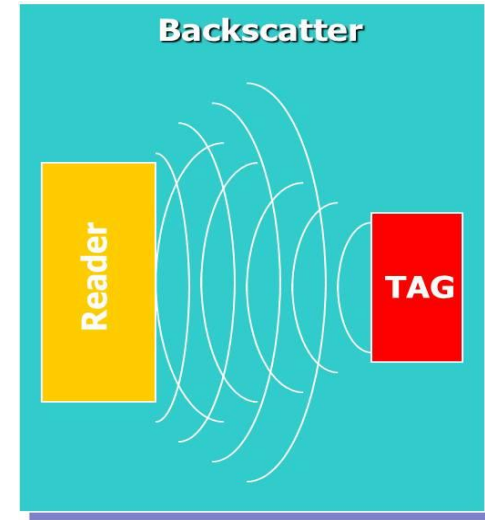
# RFID Reader and Tag Coupling

- ❑ Near-field communication (NFC): LF (125KHz) and HF (13.56MHz)
  - Low frequency magnetic coupling (5 – 10cm)
  - > 10mW can be scavenged
  - Smart card applications
  - Decay of power coupling  $\propto \exp(-x)$  or  $1/d^6$
  
- ❑ Backstandard RFID: UHF (868-968 MHz), Microwave (2.4 GHz), IMS (5.8 GHz)
  - Far-field radiation (0.3 – 100 m)
  - Only several  $\mu\text{W}$  can be scavenged
  - Square-law decay of power coupling  $\propto 1/d^2$
  - EPC and IP-X standards for multiplexing
  - Battery-assisted or **PASSIVE**

# Near Field and Far Field RFID



$$d > \frac{\lambda}{2\pi}$$



# Intended Data of RFID

## Digital ID:

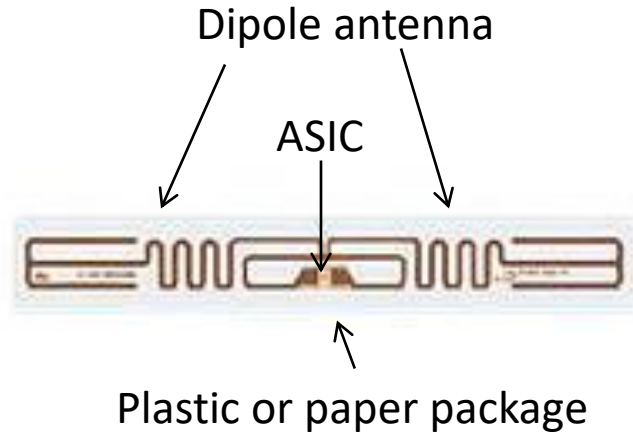
- 128 – 4,096 bits of Electronic Product Code (EPC)
- Often with burst error correction code
- Security is a MAJOR issue

## Analog Sensor:

- Analog value of transduced information from sensor
- 4 – 9 bits of sensor outputs
- Location and motion

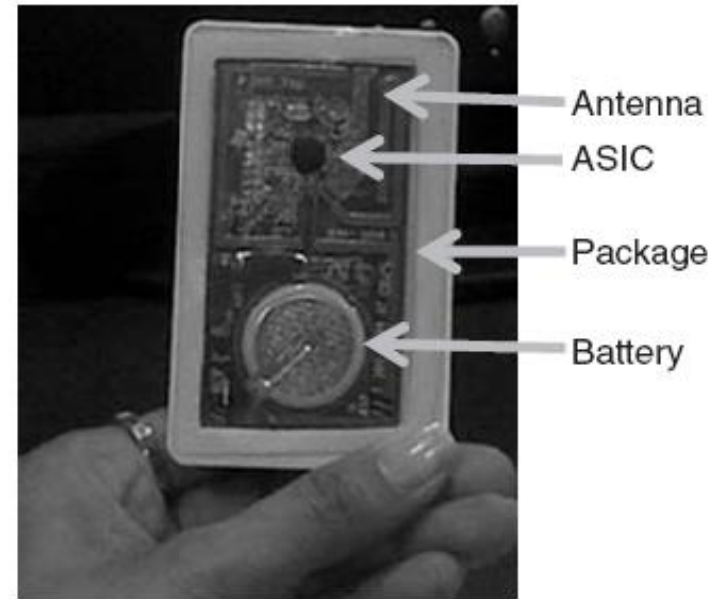
Low bandwidth requirements (in the range of 1 – 100kHz)

# Passive and Active Backscattered Tags



## Passive tags:

- Printed on paper or plastic in a roll
- Cost today: \$0.10 per tag
- Easy deployment and maintenance
- Limited by the power that can be scavenged on tag: tag sensitivity

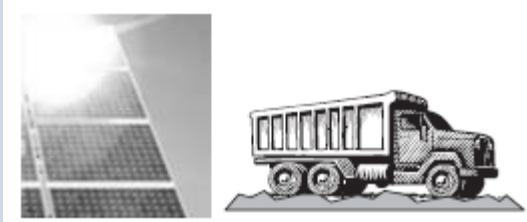

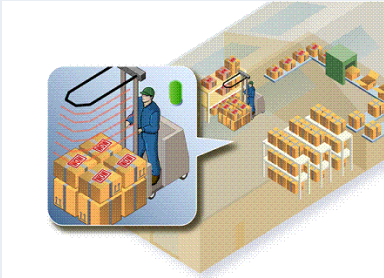



## Active tags:

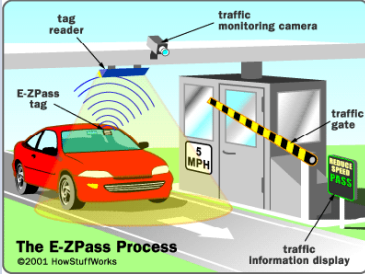

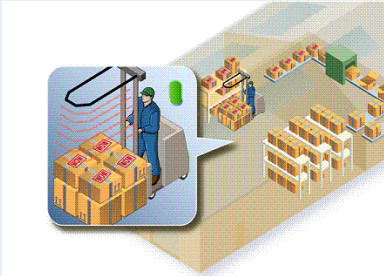

- Integrated in cards
- Cost today: \$1 - \$3 per tag
- Battery life > 2 years
- Limited by reader sensitivity



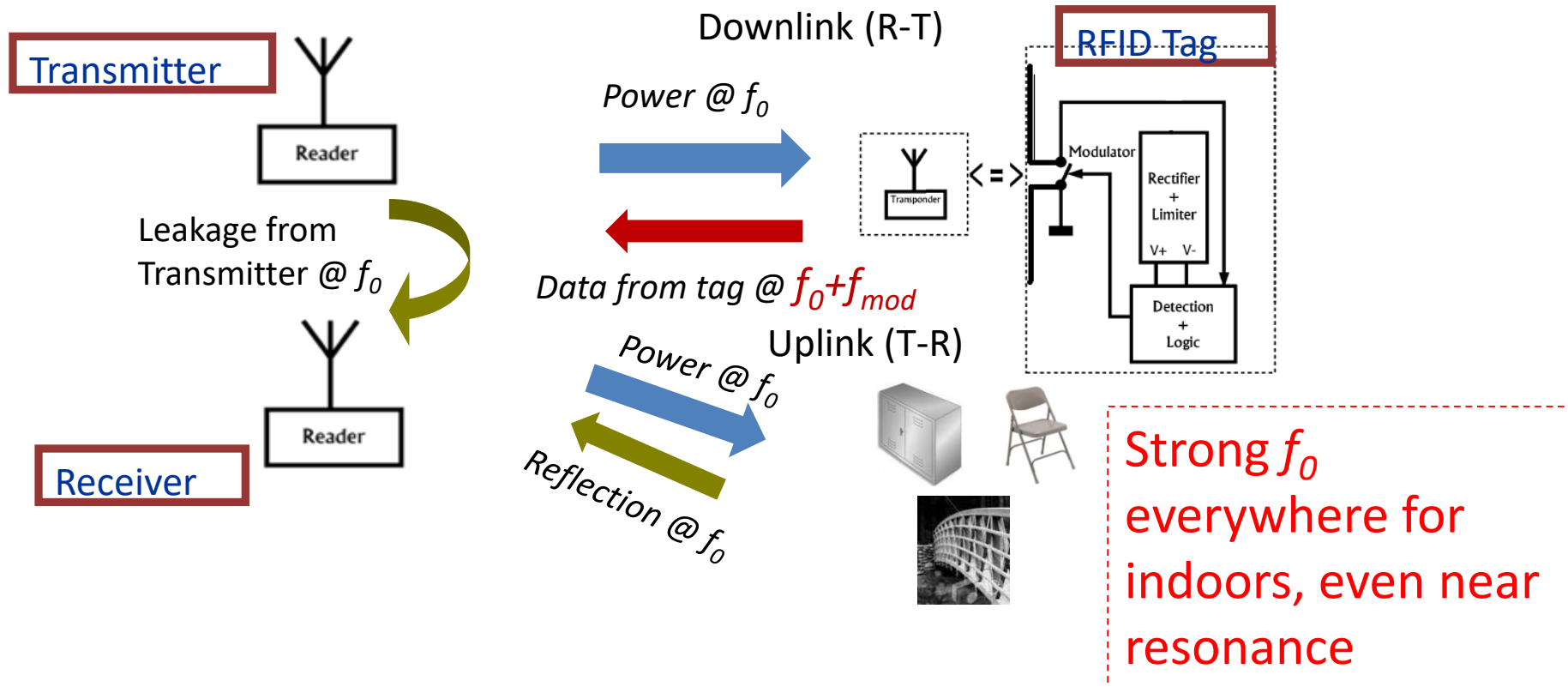
# Application Categories of Backscattered Tags

	No battery on tags	Tags with batteries
Emitted energy	<p>Energy scavenging (Semi-active)</p>  <p>Solar      Vibration</p>	<p>Active</p>  <p>Asset seal tags</p>
Reflected energy	<p>Passive</p>  <p>Supply chain labels</p>	<p>Semi-passive</p>  <p>Toll collection</p>

# Range and Throughput in RFID Applications

	Low Throughput	High Throughput
Long Range	<p>Vehicle tracking</p>  <p>Active tags; no multiplexing</p>	<p>Personnel tracking</p>  <p>Active tags; Indoor localization</p>
Short Range	<p>Shelved items</p>  <p>NFC or UHF passive</p>	<p>Conveyor belt</p>  <p>Speed; multiplexing</p>

# Conventional Backscattered Passive RFID



## Conventional Passive RFID System

### Backscattering Modulation

- Biggest Challenge: **Self and multi-path interference**

# What Did You Learn

- Brief history of RFID
- Components: reader, tag, antennas
- Main applications
- RFID as a layer in Internet network
- NFC and far-field RFID