Organizzazione di Sistemi Operativi e Reti

Reti Wireless
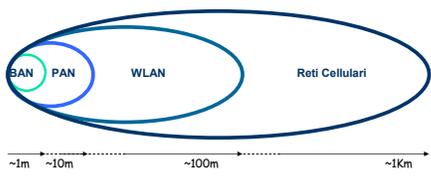

Sommario

- Classificazione
- WLAN (WiFi)
- WPAN/WBAN (Bluetooth)
- Reti di sensori (cenni)

Wi-Fi 2

Classificazione (1)

BAN	PAN	WLAN	Reti Cellulari

~1m   ~10m   ~100m   ~1Km

- Rete Cellulare   GSM/GPRS/UMTS
- WLAN   IEEE 802.11 (WiFi)
- PAN   IEEE 802.15.1/4 (Bluetooth, ZigBee)
- BAN   IEEE 802.15.1/4 (Bluetooth, ZigBee)
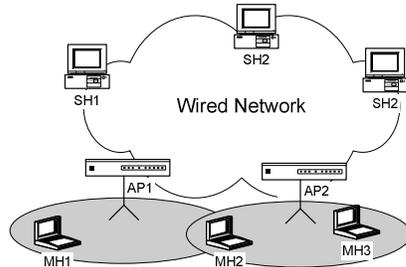
Wi-Fi 3

Classificazione (2)

- Reti wireless con infrastruttura
  - Infrastructure-based
  - Reti cellulari, WLAN (WiFi)

- Reti wireless senza infrastruttura
  - Infrastructure-less (Ad Hoc)
  - WLAN (WiFi), BAN, PAN

- Reti wireless ibride
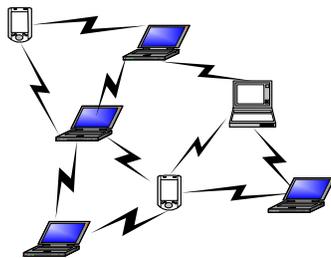 - Reti Wireless Mesh

Wi-Fi   4

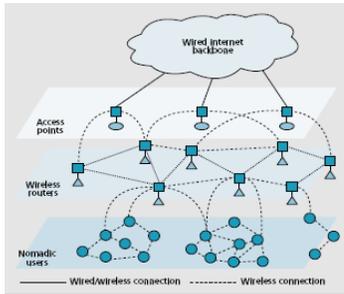## Infrastructure-based Wireless Networks

SH2

Wired Network

SH1   SH2

AP1   AP2

MH1   MH2   MH3

Wi-Fi   5

Ad Hoc Networks

Wi-Fi   6

Hybrid Networks

Wireless LANs

- Preliminari
- Famiglia IEEE 802.11
- Protocollo CSMA/CA
- Prestazioni
- Reti ad hoc 802.11

Reti Locali Wireless (WLANs)

- Le comunicazioni avvengono attraverso l'etere
  - Assenza di un mezzo trasmissivo
- Assenza di infrastruttura
  - Costruzioni di edifici nuovi
  - Emergenze naturali (terremoti, inondazioni)
  - Edifici storici o artistici (cablaggio impossibile)
  - Edifici in cui il cablaggio è oneroso
- Alta riconfigurabilità
  - Riunioni, conferenze, lezioni
  - Possibilità di mettere su delle reti ad hoc

Reti Locali Wireless (WLANs)

- Mobilità dell'utente
  - Mobilità limitata (Nomadicità)
  - Wi-Fi Hotspot (Stazioni, Aeroporti, Alberghi, ...)
  - Ufficio con WLAN
  - Casa (con accesso wireless a ADSL)
- Mobilità gestita a livello data link
  - Mobilità trasparente ai protocolli di livello superiore (IP, TCP, protocolli applicativi)
  - Nessuna modifica al software di rete o alle applicazioni
  - Mobilità a costi molto limitati

Standard IEEE 802.11

- IEEE 802.11
  - 2.4 Ghz
  - Bit rate: 1, 2 Mbps
- IEEE 802.11a
  - 5 Ghz
  - Bit rate: fino a 54 Mbps
- IEEE 802.11b (Wi-Fi)
  - 2.4 Ghz
  - Bit rate: fino a 11 Mbps
- IEEE 802.11g
  - 2.4 GHz (compatibile con Wi-Fi)
  - Bit rate: fino a 54 Mbps

Altri Task Group 802.11

- IEEE 802.11h
  - Estensione della 802.11a per evitare interferenze con satelliti NATO e sistemi radar a micro-onde.
- IEEE 802.11e
  - Supporto della QoS
  - Ridefinizione di CSMA/CA per includere gestione delle priorità
- IEEE 802.11c
  - Estensione wireless di 802.1D

Altri Task Group 802.11

- IEEE 802.11d
  - Inclusione di informazioni specifiche al paese nei beacon
  - I nodi imparano da soli lo spettro di frequenze utilizzabile e i vincoli di trasmissione (es. Potenza massima)

- IEEE 802.11f
  - Protocollo di comunicazione fra AP per il roaming degli utenti da un AP ad un altro

- ...

Modalità di funzionamento

- Con infrastruttura
  - Le stazioni comunicano mediante Access Point
  - Modalità tipica per l'accesso wireless a Internet

- Senza infrastruttura (ad hoc)
  - Comunicazione diretta
  - I nodi devono essere in visibilità (no multi-hop)

Modalita' di funzionamento

- Con infrastruttura
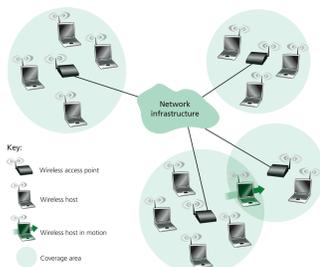

Key:

- Wireless access point
- Wireless host
- Wireless host in motion
- Coverage area

Figure 6.1 ♦ Elements of a wireless network

Modalita' di funzionamento

- Senza infrastruttura
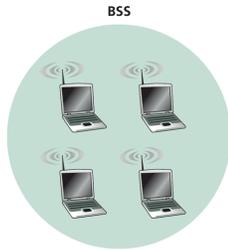
BSS

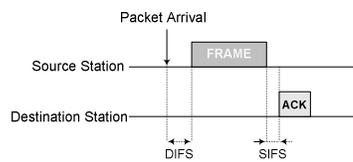**Figure 6.7** ♦ An IEEE 802.11 ad hoc network

Protocollo CSMA/CA

Station 1

Station 2

Station 3

DIFS   DIFS   DIFS

FRAME

↓ Packet Arrival   ☐ Elapsed Backoff Time

☐ Frame Transmission   ■ Residual Backoff Time

Protocollo CSMA

Packet Arrival

Source Station   FRAME

Destination Station   ACK
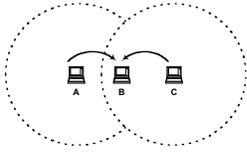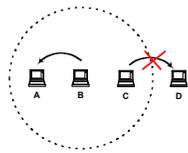
DIFS   SIFS
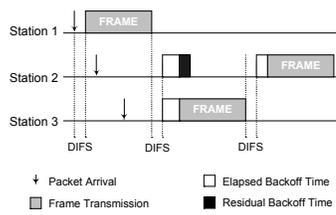
Problemi comuni

Problema del nodo nascosto   Problema del nodo esposto

Wi-Fi   19

Virtual Carrier Sensing

DIFS   SIFS

Source Station ——— RTS   FRAME

Destin. Station ———   CTS   ACK

SIFS   SIFS

Another Station ———   NAV RTS   Backoff Time
                        NAV CTS   DIFS

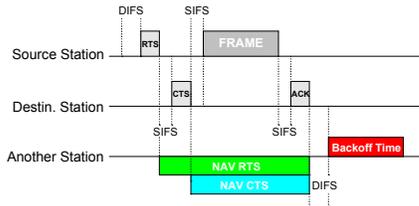Wi-Fi   20

WiFi Ad Hoc Network

BSS

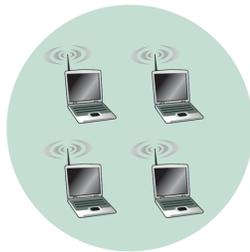**Figure 6.7** ♦ An IEEE 802.11 ad hoc network

Wi-Fi   21
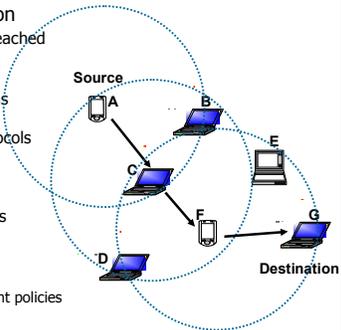
7

Multi-hop Ad Hoc Networks

- Multi-hop Communication
  - The final destination is reached through several hops
  - No dedicated router
  - Intermediate nodes act as routers
  - Appropriate routing protocols needed
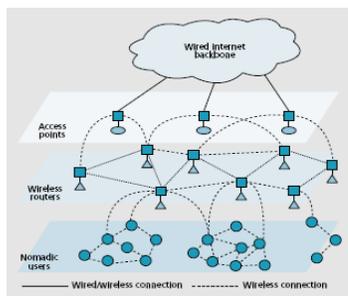
- Delivery may fail due to
  - Node Movements/Failures
  - Selfish nodes
    - Energy limitations
    - Maliciousness
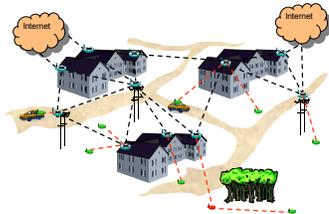   - Cooperation enforcement policies needed

Source

A   B

C   E

F   G

D

Destination

Wi-Fi   22

Mesh Networks

Wired Internet backbone

Access points

Wireless routers

Nomadic users

Wired/wireless connection --------- Wireless connection

Wi-Fi   23

Mesh Networks: Applications

Residential Broadband Internet Access

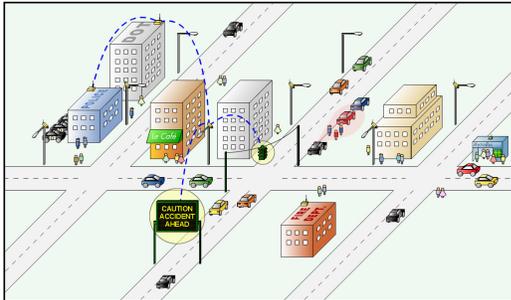Internet   Internet

Wi-Fi   24

Mesh Networks: Applications
Intelligent Transportation System

PANs/BANs

- PANs
- BANs
- Bluetooth
  - Application areas
  - Architecture

PANs

- Interconnection of **Personal** Devices
  - Cell-phone, notebook, PDA
  - Printer, mouse, camera, sensors, …
- Short Range (10 m)
- Low Power
  - Energy-limited devices
  - Minimal impact on health
- Topology
  - Ad Hoc (infrastructure-less)
  - Dynamic
- Different services supported
  - data, voice
- Internet connection
- Plug & Play

BANs

- Interconnection of **wearable** devices
  - Cell-phone, PDA
  - MP3 player, headset
  - smart watch, wearable dispalys, ...
- Very short range (1 m)
- Low Power
- Topology
  - Ad hoc
  - Basically static topology
- Different data types
- Plug & Play

Wi-Fi   28

Bluetooth

- Short range radio at 2.4 GHz
  - Available globally for unlincensed users
  - Low-power
  - Low-cost
  - Cable replacement
  - Devices within 10m can share up to 700 Kbps (1 Mbps nominal)
  - Universal short-range wireless capability

Wi-Fi   29

Bluetooth SIG

Bluetooth Special Interest Group

- Trade association comprised of leaders in the computing, telecommunications, automotive, industrial automation and network industries
  - Agere, Ericsson, IBM, Intel, Microsoft, Motorola, Nokia and Toshiba, and thousands of Associate and Adopter member companies
- Founded in September 1998
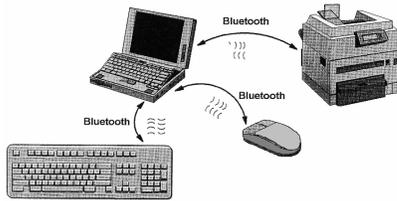- Aimed at driving the development of *Bluetooth* wireless technology

Wi-Fi   30

Application areas

- Cable replacement
  - No need for numerous cable attachments
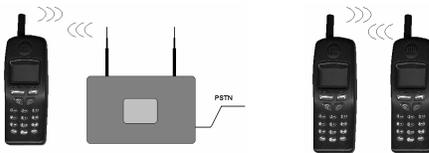 - Automatic synchronization when devices within range

Wi-Fi 31

Application Areas

Wireless Voice Transmission
- Cordless headset
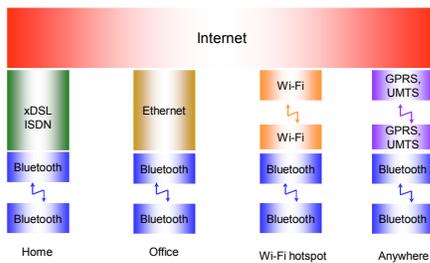- Three-in-one phones
  - cellular, cordless, walkie-talkie

Wi-Fi 32

Application areas

Wireless Data Access
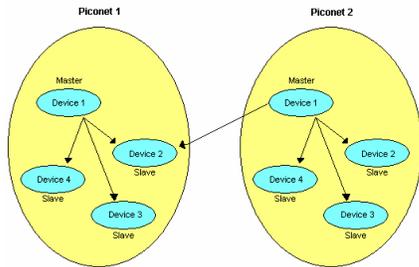

Wi-Fi 33

11

Application Areas

Ad hoc networking

- Can establish connections between devices in range
- Devices can imprint on each other so that authentication is not required for each instance of communication
- Support for object exchange
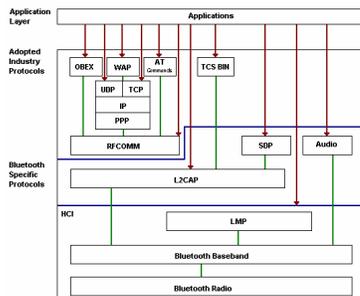 - Files
  - Calendar entries
  - Business cards
  - ...

Piconet e Scatternet

Bluetooth Architecture

Bluetooth Architecture

Bluetooth protocols are organized into three levels

- Bluetooth specific protocols
- Adopted industry protocols
  - Existing protocols included in the Bluetooth protocol stack
    - TCP/IP, PPP, WAP, ObEX
  - Allows Bluetooth to be used transparently in legacy application
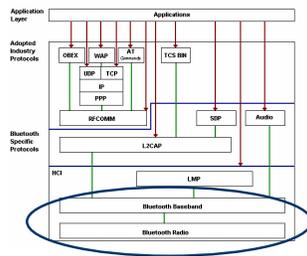- Applications

Communication Protocols

Bluetooth Radio
- Specifies the physical characteristics of transmission

Bluetooth BaseBand
- Includes the medium access control protocol
- Specifies the communication rules inside the piconet

Frequency bandwidth

1 MHz

2400 - 2483.5 MHz

78 Carrier Frequencies

Bluetooth Band

13

TDD and Timing

f(k)   f(k+1)   f(k+2)

Master

Slave

625 µs
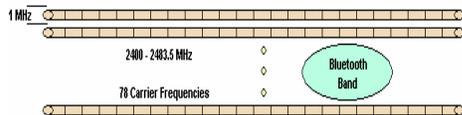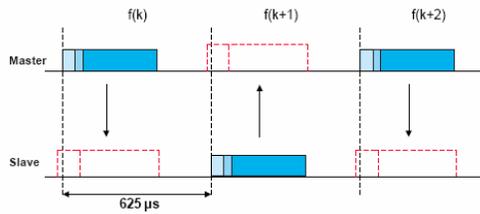
Wi-Fi 40

Multi-slot Packets

625 µs

f(k) f(k+1) f(k+2) f(k+3) f(k+4) f(k+5) f(k+6)

f(k) f(k+3) f(k+4) f(k+5) f(k+6)

f(k) f(k+5) f(k+6)
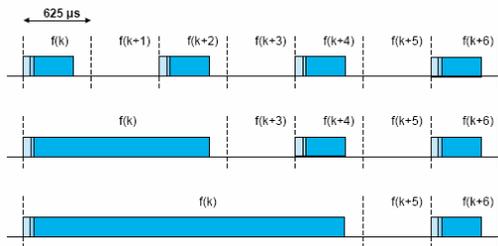
Wi-Fi 41

Connection types

SCO ACL SCO ACL SCO SCO ACL

MASTER

SLAVE1

SLAVE2

Wi-Fi 42

14
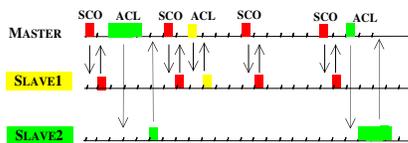
Operation Modes

- Active Mode
  - The device is continuously active
  - No more than 7 active device at a time within a piconet
  - Each node is assigned a 3-bit Active Member Address (AMA)
- Sniff mode
  - Used to reduce energy consumption in devices that are only sporadically active
  - The device does not hear all odd slots
  - It is usually sleeping and wakes up once in a while
  - The device holds the 3-bit address
- Hold mode
  - The device is not able to receive ACL packets for a pre-negotiated time interval
  - It holds the 3-bit address

Operation Modes

- Park mode
  - The device must release the 3-bit address to the master
  - It remains however synchronized to the master
    - Wakes up periodically to get Hopping Synchronization Packets containing the master clock and its frequency hopping sequence
  - Only the device clock is running
    - Energy saving mode
  - In addition to 7 active slaves in the piconet there may be up to 255 parked devices
    - If there already 7 active slaves a parked device must wait until one of the active members switches to the parked mode

MAC protocol

Polling scheme

- The master has the full control of the channel
  - slaves' transmissions are scheduled by the master
- Whenever a slave receives a packet from the master it is allowed to send a packet in the next set of 1, 3 or 5 slots
- If the slave has no data to send it replies with a NULL packet (no payload)
- If the master has no data to send uses a POLL packet to enable a slave to transmit in the next odd slot

Packet format

Access Code	Header	Payload Data
72 Bits	54 Bits	0 - 2745 Bits
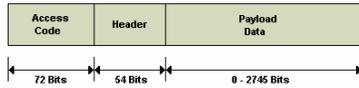
- Access code
  - Channel Access Code: used to identify the piconet
  - Device Access Code: used by the master to page the slave
  - Inquiry Access Code: used to find the address of a neighbor device
- Header
  - AM Address (3 bits) : identifies one of the 7 active stations (0: master)
  - Type (4 bits) : indicates the type/contents in the payload
  - Flow (1 bit): used for flow control in ACL mode (stop=0, resume=1)
  - ARQN (1 bit): indicates the type of acknowledgement (ACK=1, NACK=0)
  - SEQN (1 bit): modulo-2 sequence number
  - HEC (8 bits): Header Error Correction (1/3 forward error correcting code)
- Payload
  - 0-343 bytes which include an additional 1- or 2-byte header and a 2-byte CRC

Packet types

- SCO packets
  - Data packets used in SCO connections
- ACL packets
  - Data packets used in ACL connections
- Poll packets
  - Control packets used by the master to poll slaves
- Acknowledgement packets
  - ACK and NACK
- Frequency Hopping Synchronization (FHS) packets
  - Control packets send by the master to a slave to enable it to synchronize to the clock of the master and its hopping sequence

Connection set-up

- Inquiry
  - Looks for Bluetooth devices in the proximity
  - Neighbor discovery
- Paging
  - Establishes a connection with another Bluetooth device discovered in the inquiry phase
- Connection
  - Negotiates the connection parameters
  - This phase is done through the LMP

The device that started the inquiry phase becomes the master of the connection

Connection set-up
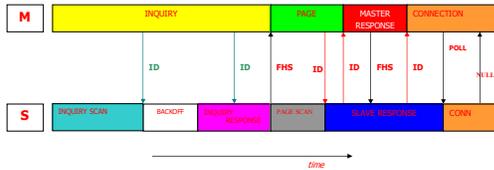
Service Discovery

- A BT device is able to provide services to other BT devices
- A BT device must monitor which service are currently available
  - The set of available service may be dynamic as BT devices join and leave the piconet
- The service discovery protocol (SDP) is used to
  - Find new service as soon as they become available
  - Deregister services that become unavailable

Service Discovery Protocol (SDP)
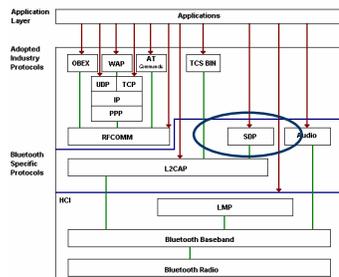
Scenario steps

- Master device (e.g., BT phone) pages for nearby devices
- Receives responses from 0,1, or more devices
  - Slave device (e.g., headphone) responds to page
- establishes the BT connection
  - Assigning paging device to be master
  - The two devices synchronize their frequency hopping
- and negotiates connection parameters
  - Authentication is part of this phase
- Devices exchange profiles they both support
- Agree upon profile (e.g., audio streaming)
- Master sends audio data
  - Keep-alive packets used to maintain connection
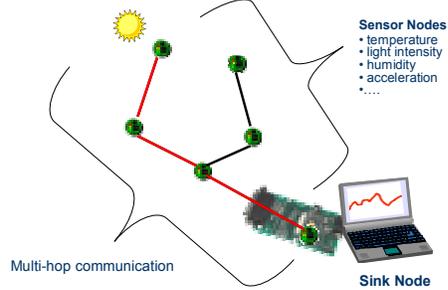
Wi-Fi 52
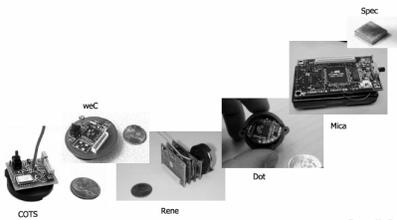
Sensor Networks

- Architettura
- Applicazioni

Wi-Fi 53

Sensor Networks

Sensor Nodes
- temperature
- light intensity
- humidity
- acceleration
- ....

Multi-hop communication

Sink Node

Wi-Fi 54

Sensor Networks

Spec

weC

Mica

Dot

Rene

COTS
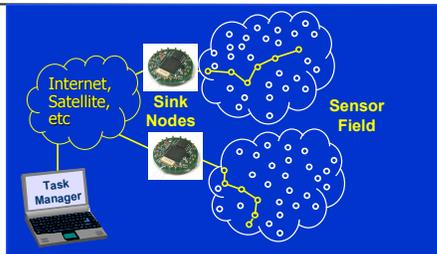
- Small Devices
  - Limited computational and energy resources
- Sensing
- Processing
- Communications

Wi-Fi   55

Sensor Network Architecture

Internet, Satellite, etc

Sink Nodes

Sensor Field

Task Manager

- Several thousand nodes
- Nodes very close to each other
- Densities as high as 20 nodes/m3

Static Sink(s)

Wi-Fi   56

Sensor Network Applications

- Military, Environmental, Health, Home, Space Exploration, Chemical Processing, Disaster Relief….

- SENSOR TYPES: Seismic, Low sampling rate magnetic, Thermal, Visual, Infrared, Acoustic, Radar…

- SENSOR TASKS: Temperature, Humidity, Vehicular Movement, Lightning Condition, Pressure, Soil Makeup, Noise Levels, Presence or Absence of Certain Types of Objects, Mechanical Stress Levels on Attached Objects, Current Characteristics Speed, Direction, Size) of an Object ….

Wi-Fi   57

Military Applications

- Monitoring
  - Friendly Forces, equipment, ammunition
- Battlefield Surveillance
- Reconnaissance of opposite forces
- Targeting
- Battle damage assessment
- Attack detection
  - Nuclear, biological, chemical

Wi-Fi 58

Environmental Applications

- Tracking of animals' movements
  - Birds, insects, …
- Habitat Monitoring
- Forest fire detection
- Flood detection
- Precision Agriculture
- …

Wi-Fi 59

Environmental Applications

- ALERT SYSTEM (Flood detection)
  - Deployment of different sensor types
    - Rainfall sensors
    - Water level sensors
    - Weather sensors
  - Sensors send information to a DB
  - Flooding detection and prevention

Wi-Fi 60

20

Environmental Applications

- Great Duck Island Project
  - Monitoring of Petrel habitat
  - Sensors in Petrel nests
    - temperature
    - humidity
    - light intensity
    - ...
  - Monitoring of data before, during and after Petrel permanency in nests

Great Duck Island Light

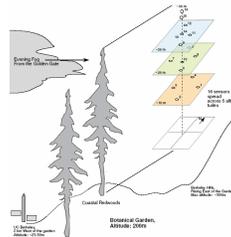Wi-Fi   61

Environmental Applications

- Berkeley Botanical garden
  - Monitoring of environmental conditions around a sequoia
  - 16 sensors deployed at different heights

Wi-Fi   62

Environmental Applications

- Precision Agriculture
  - Pesticide level
  - Soil erosion level
  - Air pollution

Wi-Fi   63

Health Applications

- Remote monitoring of physiological data
- Remote monitoring of elderly people
- Monitoring of patients in hospitals
- Tracking of doctors in hospitals
- Drug administration in hospitals
  - Minimize adverse drug events
    - e.g., allergies to a specific medicine

Wi-Fi 64

Home Applications

- Home Automation
  - Sensors and actuators inside appliances, ovens, refrigerators, ...
  - Easy management of home devices (both local and remote)
- Smart environments
  - Human centered
  - Technology centered

Wi-Fi 65

Commercial Applications

- Environmental Control in Buildings
  - Temperature and Air Flow Control
  - Light Level Control
  - Energy Saving ($ 55 billions per year)
  - Carbon Emission reduction
  - Better Quality of Life (?)

Wi-Fi 66

Commercial Applications

PerLab

- Inventory Control
    - Each item has a sensor attached
    - Easy localization of items
    - Easy management of items
- Vehicle Tracking and Detection
- Car Theft Detection
- Remote monitoring of Parking Places

Wi-Fi   67