Unit V-Ubiquitous Clouds and the Internet of Things

Cloud Trends in Supporting Ubiquitous Computing, Performance of Distributed Systems and the Cloud, Enabling Technologies for the Internet of Things (RFID, Sensor Networks and ZigBee Technology, GPS), Innovative Applications of the Internet of Things (Smart Buildings and Smart Power Grid, Retailing and Supply-Chain Management, Cyber-Physical System), Online Social and Professional Networking.

Ubiquitous Cloud Computing

Ubiquitous Cloud Computing refers to cloud services that are **seamlessly integrated** into everyday life, providing **on-demand, location-independent access** to data, applications, and computing resources.

- It enables a **"cloud everywhere"** approach, where cloud services are **automatically available across devices, networks, and geographies** without user intervention.
- Ex:youtube,spotify

Ubiquitous Clouds – A Simple Real-Time Analogy

Imagine you have **music streaming apps** like **Spotify or YouTube Music** on your phone.

👉 **No matter where you are—home, office, car, or vacation—you can access your favorite songs** instantly on any device.

- ✅ If you're at home, your **smart speaker** (Alexa/Google Home) plays the music.
  ✅ If you're in the car, your **smart dashboard** streams it via Bluetooth.
  ✅ If you switch to your **smartphone or laptop**, the music continues from where you left off.
  ✅ If you lose the internet, some songs are available **offline**, thanks to preloaded storage.

Ubiquitous Cloud Computing

Technology & Computing:

- ✅ **Ubiquitous Computing** – AI-powered devices like Alexa, Google Assistant, and Siri work seamlessly across platforms.
  ✅ **Ubiquitous Cloud** – Services like Google Drive, OneDrive, and iCloud sync data across all devices.
  ✅ **Ubiquitous IoT** – Smart homes, smart cities, and connected vehicles.
  ✅ **Ubiquitous AI** – AI-powered recommendations on YouTube, Netflix, and shopping websites.
  ✅ **Ubiquitous 5G** – High-speed mobile connectivity available almost everywhere.

Examples of Ubiquitous Cloud Platforms

1 Google Cloud Platform (GCP)

- **Used for:** AI/ML, IoT, cloud storage, real-time data processing.
- **Example:** Google Photos automatically syncing across all devices.

2 Microsoft Azure

- **Used for:** Cloud computing, IoT, hybrid cloud, enterprise solutions.
- **Example:** Smart cities use Azure IoT Hub for real-time traffic monitoring.

3 Amazon Web Services (AWS)

- **Used for:** Scalable cloud storage, machine learning, edge computing.
- **Example:** Alexa processes voice commands through AWS cloud services.

4 IBM Cloud

- **Used for:** AI-powered cloud computing, hybrid cloud, security.
- **Example:** AI-driven healthcare analytics for real-time patient monitoring.

5 Edge & Fog Computing Platforms

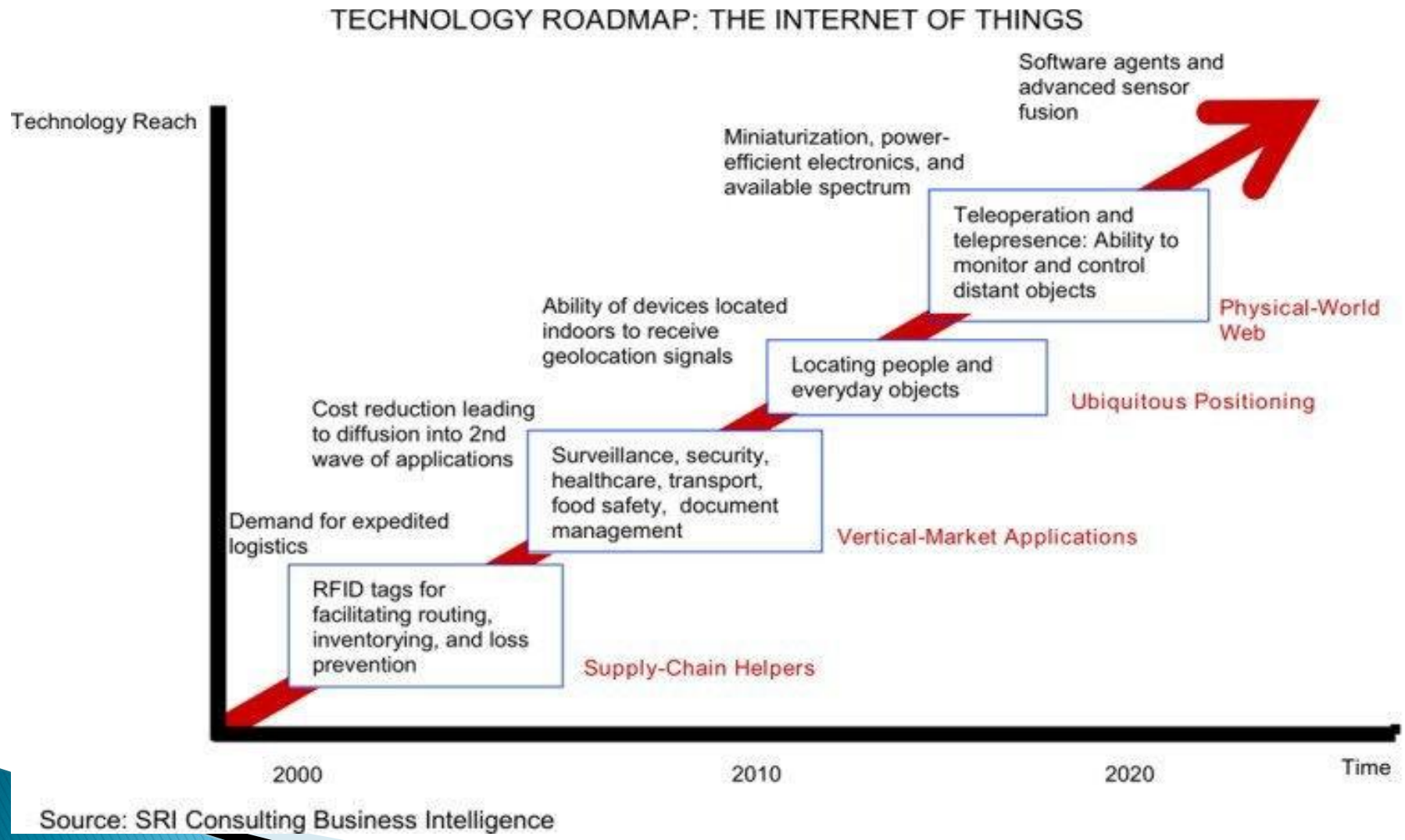
- **Google Edge TPU, NVIDIA Jetson, AWS Greengrass**
  - **Used for:** AI/ML processing directly on IoT and edge devices.
  - **Example:** Autonomous vehicles making instant decisions using edge AI.

Internet of Things

- It connects "Things" (devices) to the "Internet"
- The **Internet of Things** refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure.
- The Internet of Things (IoT) refers to a network of physical devices embedded with sensors, software, and connectivity that allows them to collect and exchange data over the internet. These devices can range from smart home appliances and wearable fitness trackers to industrial machinery and smart city infrastructure.

- The term Internet of Things was first used by Kevin Ashton in 1999.
- Ashton envisioned RFID (Radio-Frequency Identification) as a way for everyday objects to communicate over networks.

The Internet of Things : Enabling Technologies



Source: SRI Consulting Business Intelligence

The Internet of Things : Enabling Technologies

- 2000–2005 – First IoT Applications
- 2000: LG announced the first smart refrigerator, which could connect to the internet.
- 2003-2004: The adoption of RFID & wireless sensor networks (WSN) expanded IoT applications in logistics and industrial automation.

- 2008-2009 – IoT Becomes Mainstream
- 2008: The number of connected devices exceeded the global population for the first time.
- 2009: Google started testing self-driving cars, integrating IoT sensors and AI.
- 2010-2015 – Smart Homes, Wearables & Industry 4.0

•Amazon Alexa, Google Nest, and Apple HomeKit made smart home IoT mainstream.

•First IoT botnet (Carna Botnet) demonstrated security risks in IoT.

The Internet of Things : Enabling Technologies

- **2016-2019 – Security, 5G, and AI-driven IoT**
- AI-driven IoT applications expanded in healthcare, finance, and agriculture.
- **Blockchain for IoT** emerged to improve data security.
- **Tesla's AI-powered self-driving cars**
- **2020-2025 – AI, 5G, and Smart Citi real-time IoT decision-making.**

•The **COVID-19 pandemic** accelerated IoT adoption in healthcare, remote work, and smart supply chains.
•**IoT-powered smart cities** expanded globally (smart traffic, waste management, and surveillance).
•Autonomous IoT devices (drones, robots, smart assistants) gained traction.
•**AI-driven IoT security** is improving protection against cyber threats.

The Internet of Things : Enabling Technologies

- IoT has evolved from simple RFID tracking to **AI-driven automation, 5G networks, and smart cities**. As **6G, quantum computing, and edge AI** advance, the future of IoT will be **more secure, intelligent.**

The Internet of Things : Enabling Technologies

Table 9.6 Enabling and Synergistic Technologies for the IoT

Enabling Technologies	Synergistic Technologies
Machine-to-machine interfaces	Geotagging/geocaching
Protocols of electronic communication	Biometrics
Microcontrollers	Machine vision
Wireless communication	Robotics
RFID	Augmented reality
Energy harvesting technologies	Telepresence and adjustable autonomy
Sensors and sensor networks	Life recorders and personal black boxes
Actuators	Tangible user interfaces
Positioning or location technology (GPS)	Clean technologies
Software engineering	Mirror worlds

The Internet of Things : Enabling Technologies

- (IoT)Enabling Technologies
- Machine-to-machine interfaces-**Smart meters** automatically reporting electricity usage to power companies.
- Protocols of electronic communication
- Microcontrollers-ARM Cortex-M series (used in industrial IoT devices).
- Raspberry Pi (SBC) (used for AI and edge computing application
- Wireless communication-Wi-Fi, Bluetooth, LoRAWAN,5G
- RFID-Logistic,security
- Energy harvesting technologies-solar -Traffic light,thermal energy-Industrial IOT
- Sensors and sensor networks Temperature,motion,humidity,air quality
- Actuators -Hydraulic Actuator, Relay Switch-Smart lighting, IoT-controlled appliances
- Positioning or location technology (GPS)fleet management,asset tracker
- Software engineering, embedded s/w security cloud middleware

Protocols of electronic communication

Protocol	Description	Use Cases
MQTT (Message Queuing Telemetry Transport)	Lightweight, energy-efficient protocol for IoT devices	Smart homes, industrial IoT
CoAP (Constrained Application Protocol)	Optimized for resource-limited IoT devices	Wearables, smart grids
HTTP/HTTPS	Standard web protocol	Cloud-based IoT applications
Zigbee & Z-Wave	Short-range, low-power protocols	Home automation
LoRaWAN	Long-range, low-power network	Smart agriculture, logistics
Bluetooth Low Energy (BLE)	Short-range, energy-efficient	Wearables, medical devices

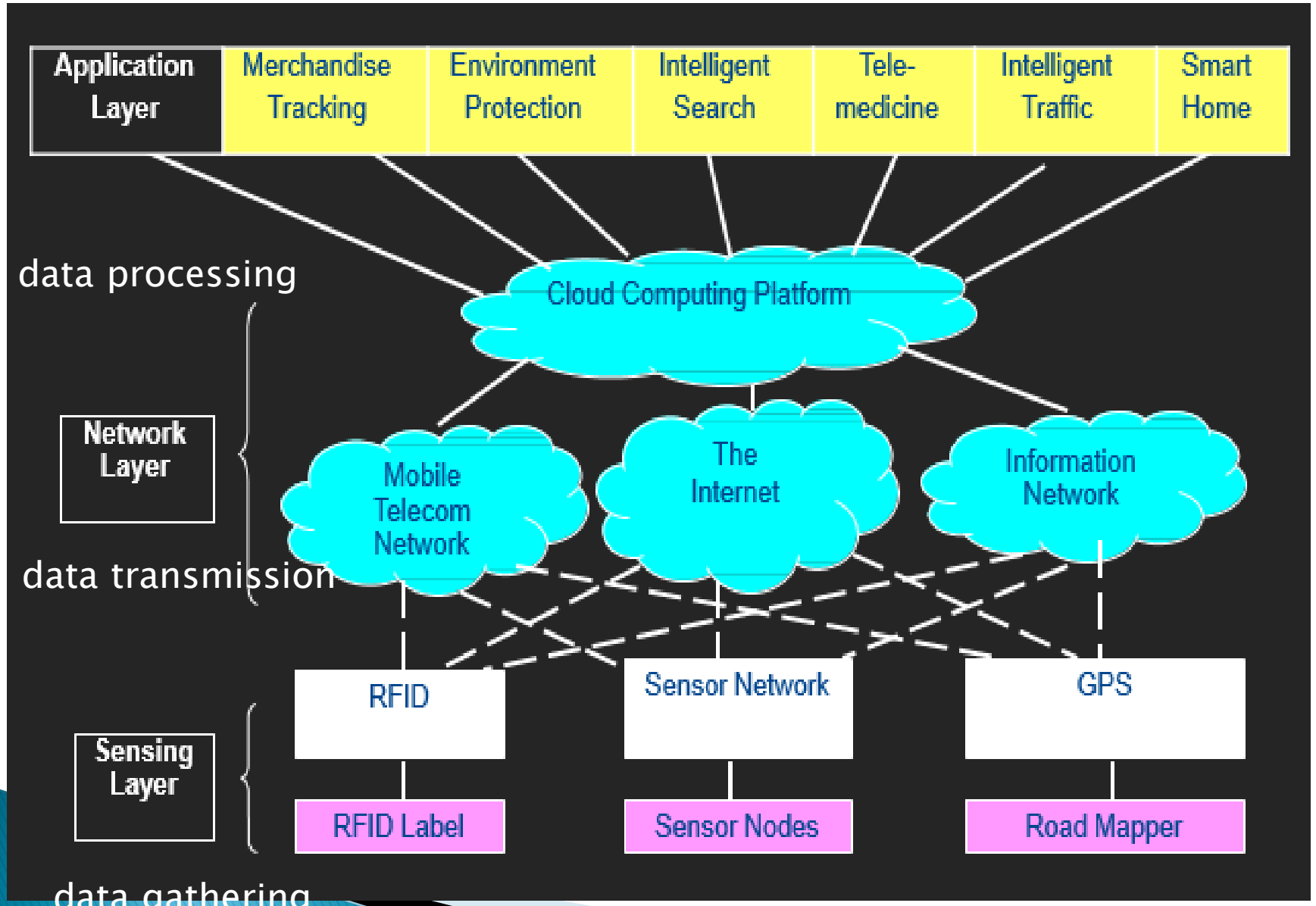
The Internet of Things : Enabling Technologies

- Synergistic Technologies:Different technologies work together seamlessly.
- Geotagging/geocaching-social media.tourism,
- Biometrics-security,authentication,healthcare
- Machine vision-Medical Imaging, Autonomous Vehicles
- Robotics-**Industrial Robots** , Autonomous Robots, **Medical Robots** ,
- Augmented reality-Pokémon GO, IKEA, Sephora, **Education & Training**
- Telepresence and adjustable autonomy-
- Life recorders and personal black boxes-**Personal Security,** Fitbit
- Tangible user interfaces-Smart Surfaces, VR gloves, Gesture Control
- Clean technologies-Electric Vehicles (EVs), **Renewable Energy**
- Mirror worlds-**Smart Cities** , Healthcare

The Internet of Things : Enabling Technologies

- **Synergistic Technologies** refers to different technologies that, when combined, enhance each other's effectiveness, leading to greater efficiency, innovation, and performance than they could achieve individually.
- **Geotagging**: Attaching location metadata (GPS coordinates) to digital content (photos, social media posts, etc.).
- **Geocaching**: A real-world treasure hunting game where participants use GPS devices to hide and seek objects.
- **Telepresence**: Remote interaction via robots or VR (e.g., video conferencing).
- **Adjustable Autonomy**: Machines that switch between human control and automation based on tasks.
- Life Recorders & Personal Black Boxes:Devices that continuously **record personal data (video, audio, biometrics, or activity logs)** for security, memory enhancement, and tracking.
- Tangible user interfaces allow **physical interaction with digital systems**, blending the virtual and real worlds.
- Clean technologies focus on **sustainable energy and eco-friendly solutions** to reduce environmental impact.
- Mirror worlds are **digital replicas of the real world** using AI, VR, and IoT.

Architecture of The Internet of Things



Architecture of The Internet of Things

The **Internet of Things (IoT) architecture** consists of multiple layers that enable seamless connectivity, data processing, and intelligent decision-making.

1) Sensing Layer,
2) Network Layer,
3) Data processing Layer, and
4) Application Layer.

Architecture of The Internet of Things

- 1. Perception Layer (Sensing Layer):The perception layer consists of **physical devices and sensors** that collect real-world data.
- **Sensors & Actuators** – Measure temperature, humidity, motion, light, etc.
  RFID (Radio Frequency Identification) – Enables object tracking.
  Cameras & Vision Sensors – Used in security and automation.
  Microcontrollers & Embedded Systems – Process sensor data.
  - **Example Use Case:**
- **Smart Homes**: Temperature sensors in a thermostat detect room temperature.
- **Smart Agriculture**: Soil moisture sensors track water levels in fields.

Architecture of The Internet of Things

2) Network Layer (Transmission Layer):This layer **transmits data** from the perception layer to processing centers.

- includes protocols and technologies that enable devices to connect and communicate
- **Wireless Communication** – Wi-Fi, Bluetooth, Zigbee, LoRaWAN
  Cellular Networks – 4G, 5G, LTE, NB-IoT
  Wired Networks – Ethernet, fiber optics
  Satellite Communication – Used for remote IoT applications
- Example: A **smartwatch** transmits heart rate data to the cloud via Wi-Fi

Architecture of The Internet of Things

3) Processing Layer (Cloud Layer):Handles **large-scale data storage, analysis, and decision-making**.

- **Key Technologies:**

- **Cloud Platforms** – AWS IoT, Microsoft Azure IoT, Google Cloud IoT.

  Big Data Analytics – AI-based insights for business intelligence.

  Databases & Storage – SQL, NoSQL, distributed storage.

•**Smart healthcare** stores patient data in the cloud for remote diagnosis.

•**Predictive maintenance** in factories uses AI to analyze equipment data.

Architecture of The Internet of Things

4) Application Layer (User Interface):Provides **user-friendly interfaces** for monitoring, control, and automation.

- **Mobile & Web Apps** – IoT dashboards, control panels.
  AI & Voice Assistants – Alexa, Google Assistant for smart home control.
  APIs & Protocols – MQTT, CoAP, REST APIs for device communication.
- **Smart Home Apps** allow users to control lights, locks, and appliances remotely.

Architecture of The Internet of Things

Layer	Function	Examples
1. Perception Layer	Sensors collect real-world data	Temperature sensors, RFID, cameras
2. Network Layer	Transmits data from devices to cloud	Wi-Fi, 5G, Zigbee, LoRaWAN
3. Edge Layer	Processes data locally	Edge AI, microcontrollers, IoT gateways
4. Processing Layer	Cloud-based analytics & storage	AWS IoT, Azure IoT, Big Data
5. Application Layer	User interface & automation	Smart home apps, AI assistants

Internet of Things

- Smart and pervasive cloud applications for individuals, homes, communities, companies, and governments, etc.
- Coordinated calendar, itinerary, job management, events, and consumer record management (CRM) services
- Coordinated word processing, on-line presentations, web-based desktops, sharing on-line documents, datasets, photos, video, and databases, content distribution, etc.
- Deploy conventional cluster, grid, P2P, social networking applications in
- the cloud environments, more cost-effectively.
- Earthbound applications that demand elasticity and parallelism to avoid large data movement and reduce the storage costs

RFID

- RFID = Radio Frequency Identification.
- Wireless technology used for **identifying, tracking, and managing objects, animals, and people**
- consists of RFID **tags**, **readers**, and a **backend system** for data processing.
- An ADC (Automated Data Collection) technology that:
  - uses radio-frequency waves to transfer data between a reader and a movable item to identify, classify and 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.

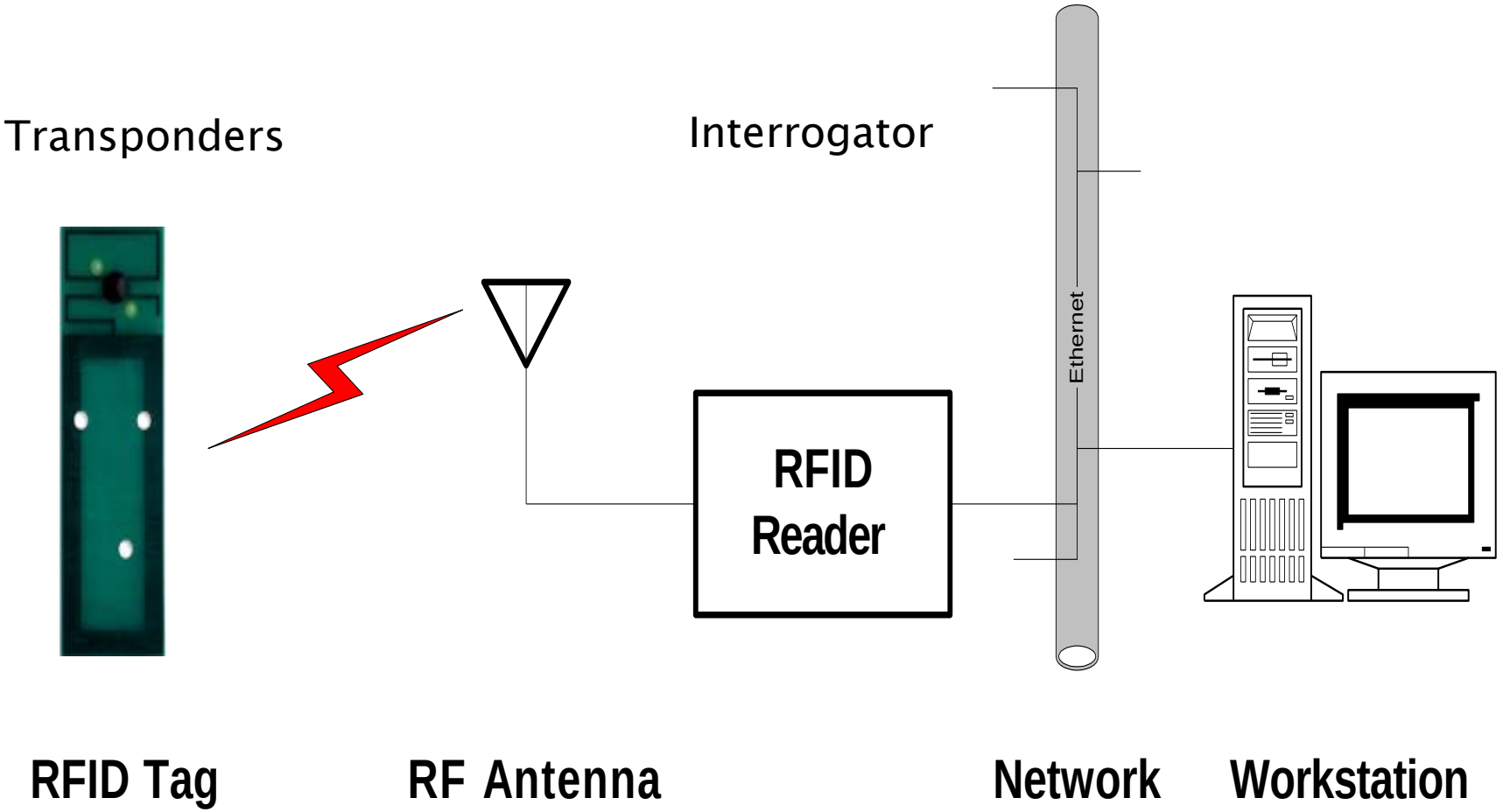
RFID Brief History

- RFID (Radio Frequency Identifier) an Auto-ID data collection system surveillance, using RF waves for Identifying, Tracking and doing Management of material flow.

- Invented and used from early 1940, commercial operation begun from 1960 and more active work start from 1970.

- Most common application were tracked person and objects, identified goods in supply chain, reusable container, high value tools, security, controlling access to building, networks, payment systems and other assets

RFID

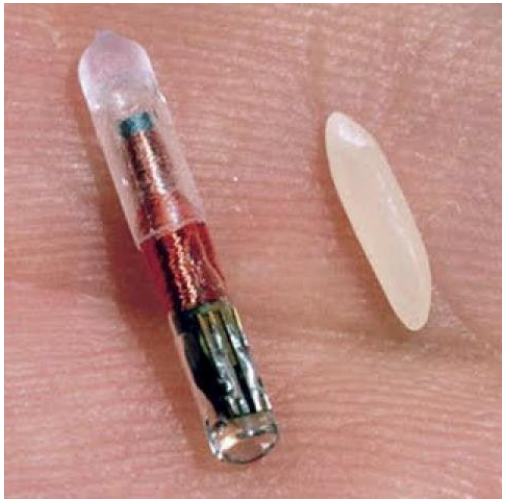

Transponders
Interrogator
Ethernet
RFID
Reader
RFID Tag
RF Antenna
Network
Workstation

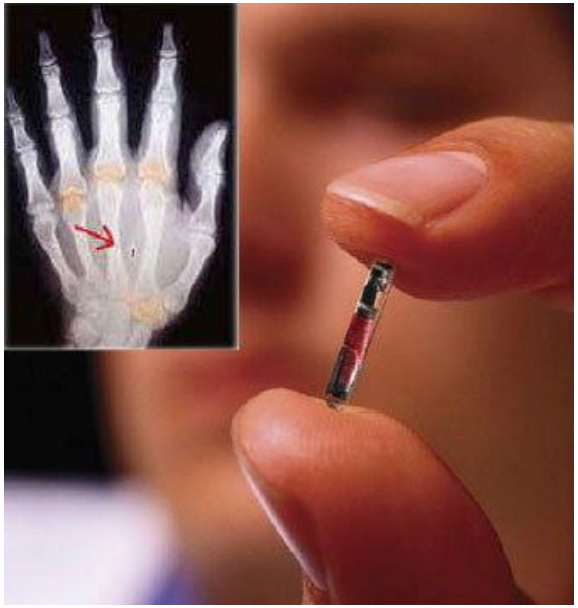
RFID Components

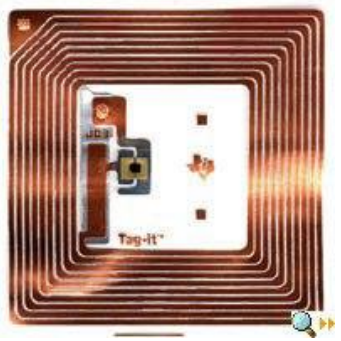
1. **RFID Tags (Transponders):**
   - Attached to objects for identification.
   - Contains a **microchip** (stores data) and an **antenna** (transmits signals).
   - **Types of RFID Tags:**
     - **Passive** – No battery, powered by reader's signal (used in retail, access control).
     - **Active** – Has a battery for longer range (used in logistics, toll collection).
     - **Semi-Passive** – Battery-powered but activated by a reader.
2. **RFID Reader (Interrogator)**
   - Sends and receives radio signals to/from tags.
   - Connected to a database for real-time tracking.
3. **Antennas**
   - Captures and transmits signals between the tags and the reader.
4. **Communication Network**
   - Connects the reader to a **central database** using Wi-Fi, IoT, LAN, or cloud storage.
5. **Backend System (Database/Software)**
   - Stores and processes RFID data.

RFID : Radio Frequency IDentification Technology

- RFID refers to small electronic devices that consist of a small chip and an antenna.
- Chip typically can carry 2,000 bytes of data or less.







RFID chip next to a grain of rice. This chip contains a radio-frequency electromagnetic field coil that modulates an external magnetic field to transfer a coded identification number when queried by a reader device. This small type is incorporated in consumer products, and even implanted in pets, for identification.

http://en.wikipedia.org/wiki/Radio-frequency_identification

RFID tags

- RFID tags are classified based on power source, frequency range, and application, how data is stored and modified..

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

- **Passive Tags**
  - Do not require power – Draws from Interrogator Field
  - Lower storage capacities (few bits to 1 KB)
  - Shorter read ranges (4 inches to 15 feet)
  - Usually Write-Once-Read-Many/Read-Only tags
  - **Used in**: Retail (inventory tracking), access control, library books, passports.
- **Active Tags**
  - Battery powered
  - Higher storage capacities (512 KB)
  - Longer read range (300 feet)
  - More expensive
  - Read-Write Memory
  - **Used in**: Vehicle tracking, toll collection, asset monitoring in industries.

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
    - ID cards
- 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
    - Electronic toll collection (vehicle ID tags)
- Read/Write
  - Tag data can be changed over time
  - Enables real-time tracking and dynamic updates.
  - Smart passports (updating travel history)

RFID tag memory

Special RFID Tags

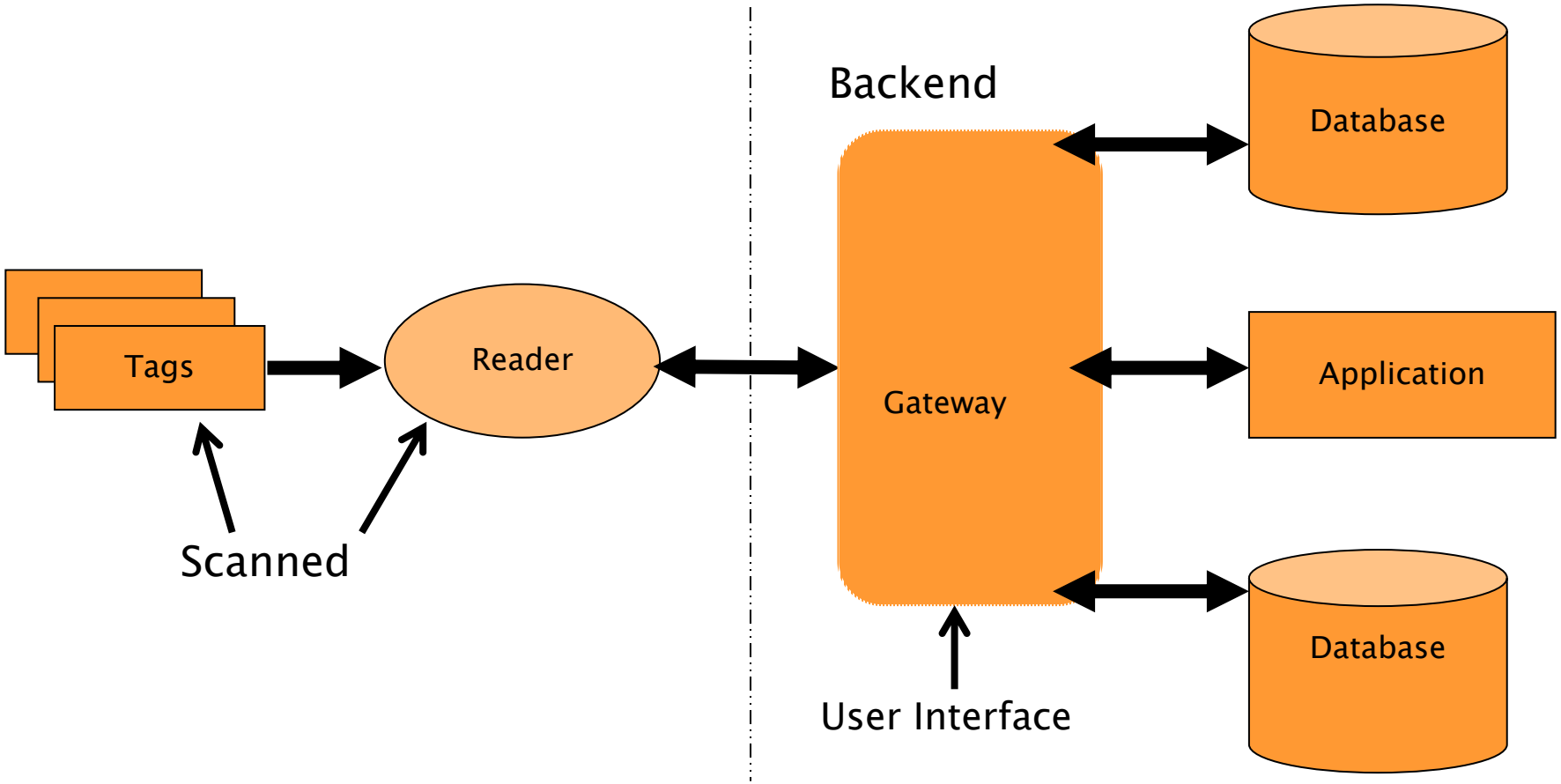
- **NFC (Near Field Communication) Tags;HF RFID** that works at very close range (a few centimeters).
- Used in **contactless payments, smart cards, and mobile payments** (Google Pay, Apple Pay).
- **On-Metal RFID Tags**:designed to **work on metallic surfaces** without interference.
- Used in **automobile manufacturing, industrial tracking, and tool management.**
- **Tamper-Proof RFID Tags**:Break or deactivate when removed to **prevent fraud**.
- Used in **secure access badges, vehicle registration plates, and anti-theft systems**.

RFID Frequencies

	Frequency band	Date Rate	Size of Tag Antenna	Read Range
LF	125 kHz to 134.2 kHz	Low Data Rate	Large	Lower
HF	13.56 MHz	High Data rate	Small	Long
UHF	860 to 915 MHz	High Data rate	Small	Long
MF	2.45 GHz to 5.8 GHz	High Data rate	Small	Long

- However, the UHF system does not work very well in the presence of metallic objects, water and the human body, compared to the LF system.

RFID Architecture



RFID Architecture

- Firstly items-tag are scanned by reader;
- Secondly in backend transmitted data coming through antenna (RF-wave) are being recognized by RFID-based system PC. It acts as a middleware communication gateway among items, reader and system database;
- And at the end it filters out and store data in RFID-databases for checking the data fault and relevant operation.

RFID readers

- **The reader emits radio waves** using an antenna.
- **RFID tags receive the signal** and send back their data.
- **The reader captures the tag data** and sends it to a connected system (computer, cloud, etc.).
- **The system processes the data** for tracking, authentication, or automation.
  - Can read 100-300 tags per second
- Readers (interrogators) can be at a fixed point such as Entrance/exit -Airport baggage tracking
- Readers can also be mobile/hand-held-Event management (checking tickets)
- Integrated RFID Readers-Smart toll booths

RFID Architecture

- Controller activates RFID reader to send RF signals
- Reader sends the signal of appropriate frequency
- Tag receives and modifies the signal
- Tag sends modified signals back through tag antenna
- Reader antenna receives the modified signal and reader decodes it
- Controller analyzes the results

RFID and Smart Sensors

- Sensors can be integrated with RF tags (Smart Sensors) and sensor data can be communicated using RF waves

- This enables RFID systems to gather and process sensor data in addition to identifying and tracking object

- Applications:

  Machine Health Monitoring, Fluid Composition Detection.

RFID Reader Antenna

- Antennas are generally the largest and the most visible component of an RFID system.

- The size of the antenna depends on the operating frequency. The size of the reader antennas are usually of the order of wavelength.

- For example, the size of the reader antenna in an UHF system is about 200 to 300 mm. The reader antenna of an HF system can be as large as a meter in size.

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
- Durable & Weather-Resistant
- Can be combined with barcode technology

RFID Advantages

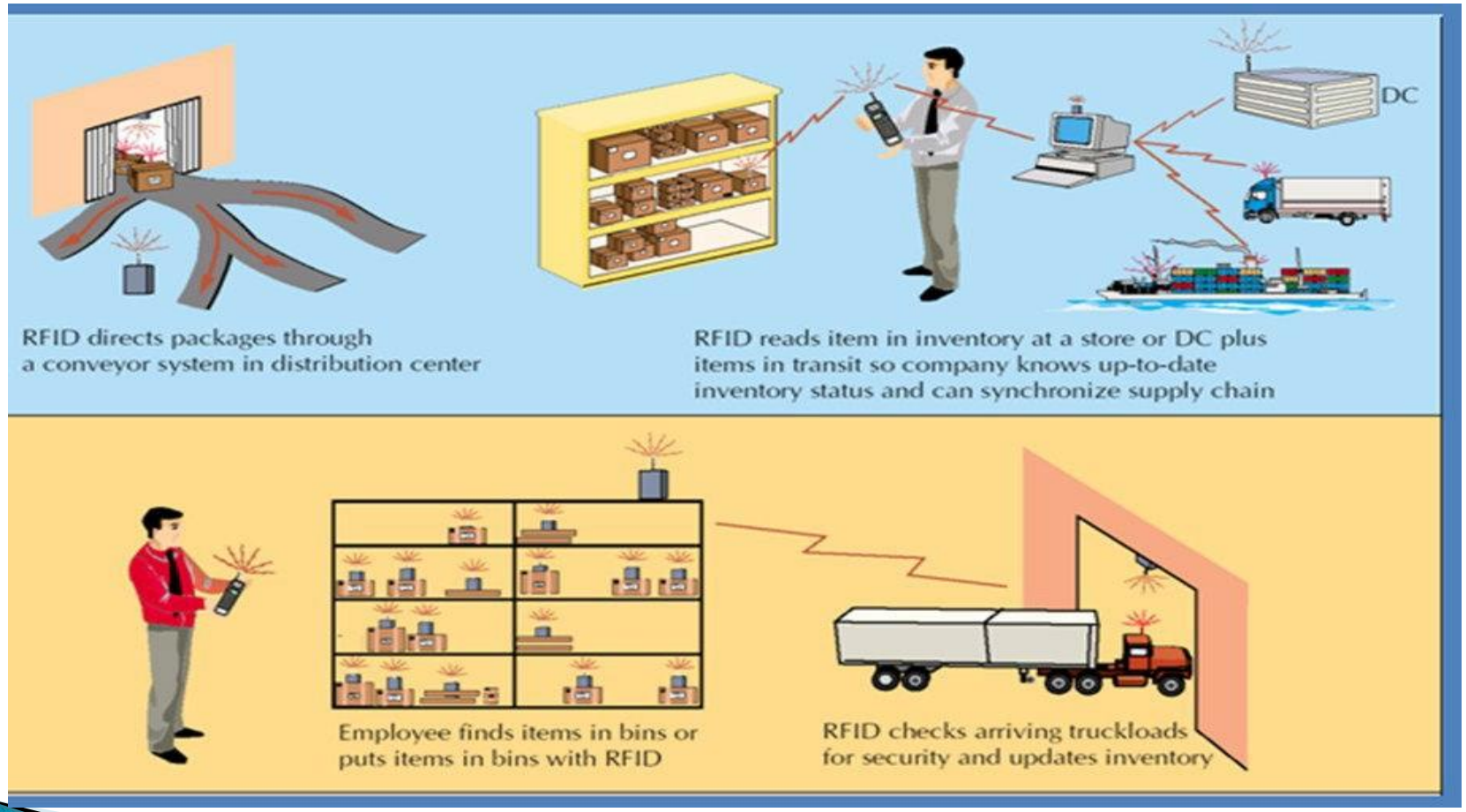
- An AUTO-ID based System
- A method for controlling inventory
- Automatically identify objects
- Saving Time and Money
- Non-Line-Sight Communication
- Minimize Work Stress of Staff
- Offering Self Check out/in
- Gathering statistics on used Items
- Improve Customer Services And
- Easily Prevent Theft

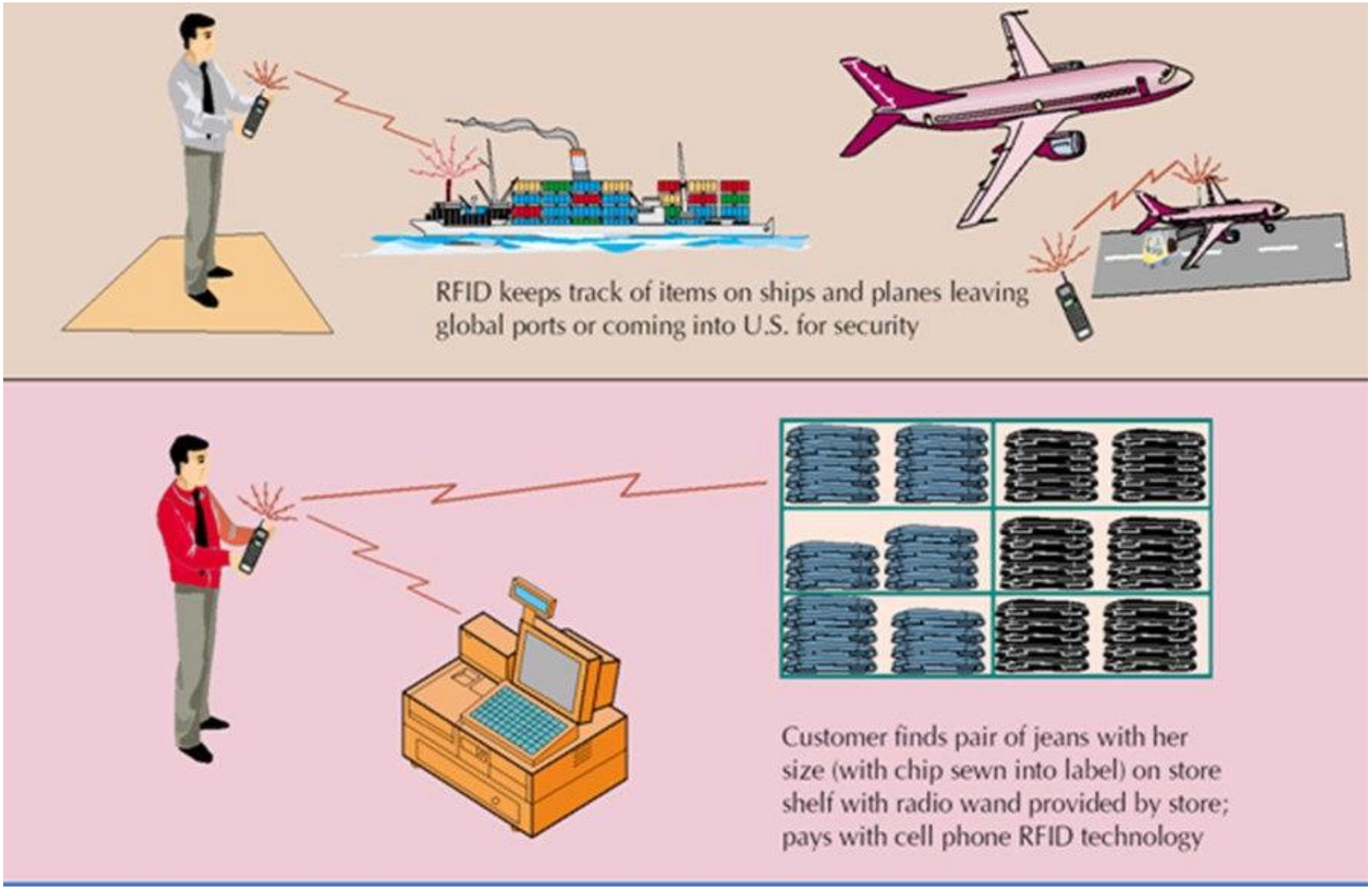
RFID applications

- **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

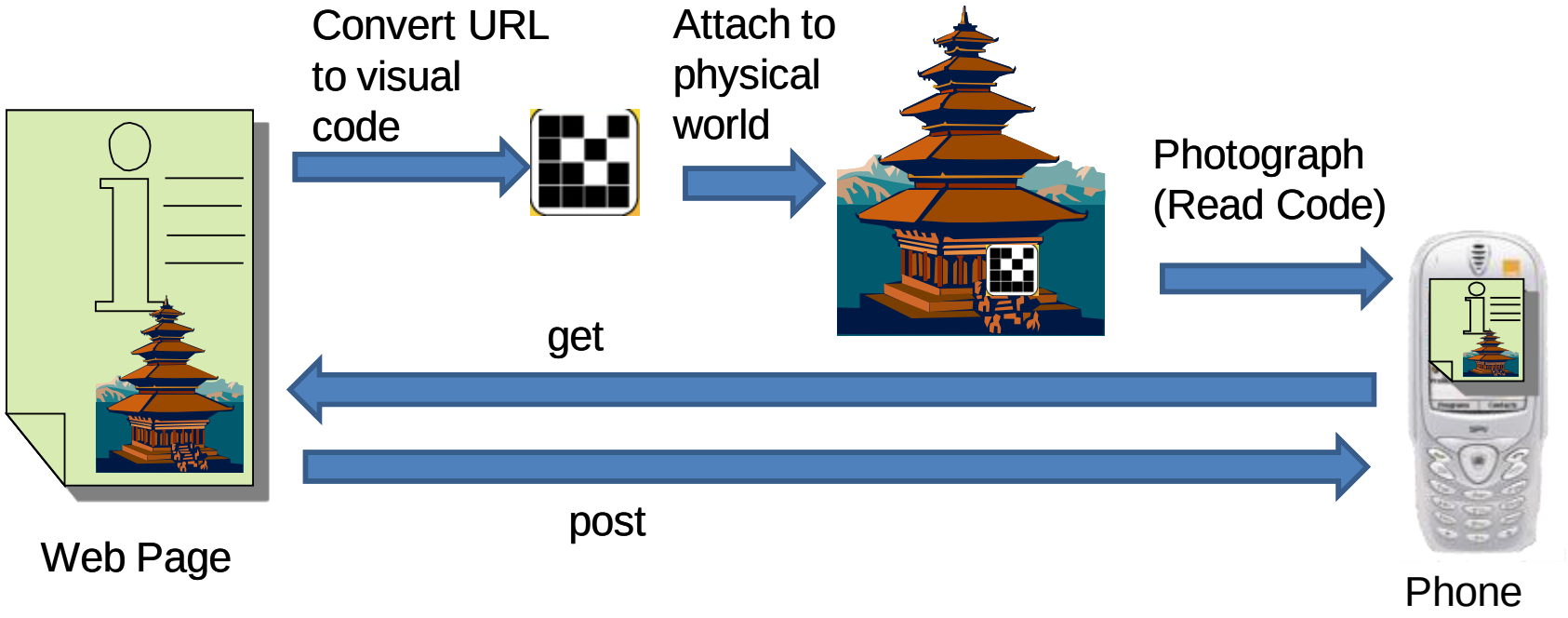
Retail and logistics : How RFID Works in Business Sales

RFID Merchandize Tracking in Distribution Center





Semacode


Convert URL
to visual
code
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UbiComp Components

- Radios
- Sensors
- Microcontrollers
- Platform Softwares
- Application Software
- Device
- Airtime
- Service