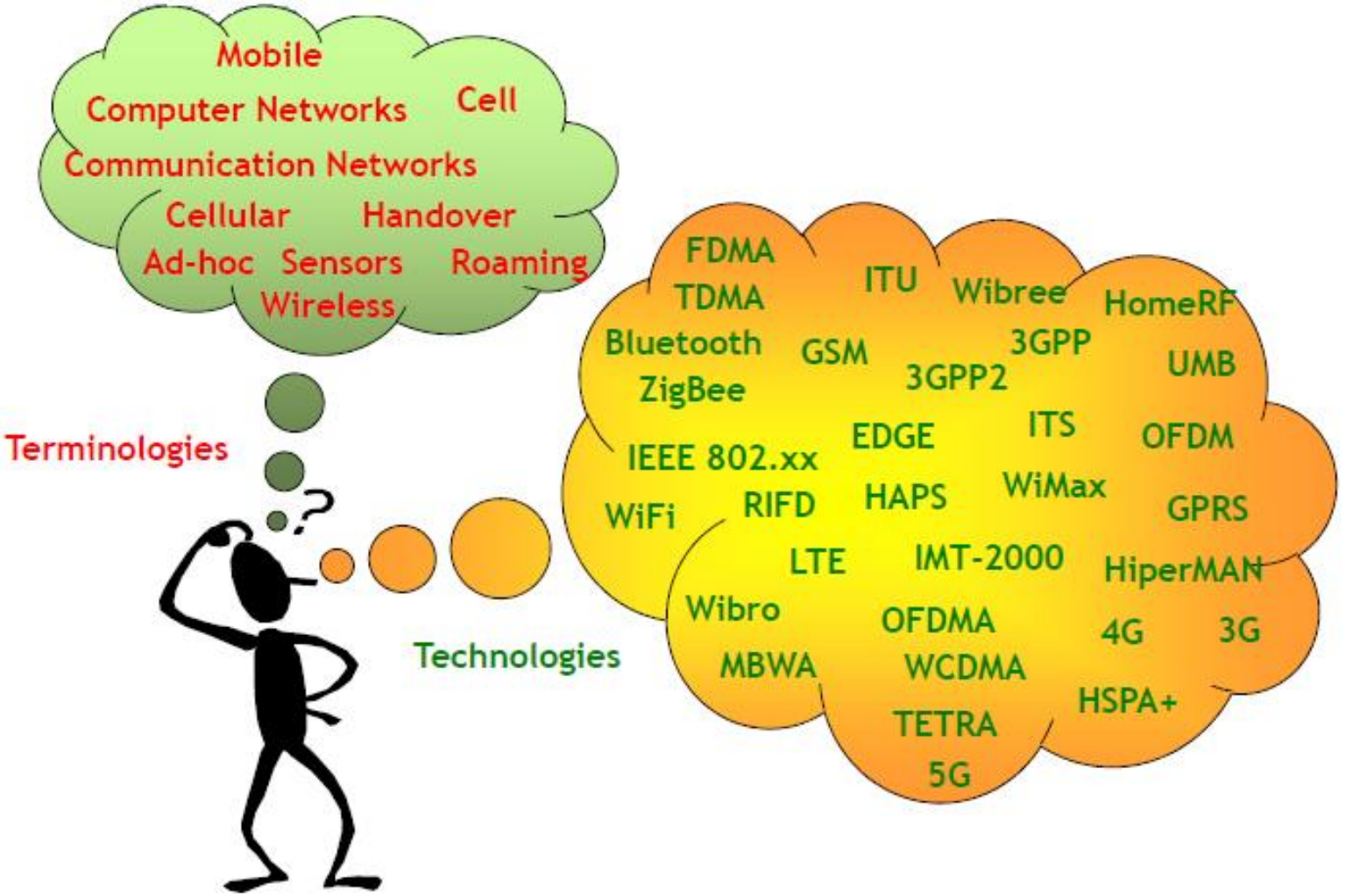
ΕΠΛ 427:
ΚΙΝΗΤΑ ΔΙΚΤΥΑ ΥΠΟΛΟΓΙΣΤΩΝ (MOBILE NETWORKS)

Δρ. Χριστόφορος Χριστοφόρου

Πανεπιστήμιο Κύπρου - Τμήμα Πληροφορικής

Introduction to Wireless and Mobile Networks

Definitions

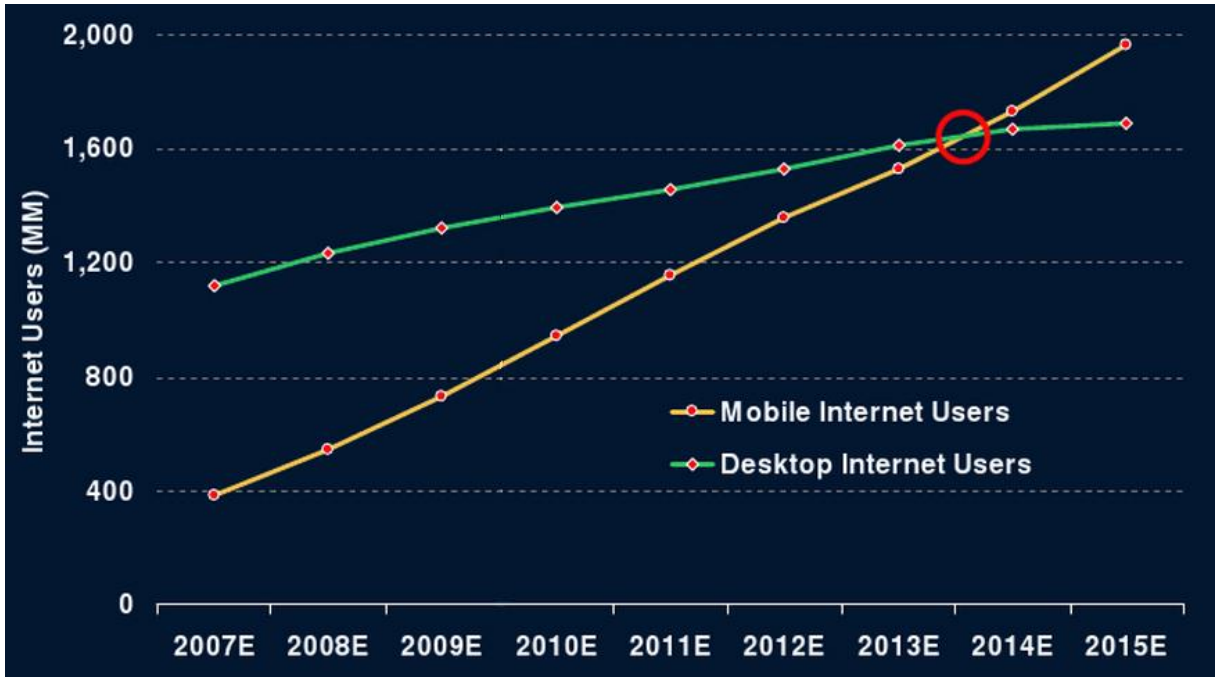


Towards Wireless/Mobile Networks

- The many advantages of cell phones and other mobile/portable devices are evident to all:
  - **Anywhere**, **Anytime**, **Untethered access** to the **global telephone network** and **internet** via a highly portable, lightweight, wireless/mobile device.
  - Smartphones, Tablets, Laptops, Netbooks, etc.

Towards Wireless/Mobile Networks

- **Mobile Internet usage (EDGE, 3G, 4G (LTE))** is ramping up substantially faster than **Desktop Internet usage** (e.g., **WiFi, Ethernet**)
- Number of Mobile Internet Users became greater than the Number of Desktop Internet Users



Towards Wireless/Mobile Networks

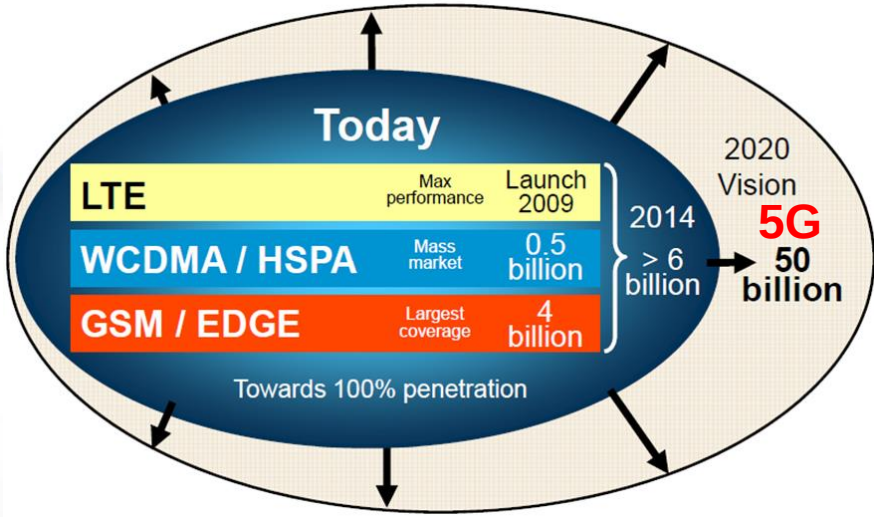
- Number of **Mobile Subscriptions** worldwide:
  - 1993 → **34 millions**
  - 2016 (According to Ericson; June 2016) → **7.4 billions**

- Number of **Mobile User Subscribers** worldwide:
  - Only around **4.5 billons** mobile users
  - **Some Mobile User have more than one subscriptions**

Towards Wireless/Mobile Networks

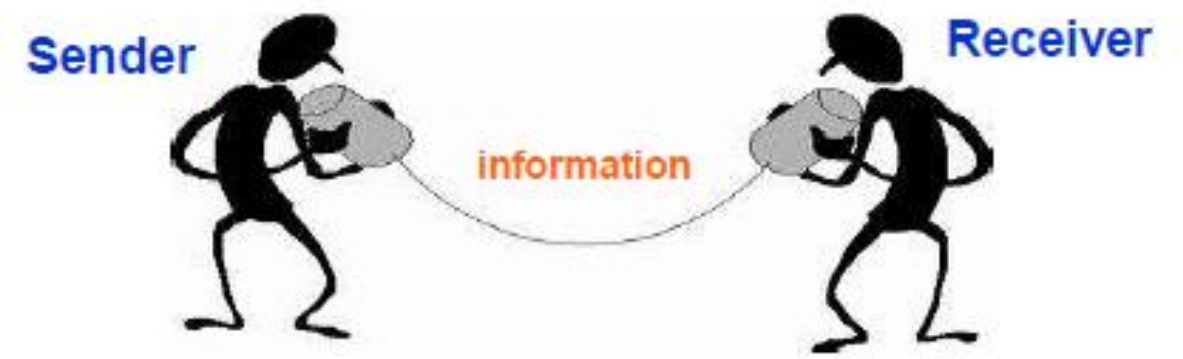
Everything that benefits from being connected will be connected!!!!

More than 50 billion connected devices are predicted for 2020



Definitions
Communication

- **Communication** in its explicit sense, is **the process** of transferring information (or data) from one **Entity** to another.
- Your next question may be: **What is an entity?**
- For now, let's call the entity that transfers information **Sender (or Transmitter)** and the entity that receives the information **Receiver**.



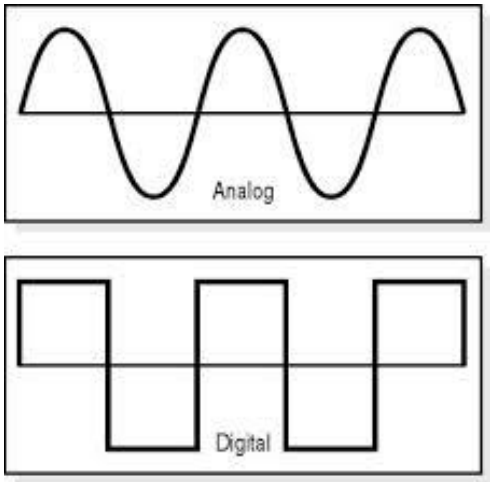
Definitions

Components of a Communication System

- **Basic components of a communication system**
  - **Communication Technologies**
    - WiFi, Bluetooth, GSM,GPRS, EDGE, 3G, 4G, 5G, etc.
  - **Communication Devices**
    - Laptops, Smart Phones, Tablets, Wearable Devices, etc.
  - **Communication Channels**
    - The physical medium (wires, **air**, or a combination) used for carrying the data between the **Communication Devices**
  - **Communication Software**
    - Applications or programs designed to pass information from one Communication Device to another.

Definitions
Analog and Digital Signals

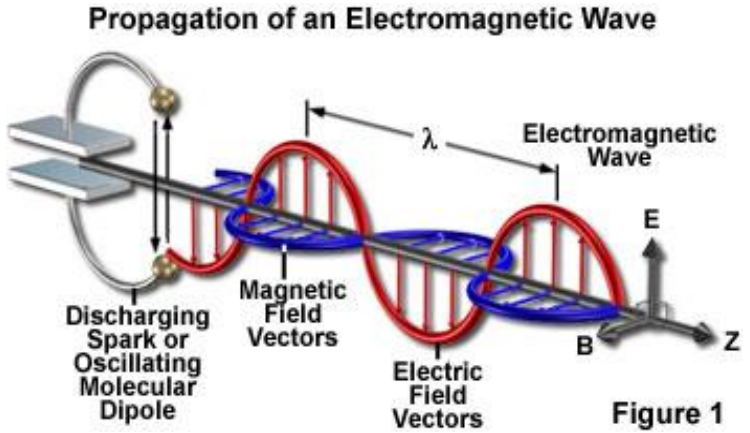
- Means by which data are propagated (διαδίδονται) over a Communication Channel.
  - **Analog Signal:** is a continuously varying electromagnetic wave that may be propagated **over a variety of media. E.g.,**:
    - Wire, coaxial, **space (wireless), etc.**
    - There are **no breaks or discontinuities in the signal** (Continuous Signal)



  - **Digital Signal:** is a sequence of discrete (διακριτές) voltage pulses that can be transmitted over a **wire medium (cannot be used to transfer data over the air)**.
    - For example, a constant **positive level of voltage is send** to represent binary 0 and a constant **negative level of voltage is send** to represent binary 1.

Definitions
Communication and Wireless Networks

- Wireless Networks **utilize Electromagnetic Waves** (radio waves) **of a certain frequency (Carrier Frequency)** to establish **Communication Channels and transmit data** between Wireless Communication Devices (e.g., Mobile Devices and the Base Station).



Challenges with Wireless/Mobile Networks

- **Two important challenges** with wireless/mobile networks (beyond those of traditional fixed networks):
  - **Wireless:** Communication over a **wireless link** - Transmitting voice and data using **electromagnetic (radio) waves in open space** (using a given frequency band).
    - The **Quality of a link connection** is **subjected to many (environmental) factors** and can vary substantially → Especially from the effects caused by the **Multipath propagation phenomenon**.
  - **Mobility:** Handling the mobile user who **changes point of attachment** (handover) to the network.

What is Mobility?

- **Two aspects of mobility**:
  - **Device Portability:** The device can **easily be carried** and can be connected (wireless) anytime and from anywhere to the network. **Changing point of attachment to the network offline** (connect from home, from work, from coffee shop, etc.)
  - **User Mobility (includes device portability):** Users communicates (wireless) with anyone, anytime and from anywhere. **Changing point of attachment (Handover) to the network online** (e.g., the user is driving from home to work and the call/connection is hand off from one cell to another during the call)

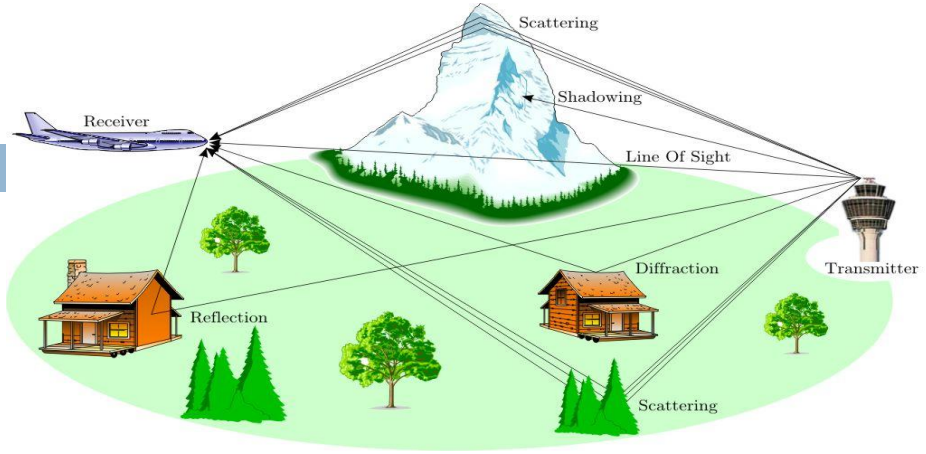
Benefits of Wireless Networking

- **Allows Mobility**
  - **Freedom to move** in the geographical area without being tethered by wires
  - Permits companies to shift toward an increasingly **mobile workforce**
- **Increased Reliability (no cables needed)**
  - **Network cable failures** is the most common source of network problems
- **Easier and Less Expensive Installation**
  - Installing network cabling can be a difficult, slow, and costly task!
  - Installation in Difficult-to-Wire Areas

Benefits of Wireless Networking

- **Expandability**
  - **Easy to add stations (Mobile/Portable Devices) on the network** since no cables or plugs are required to connect to the network
- **Long-Term Cost Savings**
  - **No need of Re-cabling** in case of re-organization of companies (i.e., new floor plans, office partitions, moving to a different building, renovations)

Wireless Networks in Comparison to Wired Networks

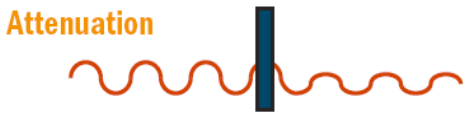


- **Higher loss-rates** due to (I):
  - **Noise and Interference. E.g.:**
    - **Self-interference**
      - **Inter-symbol interference** or **fast fading** due to **multipath propagation**
    - **Co-Channel** Interference (**Cross-Talk**):
      - **Interference with other channels** using the **same frequency band**
    - **Cross-system** Interference
      - Interference with other Radio sources in same frequency band, e.g., 2.4 GHz wireless phone interferes with 802.11b WLAN
    - **etc.**
  - **Blocking of Radio Signals** by obstacles (**Shadowing**)

Wireless Networks in Comparison to Wired Networks

- **Higher loss-rates** due to (II):
  - **Decreasing signal strength during propagation making it difficult for the Receiver to decode the signal correctly.**
    - Signal Propagation in **wired Networks** has a wire to **determine the direction of signal propagation**
    - Signal Propagation in wireless networks has **an unpredictable behavior**
      - **Attenuates** as it travels greater distance (**Pathloss**)
      - **Attenuates** as it passes **through materials** (air, snow, rain, fog, walls, water, glass, etc.)

Attenuation Effects

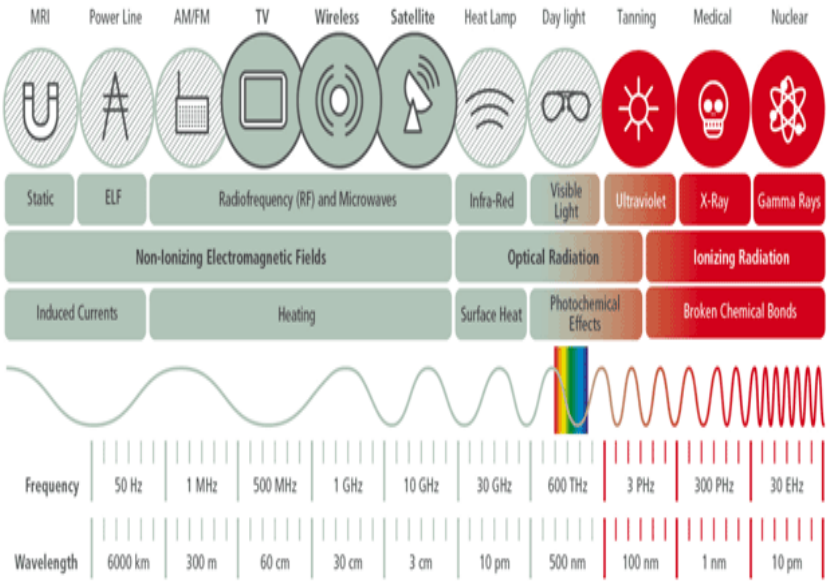


The signal strength is reduced as it passes through an object.

Material	Typical Attenuation (Loss) @ 5GHz
Cubical Wall	2dB
Drywall or Sheetrock	3dB
Brick Concrete or Block Wall	15dB
Elevator Shaft	10dB
Glass or Window	3dB
Concrete Floor	11dB

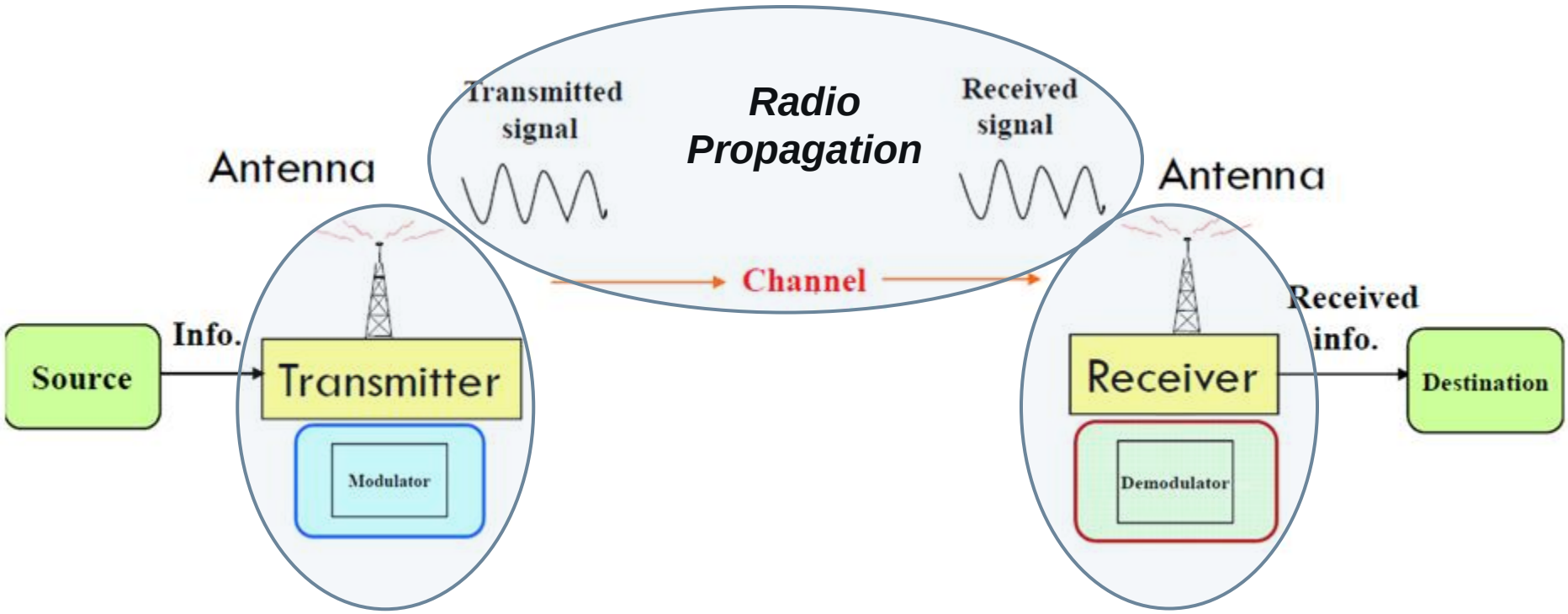
Wireless Networks in Comparison to Wired Networks

- **Limited availability of useful spectrum!!!**
  - **Radio Frequencies have to be coordinated**, all useful frequencies are “occupied”.
- **Lower security and easy to listen to/attack radio**
  - Radio interface accessible to everyone, e.g., a Base Station can be simulated, thus attracting calls from mobile phones



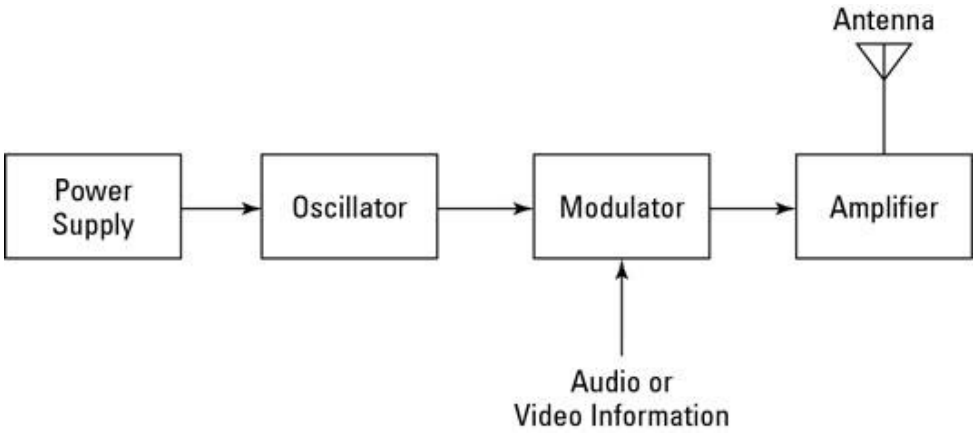
- **Always a shared medium**
  - Interference between several Senders/Receivers → **Multiple Access mechanisms (TDMA, FDMA, CDMA, OFDMA, etc.) are essential**

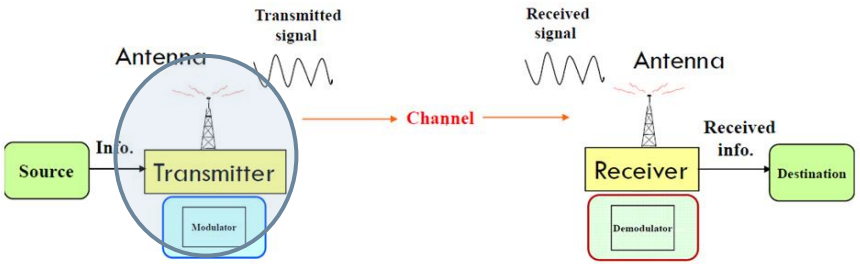
Process and Elements of Radio (Wireless) Transmission
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης



Process and Elements of Radio (Wireless) Transmission
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης

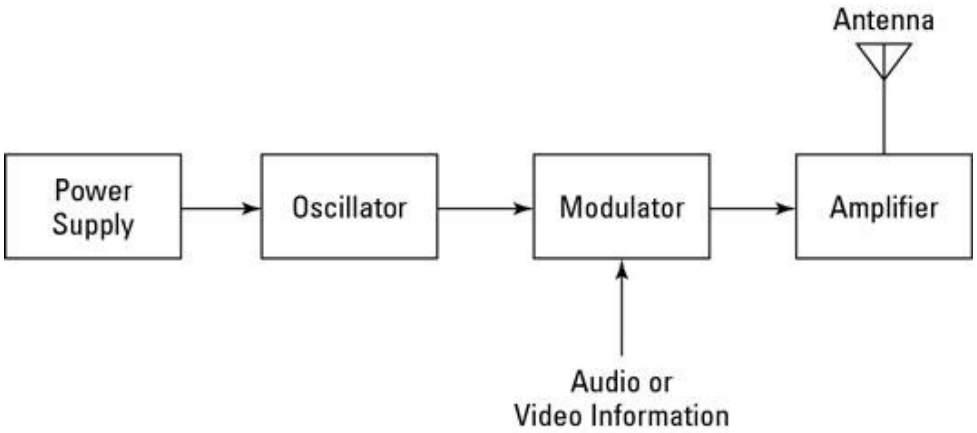
- **Radio Transmitter and Modulation (Πομπός και Διαμόρφωση)**
  - A **Transmitter (Πομπός)** or **Radio Transmitter** is an electronic device which, **with the aid of several components (Power Supply, Oscillator (Ταλαντωτής), Modulator (Διαμορφωτής), Amplifier, Antenna), produces radio waves that contain useful information** (10110111011111….) such as audio, video, or digital data.

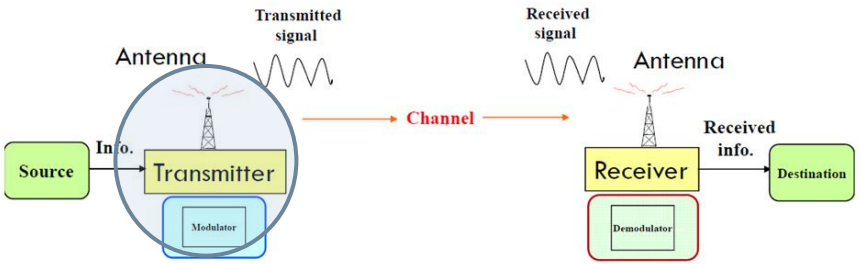




Process and Elements of Radio (Wireless) Transmission
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης

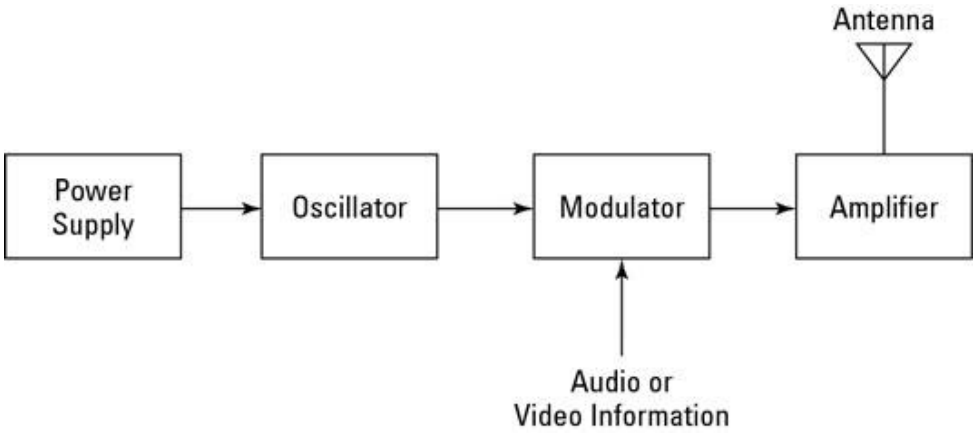
- **Radio Transmitter and Modulation (Πομπός και Διαμόρφωση)**
  - The **Power Supply** provides the necessary electrical power to operate the Transmitter.
  - The **Oscillator** **generates an alternating/oscillating (ταλαντευόμενο) electrical current** at the **specific frequency** on which the Transmitter will transmit (**carrier frequency**). The Oscillator usually generates a **sine wave**, which is referred to as a ***carrier wave (or carrier signal)***.

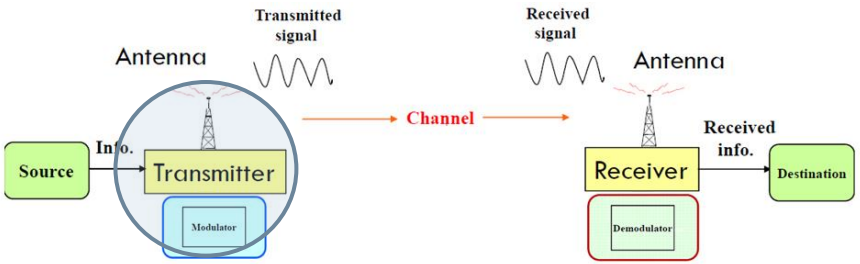




Process and Elements of Radio (Wireless) Transmission
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης

- **Radio Transmitter and Modulation (Πομπός και Διαμόρφωση)**
  - The **Modulator (Διαμορφωτής)** adds the **useful information** to the carrier wave by **modulating (changing)** **some properties of the oscillating electrical current (i.e., the carrier wave), before applied to the antenna.**
    - Such as its **Amplitude**, **Frequency**, **Phase**, or combinations of these properties. → ***Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), etc.***





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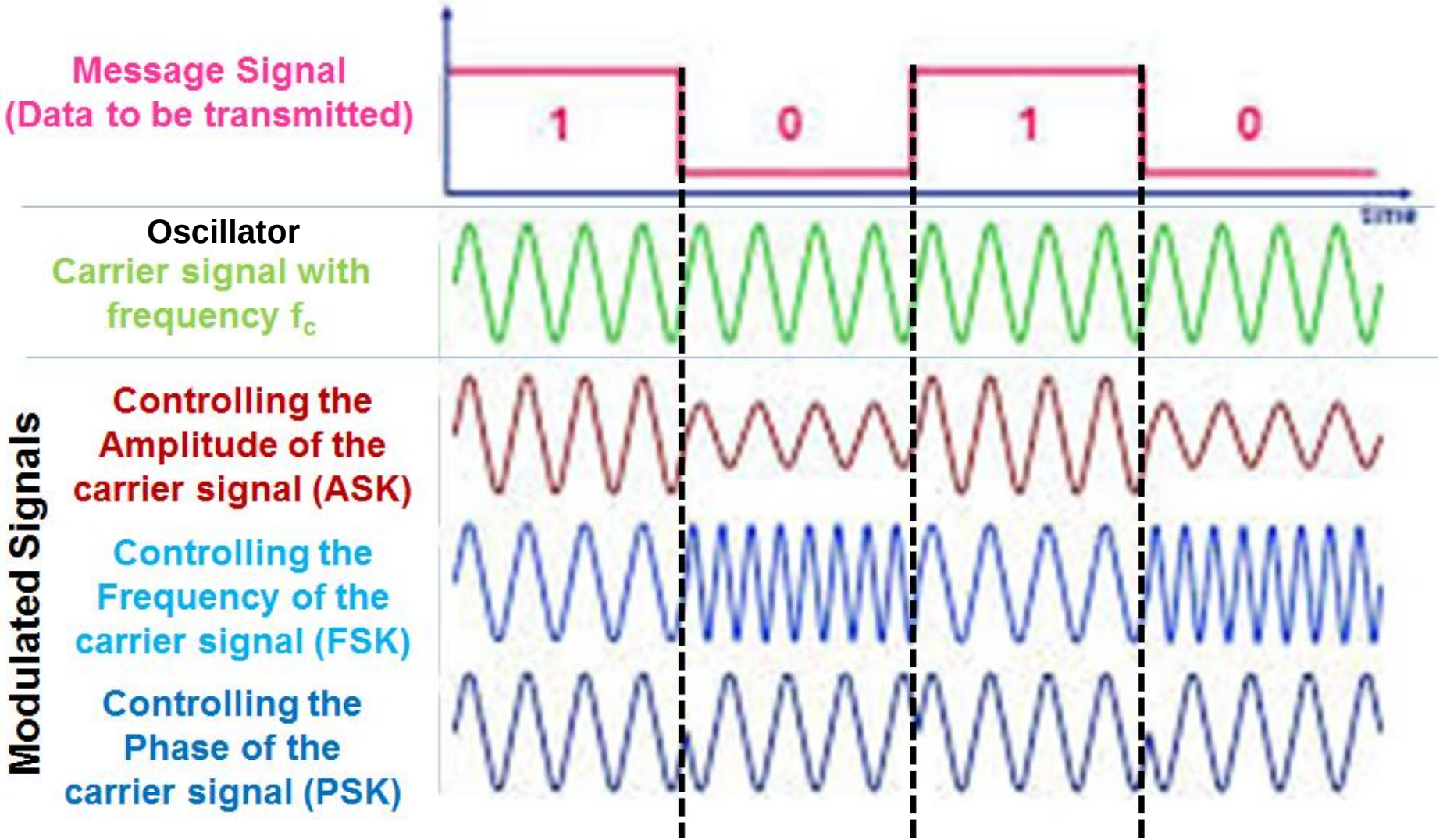
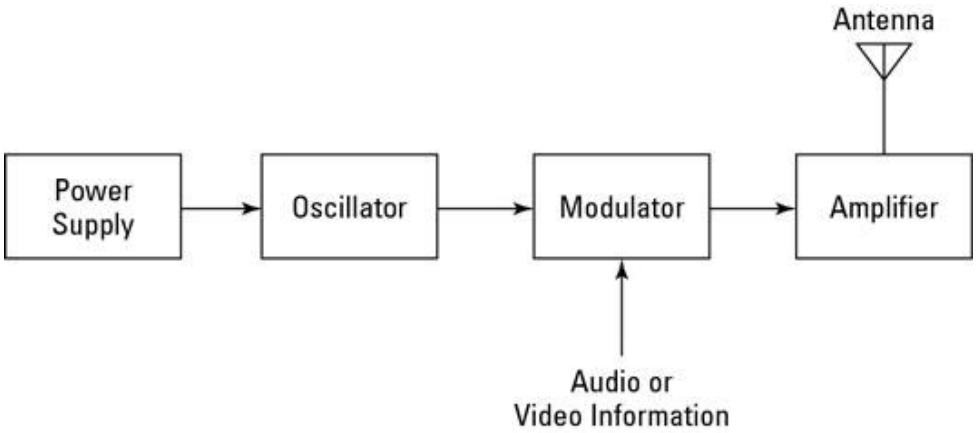
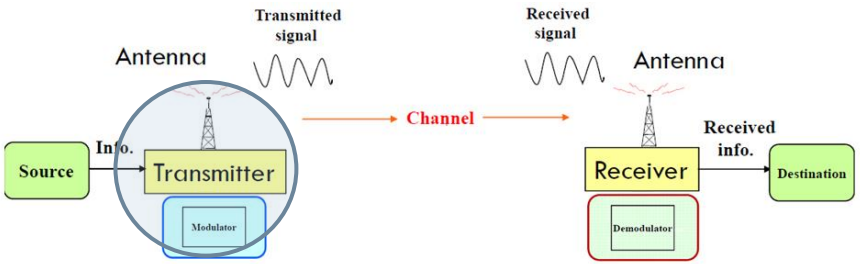
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης



Process and Elements of Radio (Wireless) Transmission
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης

- **Radio Transmitter and Modulation**
  - The **Amplifier** **amplifies** the **modulated carrier wave** to **increase its power**. The more powerful the amplifier, the more powerful the broadcast.
  - The **amplifier** applies the **amplified modulated oscillating electrical current** to the **Antenna** which converts it into an **electromagnetic wave (or radio wave)** that can propagate through the air.





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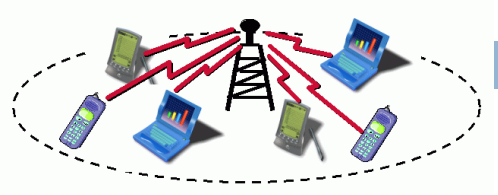


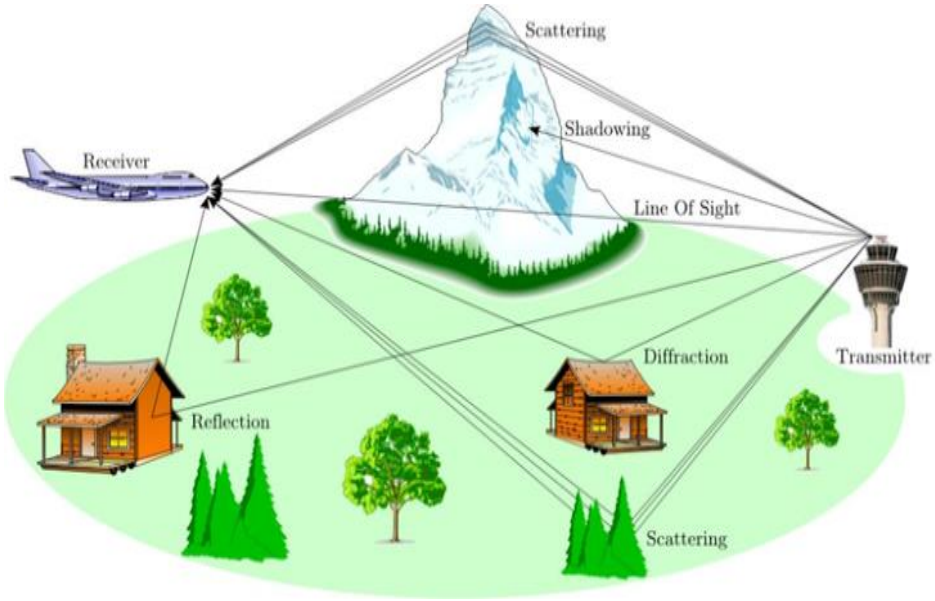
- **Radio Transmitter and Modulation**
  - In a **wireless environment**, a Base Station or an Access Point (i.e., the Antenna) needs a **radio connection between all the Mobile Stations in their transmission range**.
  - Thus, there is a need to address the issue of **simultaneous multiple access by numerous users** in the transmission range.
  - **Multiple Access techniques (Τεχνικές Πολύπλεξης)** are used to **allow a large number of mobile users to share the allocated spectrum** in the most efficient manner. E.g.:
    - Frequency Division Multiple Access (FDMA)
    - Time Division Multiple Access (TDMA)
    - Code Division Multiple Access (CDMA)
    - Orthogonal Frequency Division Multiple Access (OFDMA)

Process and Elements of Radio (Wireless) Transmission
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης

- **Radio Propagation (Ασύρματη Διάδοση Σήματος)**
  - Once generated, **electromagnetic waves travel through space either directly (line of sight)**, or have their **path altered** by Reflection (Αντανάκλαση), Diffraction (Περίθλαση) or Scattering (Διασκόρπιση) → **Multipath Propagation - Πολυδιαδρομική Διάδοση**.

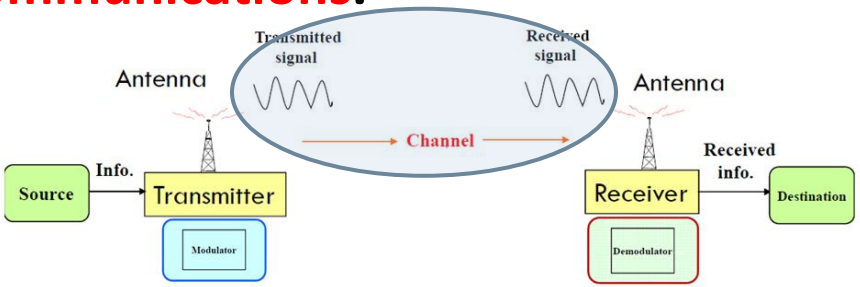
Multipath Propagation The phenomenon that results in **multiple copies of the same radio signal** reaching the receiving antenna by two or more paths.

Results in **Inter-symbol interference** and **fast fading**



Process and Elements of Radio (Wireless) Transmission
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης

- **Radio Propagation (Ασύρματη Διάδοση Σήματος)**
  - The **intensity** of the radio waves **attenuates** during propagation (**Pathloss**); some energy may also be absorbed by the **intervening medium** in some cases.
  - **Also during propagation, Noise and Interference present in the air alter the desired signal.**
  - If the **magnitude** of the **Noise + Interference is large enough** compared to the **strength of the desired signal**, the desired/original signal **will be altered** is such a way that it will **no longer be discernible (διακριτό)**; **this is the fundamental limit to the range (εμβέλεια) of radio communications.**



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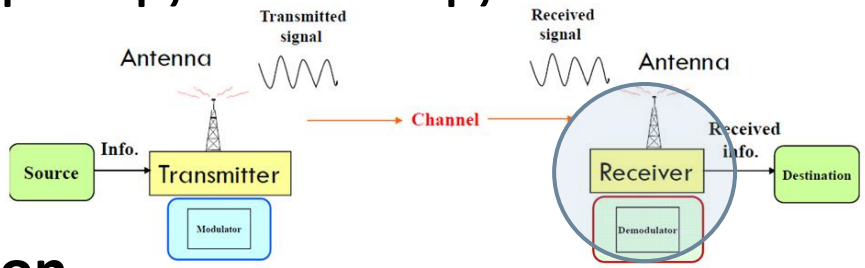
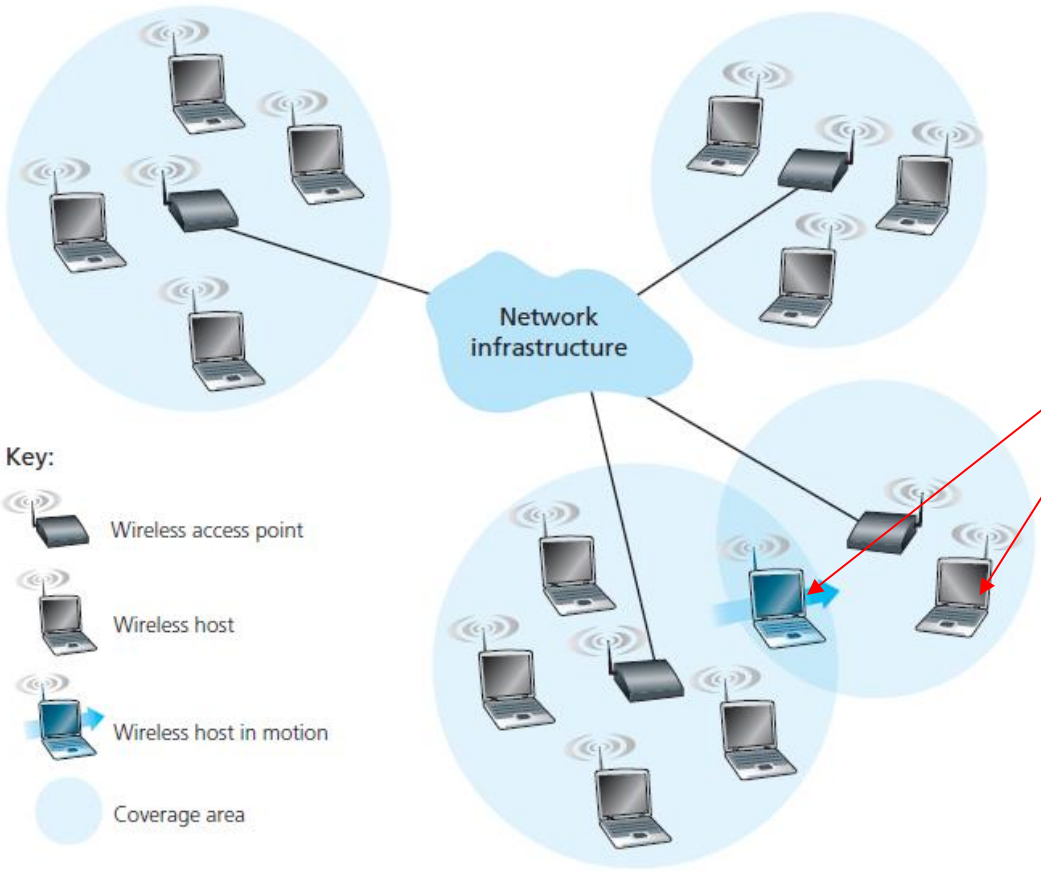
Διαδικασία και Στοιχεία Ασύρματης Διάδοσης



- **Radio Receiver and Demodulation**
  - The energy carried by the **modulated electromagnetic wave** is **captured** by the **receiving Antenna** and **returns it to the Radio Receiver** to the form of **oscillating/alternating electrical currents**.
  - The **Radio Receiver** uses **electronic filters (tuners)** to **separate the wanted radio signal** (transmitted in the **specific frequency** set for the **communication channel**) from all other signals picked up by its Antenna.
  - At the **Receiver**, these **oscillating electrical currents are amplified, demodulated** (recovers the useful information contained in the modulated radio wave) and converted into **to a usable signal form for interpreting the data.**

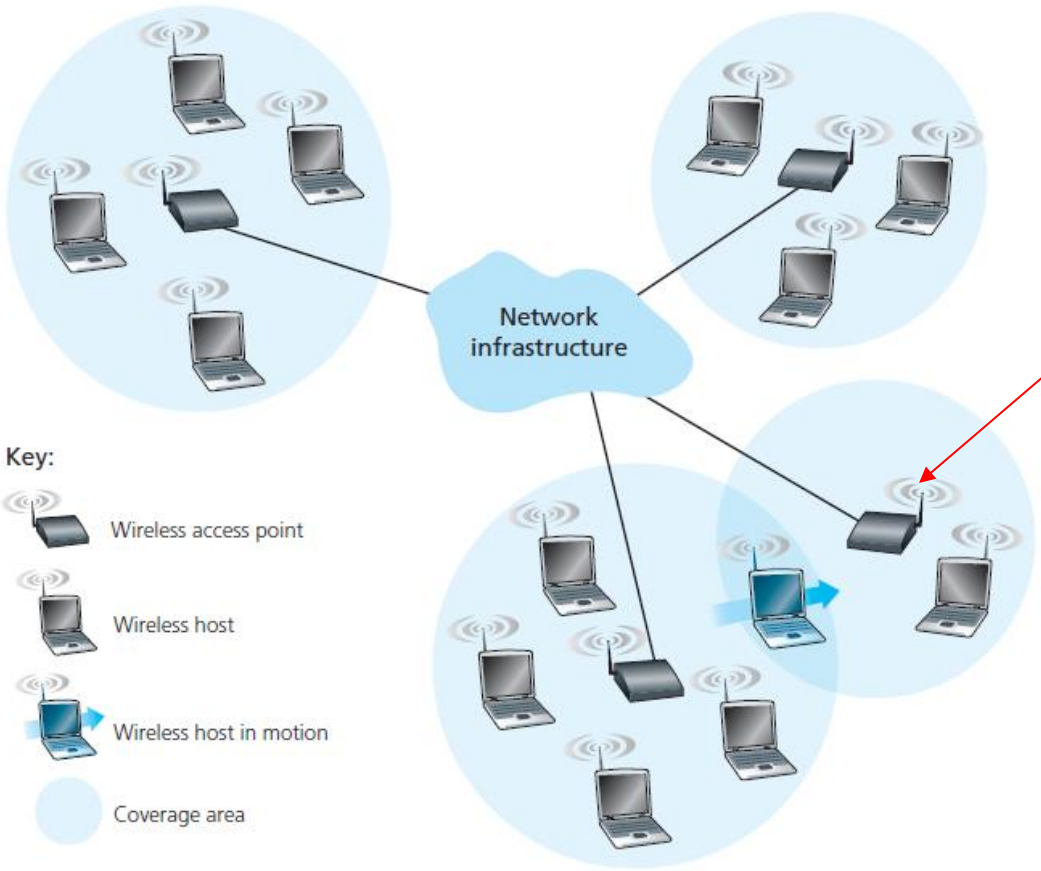
Elements of a Wireless Network
Στοιχεία ενός Ασύρματου Δικτύου



Wireless Host (Mobile Terminals)

- End system devices that runs applications
- Laptop, Smartphone, Tablet, etc.
- May be stationary (non-mobile) or mobile

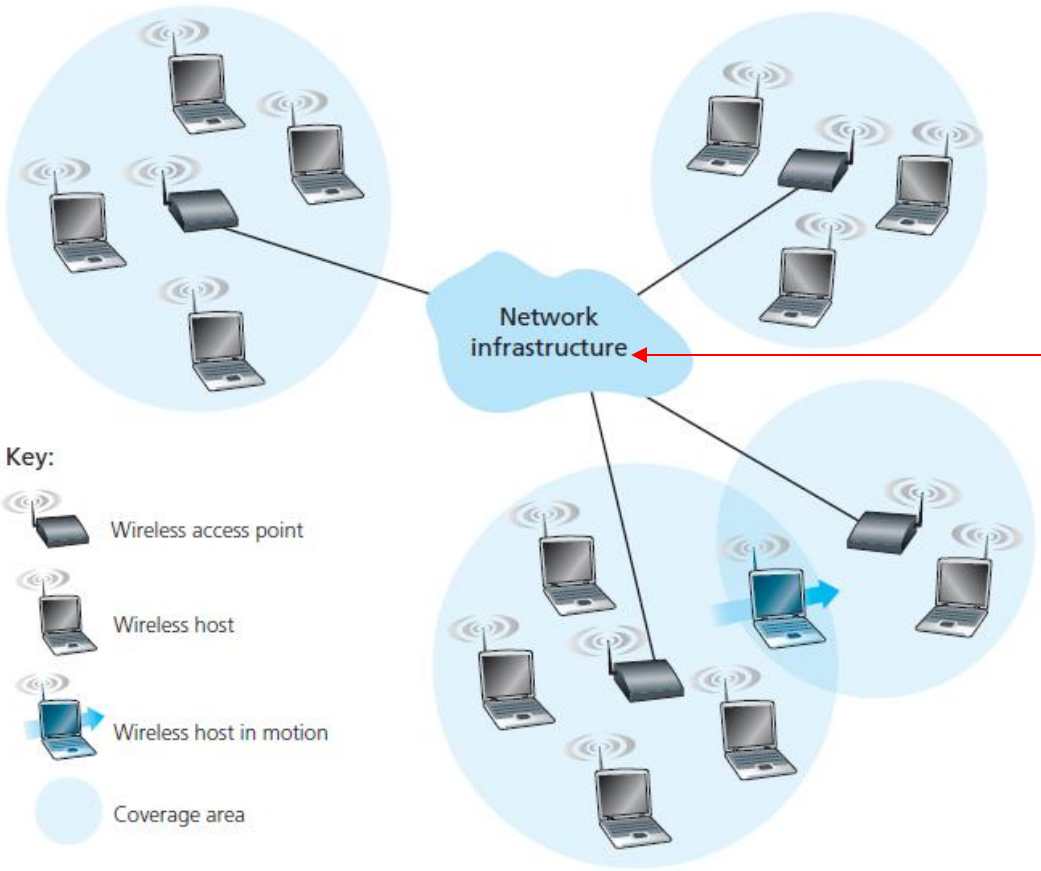
Elements of a Wireless Network
Στοιχεία ενός Ασύρματου Δικτύου



Base Station (Access Point)

- Key part of the wireless network infrastructure
- Responsible for relaying packets between the wired network and wireless Host(s) in its "area"
- E.g., Cell towers, 802.11 Access Points (WiFi)

Elements of a Wireless Network
Στοιχεία ενός Ασύρματου Δικτύου

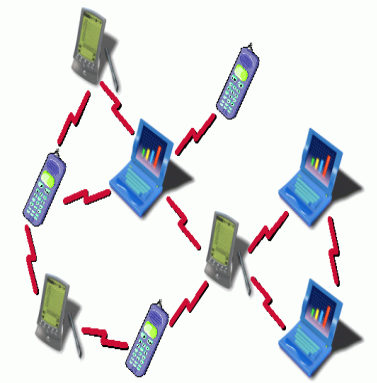


Network Infrastructure (Υποδομή Δικτύου)

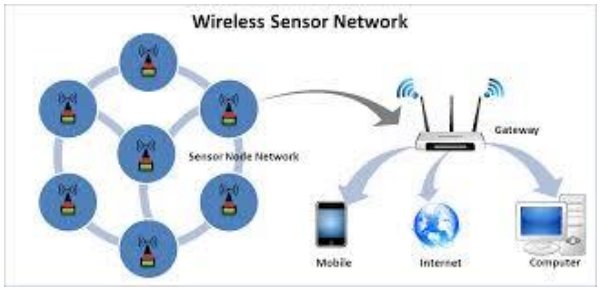
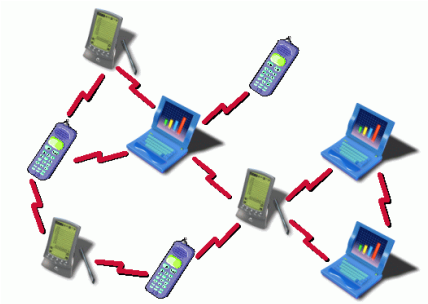
- Provides traditional network services (e.g., transmission coordination, address assignment, resource allocation, routing, access to other networks, etc.)
- **May not always exist (Ad Hoc Networks)**

Infrastructure Vs Infrastructure-less (Ad Hoc) Based Networks

- **Infrastructure-based Networks**
  - **Wireless Hosts are associated with a Base Station** and **communication takes place only between the Wireless hosts and the Access Point** (Not directly between the Wireless Nodes) which is connected to the larger network infrastructure
  - **Traditional network services** (e.g., Resource Allocation, Routing, Transmissions Coordination, etc.) are **provided by the connected network infrastructure.**
- **Infrastructure-less (Ad hoc) based Networks**
  - Wireless hosts have **no infrastructure** to connect to (not associated with a Base Station or Access Point)
  - Hosts themselves **must provide network services** (hosts must organize themselves into a network)
  - Must **cooperate together** in a decentralized manner to **find a route** from one participant to another.

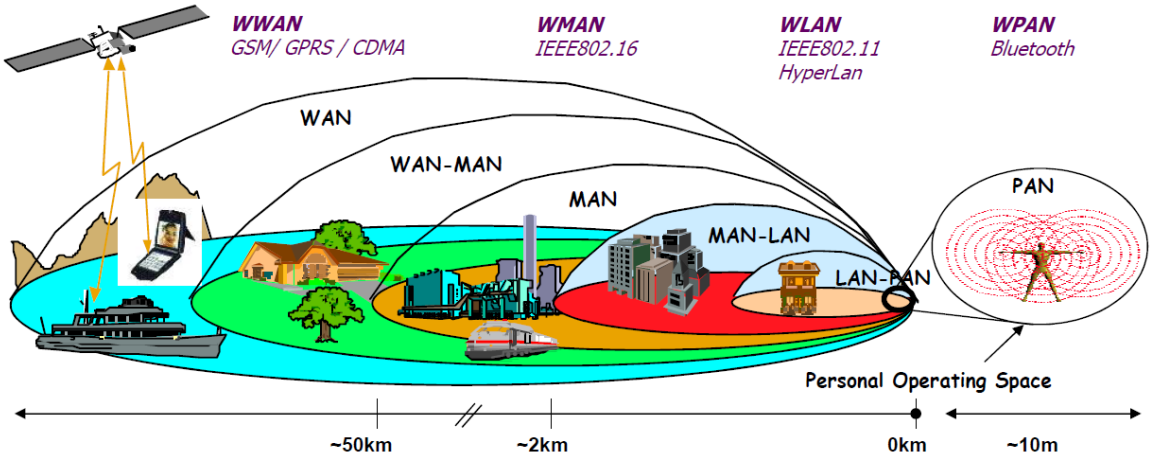


Different Types of Wireless Networks
Διαφορετικοί Τύποι Δικτύου

	Infrastructure based	Infrastructure-less based
Single hop	Base Station exists and nodes communicate directly with the Base Station (e.g., Wireless LAN, Cellular Networks) 	No Base Station Exists; One node coordinates the transmissions of the others (e.g., Bluetooth) 
Multi-hop	Base Station exists, but some nodes must relay data through other nodes (e.g., Wireless Sensor Networks) 	No Base Station exists, and some nodes must relay data through other nodes (e.g., Mobile Ad Hoc Networks) 

Wireless/Mobile Networks

- Wireless Personal Area Network (IEEE 802.15 - Bluetooth)
- Wireless Local Area Network (IEEE 802.11 - Wi-Fi)
- Wireless Metropolitan Area Network (IEEE 802.16 WiMAX)
- Wireless Wide Area Networks → Mobile Cellular Networks (2G, 2.5G, 3G, 4G, 5G)



- Mobile Ad Hoc Network (MANET)
- Wireless Sensor Networks (WSN)

WPAN (IEEE 802.15 - Bluetooth) (1/2)

- Technology used to **set up a Network between different small devices in close proximity**
  - No need of wiring or the need of an infrastructure
- Transmission Range:
  - Up to **some ten of meters**

- Designed to have **very low power consumption**.
  - Uses only 2.5 mW of power
- Bluetooth operates in the **unlicensed** **2.4 – 2.4835 GHz** band

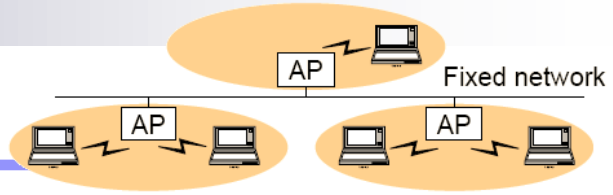
WPAN (IEEE 802.15 - Bluetooth) (2/2)

- Transmission Data Rates:

Bluetooth version	Max data rate
Bluetooth v1.0 and v1.0B	768 kbps
Bluetooth v1.1	768 kbps
Bluetooth v1.2	1 Mbps
Bluetooth v2.0 (and v2.1)+ EDR (Enhanced Data Rate)	3 Mbps
Bluetooth v3.0 + HS (High Speed)	24 Mbps
Bluetooth Smart (v4.0 and 4.1)	24 Mbps

- Why use it?
  - Eliminates cables
  - Inexpensive
  - Easy to set up and use
  - Readily available
  - Good security
  - Device compatibility

WLAN (IEEE 802.11 - Wi-Fi) (1/4)

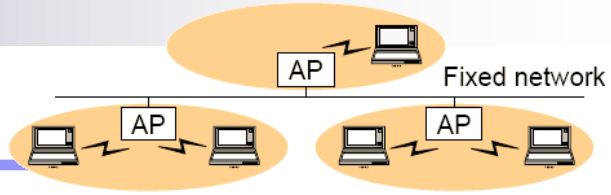


- Wireless representation of Ethernet - Replaces cabling

- **No need for spectrum license** to operate a WLAN
  - WLAN operates in **2.4 GHz** (b, g) or **5 GHz** (a, g, n, ac) **unlicensed** bands

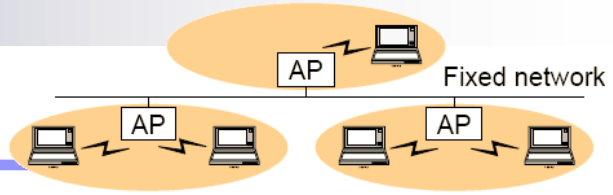
	Year Introduced	Frequency Band (GHz)	Transmit Schemes	Modulation Types
802.11a	1999	5	DSSS/OFDM	BPSK, QPSK, 16-QAM, 64-QAM
802.11b	1999	2.4	DSSS	CCK
802.11g	2003	2.4, 5	DSSS/OFDM	CCK,BPSK, QPSK, 16-QAM, 64-QAM
802.11n	2009 (est.)	5	MIMO-OFDM	BPSK, QPSK, 16-QAM, 64-QAM
802.11ac	2013	5	MIMO-OFDM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM

WLAN (IEEE 802.11 - Wi-Fi) (1/4)



- **Bluetooth also operates in the unlicensed 2.4 GHz band!!! Any conflict between the two technologies???**
  - *Possibly but not likely*. Bluetooth uses a different method for transmitting the radio signals: **Frequency Hopping Spread Spectrum (FHSS)** instead of **Direct Sequence Spread Spectrum (DSSS)**.
  - Any possible interference would be very short-lived.

WLAN (IEEE 802.11 - Wi-Fi) (2/4)

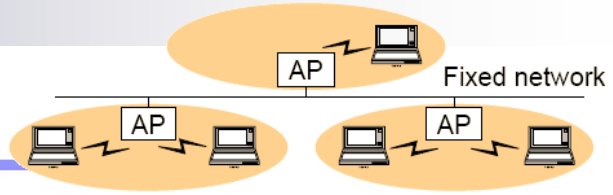


- Transmission Range and Transmission Speeds

802.11 standard version	RF Band (GHz)	Max Speed (Mbps)	Typical Speed (Mbps)	Approx. Indoor range (m)	Approx. Outdoor range (m)
a	5	54	25	40	100
b	2.4	11	6	70	150
g	2.4	54	25	80	200
n	2.4 or 5	600 (4x4 @	75 (1x1 @ 20	100	250

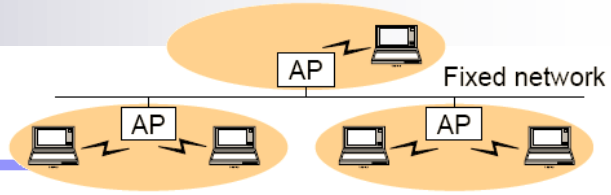
- Transmission Range and Transmission speed for **802.11 ac** (**theoretical**)
  - Transmission Range: Up to 50 meters
  - Transmission Speed: Up to 7 Gbits/sec

WLAN (IEEE 802.11 - Wi-Fi) (3/4)



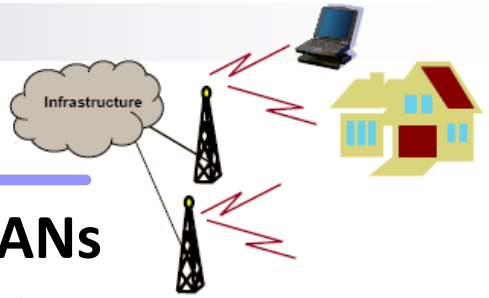
- **Advantages of WLAN**
  - **IEEE 802.11 WLAN is already affordable and popular**
    - Used widely in home, office buildings, and other public hot-spots
    - Variety of WLAN equipment available in the marketplace
  - **Easy Deployment:**
    - Only one Access Point is required
  - **Easy Access:**
    - No need for plugs. Access anywhere within coverage
  - **Installation Speed, Simplicity and Flexibility:**
    - Eliminate the need to pull cable through walls and ceilings
    - Can be set up where wires might be impossible to install
  - **Lower Cost:**
    - Eliminates cost of cabling and labor associated with installing
  - **Expandability:**
    - Can serve additional clients with existing equipment
    - In wired networks, additional clients would require additional wiring
    - Coverage can be expanded by installing more Access Points

WLAN (IEEE 802.11 - Wi-Fi) (4/4)



- **Disadvantages of WLAN**
  - **Data speed and reliability (in terms of packet losses)**
    - Not as reliable or fast as wired systems (speed of Gbit/s and more with the use of fiber optics)
  - **Coverage Range:**
    - Devices operate at a limited distance from the Access Point
  - **Interference and Noise:**
    - Microwave ovens, security cameras, cordless phones, baby monitors can cause significant interference
  - **Power consumption**
    - Fairly high compared to other standards (e.g. Bluetooth), making battery life and heat a concern.
  - **No Differentiated Services supported**
    - All users share the network's capacity and no packet gets priority over any other
  - **Security:**
    - More difficult to guarantee and requires manual configuration

WMAN (IEEE 802.16 - WiMAX) (1/2)



- Provides **much longer coverage range than WLANs**
  - Spans a particular small region or a city (up to 50 Km coverage range)

- **Fixed** and **Mobile** Versions Supported

	802.16	802.16a
Spectrum	10 – 66 GHz	2 – 11 GHz
Configuration	Line of Sight	Non- Line of Sight
Bit Rate	32 to 134 Mbps (28 MHz Channel)	≤ 70 or 100 Mbps (20 MHz Channel)
Modulation	QPSK, 16-QAM, 64-QAM	256 Sub-Carrier OFDM using QPSK, 16-QAM, 64-QAM, 256-QAM
Mobility	Fixed	Fixed
Channel Bandwidth	20, 25, 28 MHz	Selectable 1.25 to 20 MHz
Typical Cell Radius	1-3 miles	3-5 miles
Completed	Dec, 2001	Jan, 2003

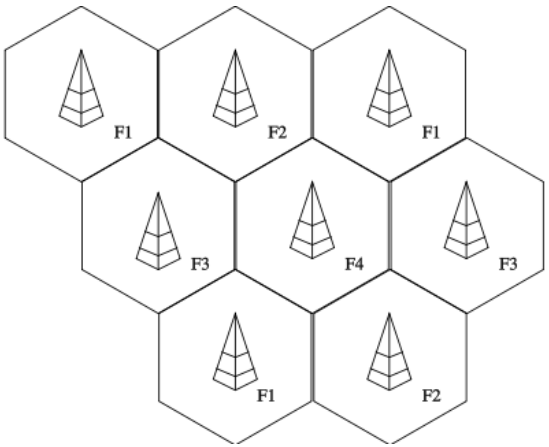
	WiMAX 802.16e (R1.0)	WiMAX 802.16m (R2.0)
Physical layer	DL: OFDMA UL: OFDMA	DL: OFDMA UL: OFDMA
Duplex mode	TDD	FDD and TDD
User mobility	37 to 74 mph (60 to 120 km/h)	217 mph (350 km/h)
Channel bandwidth	3.5, 5, 7, 8.75, 10 MHz	5, 10, 20, 40 MHz
Peak data rates	DL: 46 Mbps (2 × 2) UL: 4 Mbps (1 × 2) at 10 MHz TDD 3:1 (downlink/uplink ratio)	DL > 350 Mbps (4 × 4) UL > 200 Mbps (2 × 4) at 20 MHz FDD
Latency	Link layer – 20 ms Handoff – 35 to 50 ms	Link layer < 10 ms Handoff < 30 ms
VoIP capacity	20 users per sector/ MHz (TDD)	>30 users per sector/ MHz (TDD)

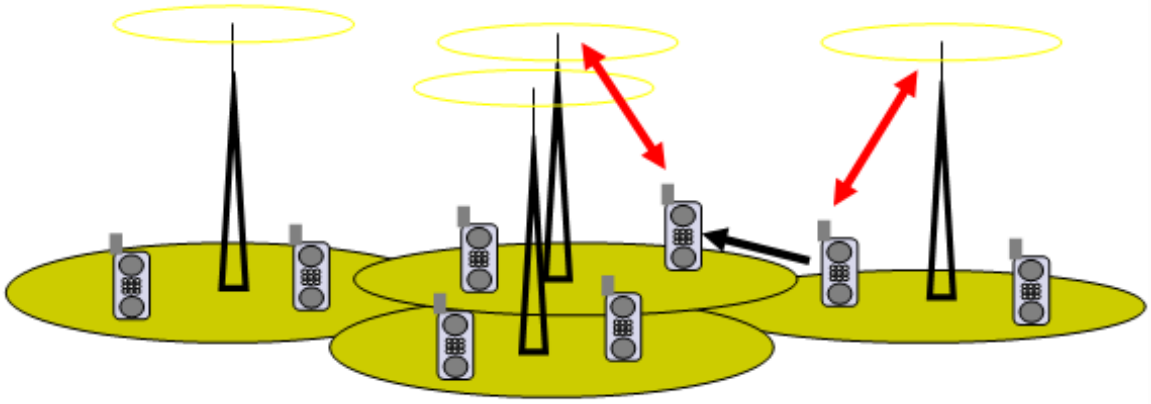
WMAN (IEEE 802.16 - WiMAX) (2/2)

- **OFDM-based physical layer**
  - Good resistance to multipath distortion (**mitigates inter-symbol interference**)
- **Differentiated Services supported**
  - The system offers support for Constant Bit Rate, Real Time, Non real Time, Best Effort etc.
- **Flexible and dynamic per user resource allocation**
  - Capacity is shared among multiple users on demand basis in view to support **Differentiated Quality of Service**.
    - This was not supported with IEEE 802.11 standard
- **Robust Security functions** are built into the WiMAX standard.

Mobile Cellular Networks (1G - 5G)

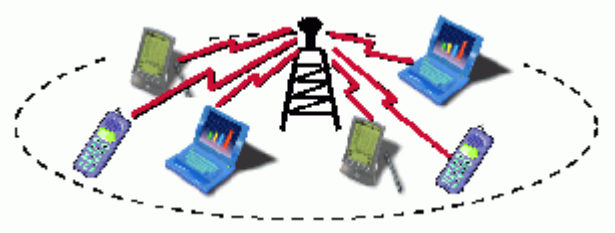
- **Mobile Cellular Networks concept:**
  - In a **Cellular** Network a geographical area is **split** into **several smaller land areas** called **Cells,** each served by a **fixed Base Station**.
  - **Service continuity** within this area is achieved by **handover**, which is the **seamless transfer of a call** from one Base Station to the other as the Mobile Station crosses Cell boundaries.





Mobile Ad Hoc Network (MANET)

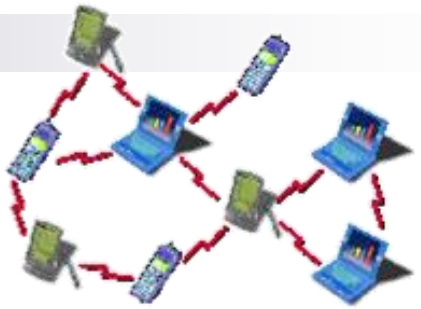
- Typical wireless networks (WLANs, GSM, GPRS, UMTS, etc.) are based on infrastructure.
  - Communication takes place only between the Wireless nodes and the Access Point (Not directly between the Wireless Nodes)



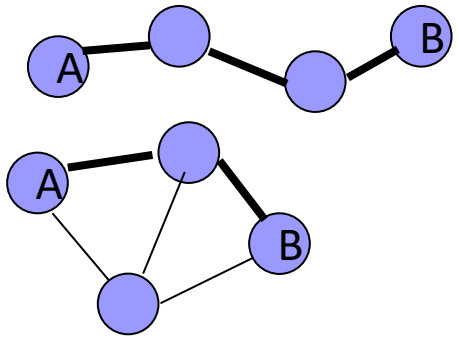
- **What if** …
  - No infrastructure is available? – E.g., in disaster areas
  - It is too expensive/inconvenient to set up? – E.g., in remote, large construction sites
  - There is no time to set up? – E.g., in military operations

- **Solution**:
  - Try to construct a network without infrastructure **using only the networking abilities of the participants** → **Create an Ad Hoc Network**

Mobile Ad Hoc Network (MANET)



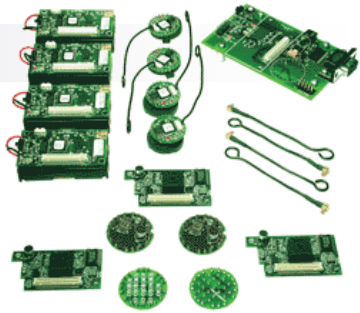
- **Definition:**
  - A Mobile Ad Hoc Network (MANET), is a collection of **autonomous mobile nodes** which **cooperatively** can **dynamically self-organized** into a **temporary** network topology **without any infrastructure support**.
- **Challenges (Προκλήσεις) of a Mobile Ad Hoc Network**
  - **Without a Central infrastructure**, things become much more difficult → Need for **de-centralized operation**
  - **Main Challenges are**:
    - **Lack of central entity** responsible for **organization → Need for Self-Organization; E.g.,** for Routing, Coordination.
    - **Limited Radio Range** of Terminals → **Need for Multihop Communication**
    - **Mobility** of participants → **Need for Dynamic Topology Reconfiguration**



Mobile Ad Hoc Network (MANET)

- MANET Applications:
  - **Military battlefield**:
    - Maintain communication network between soldiers, vehicles and military information headquarters.
  - **Car to Car Communication (VANET):**
    - Finding out empty parking lots in a city, without asking a server
    - Avoid roads with traffic, accidents, etc.
  - **Local level:**
    - Instant and temporary multimedia networks can be deployed on demand to spread and share information among participants (conference, classroom).

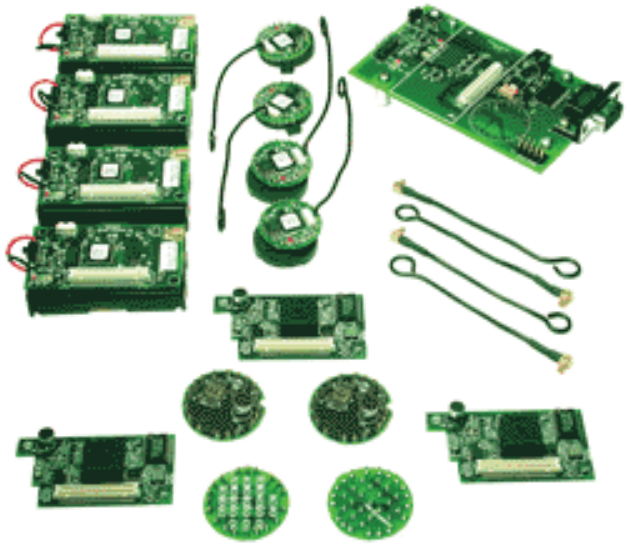
Wireless Sensor Networks (WSN)

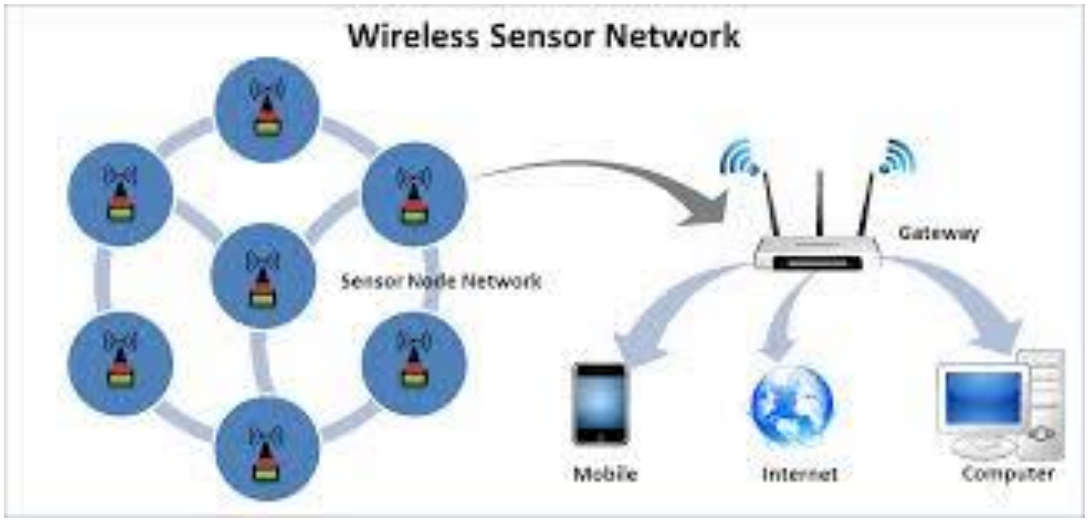


- **A new class of ad hoc networks**
  - Wireless Ad Hoc Networks are focused on **communication between humans**
  - Wireless Sensor Networks are focused on **monitoring the *environment***
- A **Wireless Sensor Network** (WSN) is a wireless network consisting of large number of **spatially distributed autonomous sensor nodes** that **cooperatively monitor physical** or **environmental conditions**, such as:
  - Temperature, Humidity, Motion, Lightning Condition, Pressure, Soil Makeup, Noise Levels, Presence or Absence of certain kinds of objects, etc.

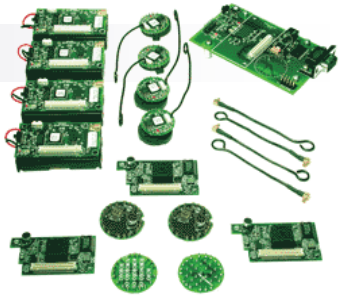
Wireless Sensor Networks (WSN)

- The position of sensor nodes **does not need to be engineered or predetermined.**
  - This allows **random deployment in inaccessible terrains** or **disaster relief operations**.
  - This also means that **sensor network protocols and algorithms must process self-organizing capabilities**.





Wireless Sensor Networks (WSN)



- **Challenges for Wireless Sensor Networks:**
  - **Fault Tolerance / Robustness**: Sensor nodes are **prone to failures** (run out of energy, physical destruction, etc.)
    - A failure should **not affect the overall task** of a sensor network.
  - **Scalability**: A Wireless Sensor Network must be able to **work with a great number of nodes without affecting its performance.**
  - **Hardware constrains:** The sensing, processing, transceiver and power units should be **fit into a tiny module**.
  - **Power consumption:** Sometimes **replacement of power resources** might be **impossible** e.g., in battlefields, in deep ocean.
    - **Power efficiency influence network life time in a sensor network and hence is of prime importance!!!**

Wireless Sensor Networks (WSN)

- Applications examples
  - **Military Applications:**
    - **Battlefield surveillance:** Critical terrains, approach routes, paths and straits can be rapidly covered with sensor networks and closely watched for the activities of the opposing forces
    - **Targeting**: Sensor networks can be incorporated into guidance systems of the intelligent ammunition.
    - **Nuclear, biological and chemical attack detection and reconnaissance**
  - **Environmental applications**
    - **Forest fire detection:** Sensor nodes densely deployed in a forest, can sense and relay the exact origin of the fire to the end users before the fire is spread uncontrollable.
    - **Environmental control:** Detecting chemicals, pollution, radiation levels etc.

Wireless Sensor Networks (WSN)

- Applications examples
  - **Health Applications**
    - **Tele-monitoring of human physiological data:** The physiological data about a patient can be collected by the sensors and stored for a long period of time which will be used for medical exploration and monitoring remotely by a doctor. This is more convenient for the patient and also allows the doctor to better understand the patient's current condition

History of wireless communication I

- **1896 Guglielmo Marconi**
  - First demonstration of wireless telegraphy (digital!)
  - Long wave transmission, high transmission power necessary (> 200kW)
- **1907 Commercial transatlantic connections**
  - huge base stations (30-100m high antennas)
- **1915 Wireless voice transmission New York - San Francisco**
- **1920 Discovery of short waves by Marconi**
  - Reflection at the ionosphere
  - Smaller sender and receiver, possible due to the invention of the vacuum tube (1906, Lee DeForest and Robert von Lieben)
- **1926 Train-phone on the line Hamburg - Berlin**
  - Wires parallel to the railroad track

History of wireless communication II

- **1928 many TV broadcast trials (across Atlantic, color TV, news)**
- **1933 Frequency modulation (E. H. Armstrong)**
- **1958 Mobile telephony, A-Netz in Germany**
  - Analog, 160MHz, connection setup only from the mobile station, no handover, 80% coverage, 1971 11000 customers
- **1972 Mobile Telephony, B-Netz in Germany**
  - Analog, 160MHz, connection setup from the fixed network too (but location of the mobile station has to be known)
  - Available also in A, NL and LUX, 1979 13000 customer in D

History of wireless communication II

- **1979 NMT at 450MHz (Scandinavian countries)**
- **1982 Start of GSM-specification**
  - Goal: pan-European digital mobile phone system with roaming
- **1983 Start of the American AMPS (Advanced Mobile Phone System, analog)**
- **1984 CT-1 standard (Europe) for cordless telephones**
- **1986 C-Netz in Germany**
  - Analog voice transmission, 450MHz, hand-over possible, digital signaling, automatic location of mobile device
  - Was in use until 2000, services: FAX, modem, X.25, e-mail, 98% coverage

History of wireless communication III

- **1991 Specification of DECT**
  - Digital European Cordless Telephone (today: Digital Enhanced Cordless Telecommunications)
  - 1880-1900MHz, ~100-500m range, 120 duplex channels, 1.2Mbit/s data transmission, voice encryption, authentication, up to several 10000 user/km2, used in more than 50 countries
- **1992 Start of GSM**
  - In D as D1 and D2, fully digital, 900MHz, 124 channels
  - Automatic location, hand-over, cellular
  - Roaming in Europe - now worldwide in more than 200 countries
  - Services: data with 9.6kbit/s, FAX, voice, ...
- **1996 HiperLAN (High Performance Radio Local Area Network)**
  - ETSI, standardization of type 1: 5.15 - 5.30GHz, 23.5Mbit/s
  - recommendations for type 2 and 3 (both 5GHz) and 4 (17GHz) as wireless ATM-networks (up to 155Mbit/s)

History of wireless communication IV

- **1997 Wireless LAN - IEEE802.11**
  - IEEE standard, 2.4 - 2.5GHz and infrared, 2Mbit/s
  - already many (proprietary) products available in the beginning
- **1998 Specification of GSM successors**
  - for UMTS (Universal Mobile Telecommunication System) as European proposals for IMT-2000
  - Iridium
  - 66 satellites (+6 spare), 1.6GHz to the mobile phone

History of wireless communication IV

- **1999 Standardization of additional wireless LANs**
  - IEEE standard 802.11b, 2.4-2.5GHz, 11Mbit/s
  - Bluetooth for piconets, 2.4GHz, <1Mbit/s
  - Decision about IMT-2000
    - Several “members” of a “family”: UMTS, cdma2000, DECT, …
  - Start of WAP (Wireless Application Protocol) and i-mode
    - First step towards a unified Internet/mobile communication system
    - Access to many services via the mobile phone
- **2000 GSM with higher data rates**
  - HSCSD offers up to 57,6kbit/s
  - first GPRS trials with up to 50 kbit/s (packet oriented!)
  - UMTS auctions/beauty contests
    - Hype followed by disillusionment (50 B$ paid in Germany for 6 licenses!)
  - Iridium goes bankrupt

History of wireless communication V

- **~ 2000 sensor networks research frenzy**
- **2001 Start of 3G systems**
  - Cdma2000 in Korea, UMTS tests in Europe, Foma (almost UMTS) in Japan
- **2002**
  - WLAN hot-spots start to spread
- **2003**
  - UMTS starts in Germany
  - Start of DVB-T in Germany replacing analog TV
- **2005**
  - WiMax starts as DSL alternative (not mobile)
  - first ZigBee products

History of wireless communication VI

- **2006**
  - HSDPA starts in Germany as fast UMTS download version offering > 3 Mbit/s
  - WLAN draft for 250 Mbit/s (802.11n) using MIMO
  - WPA2 mandatory for Wi-Fi WLAN devices
- **2007**
  - Commercial deployment of 3G becomes widespread
  - Over 3.3 billion subscribers for mobile phones (NOT 3 bn people!)
- **2008**
  - 4G Widely talked
  - “real” Internet widely available on mobile phones (standard browsers, decent data rates)
  - 7.2 Mbit/s HSDPA, 1.4 Mbit/s HSUPA available in Germany, more than 100 operators support HSPA worldwide, first LTE tests (>100 Mbit/s)

History of wireless communication VI

- **2008**
  - 4G Widely talked
  - “real” Internet widely available on mobile phones (standard browsers, decent data rates)
  - 7.2 Mbit/s HSDPA, 1.4 Mbit/s HSUPA available in Germany, more than 100 operators support HSPA worldwide, first LTE tests (>100 Mbit/s)
- **2009**
  - The story continues with netbooks, iphones, VoIPoWLAN…
- **2012**
  - LTE deployment
- **2013 + …….**

Ερωτήσεις;

Additional Slides

Effects of Device Portability/Mobility

- **Hardware Modifications**
  - Need for Lighter, more Robust and Lower Power Consuming hardware
- **Limited Resources**
  - Limited battery capacity, limited computing power, Low resolution displays, Limited memory, Low disk size
- **Loss of data**
  - Higher probability of loosing data. E.g., Defects of the device, thefts, etc. Has to be considered in advance into the design (synchronization of data)
- **Limited User Interfaces**
  - Compromise between size of fingers and portability