Distributed and Cloud Computing

K. Hwang, G. Fox and J. Dongarra

Chapter 9: Ubiquitous Clouds and The Internet of Things

Chapter 9 - Sections 9.3 – 9.4

Adapted from Kai Hwang
University of Southern California
Nov 29, 2012

Internet of Things

- The **Internet of Things** refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure.
- The term Internet of Things was first used by Kevin Ashton in 1999.

The Internet of Things : Enabling Technologies

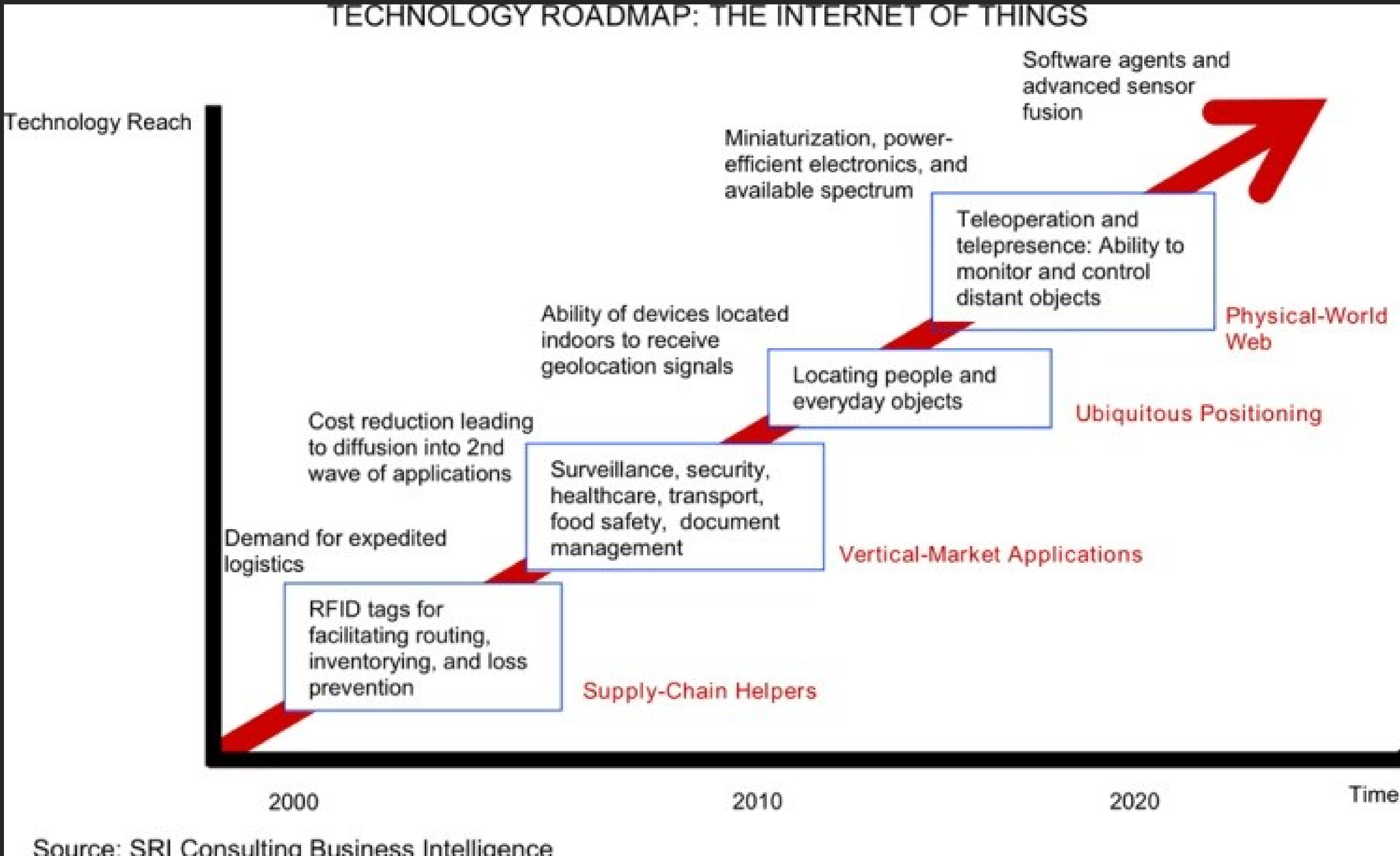
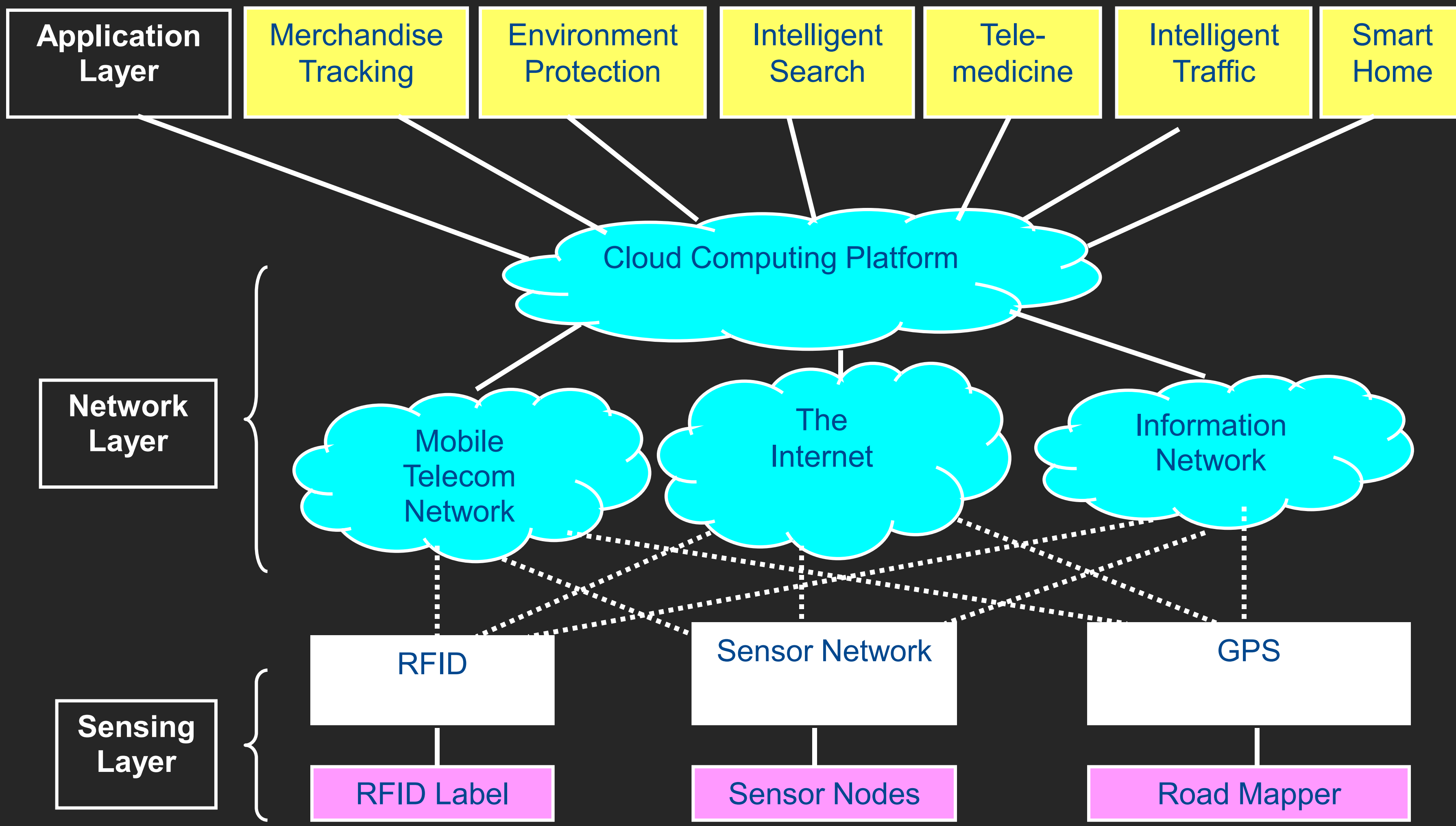


Table 9.6 Enabling and Synergistic Technologies for the IoT

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

Architecture of The **Internet of Things**



Cloud Support of the Internet of Things and Social Network Applications

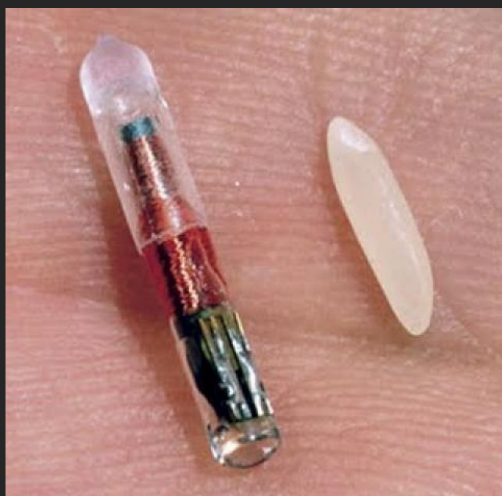
1. Smart and pervasive cloud applications for individuals, homes, communities, companies, and governments, etc.
2. Coordinated calendar, itinerary, job management, events, and consumer record management (CRM) services
3. Coordinated word processing, on-line presentations, web-based desktops, sharing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

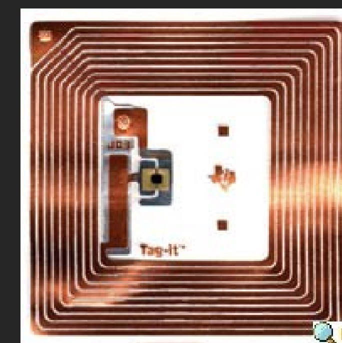
Some Cloud Services To Enable IoT Applications

1. Smart and pervasive cloud applications for individuals, homes, communities, companies, and governments, etc.
2. Coordinated calendar, itinerary, job management, events, and consumer record management (CRM) services
3. Coordinated word processing, on-line presentations, web-based desktops, sharing on-line documents, datasets, photos, video, and databases, etc.
4. Deploy conventional cluster, grid, P2P, social networking applications in cloud environments, more cost-effectively.
5. Earthbound applications that demand elasticity and parallelism rather data movement Costs

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.

An RFID tag used for electronic toll collection.

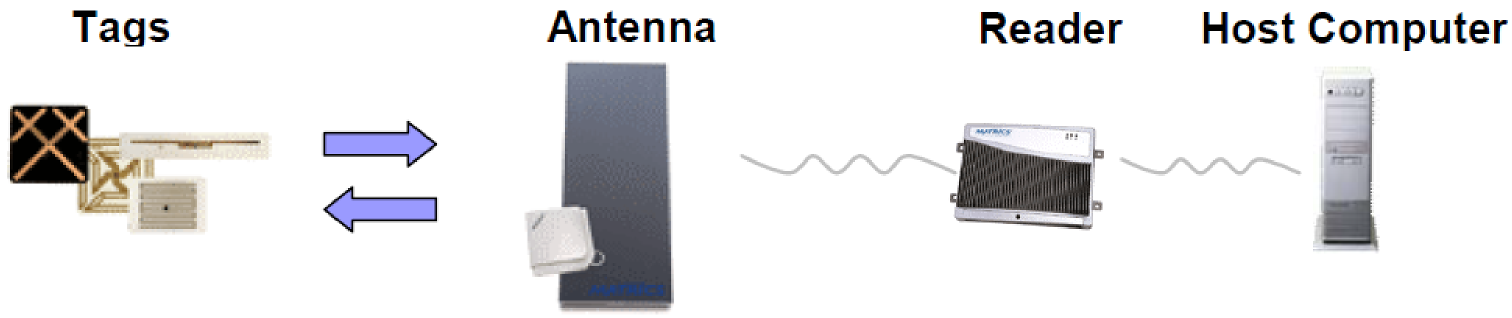
http://en.wikipedia.org/wiki/Radio-frequency_identification

Bar Codes vs. RFID

- tag, backed by data processing system
- line-of-sight
- immutable info
- zero cost (…)

- tag, backed by massive data processing system
- no line-of-sight
- reprogrammable
- non-zero cost
  (target price: 10 cents)
- more dynamic tracking

RFID Technology



Tags

- Device made up of an electronic circuit and an integrated antenna
- RF used to transfer data between the tag and the antenna
- Portable memory
- Read-only or read/write
- Hundreds of tag styles available

Antenna

- Receives and transmits the electromagnetic waves
- One or more antennae attached to a reader

Reader

- Communicates with the tag via antenna
- Receives commands from application software
- Interprets radio waves into digital information
- Provides power supply to passive tags

Host Computer

- Reads/writes data from/to the tags through the reader
- Stores and evaluates obtained data
- Links the transceiver to applications

Figure D-1 Components of a Passive RFID System

RFID Technology

Tags **Reader** **Host Computer**

Tags

- Device made up of an electronic circuit, battery and an integrated antenna
- RF used to transfer data between the tag and the antenna
- Provisions for attaching sensors
- Usually packaged for extreme conditions

Reader

- Listens for tags beaconing
- Receives commands from application software
- Interprets radio waves into digital information
- Sometimes combined with WiFi base

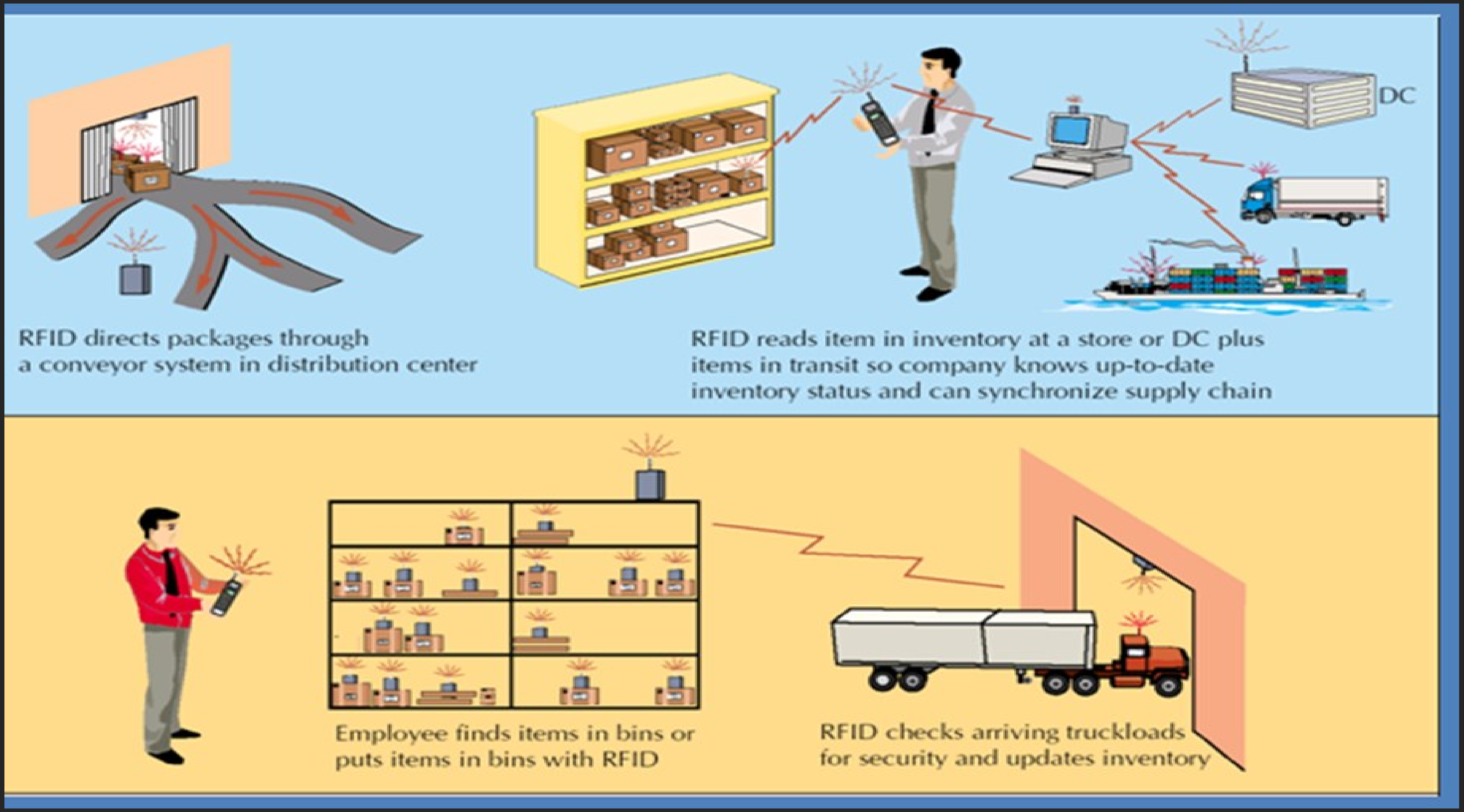
Host Computer

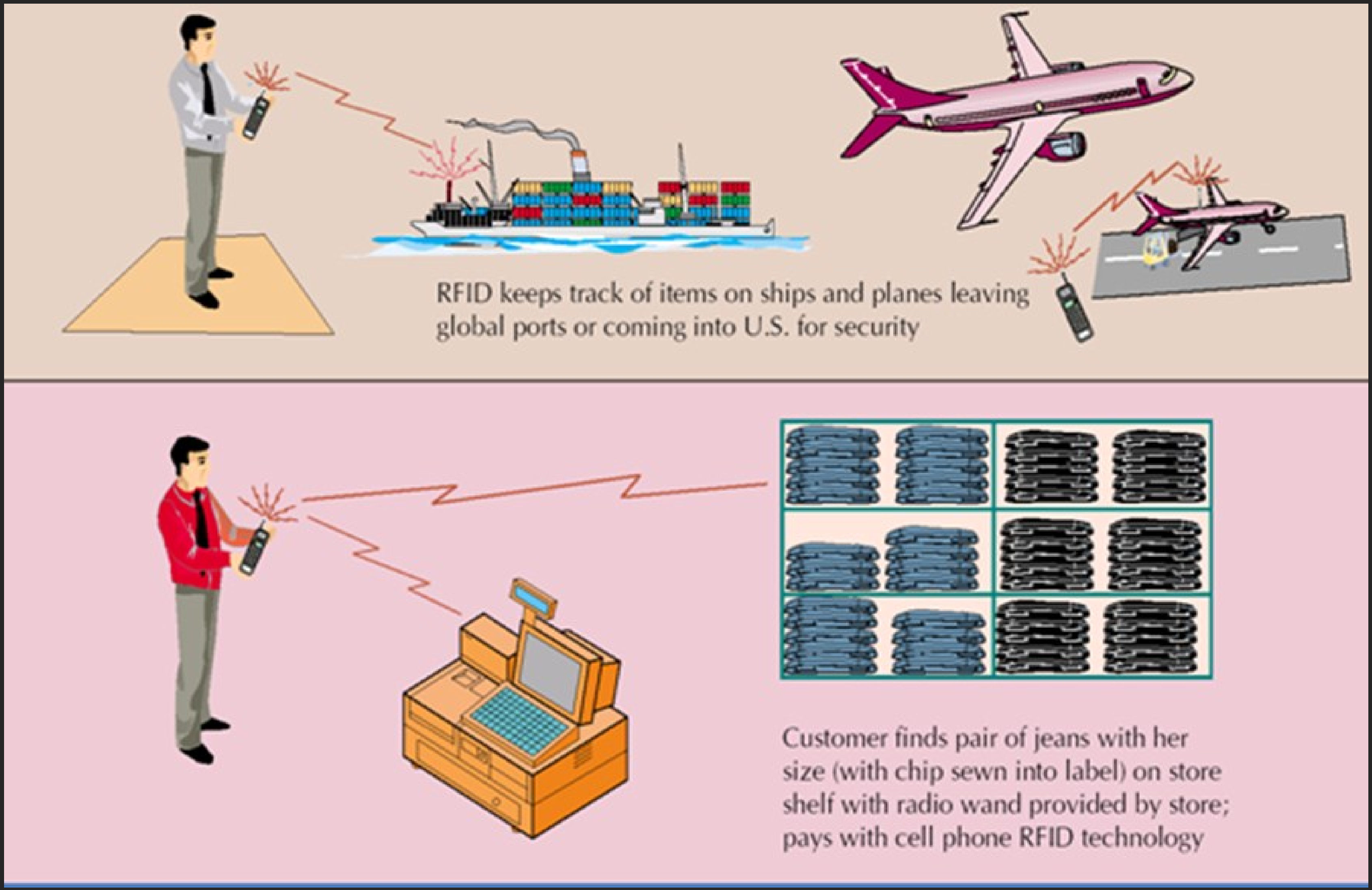
- Reads data from the tags through the reader
- Stores and evaluates obtained data
- Coordinates data from many readers to provide positioning information

Figure D-2 Components of an Active RFID System

Retail and logistics : How RFID Works in Business Sales

RFID Merchandize Tracking in Distribution Center

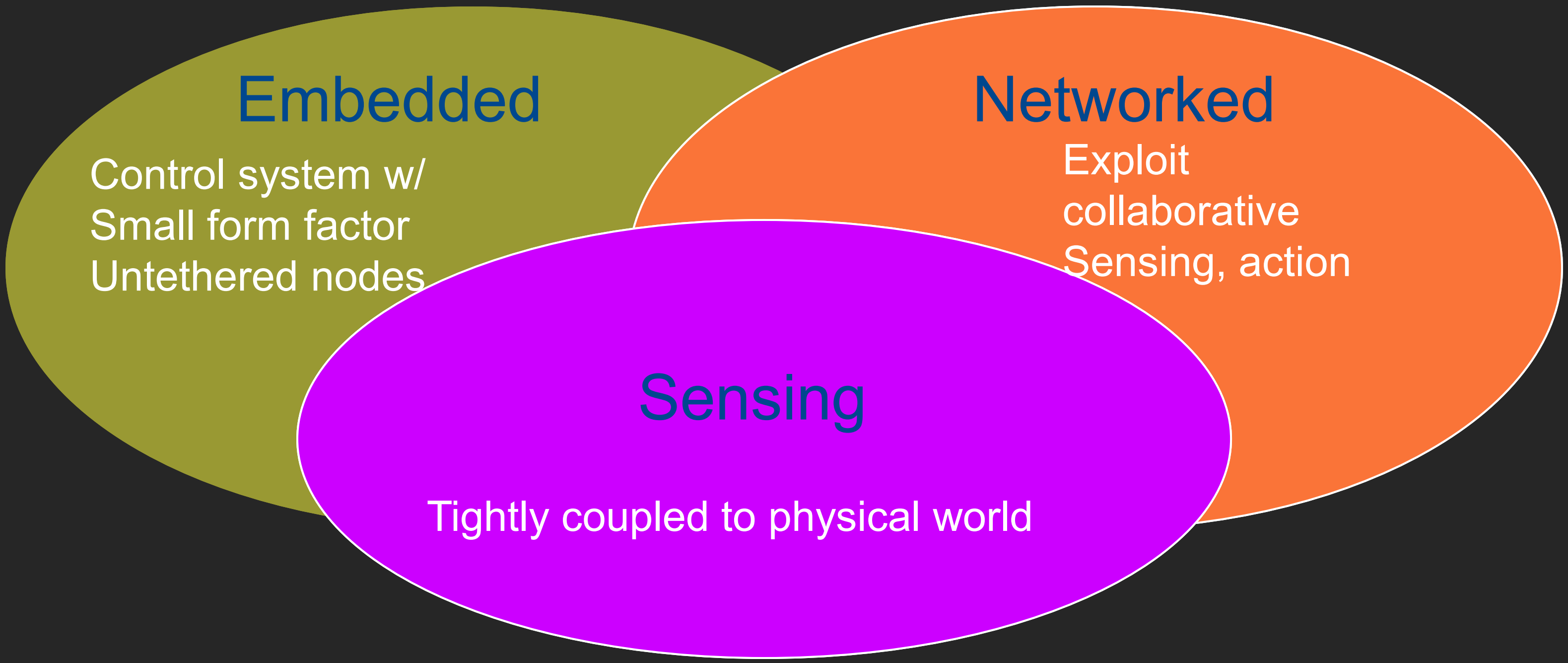



RFID keeps track of items on ships and planes leaving global ports or coming into U.S. for security
Customer finds pair of jeans with her size (with chip sewn into label) on store shelf with radio wand provided by store; pays with cell phone RFID technology

Sensor Nets: Enabling Technologies

Embed numerous distributed devices to monitor and interact with physical world

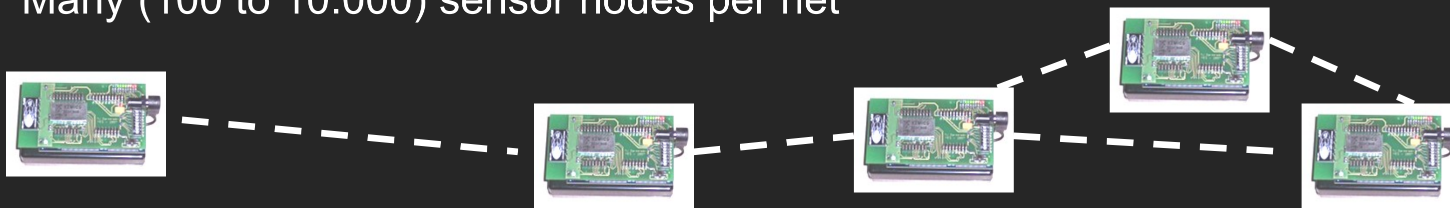
Network devices to coordinate and perform higher-level tasks



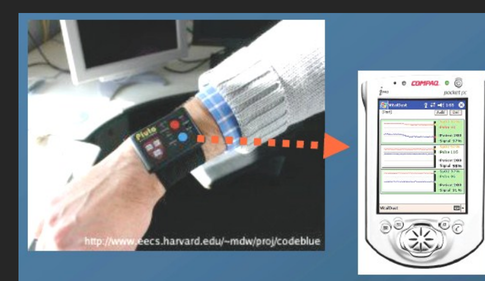
Exploit spatially/temporally dense, in situ/remote, sensing/actuation

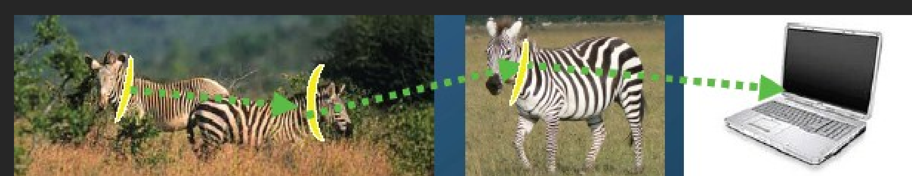
What is a Wireless Sensor Network?

- Self-organizing networks formed by many autonomous sensor nodes
  - Each node comprises its own power supply, processing unit, radio and sensors
  - Typically peer-to-peer communication (no central server)
  - Many (100 to 10.000) sensor nodes per net



- Various Applications: Industrial Automation, Building Control, Health Care, Military, Farming, Traffic Control, Home Automation, ...



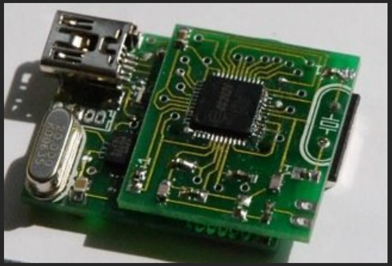


- Visions: „Smart Dust“, „Ambient Intelligence“, …

What are the requirements for a Wireless Sensor Network?

- Must be kept cheap
  because large quantities are required
- Must be robust
  to be deployable in rough environments
- **Must not be power-hungry**
  - To be deployable in remote areas without any infrastructure
  - To keep working for several years without changing of batteries
- Basic functionalities:
  - Sensing
  - Transferring data to a base station where it will be processed


FhG IIS S3-TAG


Porcupine v2.5


Crossbow Telos

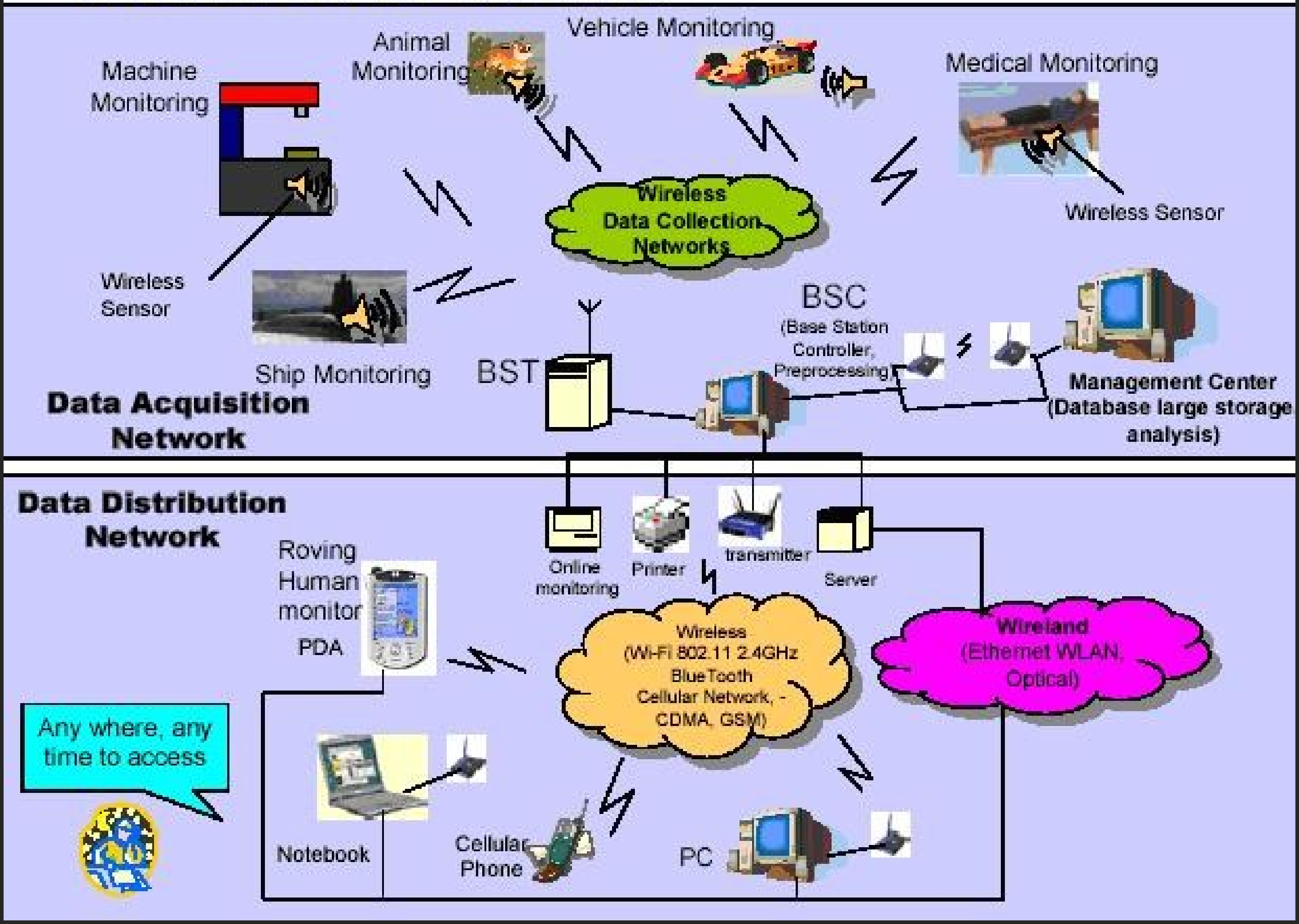

Our own (-:

Wireless Sensor Networks(WSN)

Unique characteristics of a WSN include:

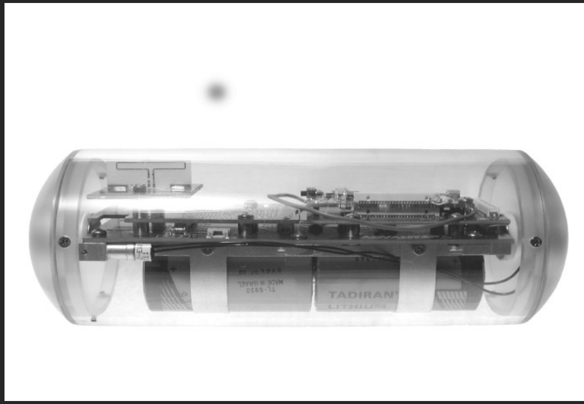
- Limited power they can harvest or store
- Ability to withstand harsh environmental conditions
- Ability to cope with node failures
- Mobility of nodes
- Dynamic network topology
- Communication failures
- Heterogeneity of nodes
- Large scale of deployment
- Unattended operation

Wireless Sensor Networks



WSN Applications

- Wide area monitoring tools supporting Scientific Research
  - Wild life Habitat monitoring projects Great Duck Island (UCB), James Reserve (UCLA), ZebraNet (Princeton.
  - Building/Infrastructure structure study (Earthquake impact)
- Military Applications
  - Shooter Localization
  - Perimeter Defense (Oil pipeline protection)
  - Insurgent Activity Monitoring (MicroRadar)



- Commercial Applications
  - Light/temperature control
  - Precision agriculture (optimize watering schedule)
  - Asset management (tracking freight movement/storage)

What is a mote?

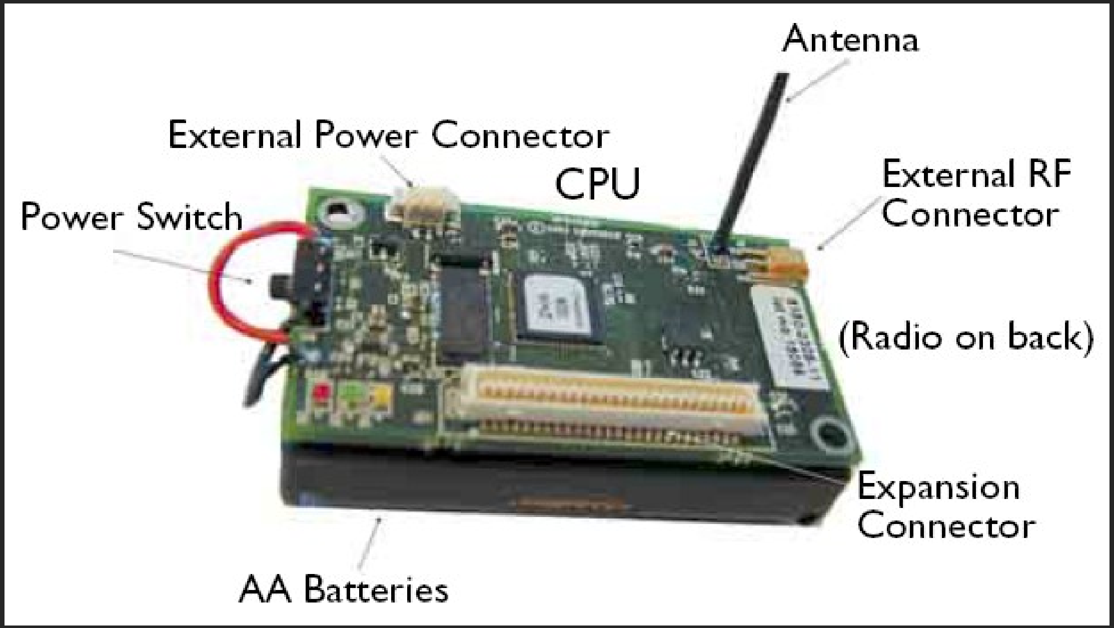
Imote2 06 with enalab camera

- **mote** noun [C] LITERARY
  something, especially a bit of dust, that is so small it is almost impossible to see
  ---Cambridge Advanced Learner's Dictionary
  http://dictionary.cambridge.org/define.asp?key=52014&dict=CALD

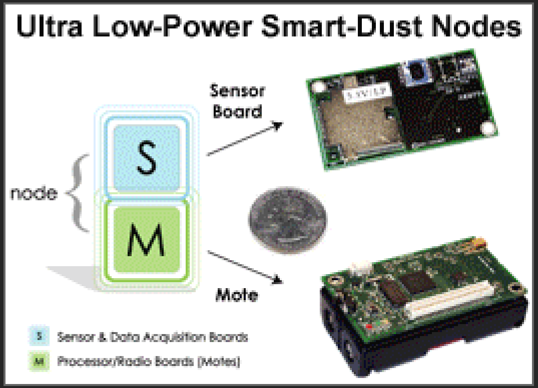
- Sensor Node

Evolution of Sensor Hardware Platform (Berkeley), [Alec Woo 2004]

Mica2 Wireless Sensors
CACM June 2004 pp. 43.



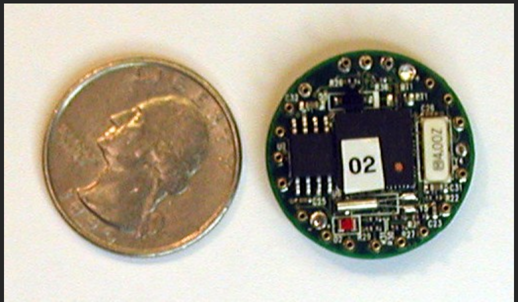
MTS310 Sensor Boards
- Acceleration,
- Magnetic,
- Light,
- Temperature,
- Acoustic,
- Sounder



New MicaZ follows IEEE 802.15.4 Zigbee standard with direct sequence spread spectrum radio and 256kbps data rate

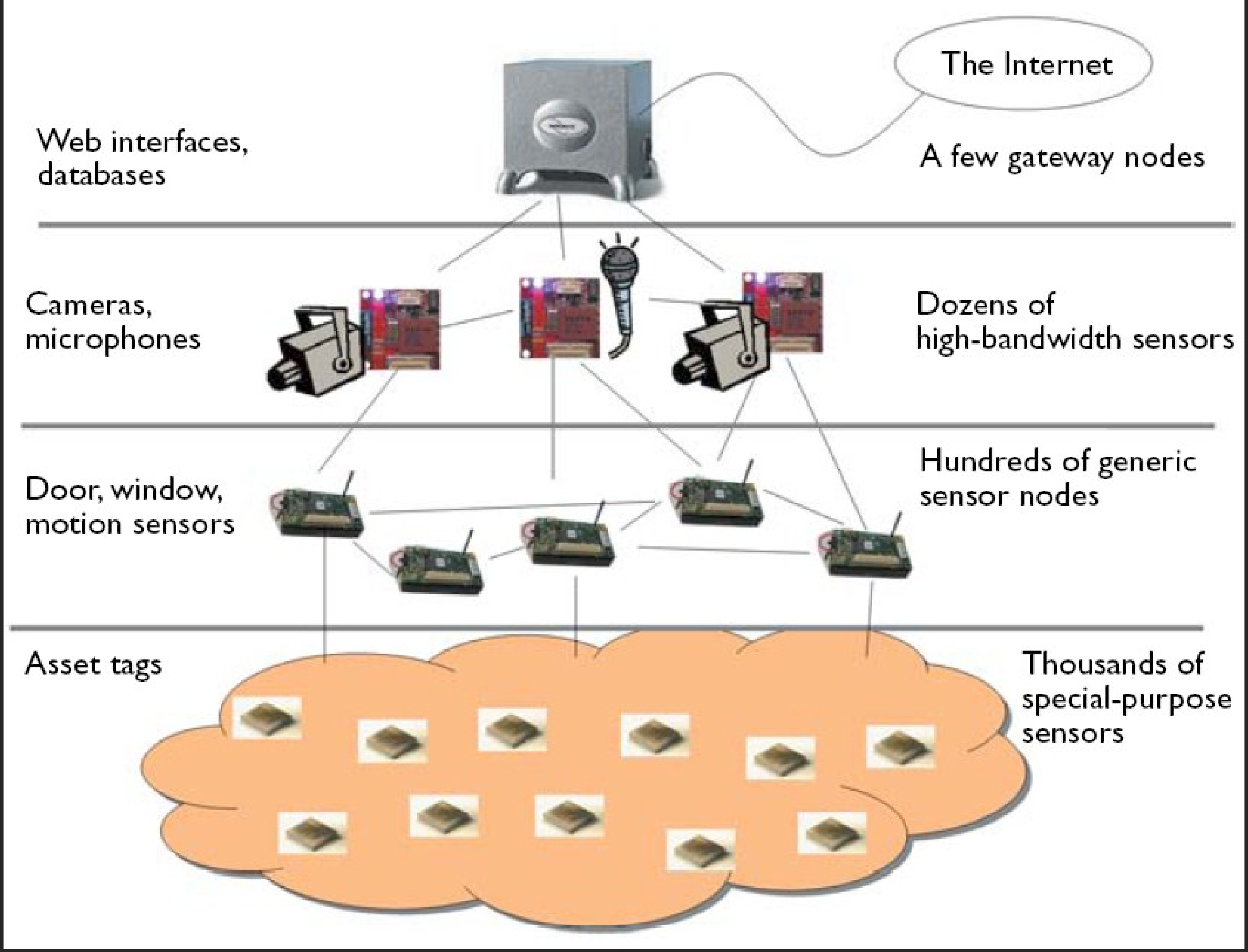
Adapted from Crossbow web site

Motes and TinyOS



- **Motes** (Mica2, Mica2dot, MicaZ)
  - ATMega128L microcontroller
  - 128KB program flash; 512KB measurement Flash; 4KB EEPROM
  - Standard platform with built-in radio chicon1000 (433MHz, 916MHz, 2.4GHz) 38.4kb; 256kbps for MicaZ IEEE 802.15.4. (1000ft, 500ft; 90/300ft) range
  - AA battery
  - Existing TinyOS code base
  - Convenient form factor for adding sensors
- **TinyOS**
  - TinyOS is an open source, BSD-licensed operating system designed for low-power wireless devices, such as those used in sensor networks, ubiquitous computing, personal area networks, smart buildings, and smart meters.

Wireless Sensor Network



Stargate

- 802.11a/b
- Ethernet
- Mica2
- PCMCIA
- Compact flash
- USB
- JTAG
- RS232

Example: *Trains in Time,* Kristian Kloeckl

http://senseable.mit.edu/trainsofdata/

Table 9.7 Wireless Networks for Supporting Ubiquitous Computing

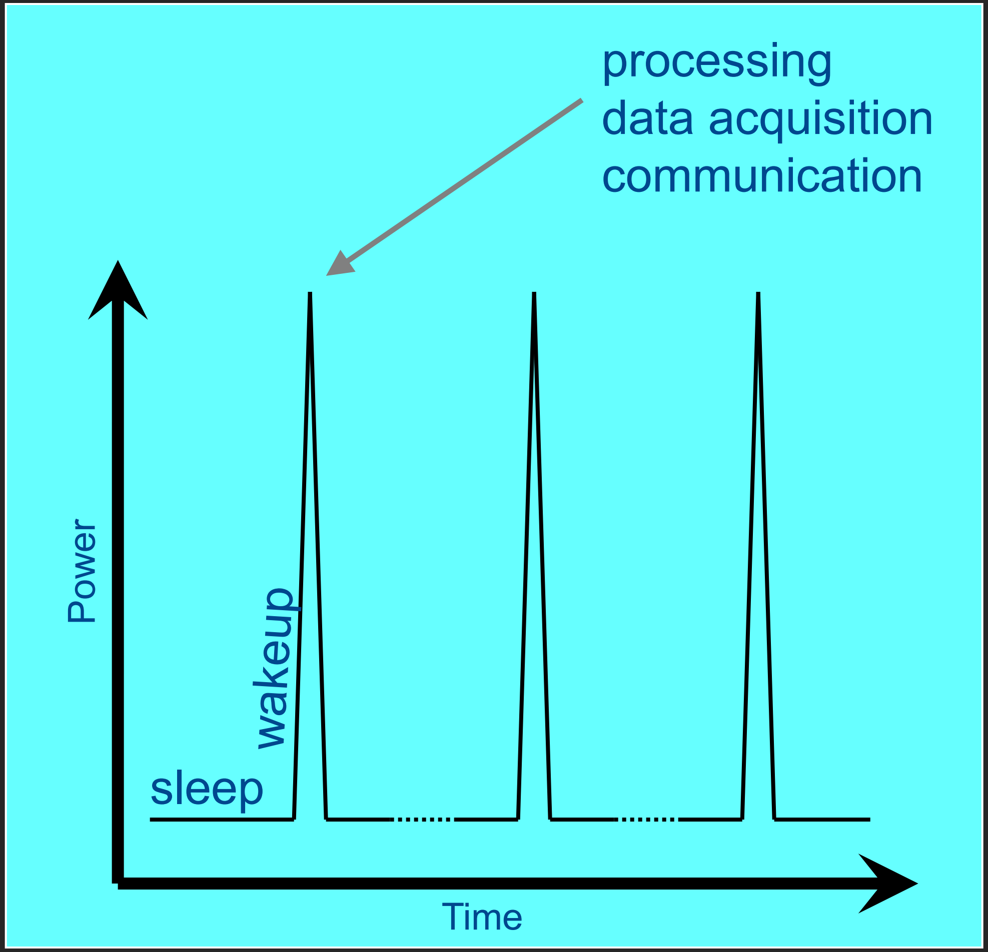
Market Name Standard	ZigBee 802.15.4	GSM/GPRS CDMA/1XRTT	WiFi 802.11g	Bluetooth 802.15.1
Application focus	Monitoring and control	Wide area voice and data	Web, e-mail, video	Cable replacement
System Resources	4 KB–32 KB	18 MB+	1 MB+	250 KB+
Battery Life (days)	100–1,000+	1–7	0.5–5	1–7
Network Size	Unlimited (2^{64})	1	32	7
Bandwidth (Kbps)	20–250	64–128+	54,000+	720
Range (meters)	1–100+	1,000+	1–100	1–10+
Success Metrics	Reliability, power, cost	Reach, quality	Speed, flexibility	Cost, convenience

Table 9.8 Three Generations of Wireless Sensor Networks

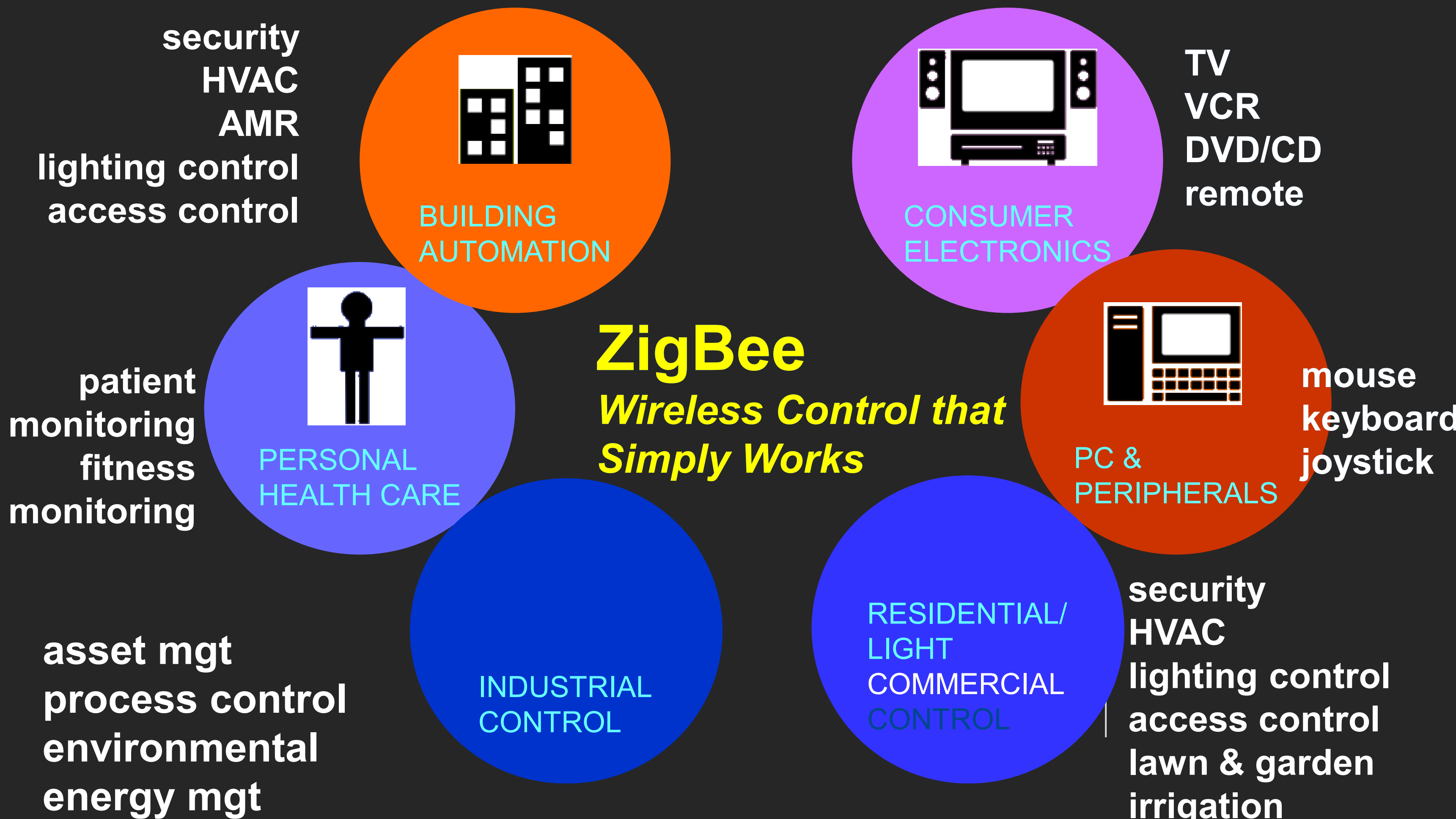
WSN Features	First Generation (1990s)	Second Generation (2000s)	Third Generation (2010s)
Manufacturers	Custom constructors (e.g., for TRSS)	Crossbow Technology, Inc., Sensoria Corp., Ember Corp.	Dust, Inc., and others
Physical Size	Large shoebox and up	Pack of cards to shoebox	Dust particle
Weight	Kilograms	Grams	Negligible
Node Architecture	Separate sensing, processing, and communication	Integrated sensing, processing, and communication	Integrated sensing, processing, and communications
Topology	Point-to-point, star	Client/server, P2P	P2P
Power Supply Lifetime	Large batteries; hours, days, and longer	AA batteries; days to weeks	Solar; months to years
Deployment	Vehicle-placed or air-drop single sensors	Hand-placed	Embedded, sprinkled, left behind

Typical Wireless Sensor Network (WSN) Application Pattern

- **Periodic**
  - **Data Collection**
  - **Network Maintenance**
  - ***Majority of operation***
- **Triggered Events**
  - **Detection/Notification**
  - ***Infrequently occurs***
    - ***But… must be reported quickly and reliably***
- **Long Lifetime**
  - **Months to Years without changing batteries**
  - **Power management is the key to WSN success**



ZigBee Applications
(Wireless Home-Area Networks, WHAN)
http://www.zigbee.org/



Why ZigBee?

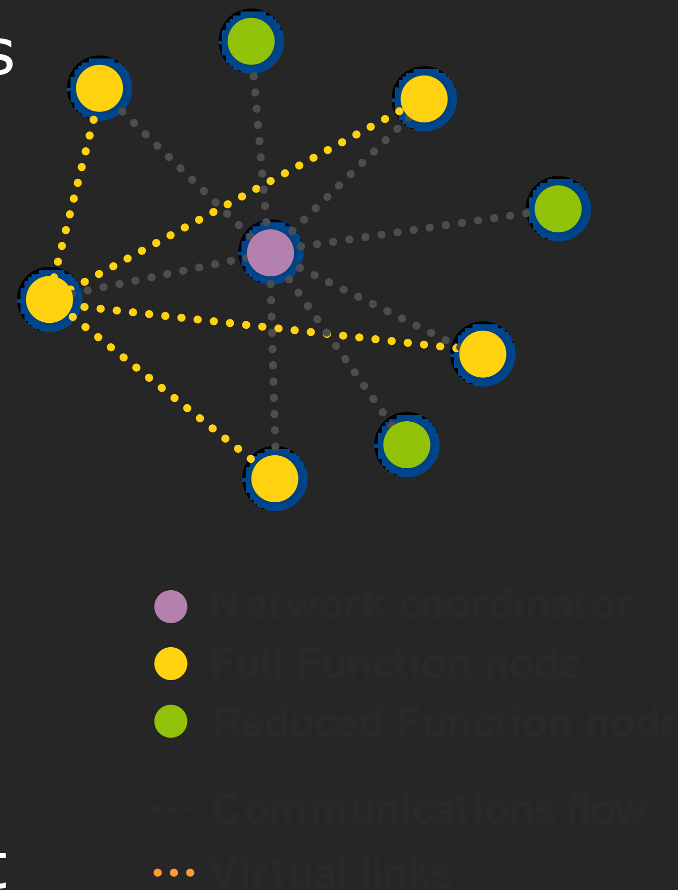
- *Pervasive Ad-hoc Self-organizing Mesh Networks*
- *Configurable Radio Range:* based on service requirements, from contactless (~cm) to meters and even kilometers, using multi-hop
- *High Security Level* (encryption and authentication at all protocol layers, concept of trust center, no collisions)
- *Easy integration with appliance/terminals in miniaturized peripherals with integrated antenna*

ZigBee Architecture

- **Zigbee Devices**
  - **Full Function Devices (FFD's)- ZigBee Coordinator , ZigBee Router**
  - **Reduced Function Devices (RFD's)- ZigBee End Device**
- **ZigBee Coordinator (ZC)**
  - **Only one required for each ZB network, Initiates network**
  - **Acts as 802.15.4 2003 PAN coordinator (FFD).**
  - **May act as router once network is formed.**
- **ZigBee Router (ZR) : Optional component, may associate with ZC , Acts as 802.15.4 2003 coordinator (FFD). Multihop routing of messages.**
- **ZigBee End Device (ZED) : Optional network component, Shall not allow association, Shall not participate in routing.**

Basic Network Characteristics

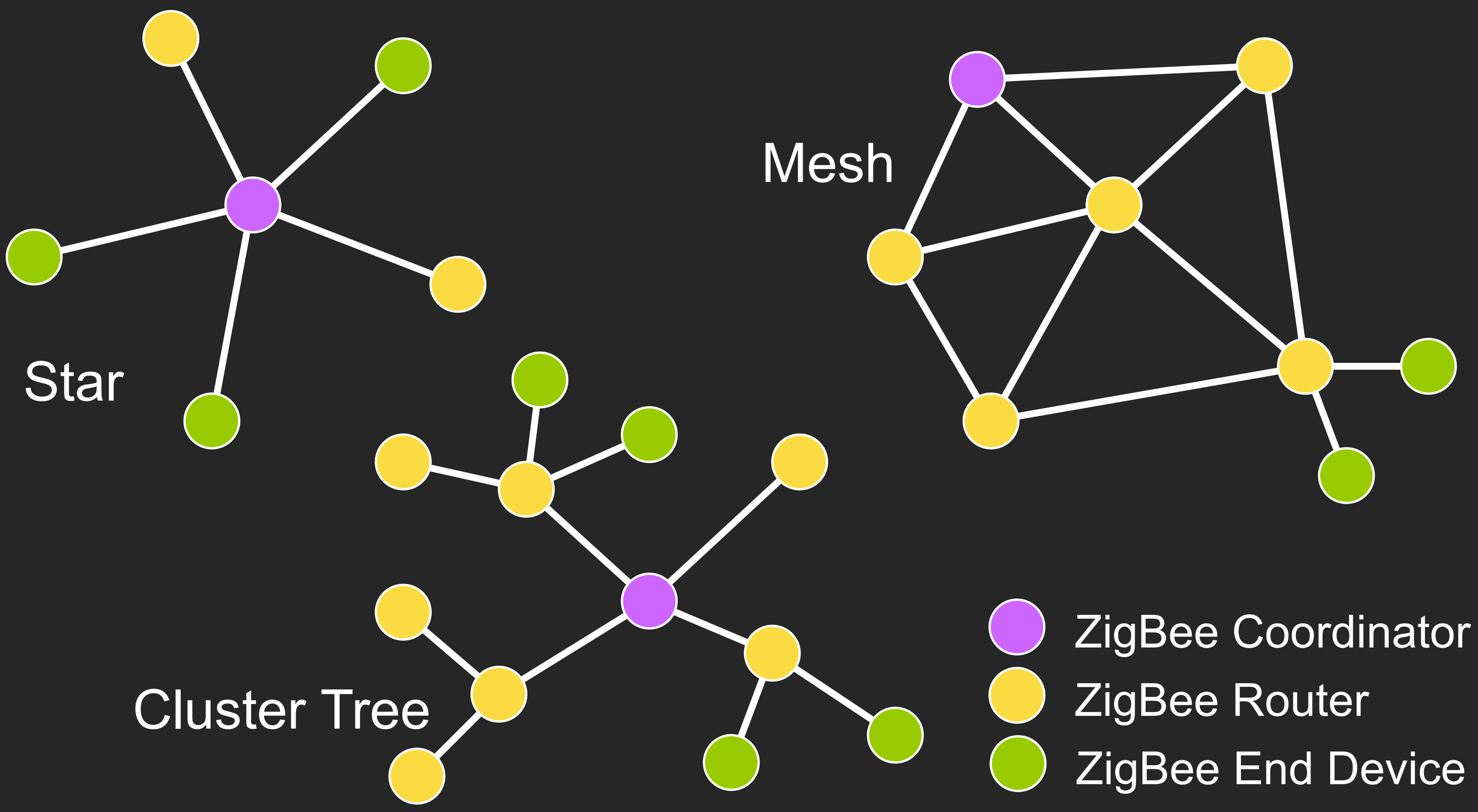
- 65,536 network (client) nodes
- 27 channels over 2 bands
- 250Kbps data rate
- Optimized for timing-critical applications and power management
- Full Mesh Networking Support



ZigBee Device Types

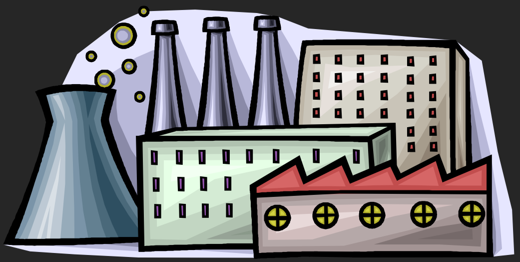
- ZigBee Coordinator (ZC)
  - One required for each ZB network.
  - Initiates network formation.
- ZigBee Router (ZR)
  - Participates in multihop routing of messages.
- ZigBee End Device (ZED)
  - Does not allow association or routing.
  - Enables very low cost solutions

ZigBee Network Topologies



Some Application Profiles

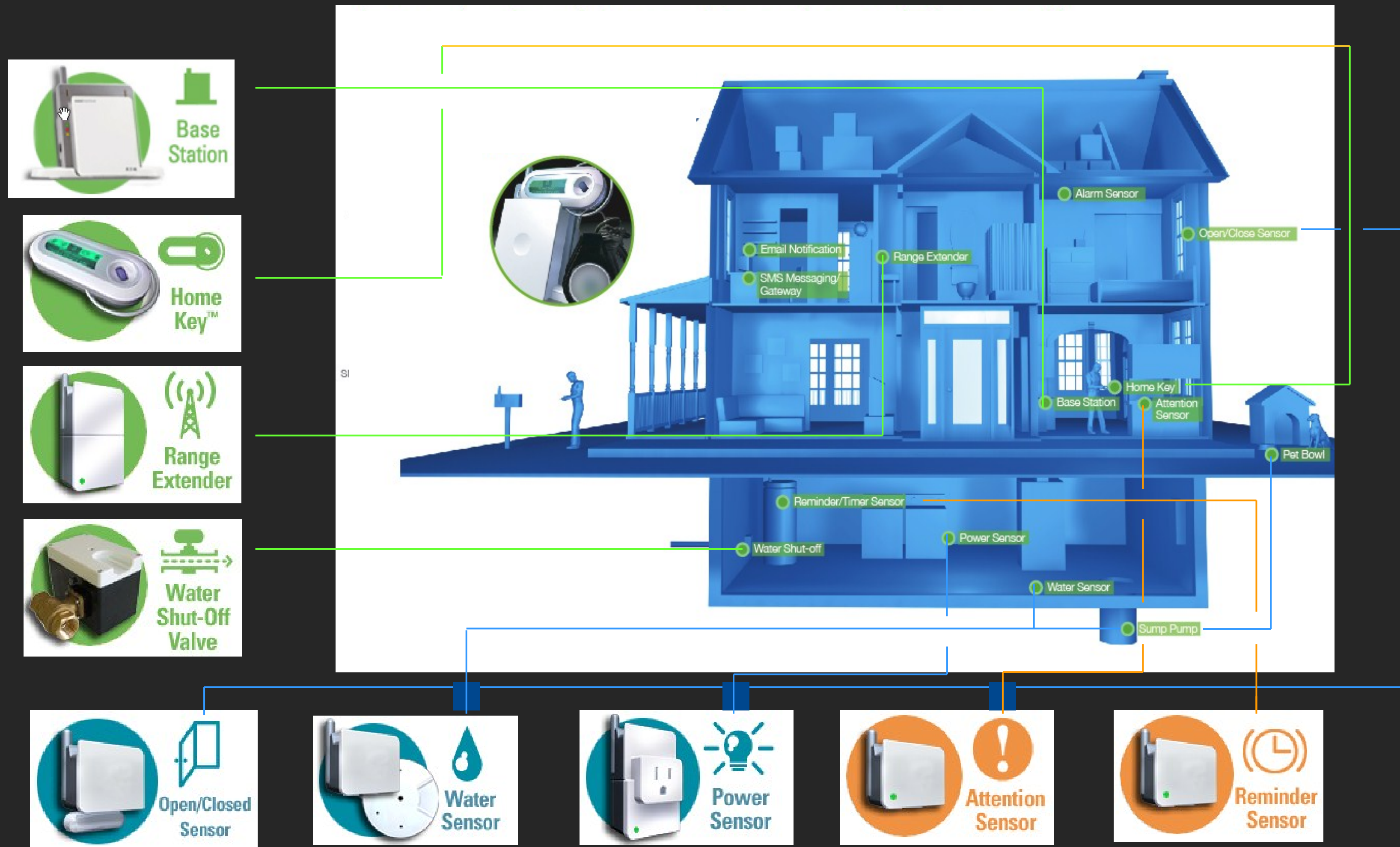
- Home Automation [HA]
  - Defines set of devices used in home automation
    - Light switches
    - Thermostats
    - Window shade
    - Heating unit
    - etc.



- Industrial Plant Monitoring
  - Consists of device definitions for sensors used in industrial control
    - Temperature
    - Pressure sensors
    - Infrared
    - etc.

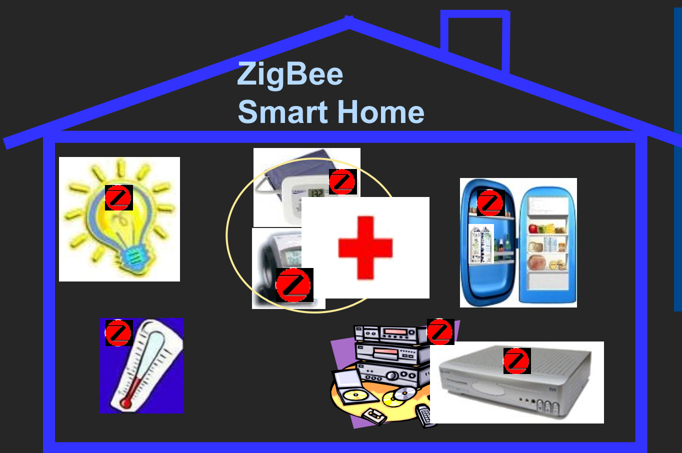
Home Awareness

Home Heartbeat



Z-SIM: M-commerce and Beyond

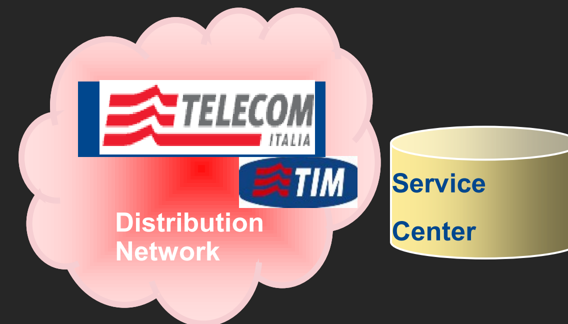
Z-SIM is the hub of the interaction between user and objects



Home Automation&Control

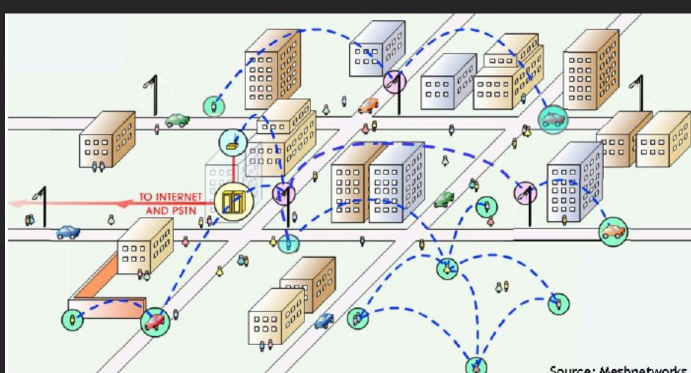
- Lights, HVAC, Domestic appliances
- Entertainment (e.g. DTT)
- Healthcare, Tele-assistance
- Monitoring & Security (e.g. temperature, gas)

Mobile Terminal



M-Commerce Services

- m-payments (bar, shops, supermarkets)
- m-ticketing (cinema, train, bus)

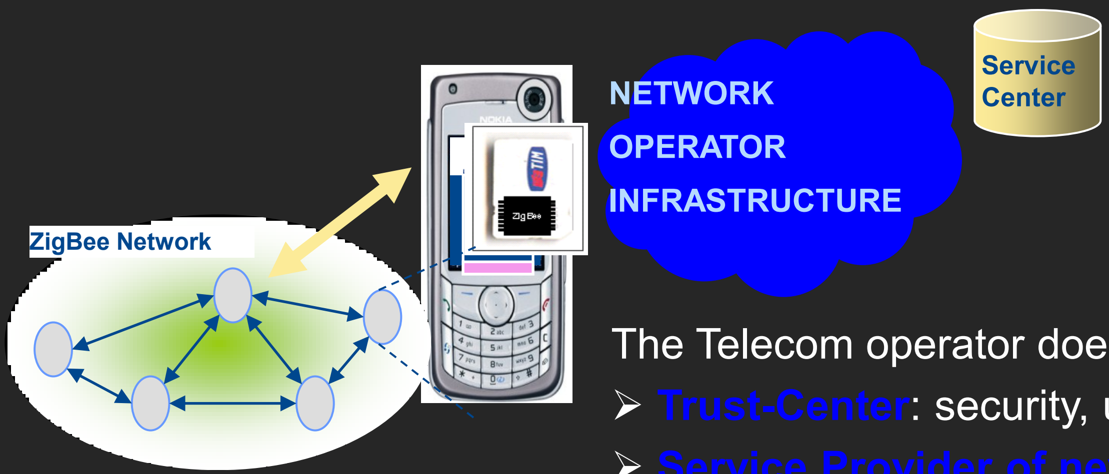


Digital Smart City

- Access Control
- Parking payment system
- Infomobility services (e.g. traffic control)
- Environmental Monitoring
- Localization

Mobile Handset as ZigBee Gateway

- Use mobile handset as a gateway to collect and display information
- In a mobile phone a ZigBee enabled SIM, the personal token, can play the ***Gateway*** **role**



The Telecom operator does more than transport data:

- **Trust-Center**: security, user authentication, reliability
- **Service Provider of new value-added services**
- **Service management, configuration and personalization**

Use Case : Cinema Example

STEP 1:

Environment with ZigBee node

Cinema

Step 3:

The users with SIMTOOLKIT application buy the content. The operator manages the bill transaction and downloads the token to the SIM for enabling the access to the cinema

GPRS/UMTS

STEP 2:

User having Z-SIM is recognized by the environment and is invited to buy a cinema ticket

Encrypted SMS

Step 4:

The token is received and sent to the printer via ZigBee

The ticket is automatically printed

What's Z-SIM?

ZigBee node fully integrated in a SIM card (Antenna + RF + Processing)

- User centric approach

The SIM has all the user information in terms of profiling, service personalization, credit

SIM is the Key-element for security, trusted environment (user authentication, content protection)

Gateway on SIM guarantees the permanent connection between Service Center and Ad hoc network for gathering info and reconfiguration

A SIM usable in all mobile terminals

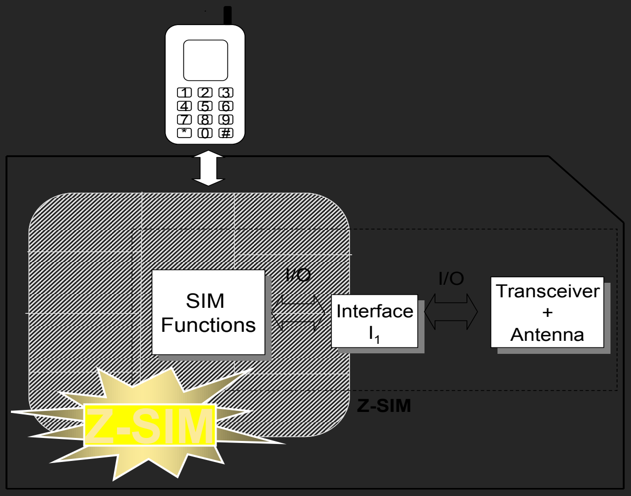
- Mobile terminal independency (no changes needed in the mobile terminal, like for BT, NFC)

ZSIM is independent from terminal tiers

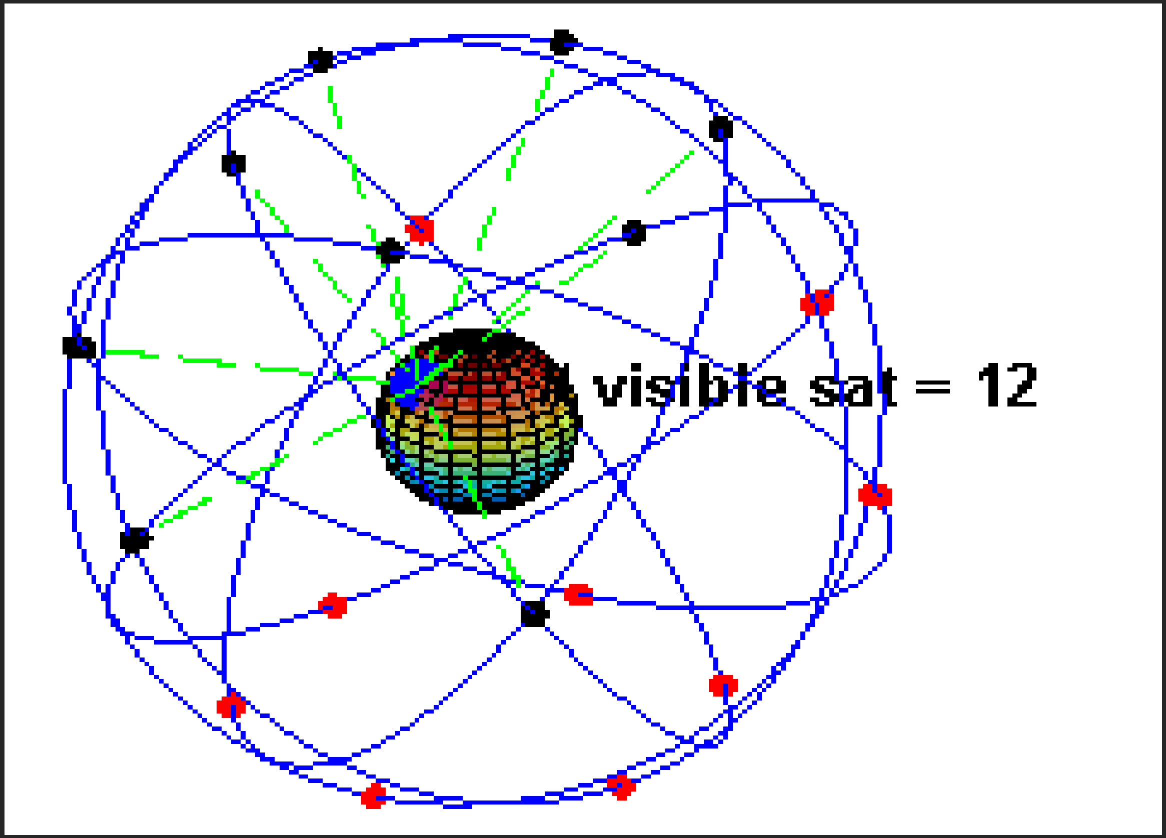
- Not invasive technology: transparent to the user

Enabler for a multitude of innovative services

- Interaction with objects (Internet of Things)
- M-commerce: payments and ticketing
- Accelerating fixed and mobile convergence



24 Satellites of GPS Deployed in Outer space



GPS Operation Principle

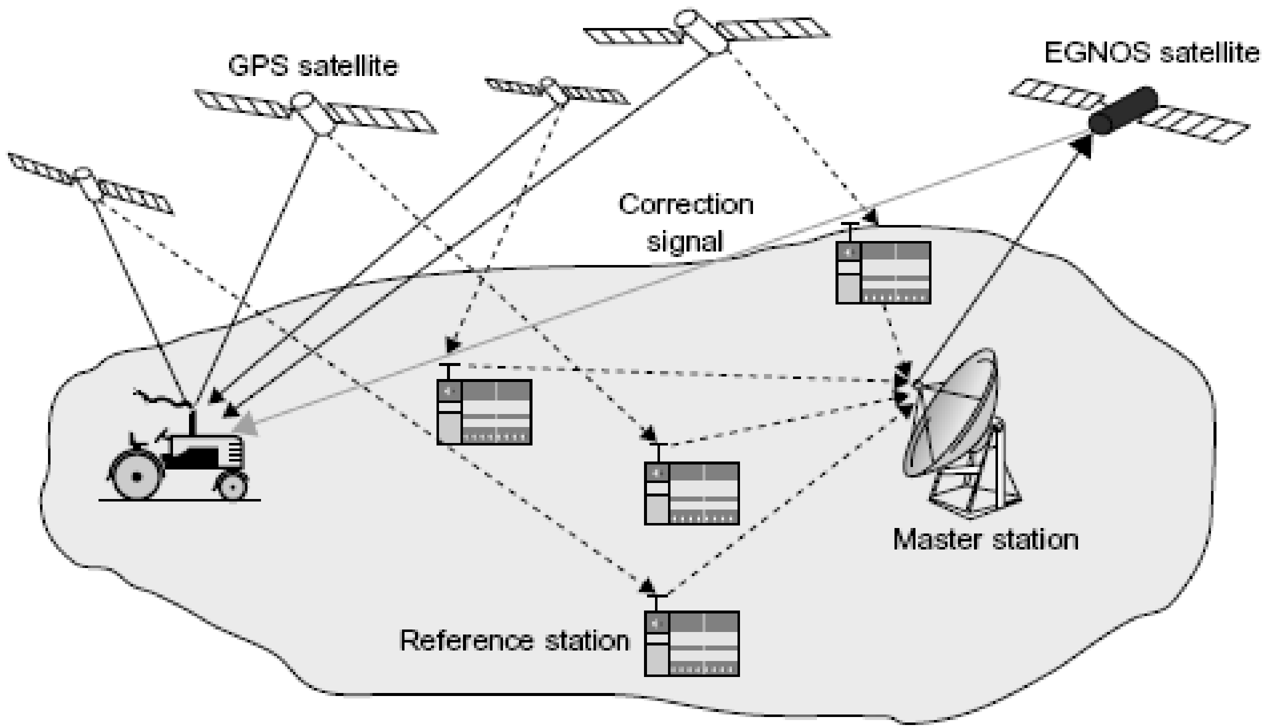
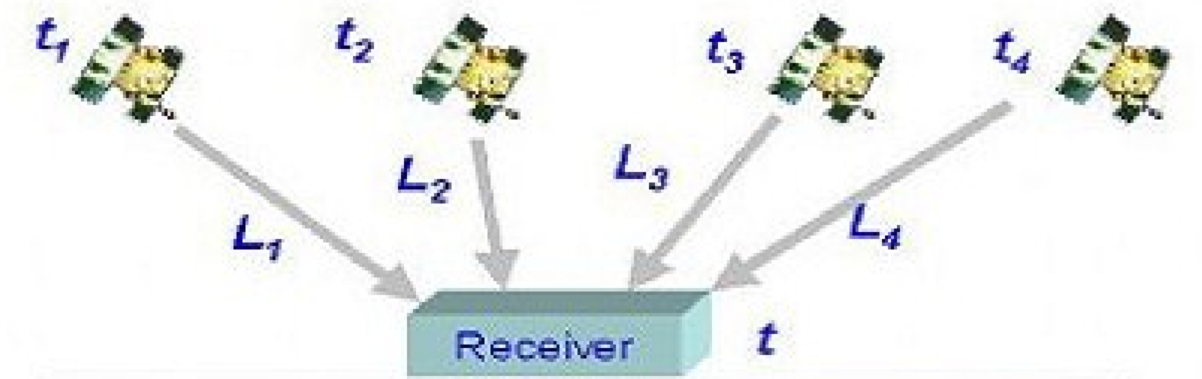


FIGURE 9.20

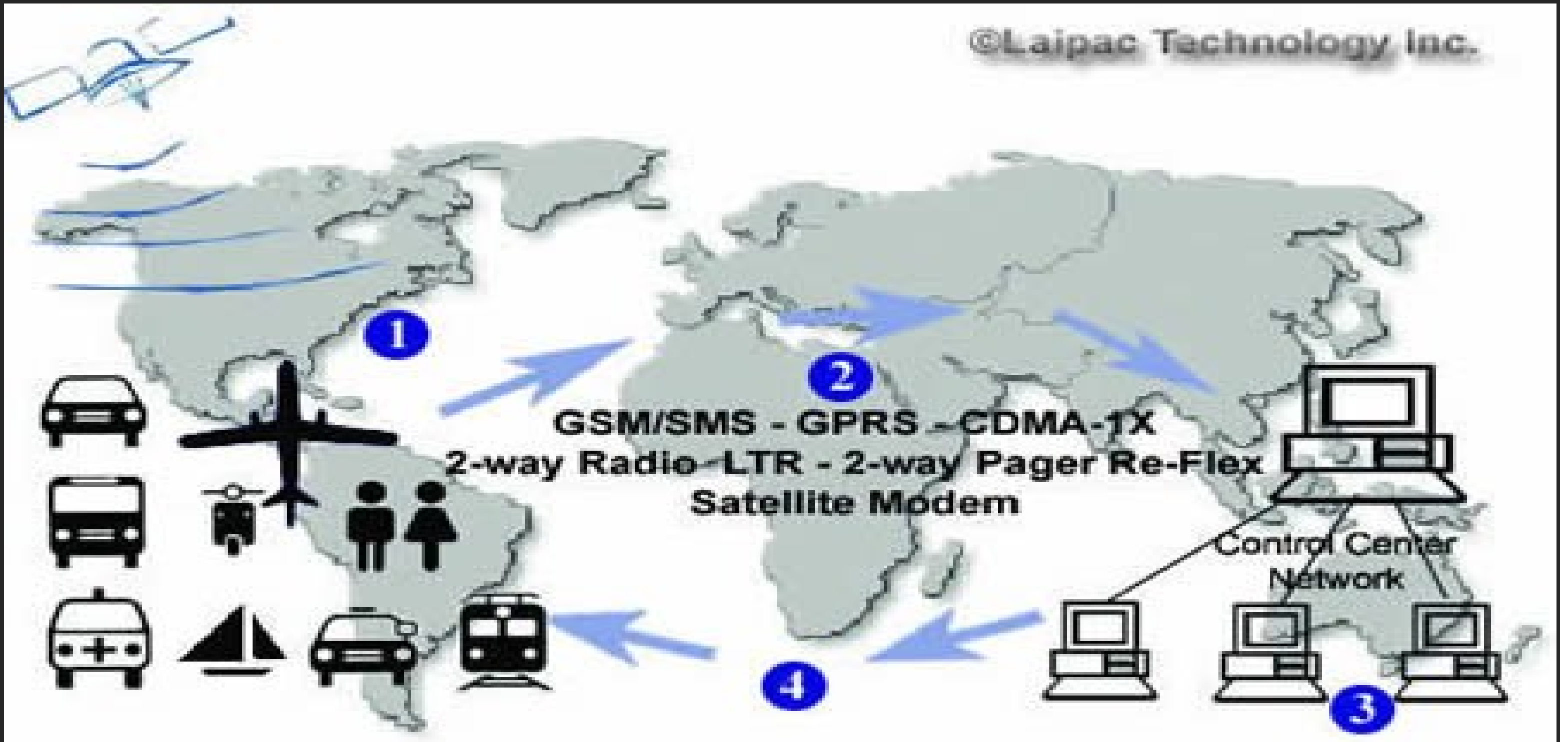
The Ground GPS Receiver, Which Calculates Its 3D Location from Four or More Satellites with Help from a Few Ground Reference Stations and a Master Station.



$$L_1 = c\,(t - t_1) = \sqrt{(x-x_1)^2 + (y-y_1)^2 + (z-z_1)^2}$$
$$L_2 = c\,(t - t_2) = \sqrt{(x-x_2)^2 + (y-y_2)^2 + (z-z_2)^2}$$
$$L_3 = c\,(t - t_3) = \sqrt{(x-x_3)^2 + (y-y_3)^2 + (z-z_3)^2}$$
$$L_4 = c\,(t - t_4) = \sqrt{(x-x_4)^2 + (y-y_4)^2 + (z-z_4)^2}$$

Triangulation method to calculate delayed location signals from 4 satellites.

Real-time GPS Tracking System



1 - GPS receivers in each mobile asset receive signals from a network of overhead satellites.
2 - Transmit the data to the communications center via different networks.
3 - The control center receive and process this data and shows real-time pinpoint information over maps.
4 - The Control center is able to send commands to each unit (trigger alarms, stop engines, change direction, personal messages, etc.)

Example:

Service Oriented Architecture for Geographic Information Systems Supporting Real Time Data Grids

Galip Aydin Department Of Computer Science, Indiana University

- A **Geographic Information System** is a system for creating, storing, sharing, analyzing, manipulating and displaying spatial data and associated attributes.
- Modern GIS requires:
  - Distributed data access for spatial databases
  - Utilizing remote analysis, simulation, or visualization tools.

Requirements for a GIS/Sensor Grid

- Requirements of service orchestration capabilities
  - Complex problems require GIS applications to collaborate.
- Coupling data sources to scientific applications
- Data transport requirements
- Proliferation of Sensors
  - Ability to analyze data on-the-fly, continuous streaming support, scalable systems for addition of new sensors.
- High performance and high rate messaging
  - Real-time data access, rapid response systems, crisis management etc.
- From the Grids perspective the Motivations are
  - To apply general Grid/Distributed computing principles to GIS
  - Investigate how to integrate with geophysical and other scientific applications with data sources

PBO and CRTN GPS Stations

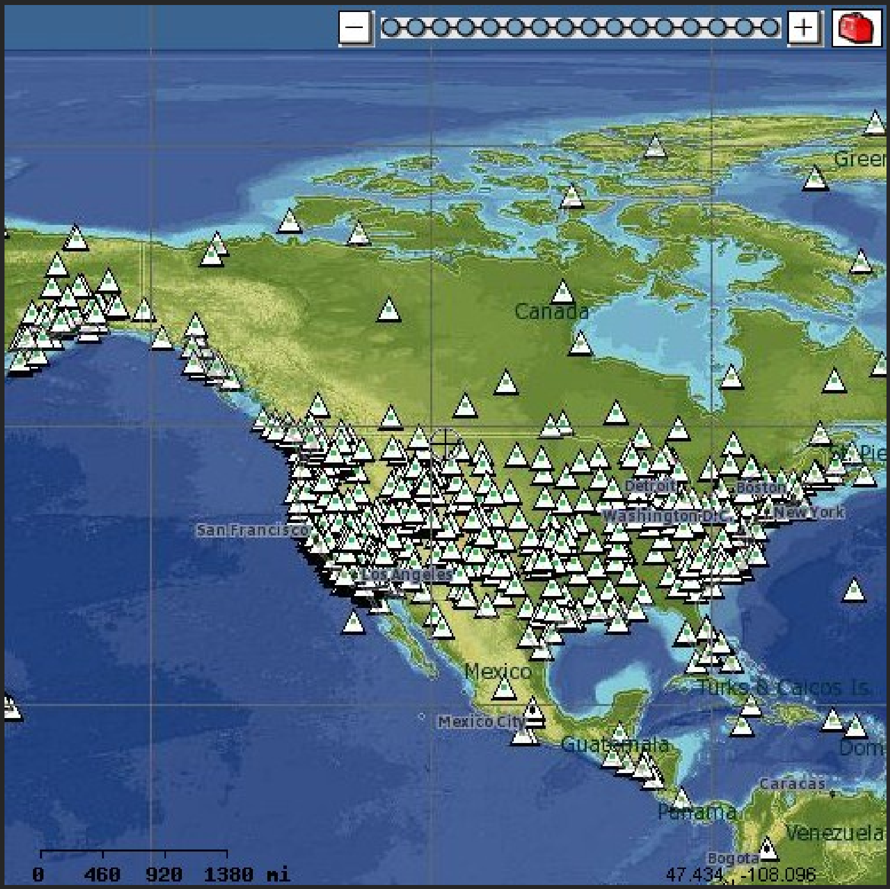
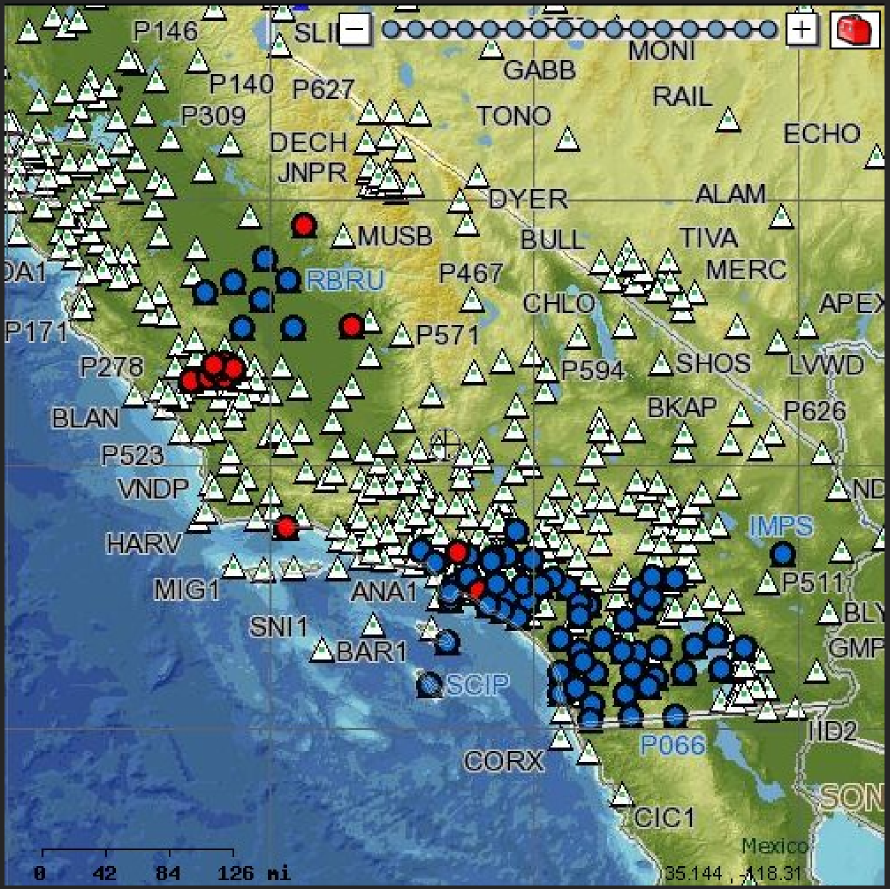


Plate Boundary Observatory (PBO) GPS Stations in North America



California Real-Time GPS Network (CRTN).

Research Issues 1

- **Applying Web Service principles to GIS data services**
  - Orchestration of Services, workflows. We need services suitable for large data sets and where quick response is required.
- **High Performance** support in GIS services
  - The performance problem must be addressed in a complete and general framework supporting different data requirements
- **Interoperability**
  - The system should bridge GIS and Web Service communities by adapting standards from both.
  - Other GIS applications should be able to consume data without having to do costly format conversions.

Research Issues 2

- **Scalability**
  - The system should be able to handle high volume and high rate data transport and processing.
  - Plugging new sensors, data sources or geo-processing applications should not degrade system’s overall performance.
- **Flexibility and extendibility**
  - How to develop real-time services to process sensor data on the fly.
  - Ability to add new filters without system failures.
- **Quality of Service Issues**
  - Is latency introduced by services in processing real-time sensor data acceptable?

SOA for GIS – Geophysical Data Grid

- To create a GIS Data Grid (Geophysical Grid) Architecture we utilize
  - Web Services to realize Service Oriented Architecture
  - OGC data formats and application interfaces to achieve interoperability at both data and service levels.
- GIS Data Grid Features
  - Depending on the source, geospatial data can be archival or real-time. The architecture provides standard control and access interfaces for both types.
  - Supports alternate transport and representation schemes, uses topic based messaging infrastructure for data and message exchange.
  - Streaming and non-streaming services to access archived data.
  - Real-Time and near real-time filter services for accessing sensor metadata and sensor measurements.

GIS Grid Usage Model – Earthquake Science

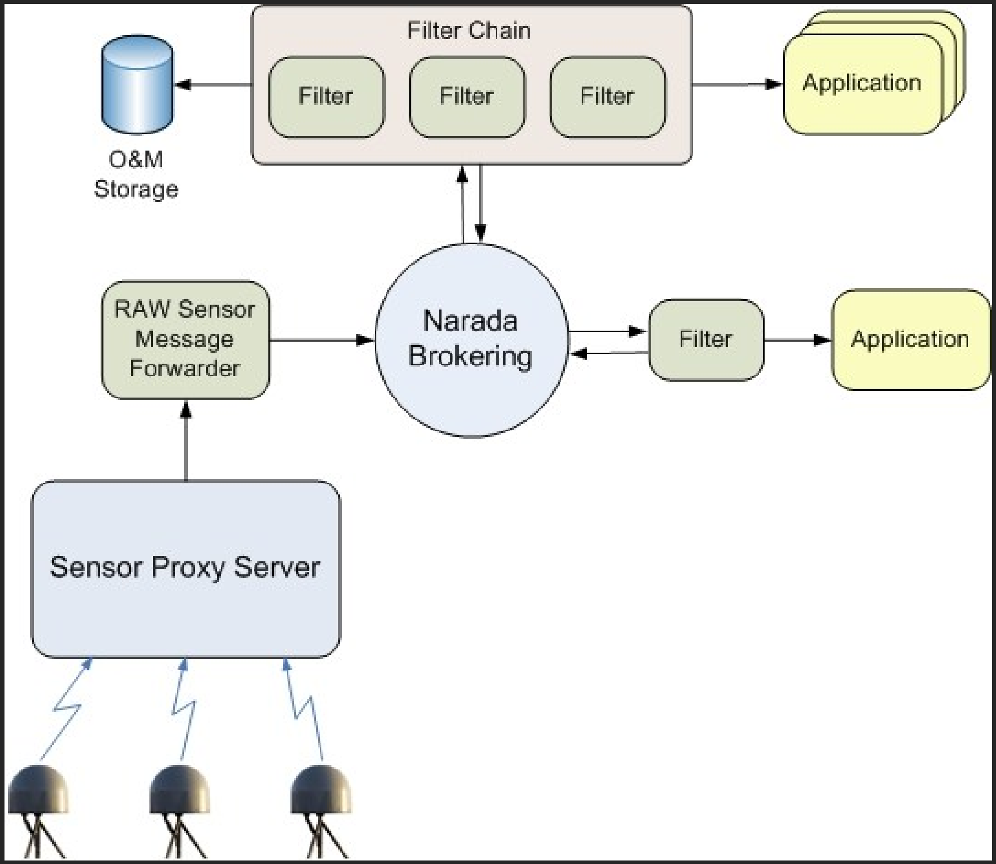
- Supporting geophysical repositories and real-time sensors is essential
- To analyze a typical earthquake it is important to access to precise measurements of the initial earthquakes and aftershocks
- To support earthquake forecasting and the time and spatial positions of the forecasts
- Earth Science field is moving from a previously data poor field to a data rich world. There will be thousands of sensors spread around the world. (i.e. GPS sensors, satellites)

GIS Grid Part 1 - Real-Time Data Services

- Sensors and sensor networks are being deployed for measuring various geo-physical entities.
- Sensors and GIS are closely related. Sensor measurements are used by GIS for statistical or analytical purposes.
- With the proliferation of the sensors, data collection and processing paradigms are changing.
- Most scientific geo-applications are designed to work with archived data.
- Critical Infrastructure Systems and Crisis Management environments require
  - fast and accurate access to real-time sources
  - a flexible/pluggable architecture for coupling geo-processing applications with the data.

Sensor Grid Architecture

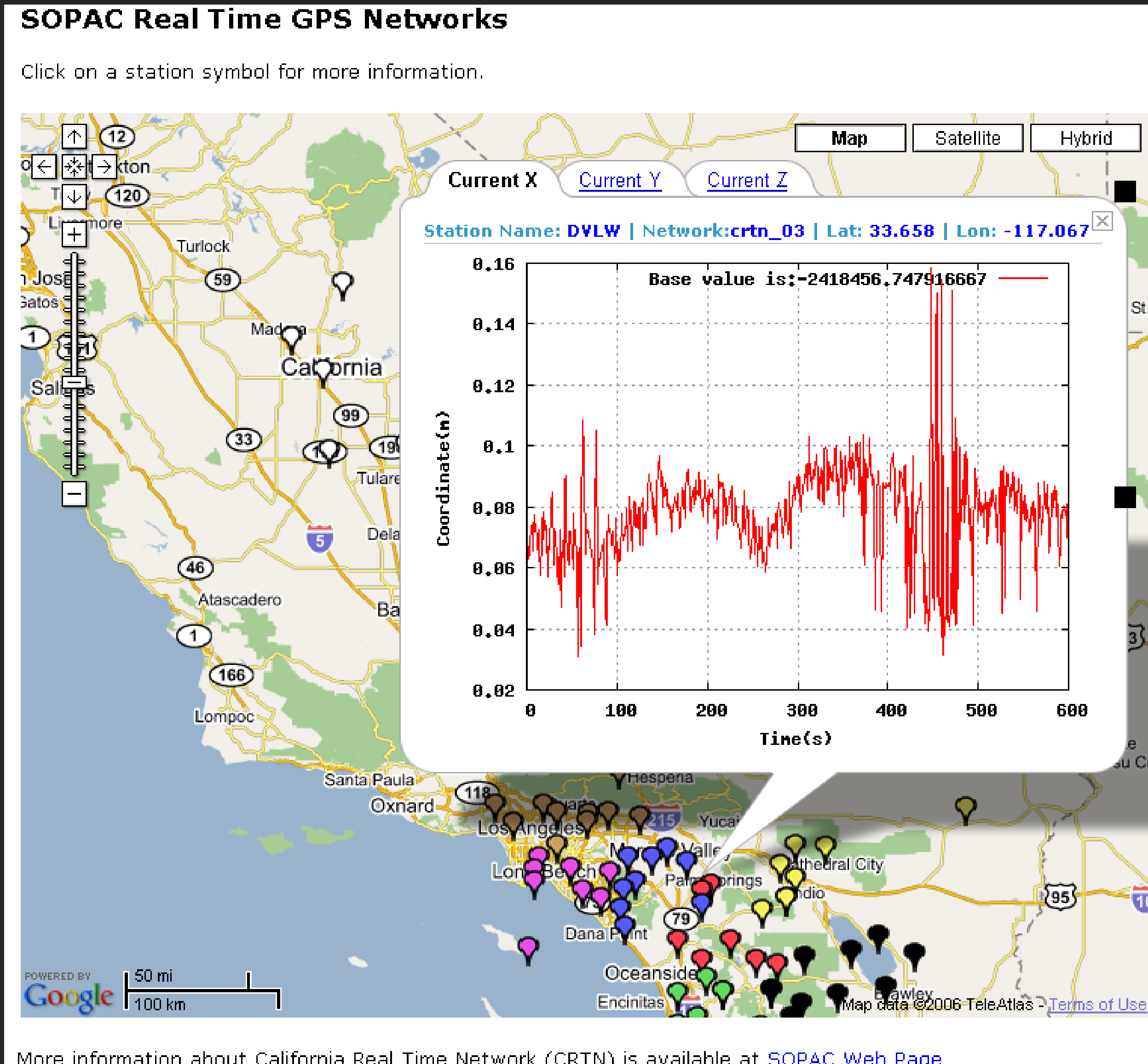
- Major components:
  - Real-Time filters
  - Publish-Subscribe System
  - Information Service
- Filters can be run as Web Services to create workflows.
- Filter Chains can be deployed for complex processing.
- Streaming messaging provides high-performance transfer options.



Use Case - GPS Sensors

- GPS is used to identify long-term tectonic deformation and static displacements.
  - Southern California Integrated GPS Network (SCIGN) has 250 Real-Time GPS Stations.
- Scripps Orbit and Permanent Array Center (SOPAC) GPS networks:
  - 8 networks for 80 stations produce 1Hz high resolution data.
  - Filters to provide real-time streaming access.
- Architecture
  - Uses publish/subscribe based NaradaBrokering for managing real-time GPS streams
  - Utilizes topics for hierarchical organization of the sensors
  - Deploy successive data filters ranging from format translators to data analysis codes
  - Could potentially be used to run RDAHMM clones to monitor state changes in the entire GPS network

Application Integration with Real-Time Filters



- **Station Monitor Filter** records real-time positions for 10 minutes and calculates position changes
- **Graph Plotter** Application creates visual representation of the positions.

Cyber Physical Systems (CPSs)

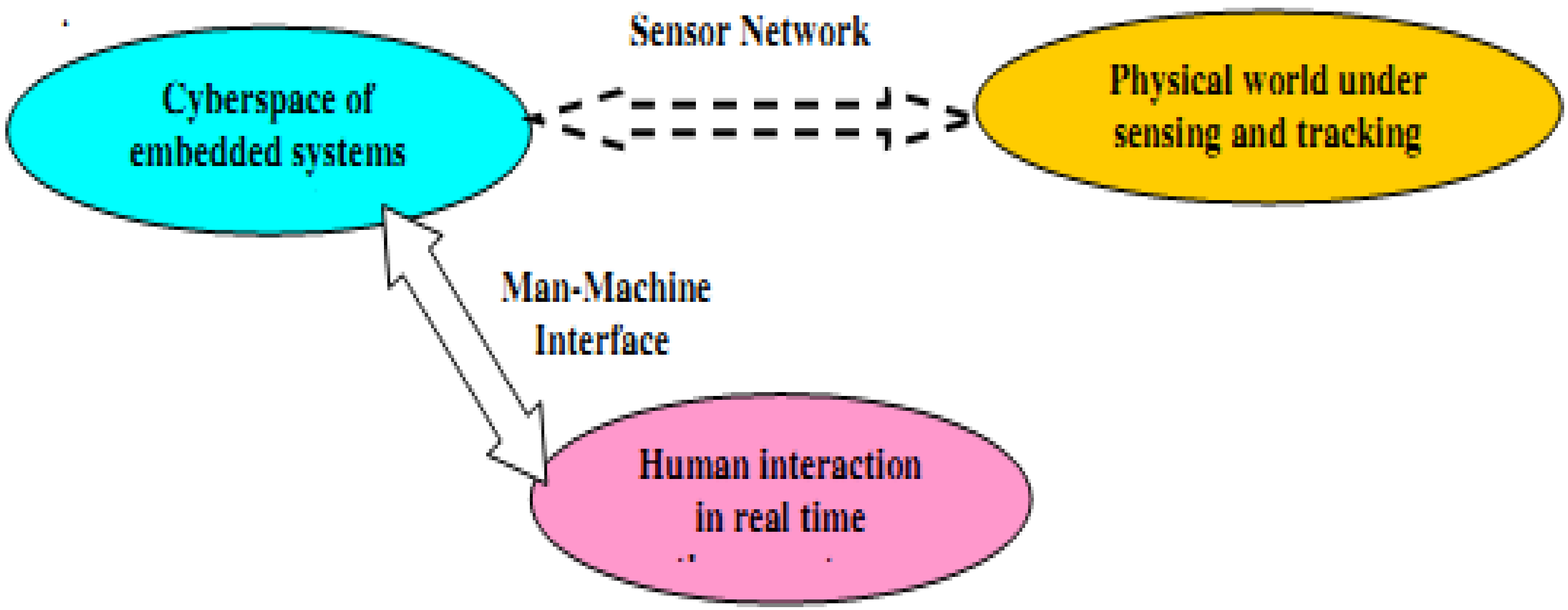
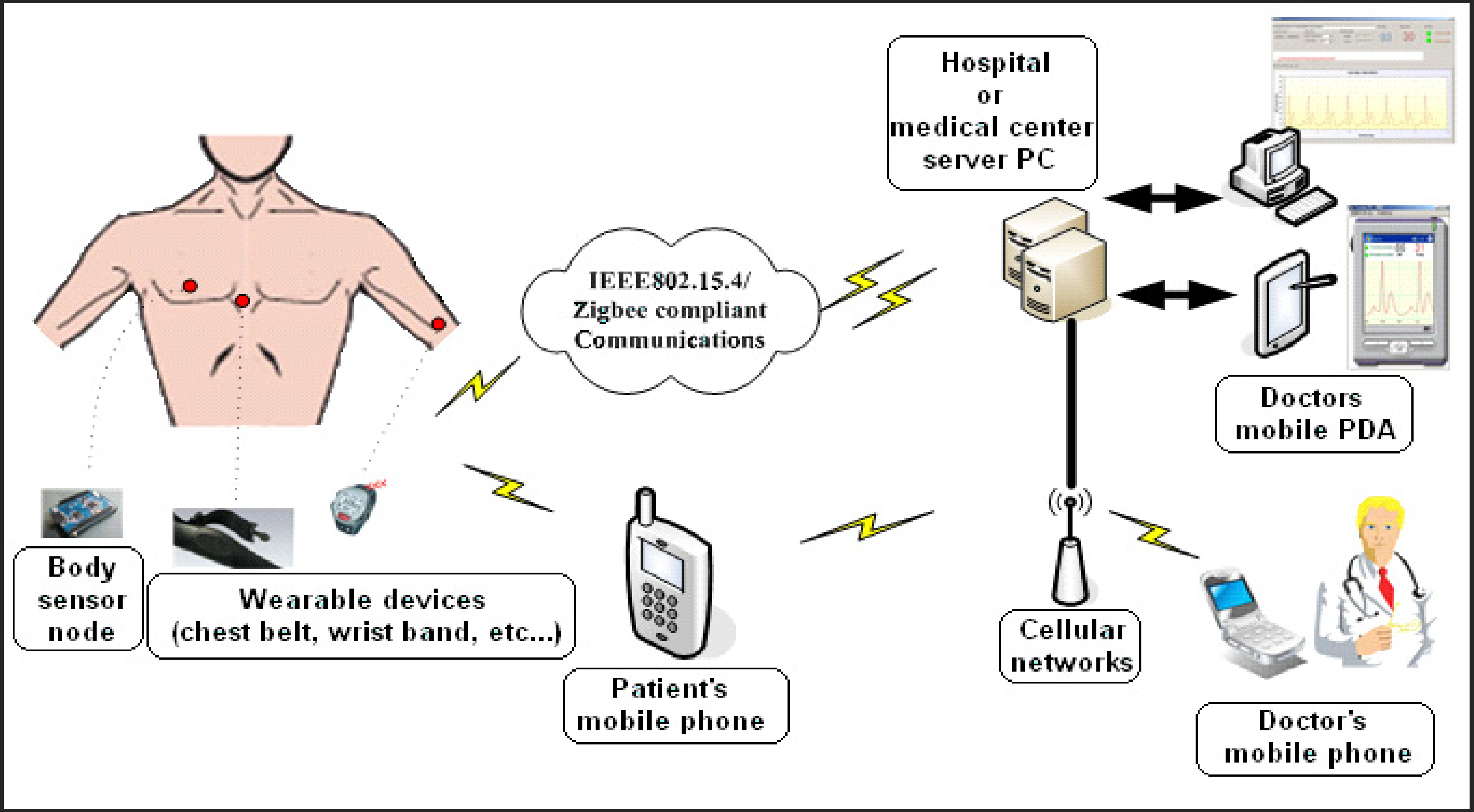


Figure 9.29 Three major components working together interactively and intelligently in a cyber-physical system (CPS)

IoT Telemedicine Applications:

Patient Data Transferred Using a Wireless Sensor Network.



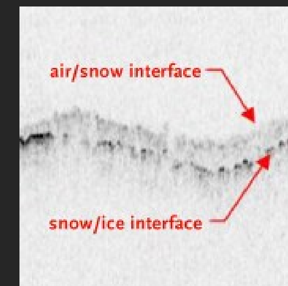
(Courtesy of Inftech, 2007)

Example: Internet of Things: Sensor Grids
A pleasingly parallel example on Clouds

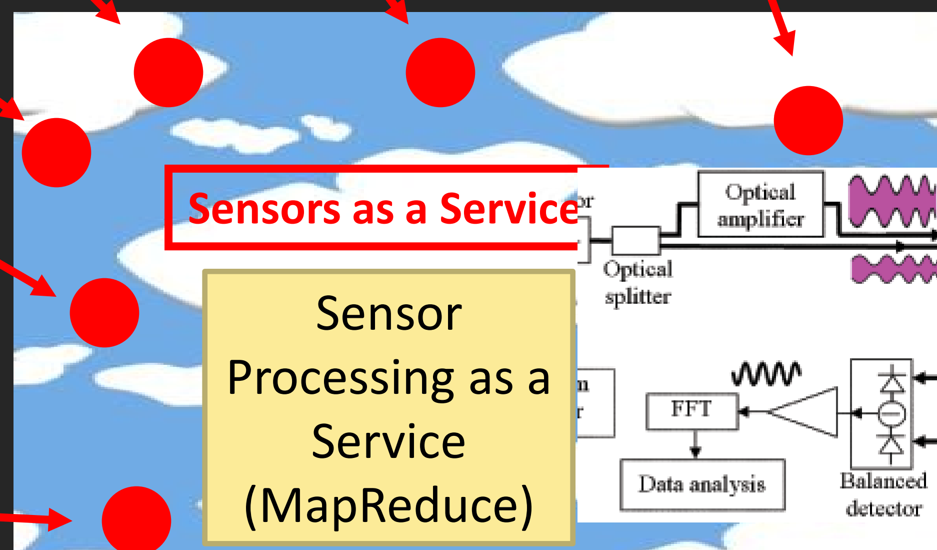
- A sensor ("Thing") is any source or sink of time series
  - In the thin client era, smart phones, Kindles, tablets, Kinects, web-cams are sensors
  - Robots, distributed instruments such as environmental measures are sensors
  - Web pages, Googledocs, Office 365, WebEx are sensors
  - Ubiquitous Cities/Homes are full of sensors
  - They have IP address on Internet
- Sensors – being intrinsically distributed are Grids
- However natural implementation uses clouds to consolidate and control and collaborate with sensors
- Sensors are typically "small" and have pleasingly parallel cloud implementations

(Courtesy of Geoffrey Fox, 2012)

Sensors as a Service (SaaS)



Output Sensor



(Courtesy of Geoffrey Fox, 2012)

Example:

Sensor Service GRID for Publishing Atmospheric Brown Cloud Observation Data in ICIMOD

HONDA Kiyoshi, A. Witayangkurn, R. Chinnachodteeranun, A. Shrestha, P. Koanantakool

Asian Institute of Technology

KhunSan Aung

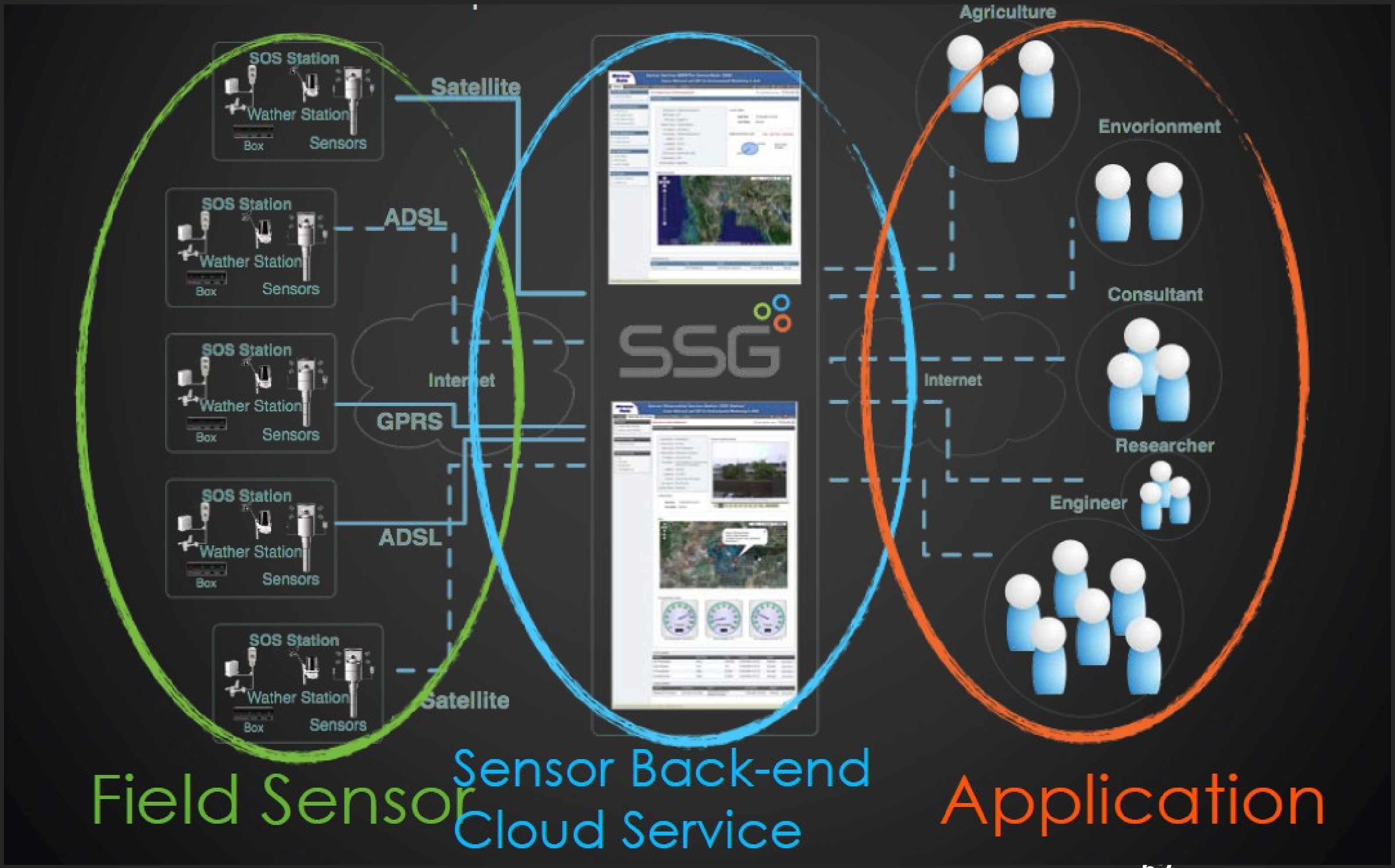
ICIMOD

Background

- Field Sensor Network
  - Small and Low Cost Sensors
  - Wireless Field Platform
  - Mobile Internet
- Real-Time Field Data
  - Environment, Disaster, Agriculture
- High Investment for System Development
  - Communication
  - Archiving
  - Publishing

Concept

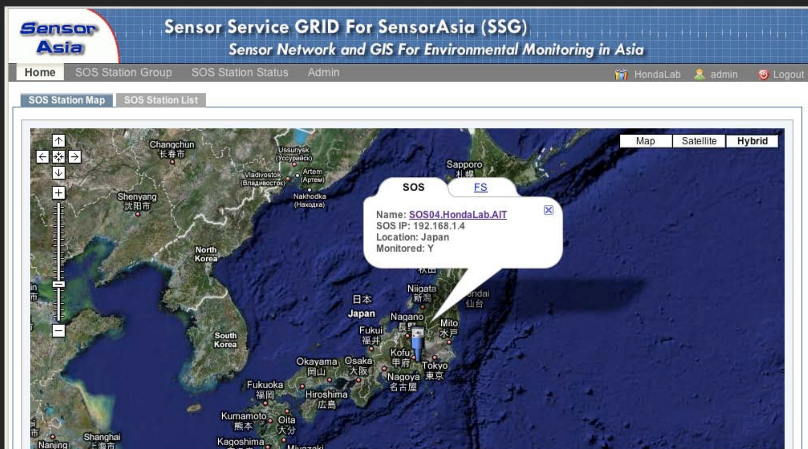
- SSG provides sensor back-end services as a “Cloud”.
- It releases users from complicated real-time sensor system development and reduces cost and time

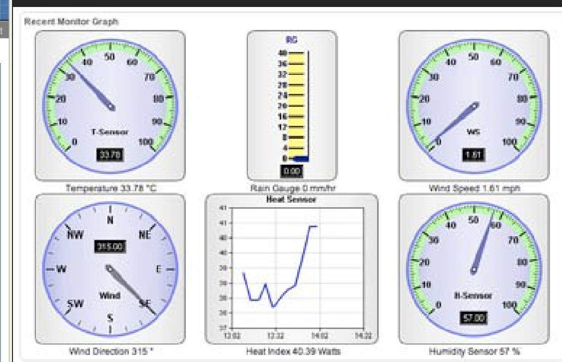


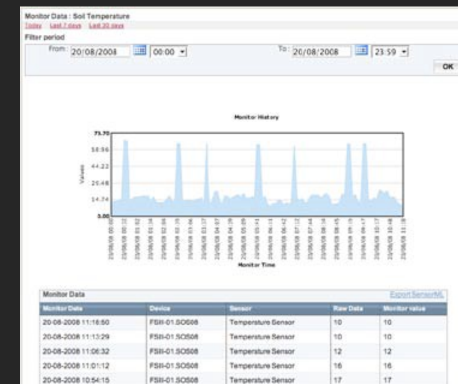
Features and Benefits

- Cloud Service (No Server Setup)
- Sensor Plug & Play
- Immediate Visualization
- Immediate Web Publishing
- API (int'l Standard, Native) for Application Development
- Reduced Cost and Time
  - Sensor Connection, Serve Setup & Maintenance
  - Application Development

SSG, GIS & Visualization Interface

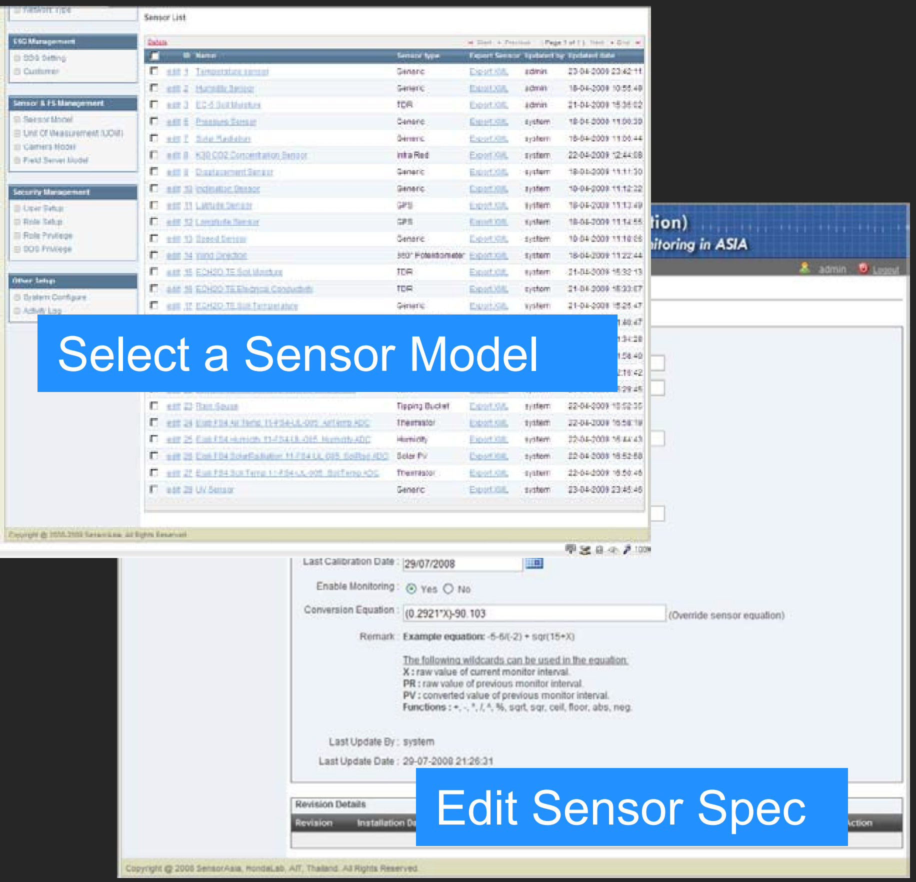




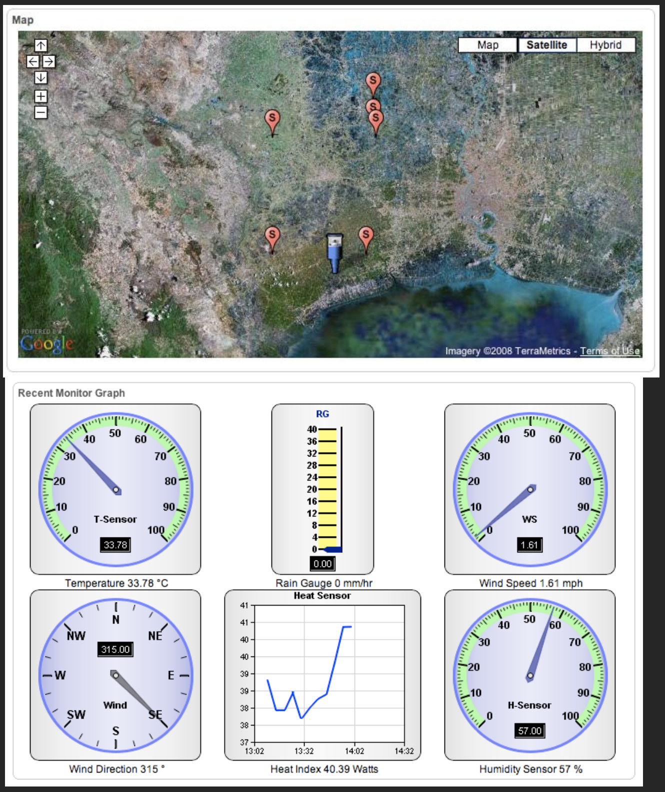


- SSG provides a user-friendly GIS visualization interface
- Locations of Remote Node on web-maps
- Visualize data from various kinds of sensors and weather-stations in easy-to-understand graphs and dials.

Sensor Plug and Play
Easy to add new sensor to SOS station



Add Sensor



- Select Sensor Model and Edit
- Configure Sensor Setting even Remotely
- The system automatically starts archiving, changes interface.
- No Programming Required -> Reduce Cost

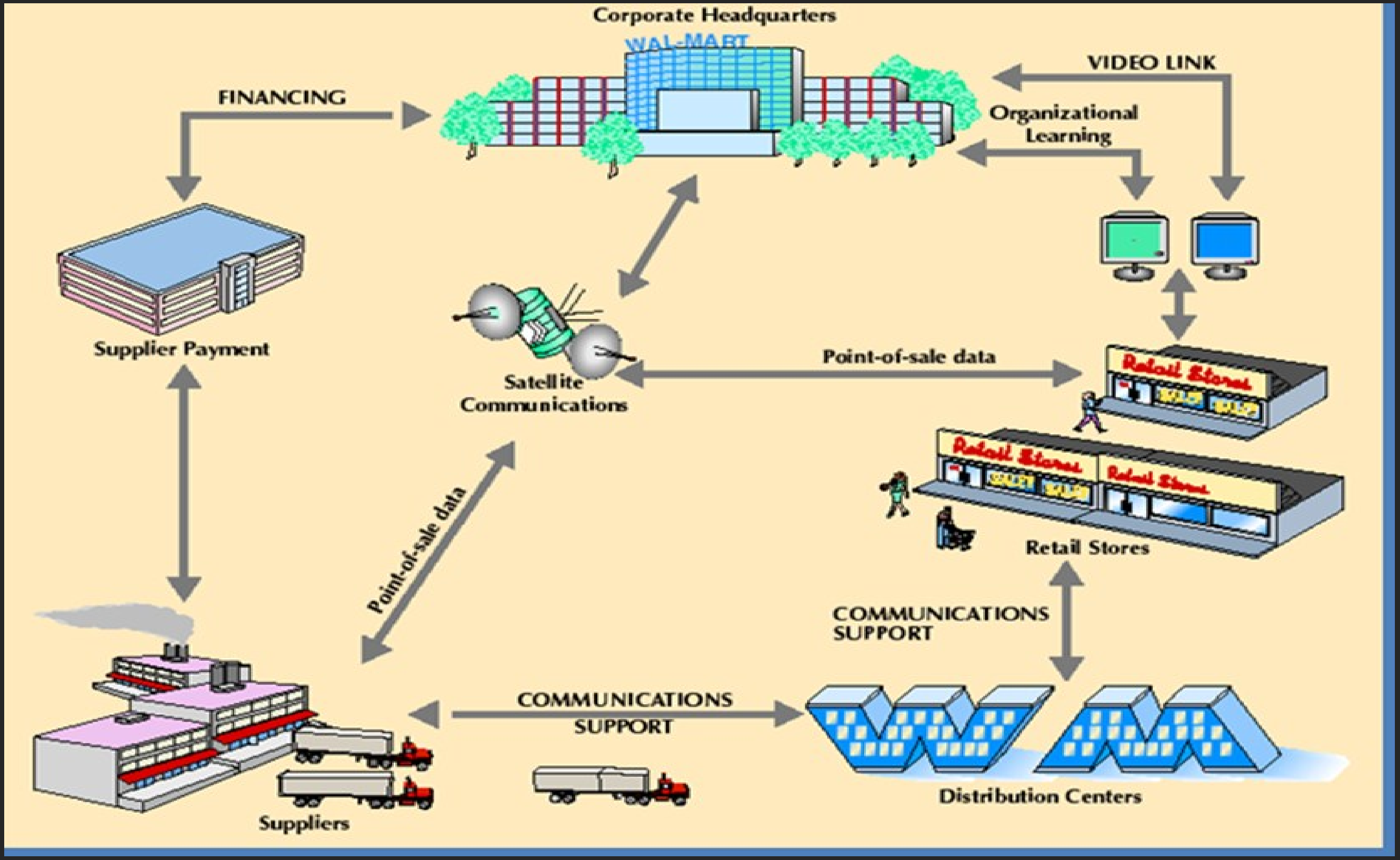
Innovative Applications of The Internet of Things

Table 9.9 Some Application Domains of the Internet of Things

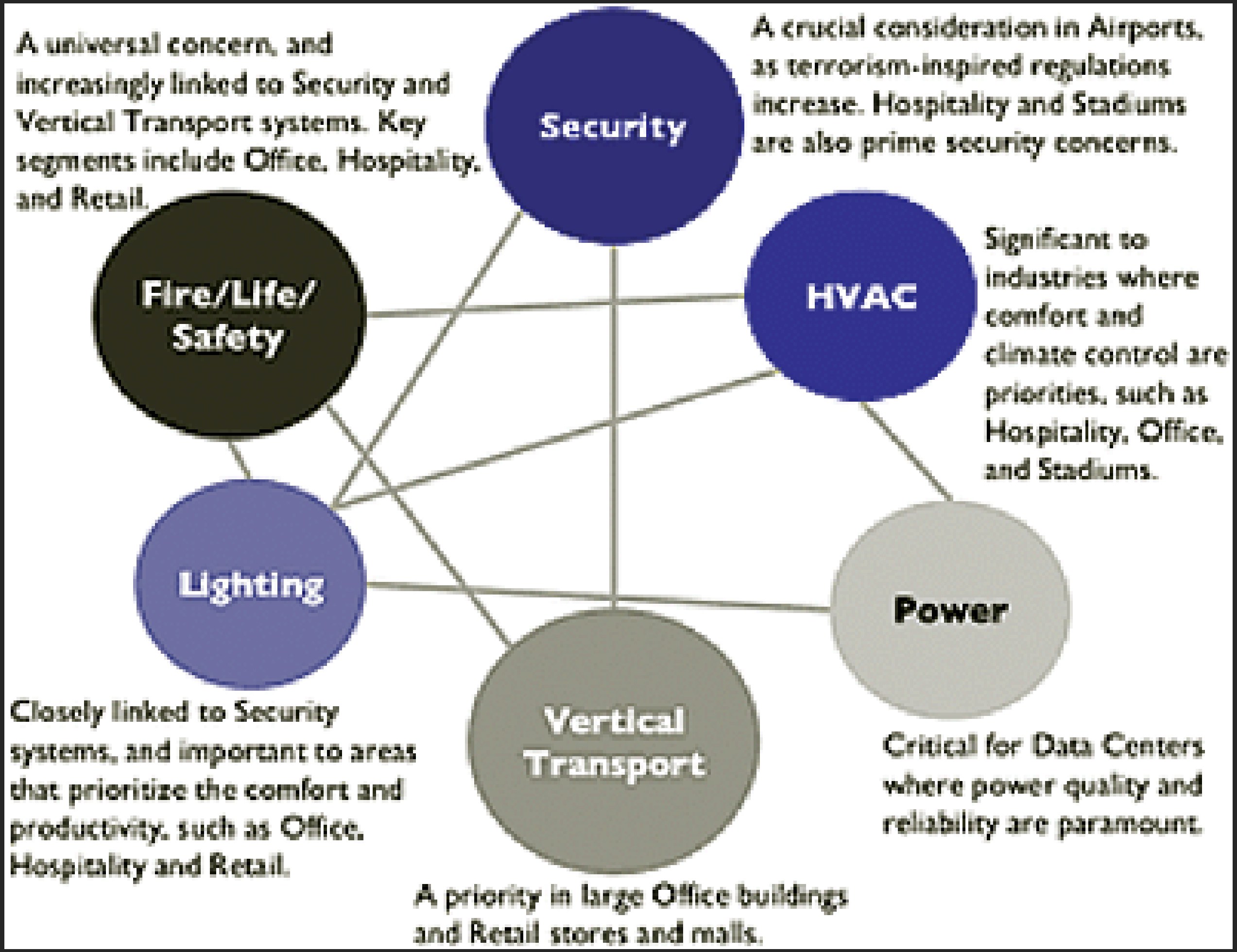
Domain	Brief Descriptions	Indicative Examples
Growth in Industry and Economy	Activities involving financial or commercial transactions between companies and organizations	Manufacturing, logistics, service sector, banking, financial governmental authorities, intermediaries, etc.
Environment and natural resources	Activities regarding the protection, monitoring, and development of all natural resources	Agriculture and breeding, recycling, environmental management services, energy management, etc.
Society and daily life	Activities/initiatives regarding the development and inclusion of societies, cities, and people	Governmental services toward citizens and society structures, e-inclusion (aging, disabled people), etc.

Supply Chain Management

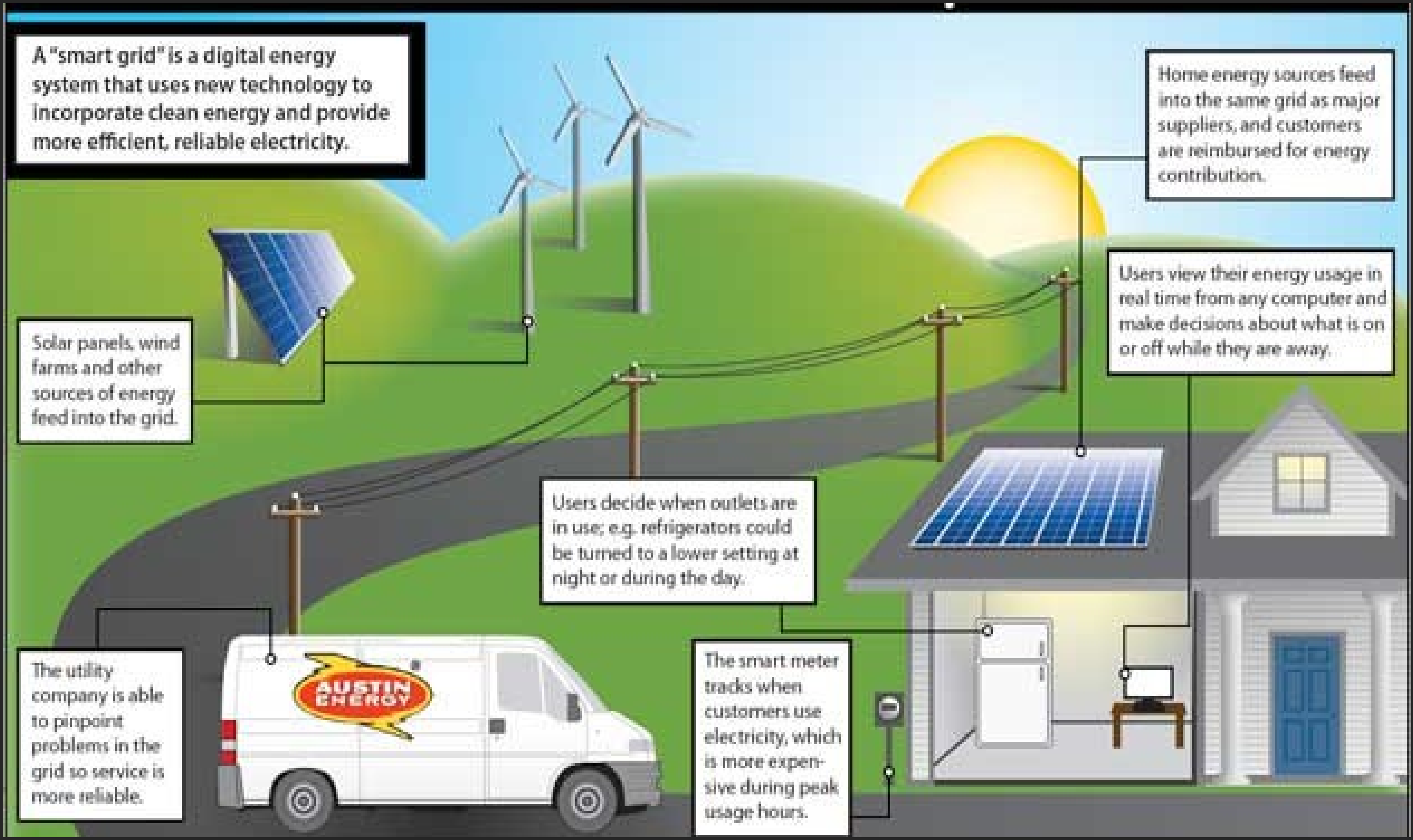
supported by the Internet of Things. (http://www.igd.com)



Smart Building Using IOT Technology



Smart Power Grid



Opportunities of IOT in 3 Dimensions