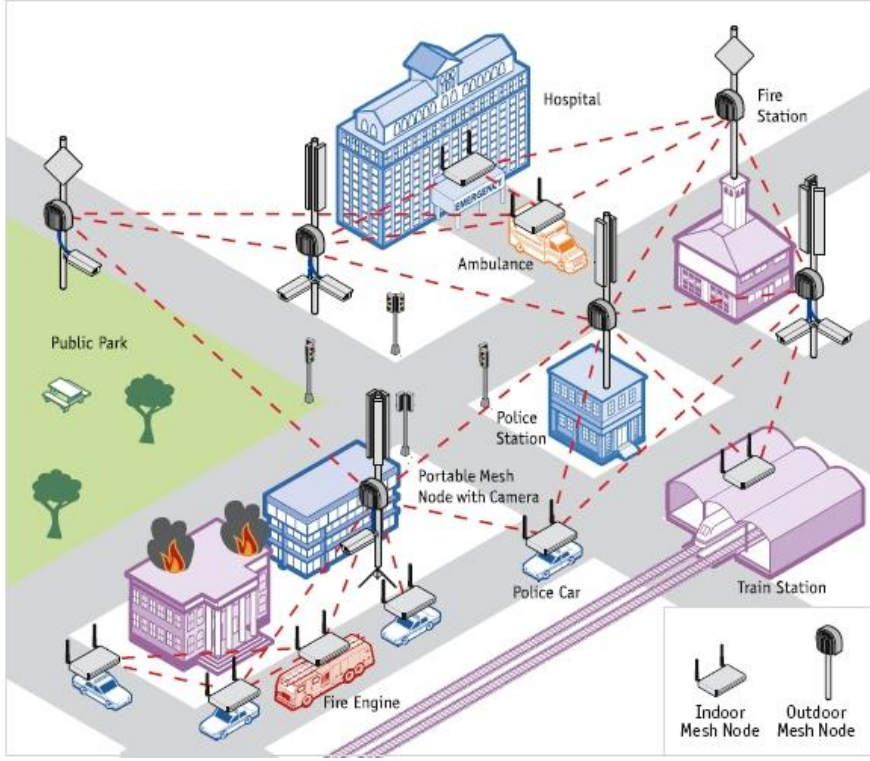

Wireless Networking Technologies for ICOM 5047

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Outline

- Objectives
- Introduction
- Wireless networks
- How to design?

The Objectives

- This talk is prepared for ICOM students who are taking course ICOM 5047 (capstone)
- The main objectives are
  - To present a wide range of available wireless networking technologies
  - To discuss how to select appropriate technologies for a capstone project
  - To provide information about regulation, standard, etc.

What Do We Have Today?

- Cellular networks
  - AT&T
  - Claro
  - T-Mobile

- WiFi
  - IEEE 802.11 based wireless local area networks
  - RUMNET

- Bluetooth

What's Next?

- We are currently moving from the ***Personal Computer Age*** towards the ***Ubiquitous Computing Age***
  - People can access required information **anytime and everywhere**
- In this transition, wireless networks are the essential elements

Wireless Networks

- A network that uses radio/mechanical signals to enable communication among computers and other network devices
- One of the most important technologies today!

A wireless network in home

Benefits of Wireless Networks

Mobility	• People moves, devices too.
Cost	• Cheap to develop.
Installation	• Wireless can install anywhere.
Ease of use	• Plug & Play.
Transparency	• Users work similar like wired LANs.
Time savings	• Temporary networks

Outline

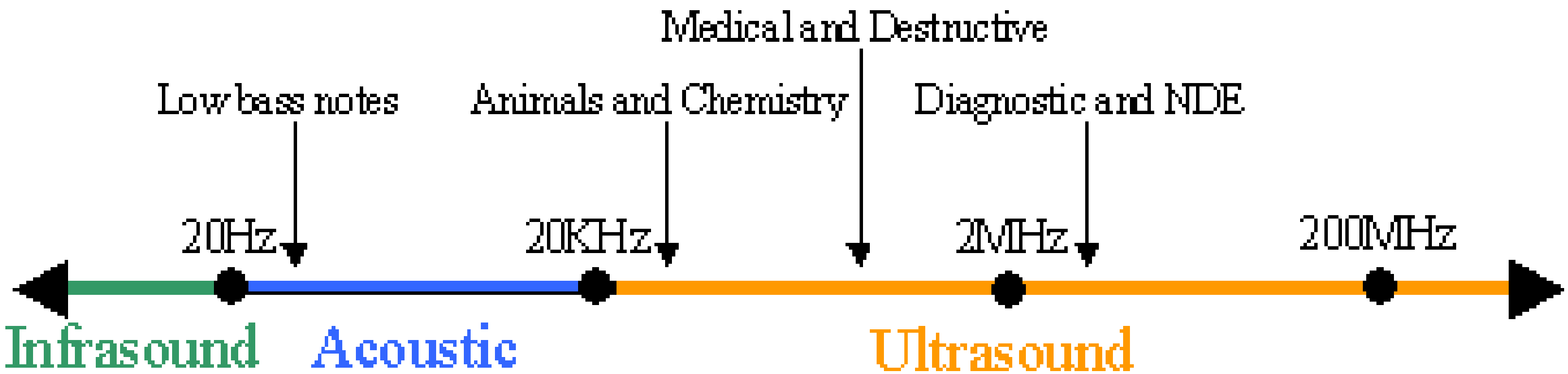
- Objectives
- Introduction
- Wireless networks
  - Fundamentals
  - Categories
  - Existing wireless networks
- How to design?

Fundamentals

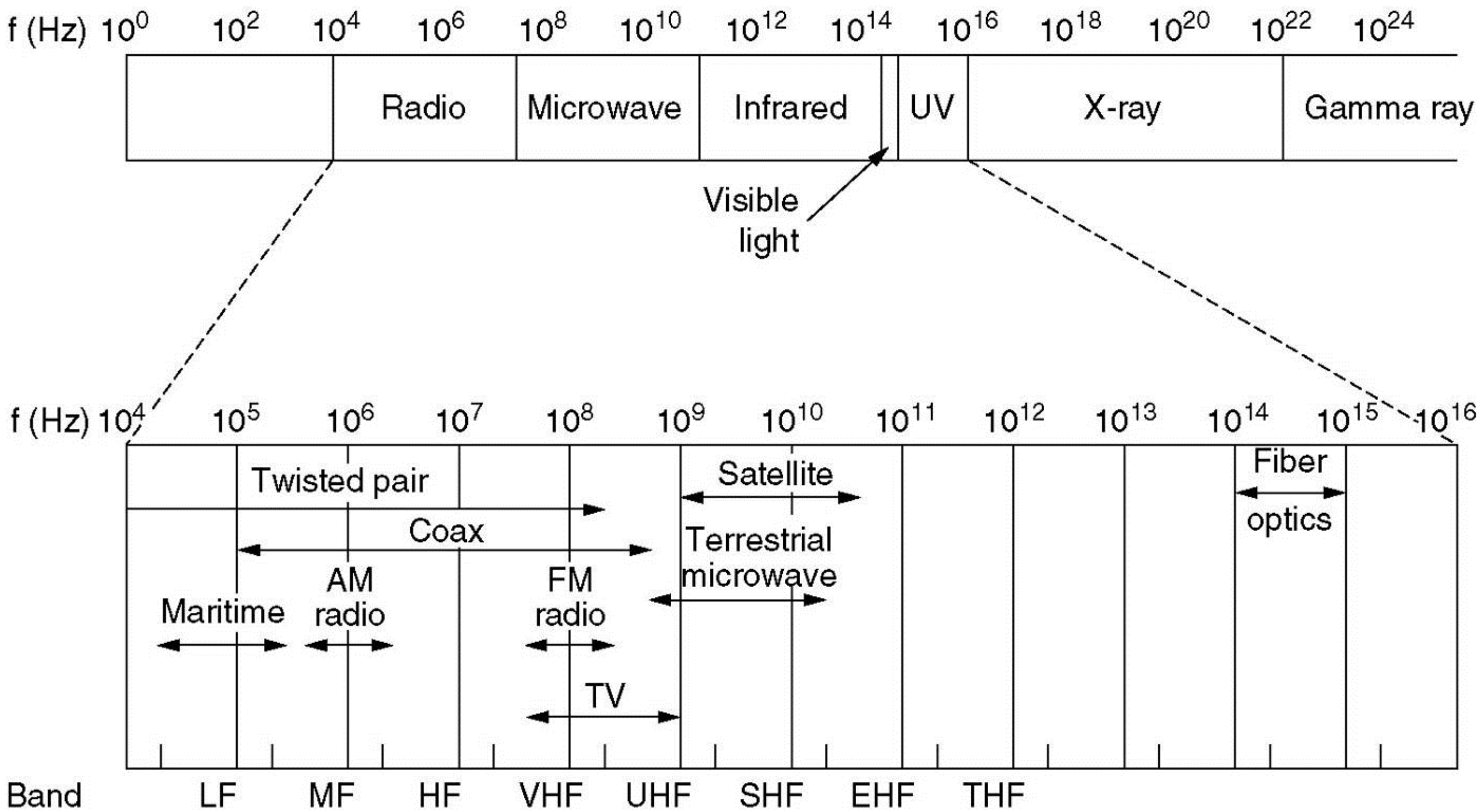
- Two types of waves can be used for wireless communications
  - Electromagnetic
  - Mechanical (acoustic)
- <u>Frequency</u>: the number of oscillations per second of a wave
  - Denoted as f and the unit of frequency is Hz (Hertz)
- <u>Wavelength</u>: The distance between two consecutive maxima (minima)
  - Denoted as λ and the unit of wavelength is meter (m)

Mechanical Wave

- Mechanical waves can be transmitted in gases, liquids, and solids



The Electromagnetic Spectrum



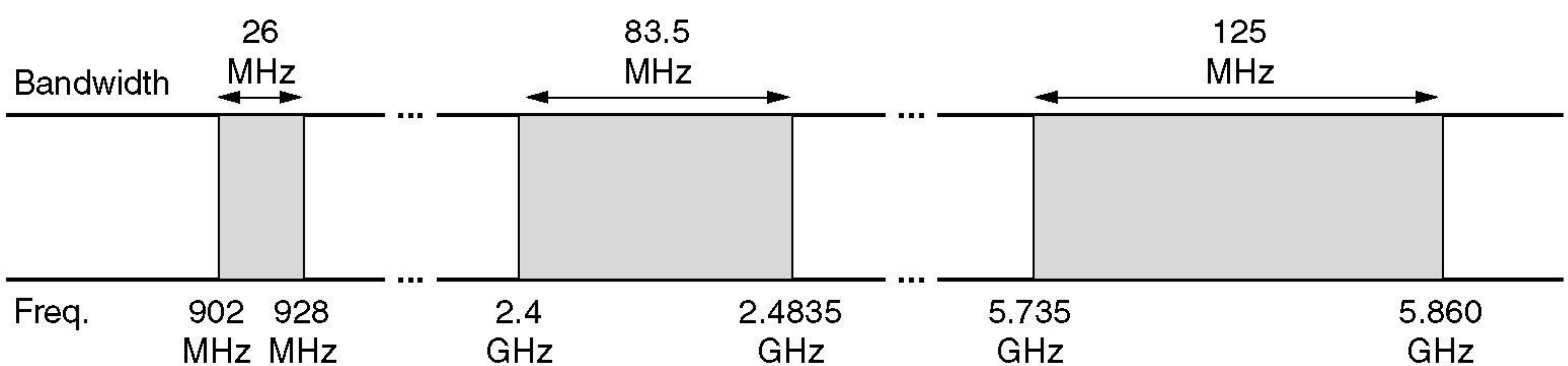
The Electromagnetic Spectrum

- Band names (defined by the ITU)
  - VLF: very low frequency
  - LF: low frequency
  - MF: medium frequency
  - HF: high frequency
  - VHF: very high frequency
  - UHF: ultra high frequency
  - SHF: super high frequency
  - EHF: extreme high frequency
  - THF: tremendous high frequency

- ITU = International Telecommunication Union
  - ITU-R = Radio communication sector

Regulation for Using the EM Spectrum

- US: FCC (Federal Communications Commission)
  - The ISM bands in the United States
    - ISM: Industrial, Scientific, Medical

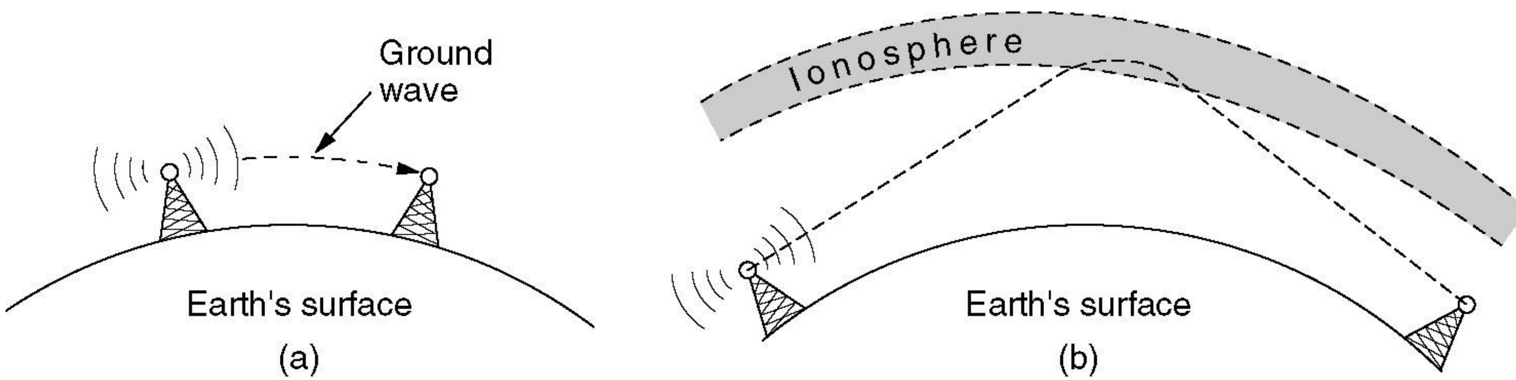


802.11b
Bluetooth
Microwave oven

802.11a

Radio Transmission

- In the VLF, LF, and MF bands, radio waves follow the curvature of the earth.
- In the HF band, they bounce off the ionosphere.



Microwave Transmission

- If the frequency of a wave is larger than 100MHz, then the transmission is nearly straight lines
  - Energy can be concentrated into a small beam
  - Wave can hardly pass through building
- Usage
  - Long distance telephone communications
  - Mobile phone
  - Television

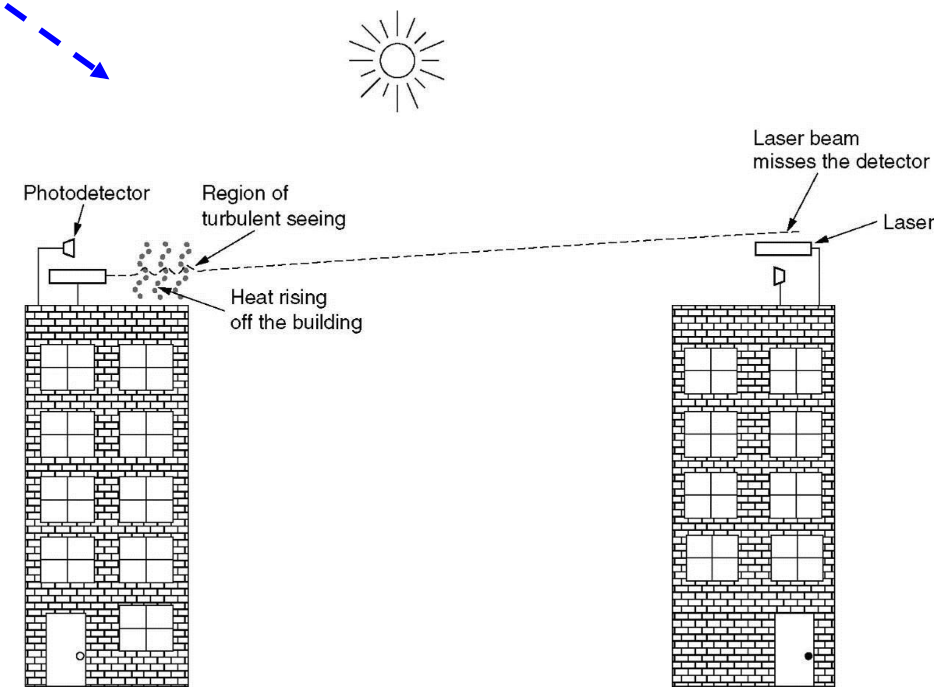
Infrared and Millimeter Waves

- Transmission: directional
- Cost: low
- Cannot pass object
  - Pros: less interference, security
  - Cons: limited coverage
- Usage:
  - Remote controller

Light Wave Transmission

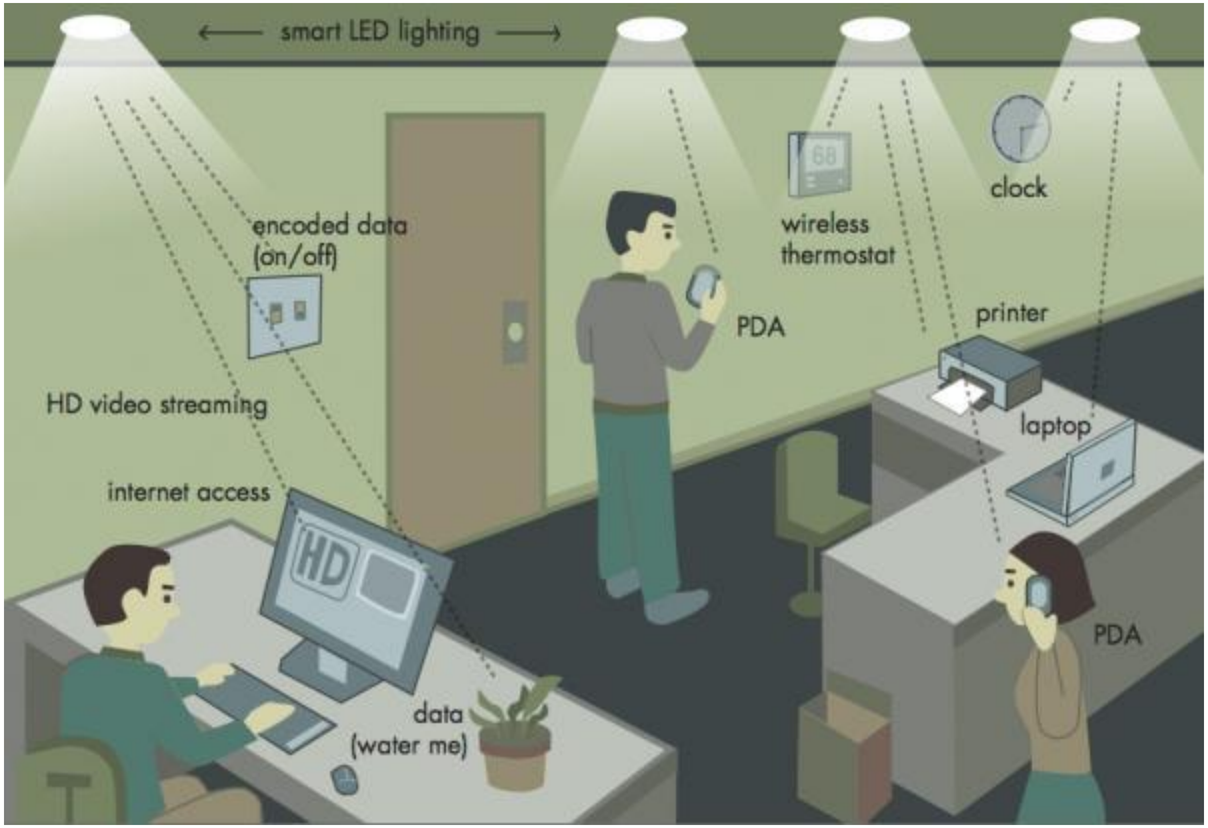
- A bidirectional system with two lasers

Convection currents can interfere with laser communication systems



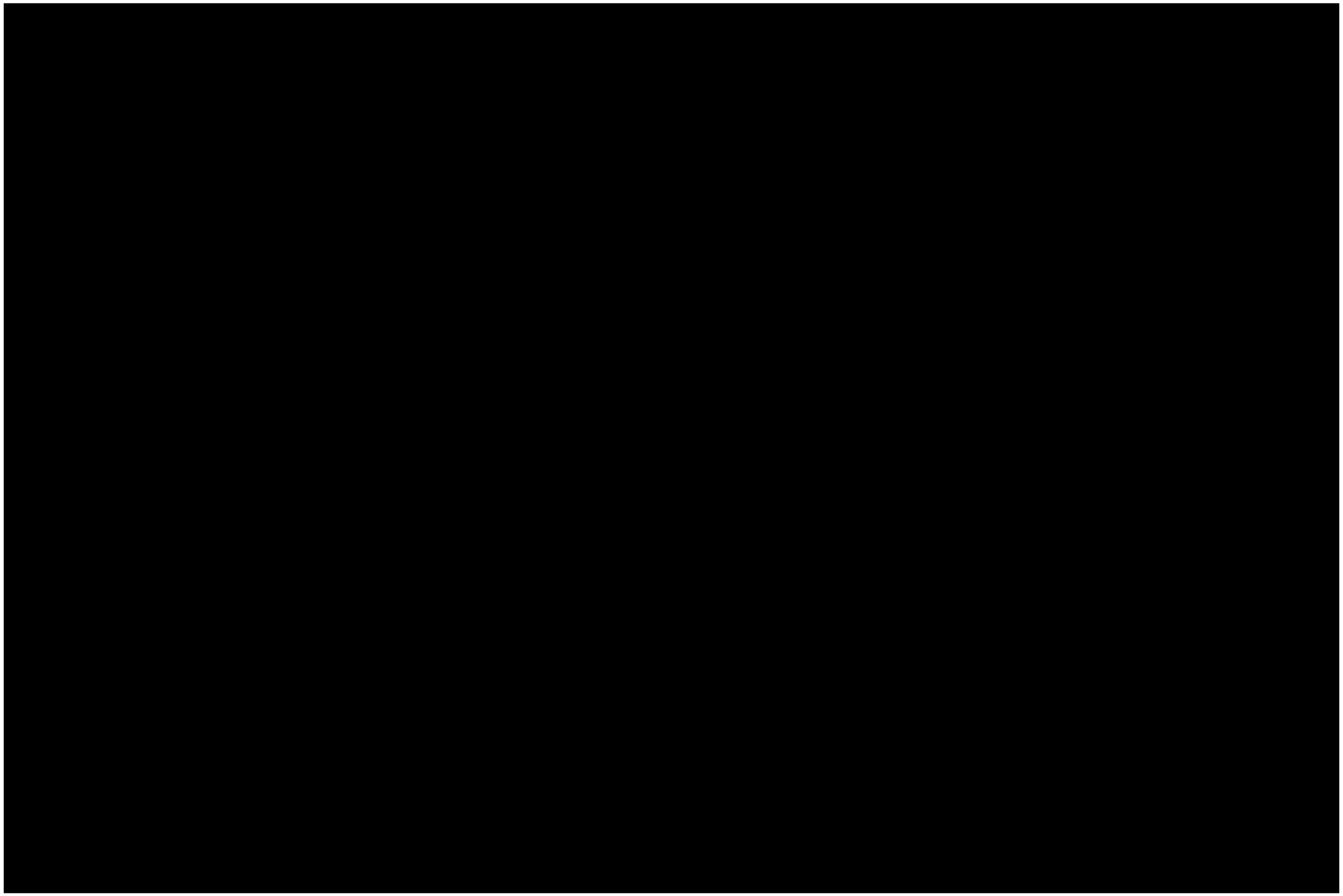
Light Wave Transmission

- An in-door visible light communication system



Light Wave Transmission

- An in-door visible light communication system



Outline

- Objectives
- Introduction
- Wireless networks
  - Fundamentals
  - **Categories**
  - Existing wireless networks
- How to design?

Categories of Wireless Networks

- By scale
- By structure
- By application

Categories by Scale

- Body area network (BAN)
  - Cover 1 meter
- Personal area network (PAN)
  - Cover 10 meters
- Local area network (LAN)
  - Cover a few hundred meters
- Metropolitan area network (MAN)
  - Cover up to a few tens kilometers
- Wide area network (WAN)
  - Cover a large area

Categories by Scale

- Wireless Personal Area Networks (WPAN)
  - Bluetooth, Wibree, Zigbee
  - Standards in IEEE 802.15
- Wireless Local Area Networks (WLAN)
  - Standards in IEEE 802.11 (Wi-Fi)
- Wireless Metropolitan Area Networks (WMAN)
  - Standards in IEEE 802.16 (WiMAX)
    - With a single base station
- Wireless Wide Area Networks (WWAN)
  - Cellular networks
    - 2G, 3G, 4G
  - Satellite networks (GPS)

Categories by Structure

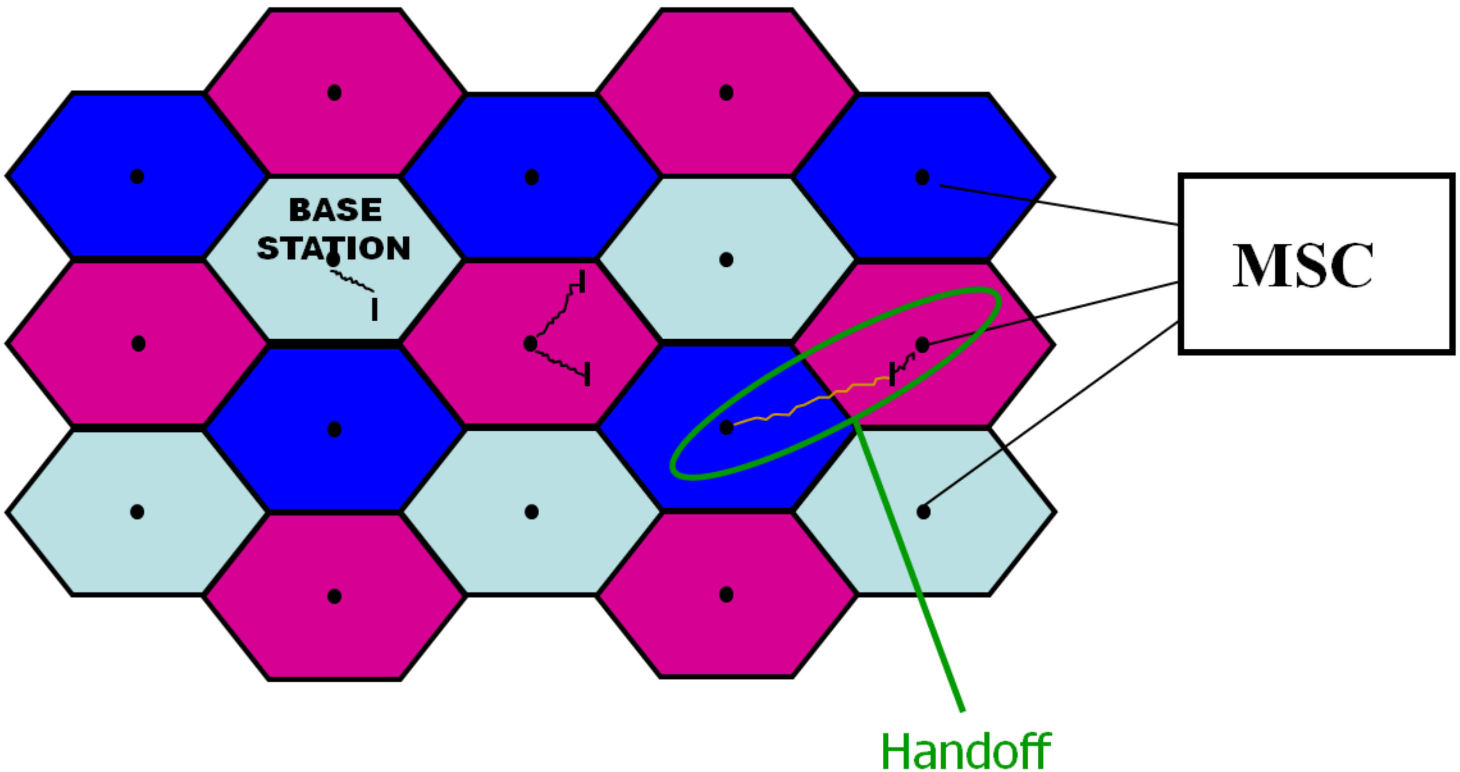
- One-hop networks
  - Wi-Fi, WiMAX
- Cellular networks
  - GSM, CDMA, WiMAX, 2G, 3G, 4G
- Mobile Ad Hoc Network (MANETs)
  - Nodes with mobility and ad hoc connectivity (e.g., soldiers and vehicles in battle field)
- Wireless Mesh Networks (WMNs)
  - Built with the existing network technologies: WPAN, WLAN, WMAN

Categories by Structure

- One-hop networks

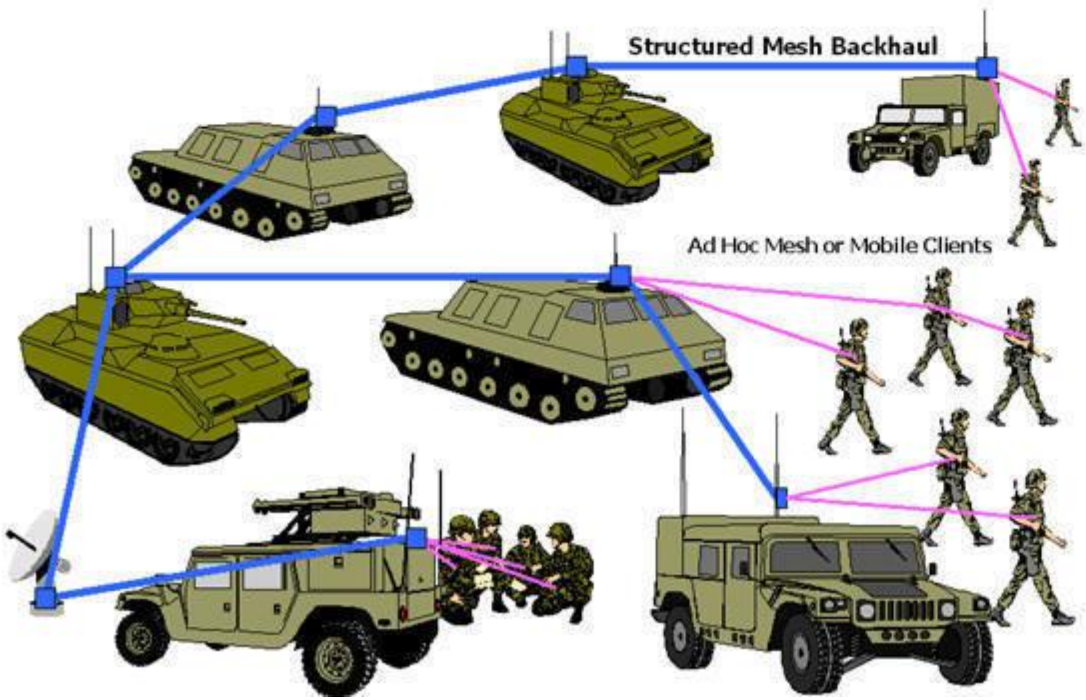
Categories by Structure

- Cellular networks



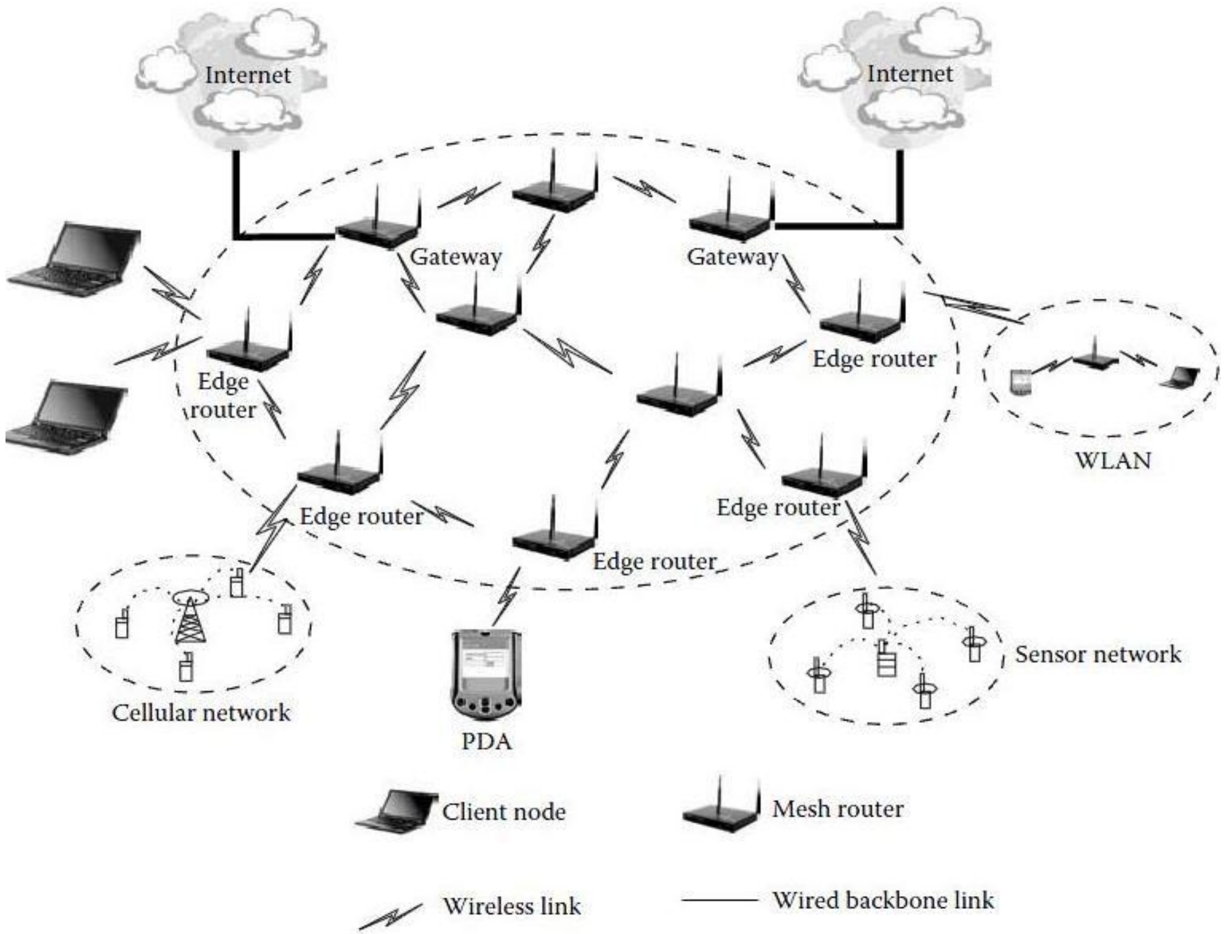
Categories by Structure

- Mobile ad hoc networks (MANETs)



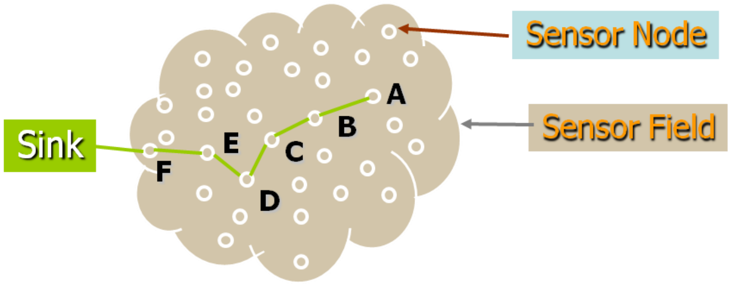
Categories by Structure

- Wireless mesh networks (WMNs)

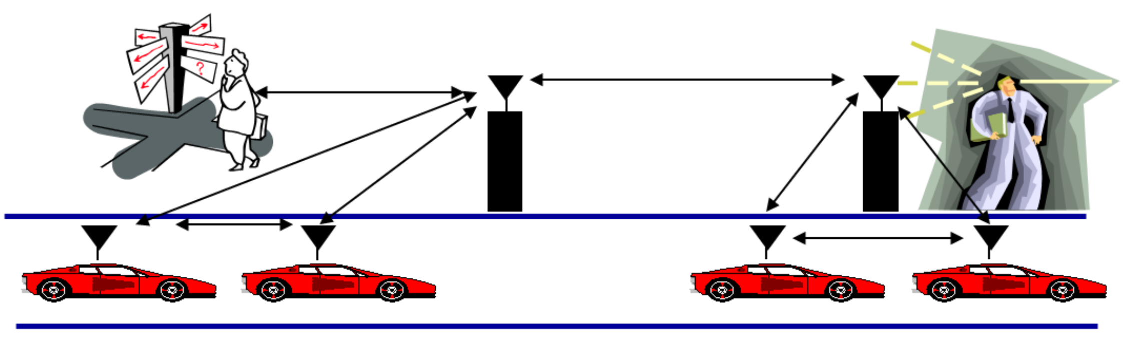


Categories by Application

- Wireless Sensor Networks (WSN)
  - Sense data from surrounding environment



- Vehicular Ad hoc Networks (VANET)
  - Exchange traffic related information



Outline

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  - Fundamentals
  - Categories
  - **Existing wireless networks**
- How to design?

Cellular Networks

Gen.	Technology	Features
1G	• AMPS	• Analog Voice Communication only.
2G	• GSM • IS-95 CDMA	• Digital voice and data • Simple email and text messages
3G	• WCDMA (European) • CDMA2000 (USA) • TD-SCDMA (China)	• Based on CDMA • Data transfer rates up to 2.4Mbps • Supports better Internet connections • Video

4G	• IEEE 802.16m
	• LTE Advanced
		• Based on OFDM and MIMO
		• Very high speed
		  • 100Mbps for high mobility
		  • 1000Mbps for low mobility

LTE: Long term evolution

Wireless Personal Area Networks (WPAN)

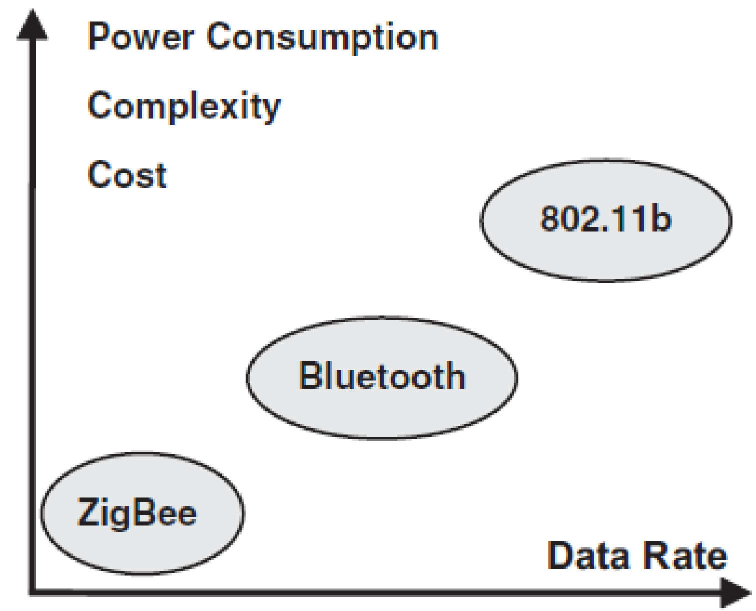
- Bluetooth, Wibree and Zigbee.
- Features:
  - Low Power
  - Coverage (radius < 10 meters)
- Bluetooth™
  - Operates in the 2.4 GHz spectrum.
  - Standards:
    - Bluetooth v1.1
    - IEEE 802.15.1

wibree

  - Bluetooth low energy technology
    - Bluetooth ULP (Ultra Low Power)

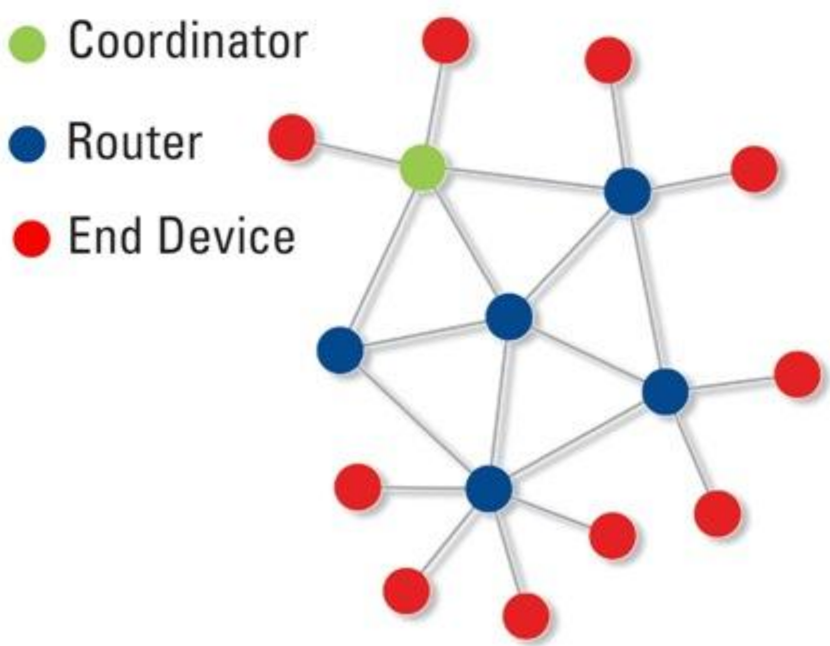
Zigbee - IEEE 802.15.4

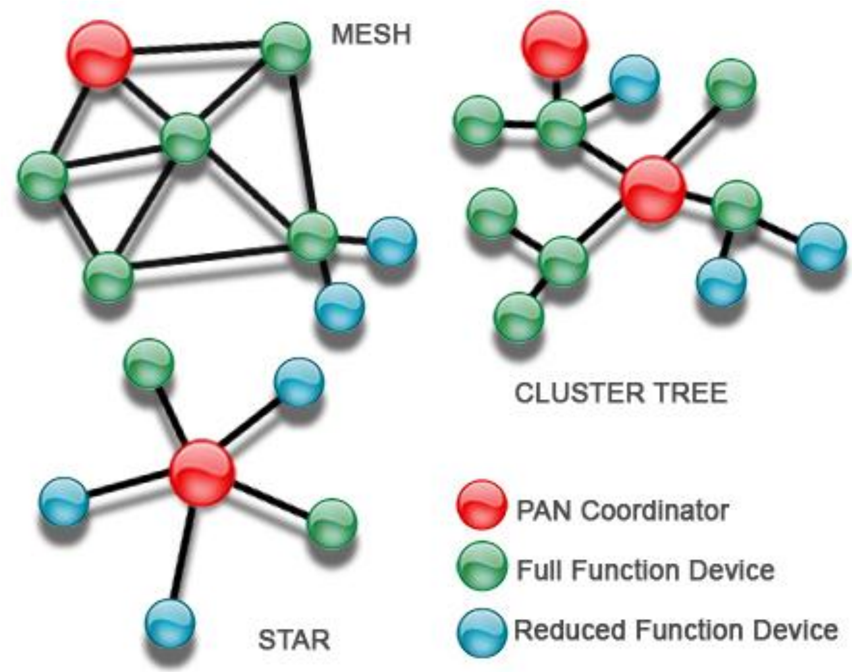
- Zigbee Alliance
  - Group of developers, vendors and manufacturers.
- IEEE 802.15.4 standard
- Uses 2.4 GHz spectrum
- Features:
  - Low cost, power and bandwidth.
  - Powered by long-life batteries
  - Simpler, cheaper than Bluetooth



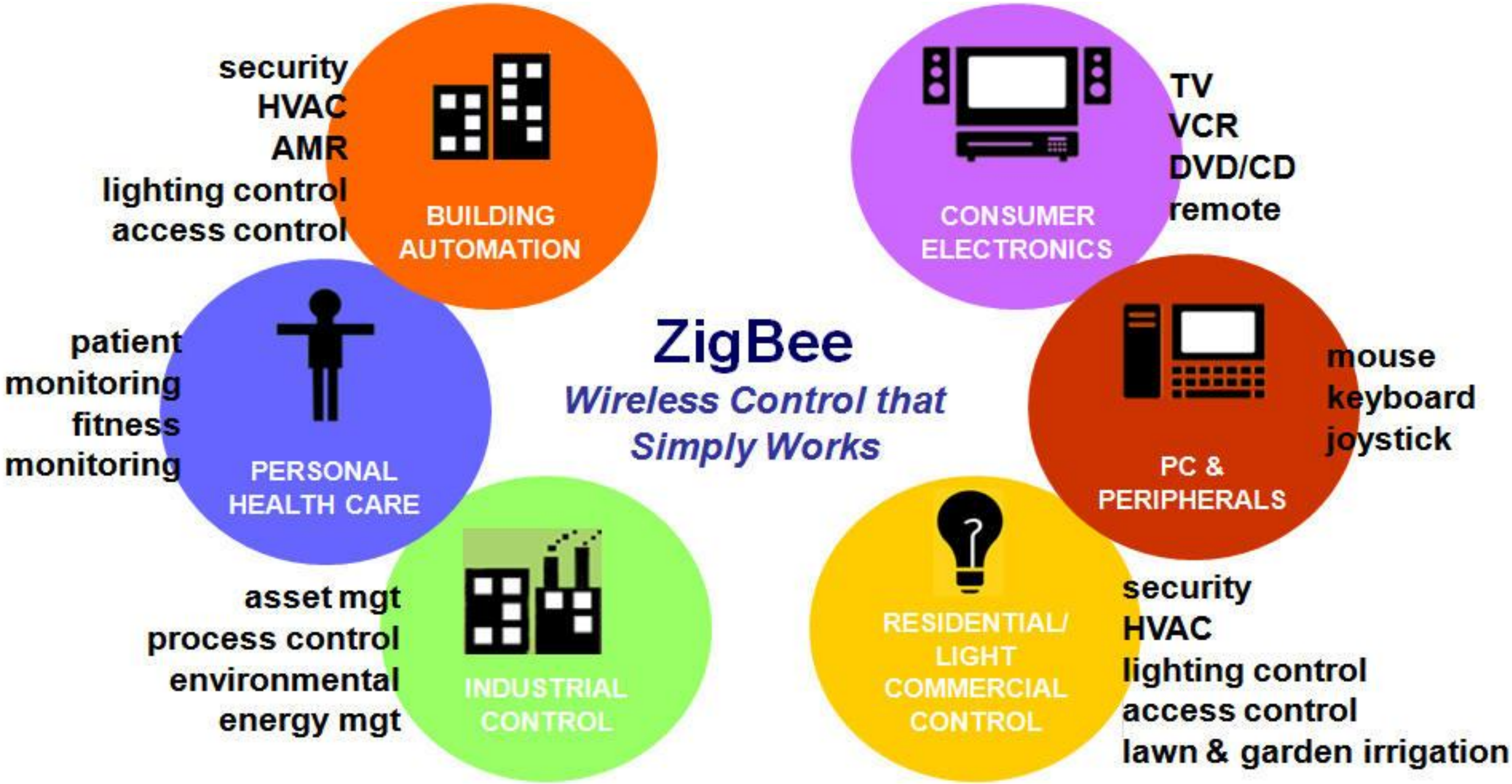
Zigbee: Topology

- Coordinator (ZC): Only one, Most Capability, functionality.
- Router (ZR): Passes data among end-devices.
- End Device (ZED): switches, detectors.





Zigbee: Applications



WPAN: Comparison

	Bluetooth	Wibree	ZigBee
Band	2.4GHz	2.4GHz	2.4GHz, 868MHz, 915MHz
Antenna/HW	Shared		Independent
Power	100 mW	~10 mW	30 mW
Target Battery Life	Days - months	1-2 years	6 months - 2 years
Range	10-30 m	10 m	10-75 m
Data Rate	1-3 Mbps	1 Mbps	25-250 Kbps
Component Cost	$3	Bluetooth + 20¢	$2
Network Topologies	Ad hoc, point to point, star	Ad hoc, point to point, star	Mesh, ad hoc, star
Security	128-bit encryption	128-bit encryption	128-bit encryption
Time to Wake and Transmit	3s	TBA	15ms

Wireless Local Area Networks (WLANs)

- The most popular Wireless network
- IEEE 802.11 standards.
- Coverage
  - radius < 200~500 meters
- Applications: Medicine, Education, Government, Public Access, etc.

Protocol	Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
Legacy	1997	2.4 -2.5 GHz	1 Mbit/s	2 Mbit/s	?
802.11a	1999	5.15-5.35/5.47-5.725/5.725-5.875 GHz	25 Mbit/s	54 Mbit/s	~50 meters
802.11b	1999	2.4-2.5 GHz	6.5 Mbit/s	11 Mbit/s	~100 meters
802.11g	2003	2.4-2.5 GHz	11 Mbit/s	54 Mbit/s	~100 meters
802.11n	2006 (draft)	2.4 GHz or 5 GHz bands	200 Mbit/s	540 Mbit/s	~250 meters

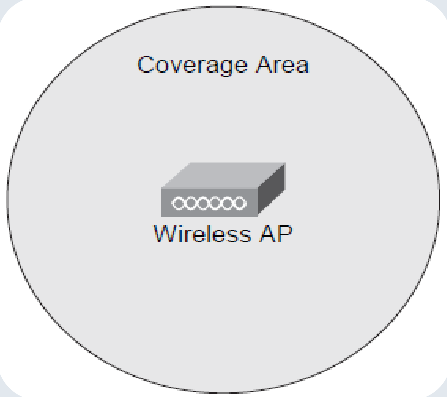
WLAN: More Standards (1)

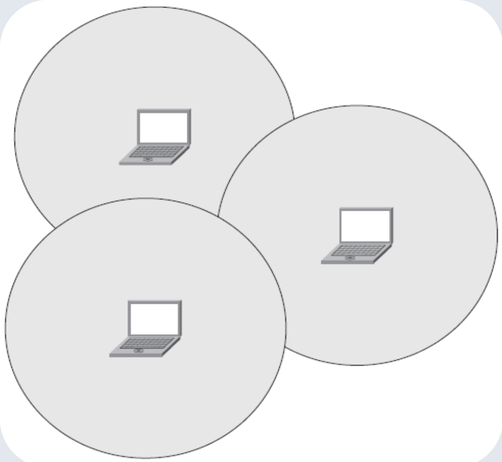
- IEEE 802.11a - 54 Mbit/s, 5 GHz standard (1999, shipping products in 2001)
- IEEE 802.11b - Enhancements to 802.11 to support 5.5 and 11 Mbit/s (1999)
- IEEE 802.11c - Bridge operation procedures; included in the IEEE 802.1D standard (2001)
- IEEE 802.11d - International (country-to-country) roaming extensions (2001)
- IEEE 802.11e - Enhancements: QoS, including packet bursting (2005)
- *IEEE 802.11F - Inter-Access Point Protocol (2003) Withdrawn February 2006*
- IEEE 802.11g - 54 Mbit/s, 2.4 GHz standard (backwards compatible with b) (2003)
- IEEE 802.11h - Spectrum Managed 802.11a (5 GHz) for European compatibility (2004)
- IEEE 802.11i - Enhanced security (2004)
- IEEE 802.11j - Extensions for Japan (2004)
- IEEE 802.11-2007 - A new release of the standard that includes amendments a, b, d, e, g, h, i & j. (July 2007)
- IEEE 802.11k - Radio resource measurement enhancements (2008)
- IEEE 802.11n - Higher throughput improvements using MIMO (multiple input, multiple output antennas) (November 2009)
- IEEE 802.11p - WAVE - Wireless Access for the Vehicular Environment (such as ambulances and passenger cars)

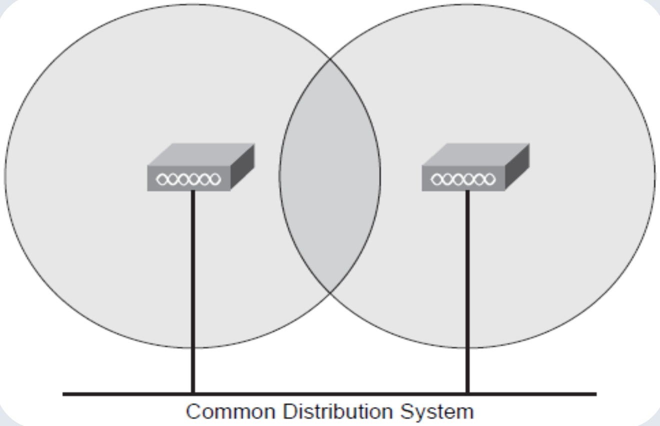
WLAN: More Standards (2)

- IEEE 802.11r - Fast roaming Working "Task Group r" - (2008)
- IEEE 802.11s - Mesh Networking, Extended Service Set (ESS) (working - September 2010)
- IEEE 802.11T - Wireless Performance Prediction (WPP) - test methods and metrics Recommendation cancelled
- IEEE 802.11u - Interworking with non-802 networks (for example, cellular) (working - September 2010)
- IEEE 802.11v - Wireless network management (working - June 2010)
- IEEE 802.11w - Protected Management Frames (working - September 2009)
- IEEE 802.11y - 3650-3700 MHz Operation in the U.S. (2008)
- IEEE 802.11z - Extensions to Direct Link Setup (DLS) (August 2007 - December 2011)
- IEEE 802.11aa - Robust streaming of Audio Video Transport Streams (March 2008 - June 2011)
- IEEE 802.11mb - Maintenance of the standard. Expected to become 802.11-2011. (ongoing)
- IEEE 802.11ac - Very High Throughput <6GHz (September 2008 - December 2012)
- IEEE 802.11ad - Extremely High Throughput 60GHz (December 2008 - December 2012)

WLAN: Topologies







Infrastructure

- BSS
  - Basic Service Set
- Needs an AP
- BSSID = SSID
  - Basic Service Set Identifier

Ad-Hoc

- IBSS
  - Independent BSS
- Peer to peer
- AP is not necessary

Extended Service Set

- ESS=BSSs+DS
  - Multiple BSS
  - Distribution System

WLAN: Security

WEP
- RC4 Algorithm
- Vulnerable to attacks
- 64 &128 bit keys

SSID Hiding
- Do not allow SSID broadcast.

MAC Filtering
- Set up into the router.

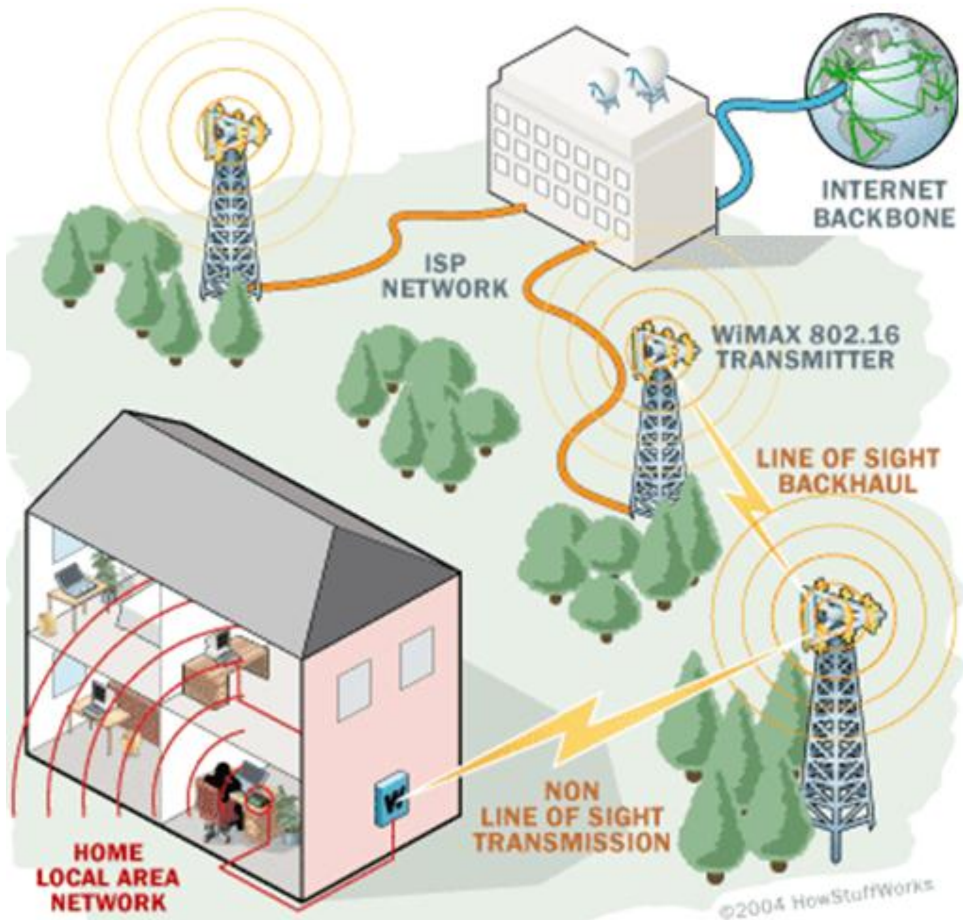
WPA & WPA2
- Replacement for WEP
- WPA2
  - Based on IEEE 802.11i
- Use AES & TKIP

Wireless Metropolitan Area Networks (WMAN)

- IEEE 802.16 (WiMAX).
- WiMAX Forum: To promote compatibility and interoperability

Extends WLANs.

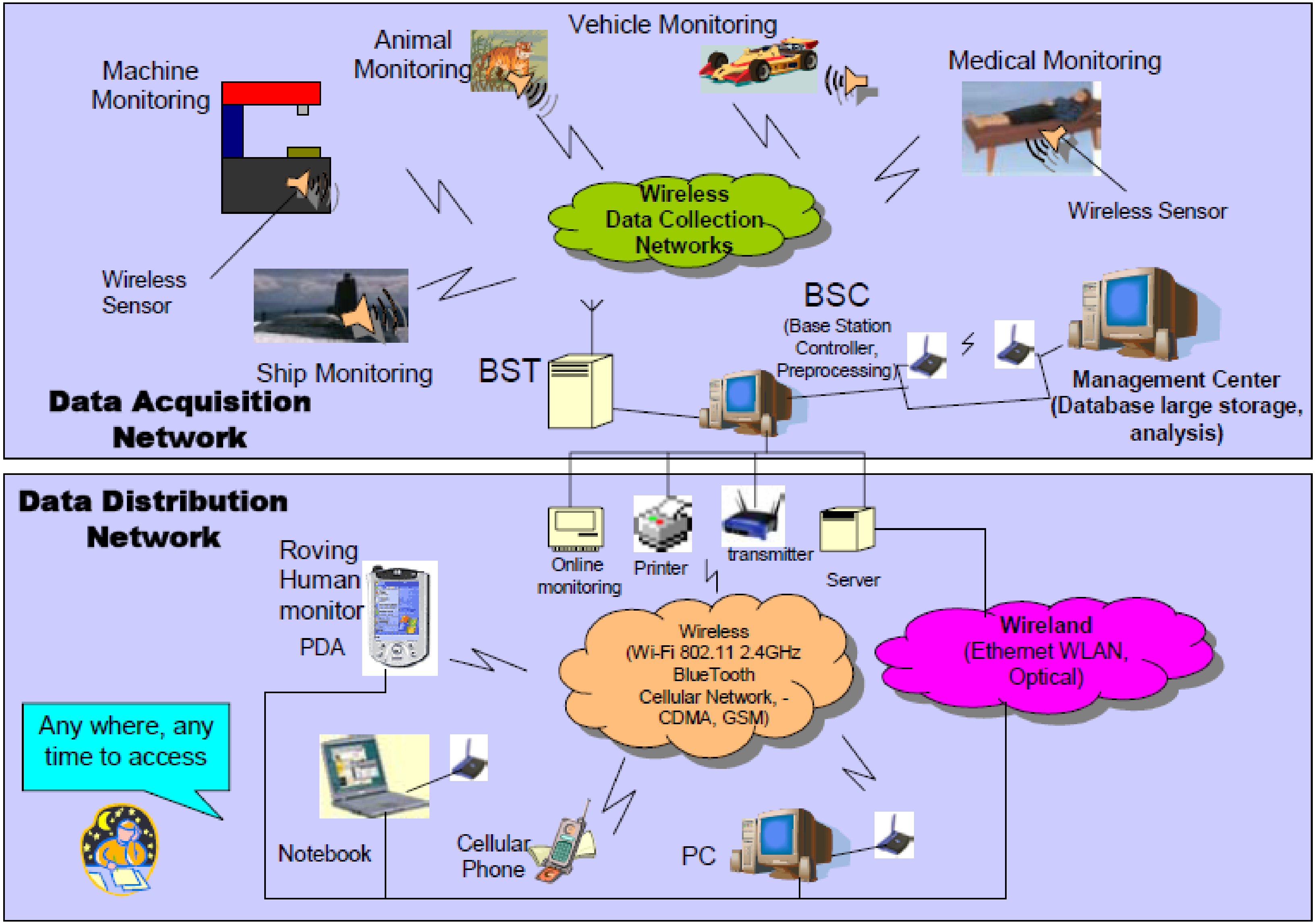
Connects Wi-Fi hotspots to the Internet



Up to 70 Mbps data rate.

Provides a wireless alternative to cable and DSL

Wireless Sensor Networks (WSN)

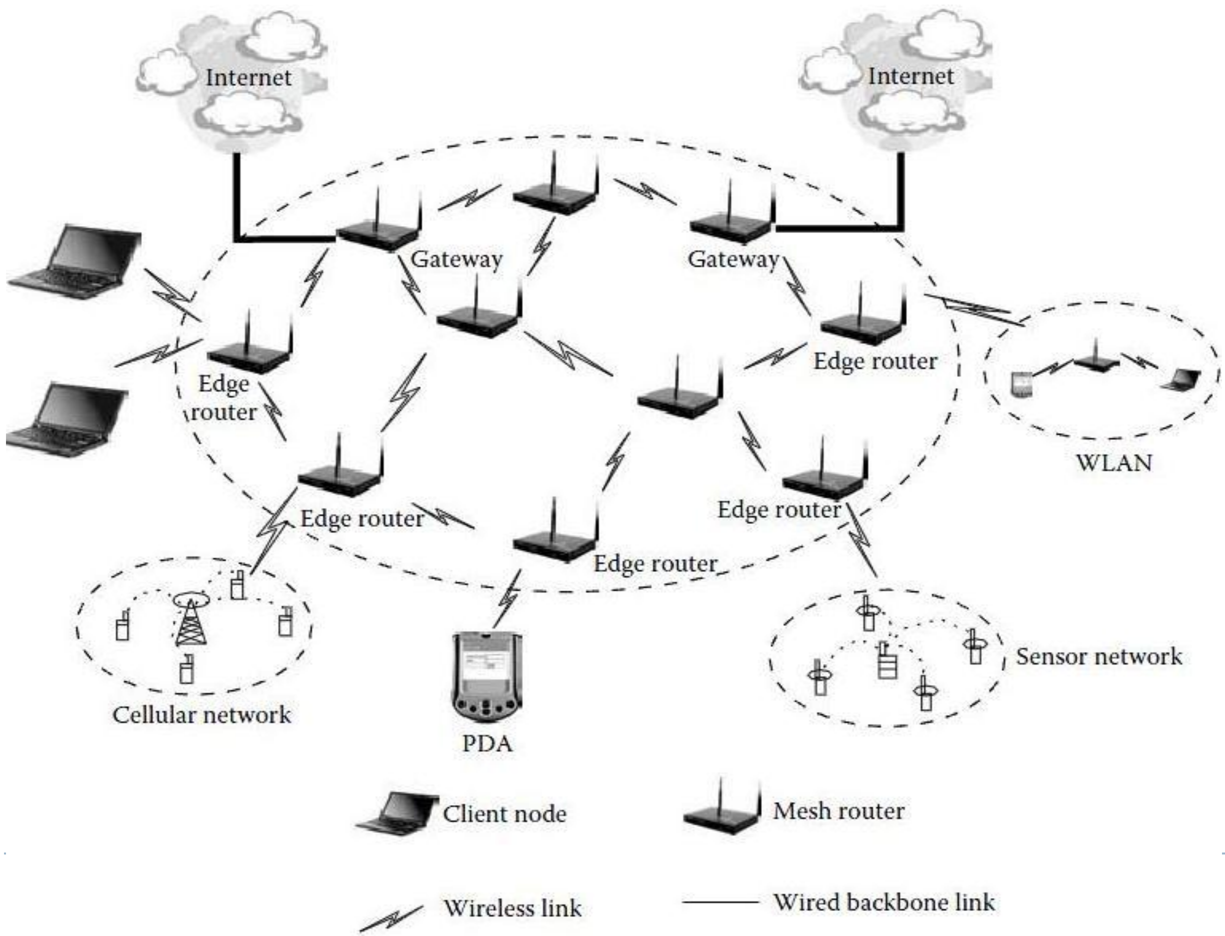


Wireless Mesh Networks (WMNs)

- Compared to mobile ad hoc network (MANET), WMN does not emphasize mobility
- Built with the existing network technologies
  - WPAN, WLAN, WMAN
- Focus:
  - Multihop communications.
- **Principal Features:**
  - Self-forming
  - Self-healing
  - Self-organizing

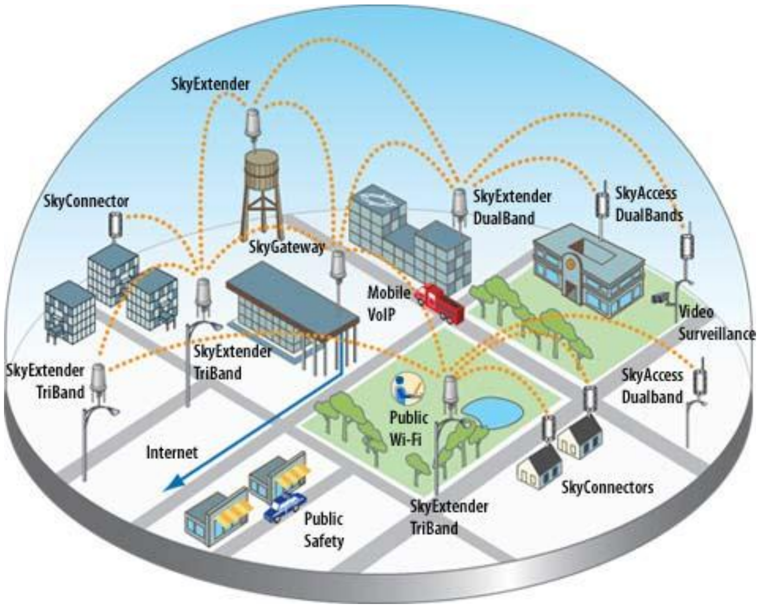
WMNs: Architecture

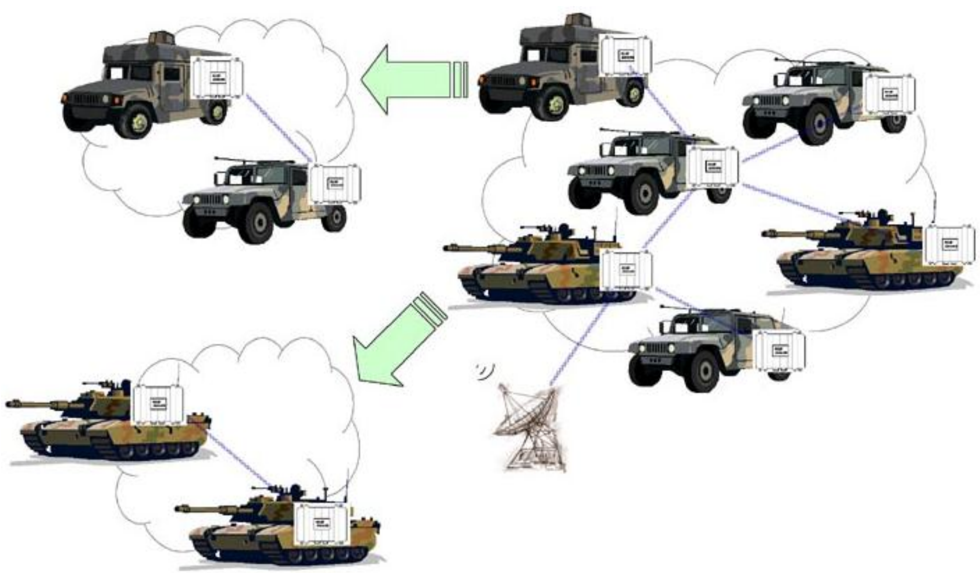
- Consist of mesh routers and mesh clients.
  - Mesh routers have minimal mobility and form the mesh backbone for mesh clients.



WMNs: Applications

- Community networks
- Municipality networks
- Defense
- Emergency networks
- Intelligent transport systems, ..





Existing Testbeds

OVERVIEW OF WMNs TESTBED PROJECTS

Project	Nodes	802.11	Software	Routing		Roaming	Config	MANET
				Layer	Protocol			
MIT Roofnet	37	b/g	Linux	RL	SrcRR	–	×	–
Microsoft	21	a/b/g	Windows CE	MAC	MCL	–	×	×
USCB MeshNet	25	a/b/g	OpenWRT	IP	MCL	–	×	–
Purdue	32	a/b/g	–	IP	AODV	–	×	–
Georgia Tech	15	b/g	–	–	AODV,OLSR	–	–	–
Carleton Univ.	??	a/g	µClinux	IP	–	–	×	–
Hyacinth	10	a	Windows XP	–	OLSR	×	×	–
UMIC-Mesh.net	51	a/b/g	Linux	IP	DYMO,OLSR	×	×	×

Outline

- Objectives
- Introduction
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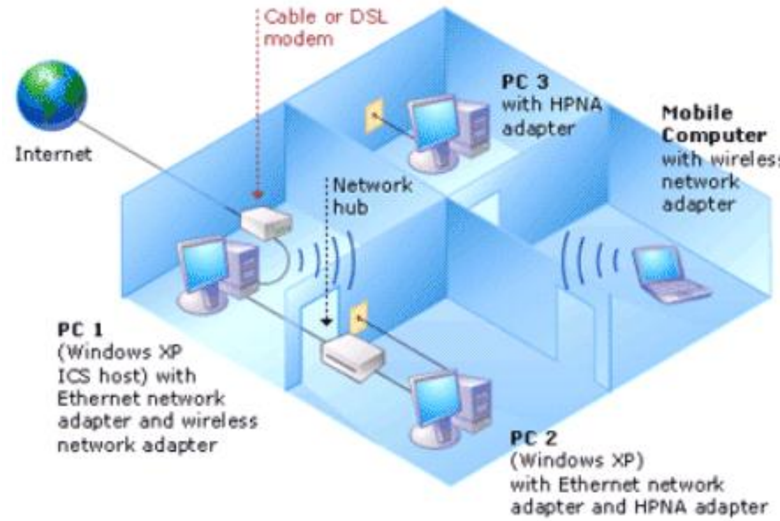
Design a Wireless Network: Requirements

- Before choosing a <u>wireless networking technology</u>
  - Try to understand the requirements.
- Find the right technology

- Coverage
- Data rate
- Cost
- Mobility
- Security
- Power consumption

Design a Wireless Network: Examples

- In the office environment, we need:
  - Basic deployment (<$)
  - Small coverage
  - High data rate
  - Low cost
  - Moderate mobility
  - Security



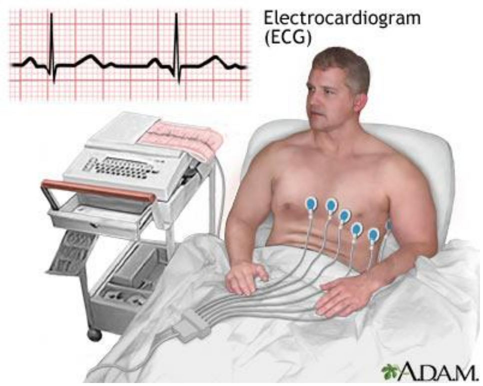
- In the battle field, we may need:
  - Strong planning and design
  - Large coverage
  - High mobility
  - Reliability
  - Strong security

Some Commonly Used Technologies

- In the last few semesters, the following technologies have been used in different capstone projects
  - Bluetooth
  - Cellular network
  - GPS
  - Infrared
  - RFID
  - Wi-Fi
  - Zigbee

Case Study 1

- A capstone project in Fall 2008
  - Mobile Electrocardiogram (ECG)
    - To develop a portable device to sense the ECG signals and trigger alarm if abnormal conditions are detected



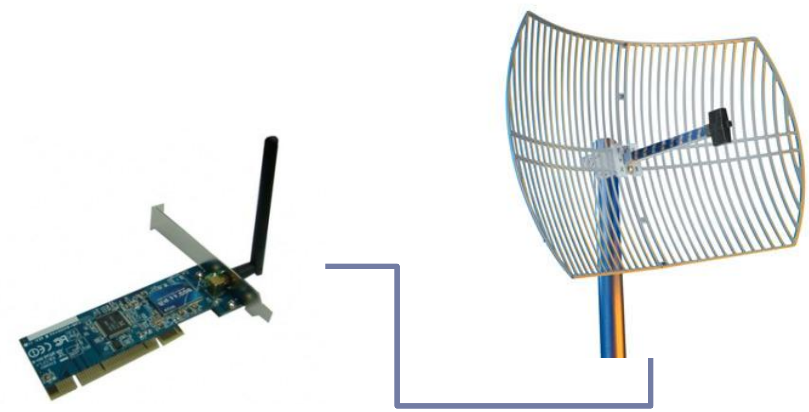
    - The design utilizes the following wireless components
      - Bluetooth
      - GSM
    - Why?

Case Study 1

- The team decided to design a system that consists of
  - A small device to sense the ECG signals and trigger alarm
  - A cell phone that can set up the small device and can receive/forward the alarm
- Why choose GSM?
  - It provides a large coverage
    - To send alarm to doctors, nurses, relatives
  - Cell phone is very common
- Why choose Bluetooth?
  - Short range communications
  - Bluetooth is supported by most cell phones

Case Study 2

- Team: a group of undergraduate students in UMASS
- Objective: to build a low-cost and long-range (>1 mile) communication system
- Solution
  - Using Wi-Fi adapter:
    - Low-cost
  - Using directional antenna:
    - Concentrating the energy to reach a longer distance
  - **Question: does this work?**



Case Study 2

- The Answer
  - Yes, after fixing a software problem
  - Wi-Fi is designed as a LAN technology
- Their design is used for the CASA project

Projects in the Previous Semesters

- Fall 2010
  - E.A.R.S. Electronic Attendance Registry System
    - Zigbee, RFID
  - Zero-Force Mouse
    - Zigbee
  - TempMon
    - Zigbee, infrared
  - OnPet
    - GSM, GPS

Projects in the Previous Semesters

- Fall 2011
  - Biometric access for electronic medical records
    - Bluetooth, GSM
  - Boardcaster
    - Wi-Fi
  - Ultra-Deep-Oceanic-Free-Vehicle
    - Bluetooth
  - Universal Remote for Disabled People
    - Infrared, GSM
  - Octo-Controller
    - Bluetooth
  - JAM2
    - Bluetooth, GSM
  - Smart Traffic Signal Preemption System
    - GSM
  - SZDS: Surf Zone Drifter System
    - Zigbee
  - Virtual Infrared Remote Control
    - Infrared, Zigbee

Questions