



# Wireless Networks

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# Wireless Lectures Outline

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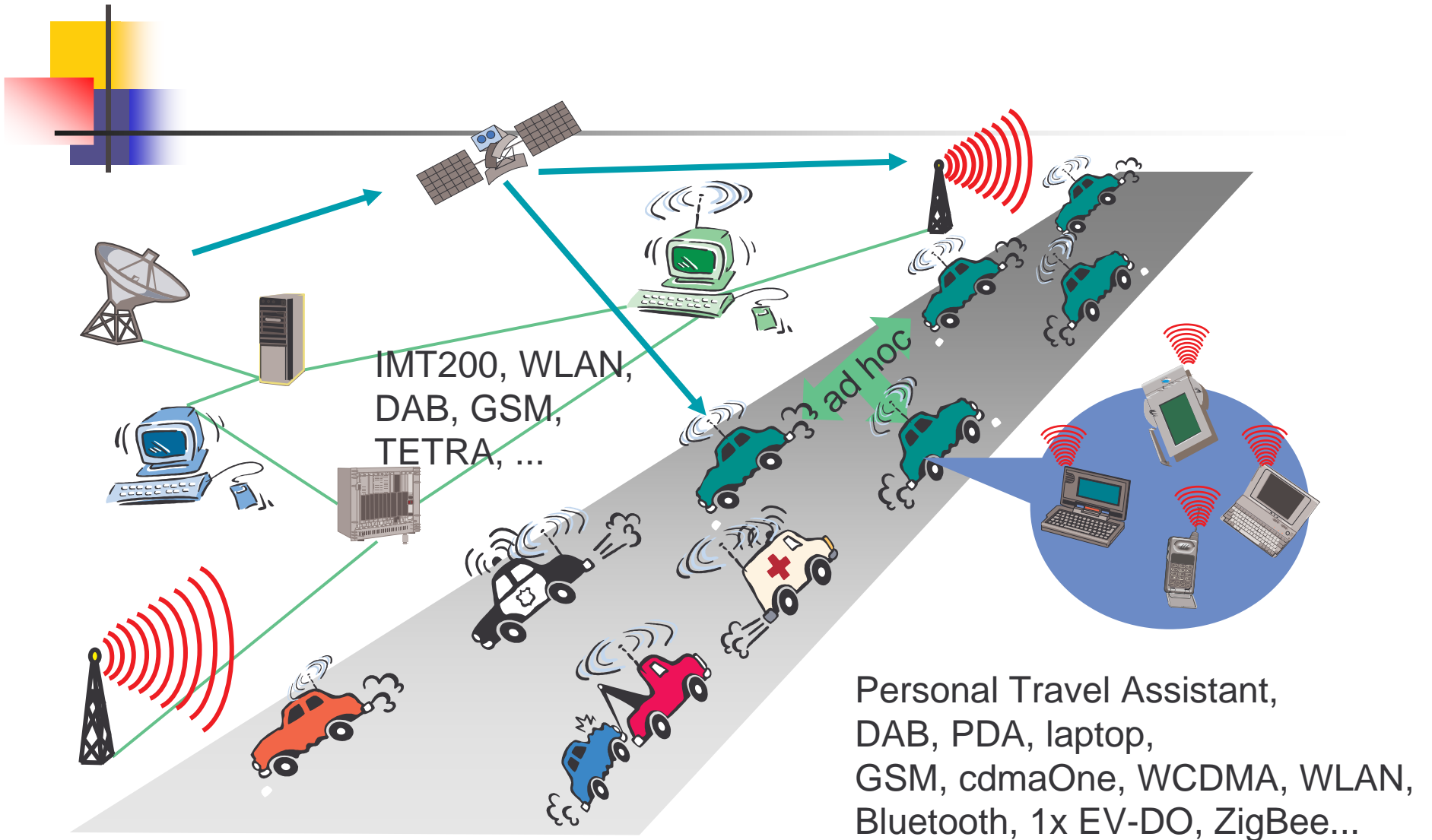
- Overview of Wireless Systems
  - Terminology, types of systems, issues, etc.
- Wireless LANs
  - IEEE802.11, Hiperlan1/2
- Personal Area Networks
  - Bluetooth
- Cellular Telecommunication Systems
  - GSM, CDMA (e.g., IS-95)
- Ad Hoc Networks



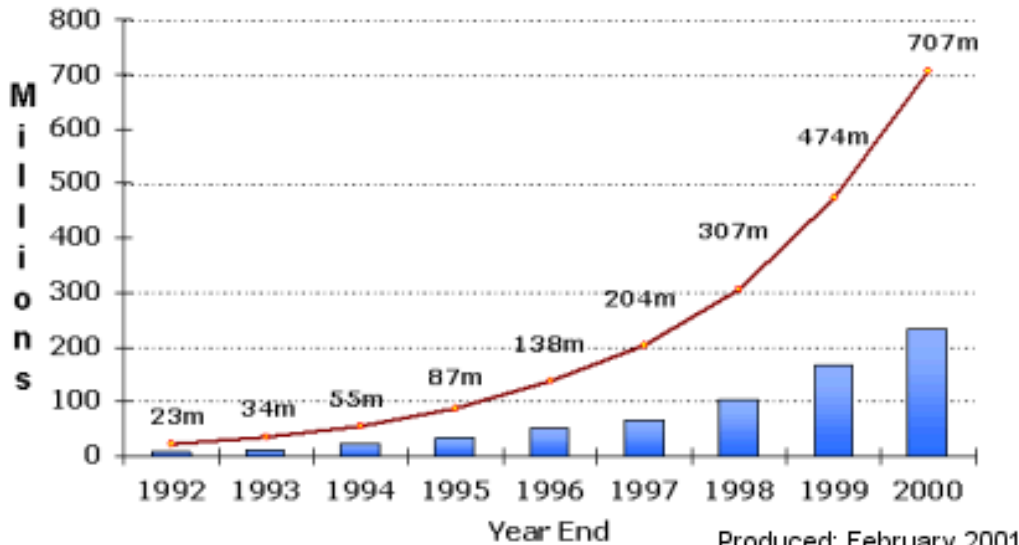
# Wireless Communication Systems

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- n Target Information Systems:
  - "Anytime, Anywhere, Anyform"
- n Applications: Ubiquitous Computing/Information Access
- n Market in continuous growth:
  - n 35-60% annual growth of PCS
  - n Number of subscribers:
    - n 2001: over 700M wireless subscribers
    - n 2003: 1.160 billion wireless subscribers
    - n 2006: over 2 billion wireless subscribers (source [www.wirelessintelligence.com](http://www.wirelessintelligence.com), [www.gsmworld.com](http://www.gsmworld.com))
- n Large diversity of standards and products!!!
- n Confusing terminology



# Evolution of Number of Subscribers



Cellular subscribers (analogue, CDMA, GSM, etc.)

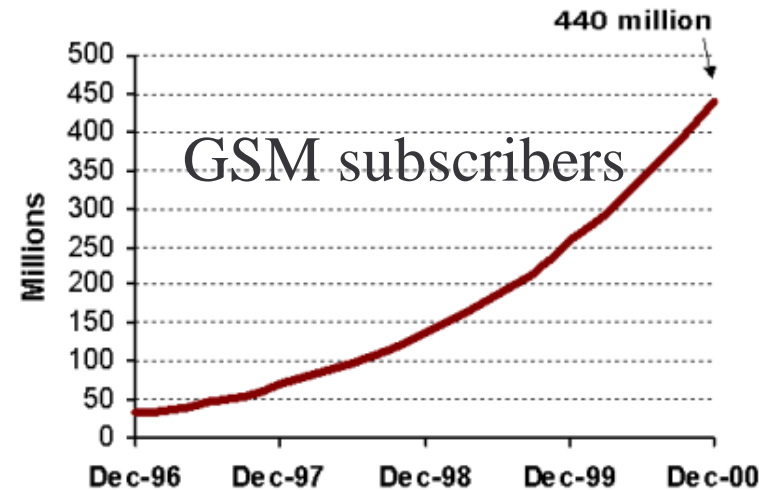
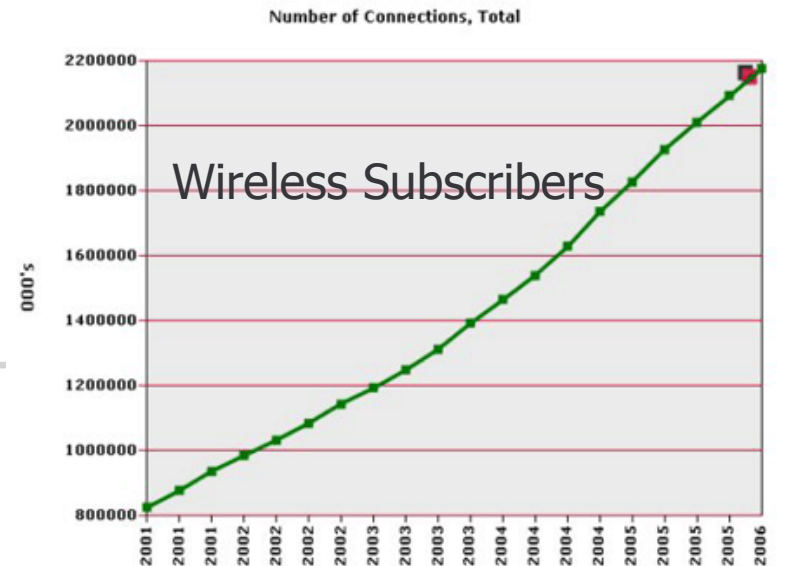
March 2003: Total(1.160B), GSM (825M),

US: Total: 140M, CDMA: 60M

September 2005: over 2B ; GSM family (inc. WCDMA): 1.6B

Source:

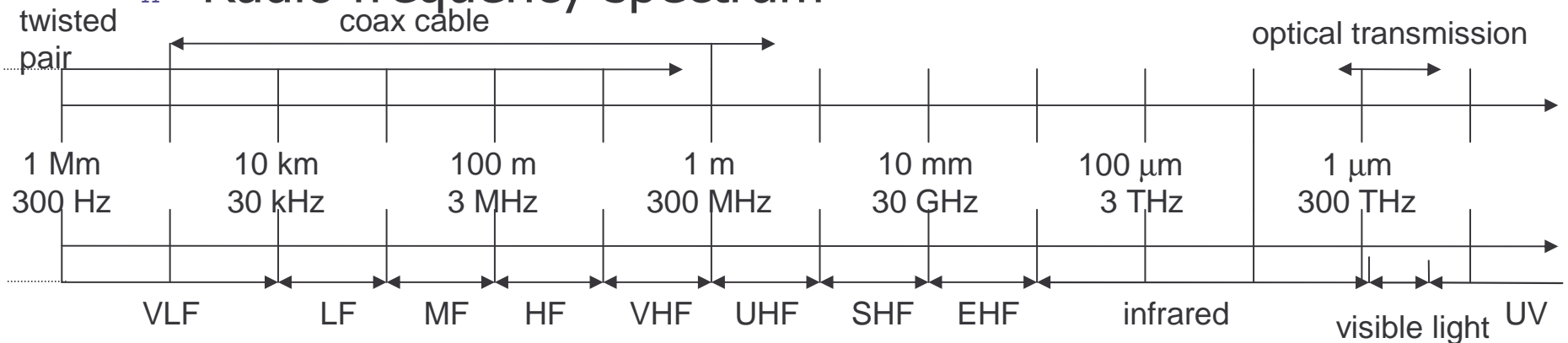
- EMC World Cellular Database ([www.emc-database.com](http://www.emc-database.com))
- GSM World Association [http://www.gsmworld.com/membership/ass\\_sub\\_stats.html](http://www.gsmworld.com/membership/ass_sub_stats.html)
- Wireless Intelligence ([www.wirelessintelligence.com](http://www.wirelessintelligence.com))



# Wireless Communication

n Types of wireless communications?


n Radio frequency spectrum



n **ISM:** Industrial, Scientific and Medical frequency bands

n Wireless versus Mobile:

n Can we have wired-mobile node or wireless-fixed node?



# Attributes of Wireless & Mobile Communication Systems

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## n Wireless:

- n limited bandwidth: frequencies have to be coordinated, useful frequencies are almost all occupied
- n broadcast medium: requires efficient access mechanisms
- n variable link quality (noise, disconnection, interference)
- n high latency, higher jitter (cellular):
  - n connection setup time: several hundred milliseconds ; Packet/bit interleaving
- n heterogeneous air interfaces
- n security: easier snooping

## n Mobility:

- n user and terminal location is a dynamic system variable
- n speed of mobile impact wireless bandwidth
- n Security: easier spoofing

## n Portability:

- n limited battery capacity
- n limited computing and memory
- n small dimensions (limited user interfaces)



# Classification of Wireless Personal Communication

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- n Mobility scale:

- n within a house or building: cordless telephone, WLAN
- n within a campus, city: (cellular radio, WLAN, wide area wireless data, radio paging, extended cordless)
- n throughout the world: cellular radio, paging, satellite-based wireless

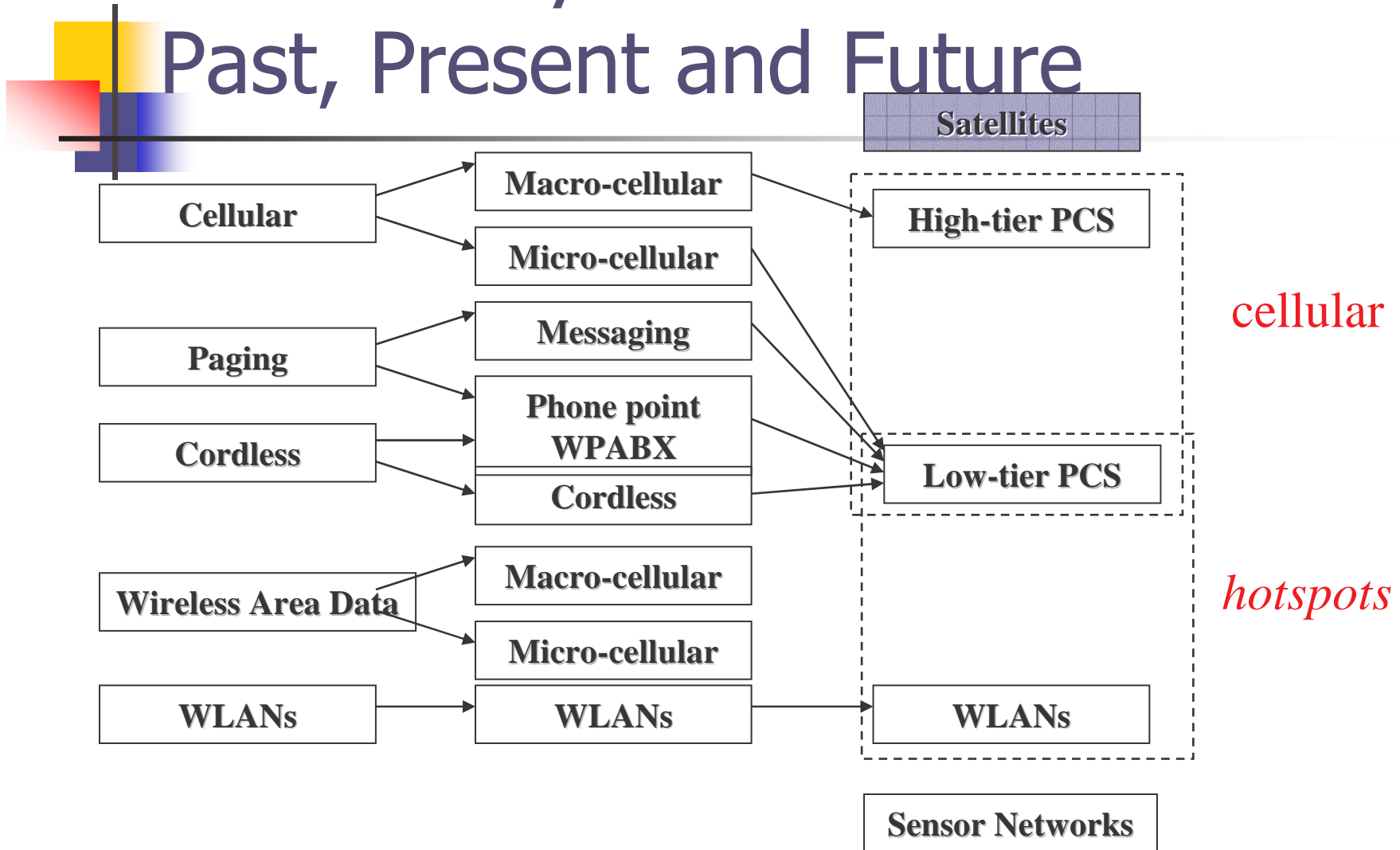
- n Communication modes:

- n two-way voice
- n data and multimedia
- n messaging

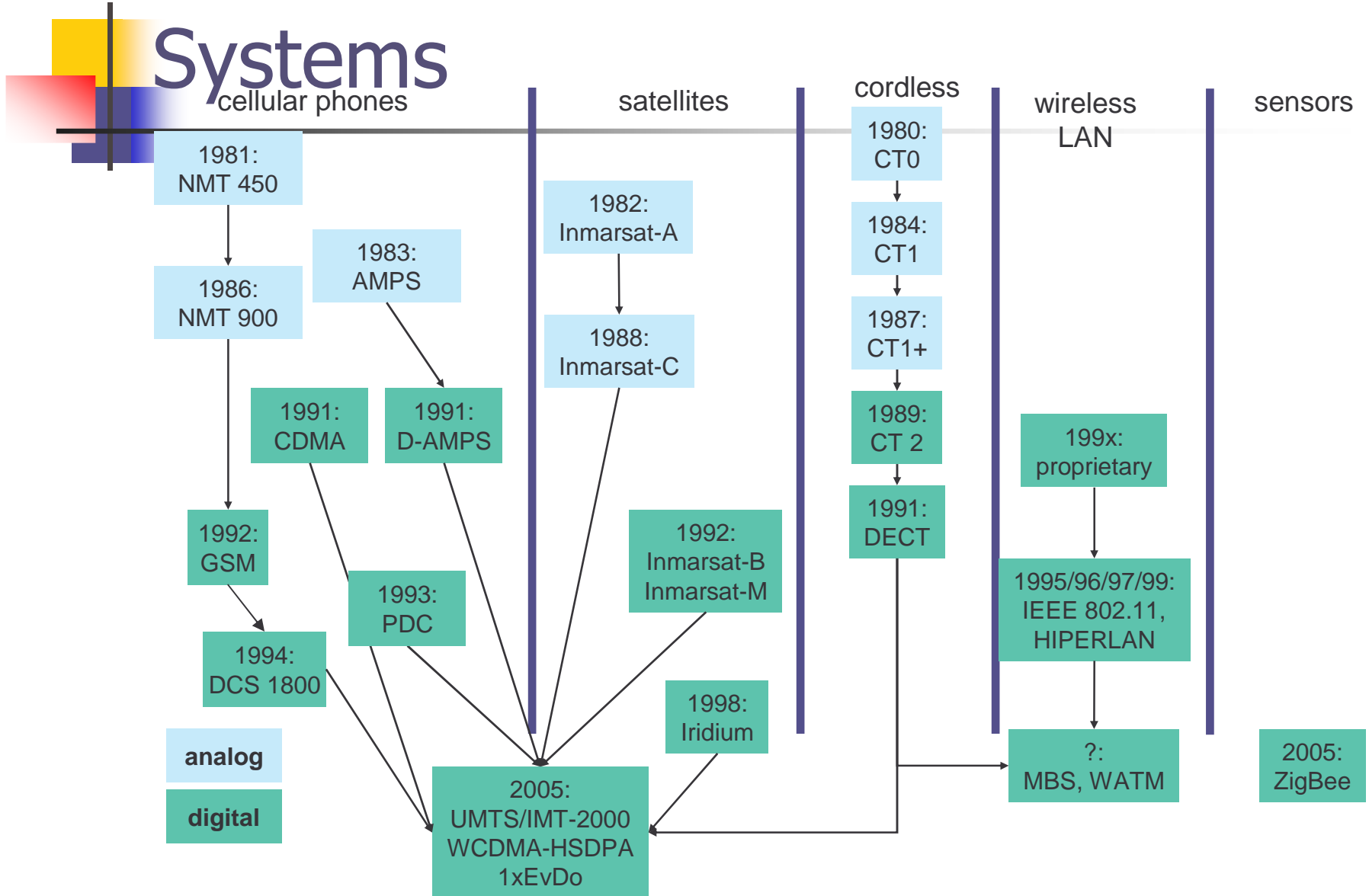
- n Convergence through all-IP networks and voice-over-IP with multiple physical layer interfaces



# Wireless Systems: Past, Present and Future

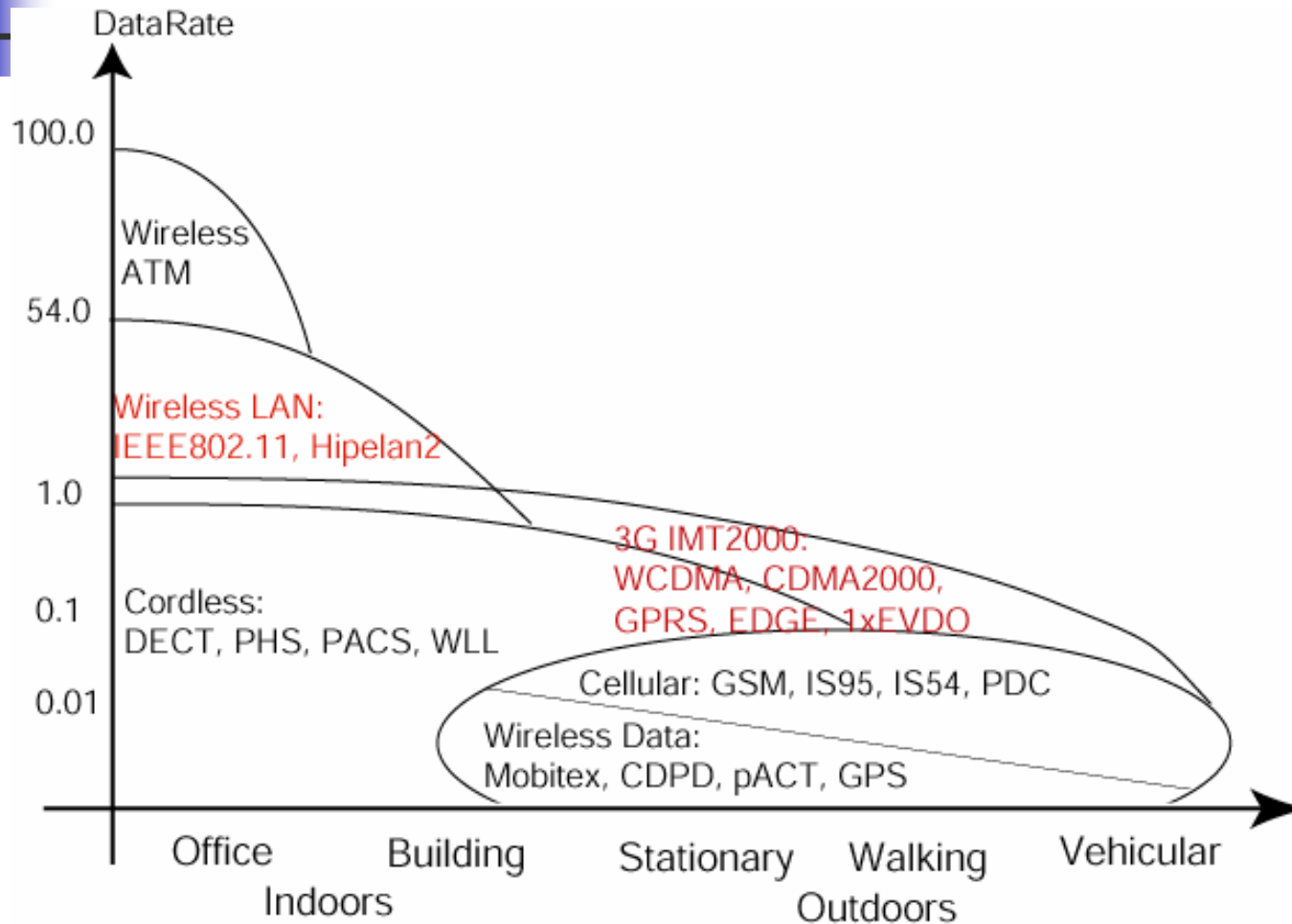


# Evolution of Some Wireless Systems





# Wireless "Standards"





# Cordless Telephones (1970s- )

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- n Evolved from analog to digital:
  - n Low transmission power:  $\leq 10\text{mW}$  (limited radio range)
  - n Low transmission delay:  $\leq 10\text{ms}$
  - n Dynamic Channel Allocation
- n Products
  - n Europe-Asia:
    - n CT-2 (864-868MHz, bitrate 72Kpbs), DECT (1880-1990MHz, 1.2MBps)
  - n USA: several products based on spread-spectrum or very low power transmission systems over the ISM frequency bands (900MHz, 2.4GHz)
  - n Japan: PHS (1895-1907MHz, upto 384KBps)
- n New services on cordless phones:
  - n PhonePoint (CT-2, PHS), WPABX (DECT)
  - n Limitations: reduced coverage, inefficient handoffs
  - n Combination with cellular phones: GSM-DECT dual mode



# Cellular Mobile Radio Systems (Past/Present)

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## n Characteristics:

- n Two-way voice service
- n High mobility
  - n Higher coverage, vehicular speed handoffs
- n Messaging
- n Mobile transmission power:  $\sim 2W$
- n Low data rate:  $< 10KBps$
- n Higher RTT:  $\sim 200ms$  (due to interleaving, FEC etc.)

## n Standards/Products:

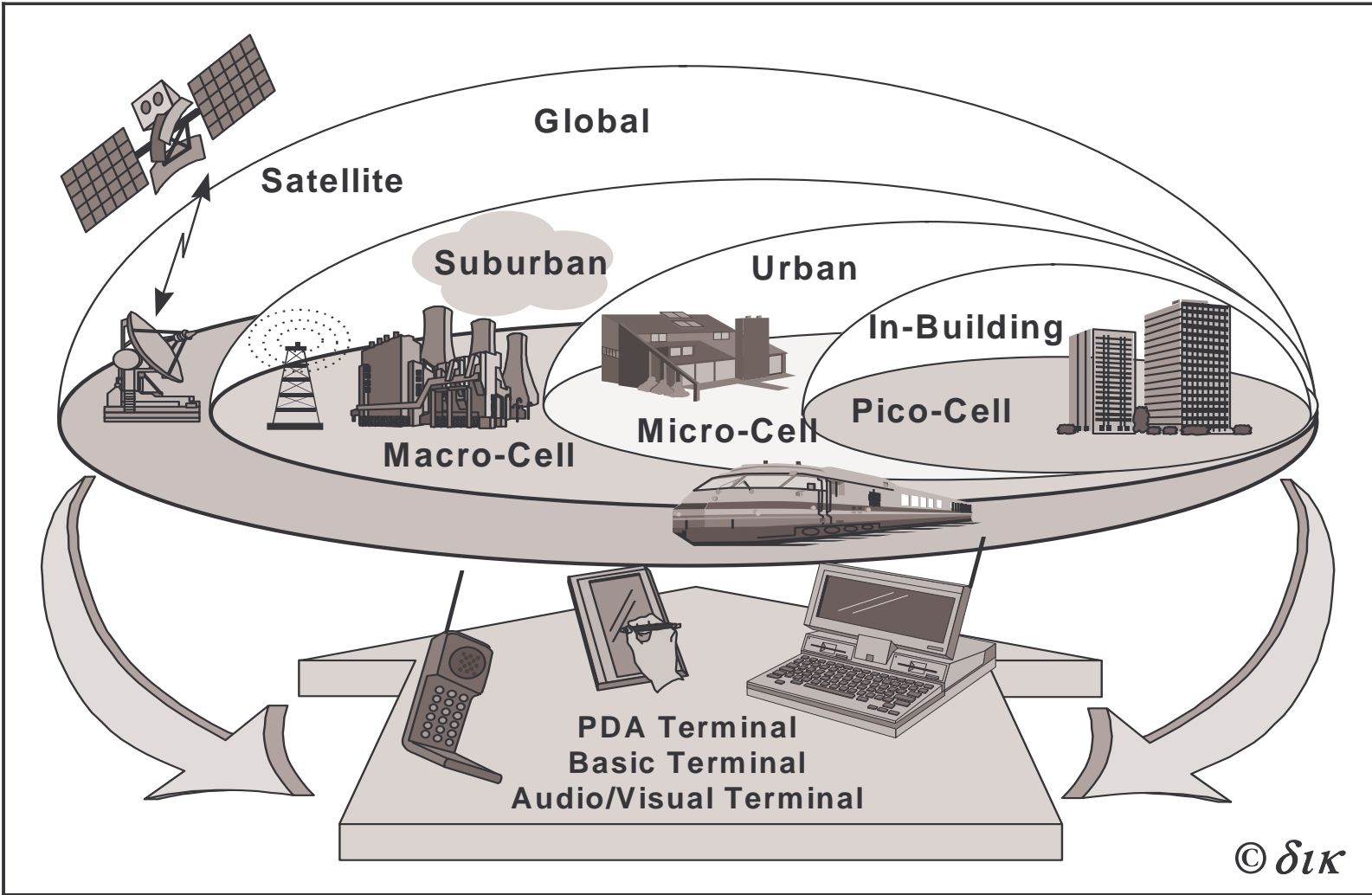
- n Global Standard for Mobile (GSM):
  - n  $\sim 825M$  subscribers (Europe, Asia, USA)
  - n Extensions: HSCSD (in practice 28Kbps UL/28Kbps), GPRS (50Kbps)
- n Japanese of Personal Digital Cellular (JDC or PDC)
- n USA: IS-54/IS-136/DAMPS, GSM/GPRS (TDMA), IS-95/1x/1xEV-DO (CDMA)

# Cellular Mobile Radio Systems

## Today?



- n Third Generation PCS initiated by ITU's call for proposals (IMT2000)
  - n Convergence of wireless PCS into a unique system
  - n Efficient coverage
  - n High data rates: 144Kbps (high mobility), 384Kbps (low mobility), and up-to 2Mbps for indoor
  - n Multi-QoS connections (data-rate, delay, FER)
- n Most likely: three standards
  - n WCDMA:
    - n ETSI proposal (FRAMES European project) [[www.3GPP.org](http://www.3GPP.org)]
    - n ARIB proposal (Japan)
  - n CDMA2000 – 1xRTT – 1xEvDo is an enhancement of Qualcomm's IS-95 [[www.3GPP2.org](http://www.3GPP2.org)]
  - n EDGE (2.5G): convergence of 2<sup>nd</sup> generation PCS (TDMA)
    - n GSM, D-AMPS, IS-54, IS-136





# Wide-Area Wireless Data Systems

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## n Characteristics:

- n High mobility (vehicular/pedestrian speed)
- n Wide range coverage

## n Products:

- n ARDIS (USA: Motorola), RAM (Ericsson): low data rate <8Kbps
- n Metricom (76Kbps):
  - n large number of inexpensive base stations,
  - n connected through wireless links
  - n each base stations has small coverage
  - n Deployed in San Francisco Bay area, Washington D.C.
  - n Slow frequency hopping, Pwr <1W over 902-928MHz ISM band

- n WiMax IEEE802.16 (the wireless DSL)

n Past wide area wireless data systems did not succeed to attract enough users! WiMax future seems brighter.





# Wireless Local Area Networks

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- n Characteristics:

- n low-mobility
- n high data-rate: 1Mbps-54Mbps
- n campus/building coverage

- n Products/standards:

- n IEEE802.11, Hiperlan 1/2, Bluetooth, HomeRF,
- n Altair Plus, AirLan, Freeport, Intersect, LAWN, WILAN, RadioPort, ArLAN, Radio Link, Range LAN 1-2, Netware, FreeLink

- n Operate over ISM frequency Band:

- n 2.4GHz, 900MHz, 5GHz



# Other Wireless Systems

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- n Paging/Messaging:

- n Evolution: from 1 bits info, to two-way
- n Combined with CT-2 (Phone point), GSM (Short Message Service: SMS)

- n Blackberry (RIM):

- n Initially proprietary basic email services now over GSM

- n Satellite-Based Mobile Systems:

- n Large coverage
- n Constellation of satellites (LEO)
- n Products: *stopped*
  - n Iridium (Motorola):
  - n Globalstar
  - n Teledesic (Lockheed Martin, Microsoft, Motorola)



# Summary

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- n WLAN/PAN

- n Designed for high bit-rate data transmission
- n Low-scale mobility, small area coverage
- n Use unlicensed ISM frequency bands

- n PCS

- n Originally (2<sup>nd</sup> generation) designed for voice communication
- n Limited bit-rate data transmission
- n Large scale mobility and coverage (high-speed, big cells)
- n Operate over licensed frequency bands

- n Wireless Metropolitan Area Networks

- n Sensor Networks

- n Low data rate
- n Low power consumption
- n Low mobility
- n Over ISM



# Common Components of Wireless Systems

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- n Antenna:

- n transducer that transforms an electric signal into an electromagnetic signal and reciprocally

- n Radio-Frequency Front-End:

- n Filters
  - n Power-Amplifier
  - n Mixers
  - n PLLs

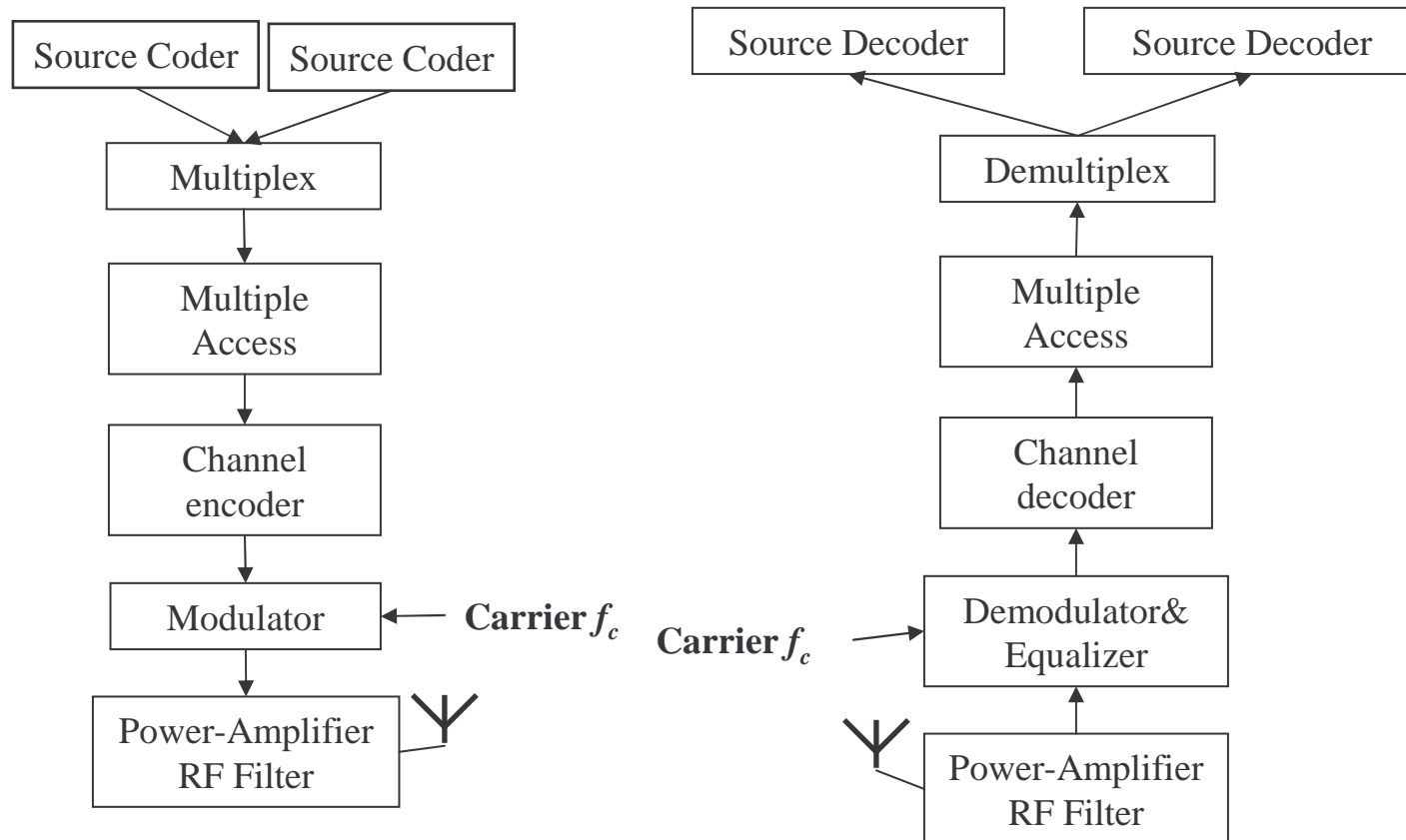
- n Base-Band:

- n Demodulation, Forward Error Correction

- n Multiple-Access Scheme

- n FDMA, TDMA, CDMA, etc.

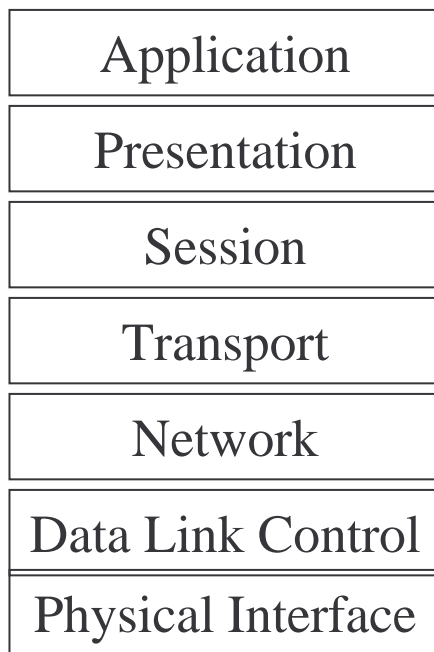
# EE view vs. CS view



Electrical Engineer view:

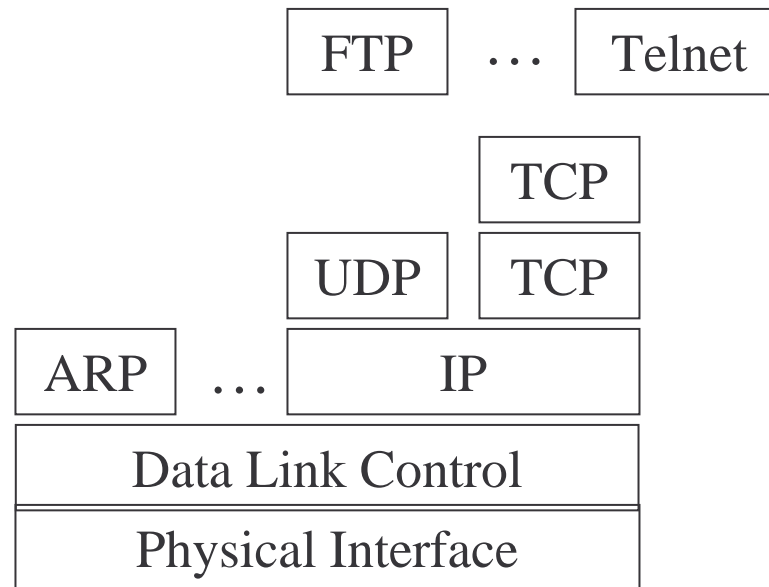
- Ignores issues of routing, reliable transport, various applications requirements

# ISO view vs. IETF view



OSI stack

## *Computer Network Engineer view*



Lack of coordination between higher layers and physical layer



# WLAN Architectures

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## n Terminology:

- n Mobile Terminal (MT) or Mobile Station (MS) to denote and mobile node
- n Access Point (AP) or Base-Station (BS) to denote the central entity that coordinates and wirelessly connects the mobiles to the wired network

## n Types of WLAN:

- n Infrastructure WLAN
- n Ad Hoc WLAN:
  - n Single: peer-to-peer communication
  - n Multi-hop: nodes act both as terminals and routers



# Issues in WLAN

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- n Physical Layer

- n How to resist to the wireless link limitations? → multiple error control coding schemes

- n Medium Access Layer

- n Coordination of nodes
  - n Dealing with wireless limitations (medium sensing and collisions detections)

- n Network Layer

- n How to maintain the routing tables in the context of highly mobile nodes (multi-hop routing)?

- n Transport Layer

- n TCP is optimized for congestion avoidance how to extend to error control

- n Application Layer

- n How to satisfy the application requirements (delay, throughput)?
  - n How can the application adapt to the channel?

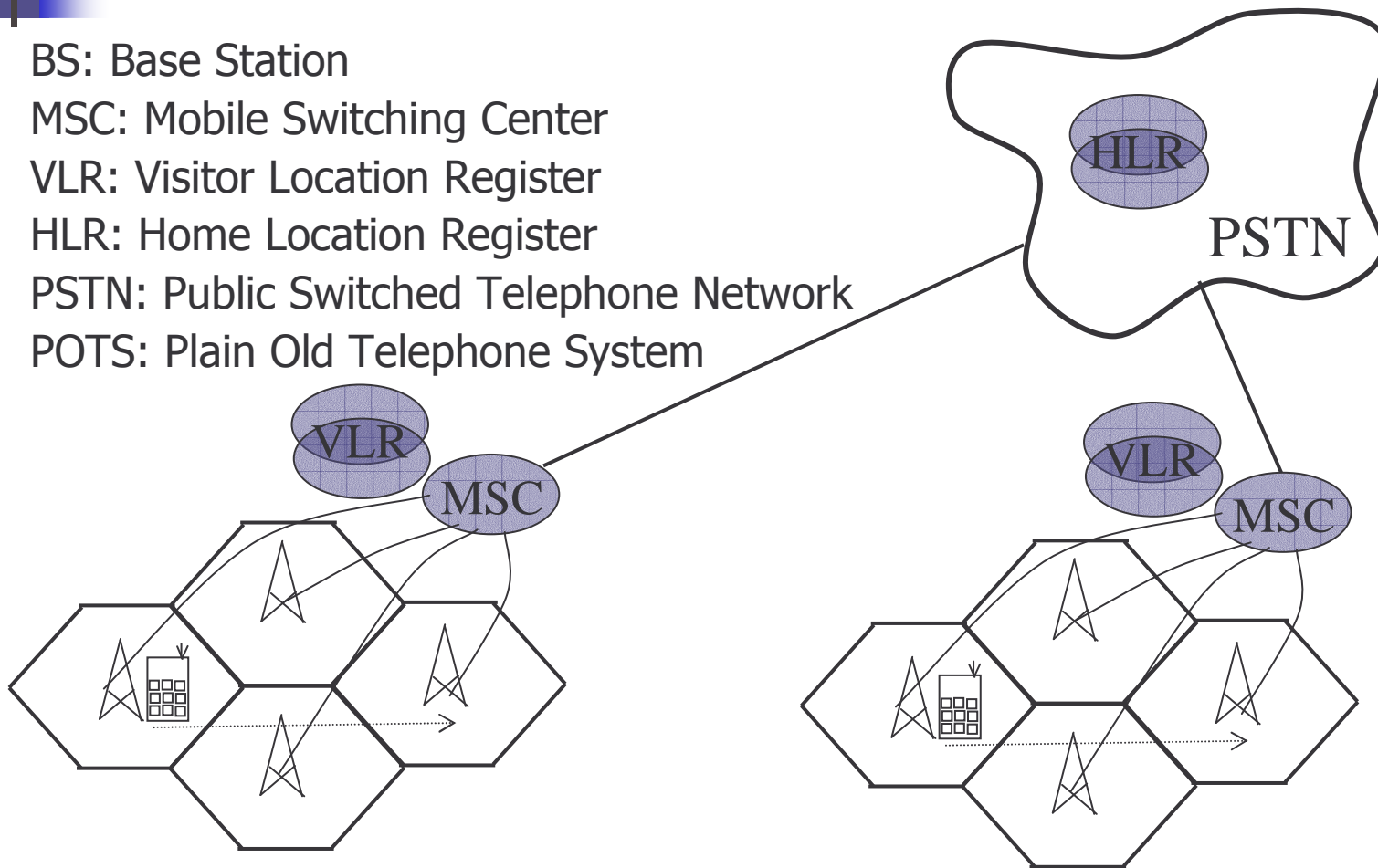
- n Resource conservation:

- n Power-consumption, bandwidth optimization
  - n Planning for infrastructure networks (location identification, tele-traffic analysis)
  - n Self-configuration for multi-hop ad hoc networks



# PCS Architectures

- BS: Base Station
- MSC: Mobile Switching Center
- VLR: Visitor Location Register
- HLR: Home Location Register
- PSTN: Public Switched Telephone Network
- POTS: Plain Old Telephone System



CSU610 - SWARM

Wireless Networks



# Issues in PCS

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## n Planning

- n Infrastructure planning:
  - n Location of base stations
- n Resources planning and management:
  - n Frequency, timeslots, codes
  - n Fixed (FCA), Dynamic (DCA), Hybrid, etc.

## n Mobility:

- n Handover (or handoff) types:
  - n Soft/hard/seamless (data flow), backward/forward (control flow)
  - n Mobile controlled (DECT, PACS), network controlled (AMPS, CT-2), mobile assisted (GSM, IS-95)
  - n Intra-system handover, inter-system handover
- n Admission Control
- n Roaming



# Summary: Main Wireless Systems

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- n Wireless Local Area Networks:

- n WiFi: IEEE802.11

- n Cellular:

- n Today: GSM (= DCS1800, PCS1900 , GPRS), CDMA (= IS-95), DAMPS (= TDMA, IS-136, IS-54)

- n Being deployed: WCDMA (UMTS = 3GPP, HSDPA), Cdma2000 (=3GPP2: 1xEV-DO)

- n Wireless Metropolitan Area Networks:

- n WiMax: IEEE802.16

- n Wireless Personal Area Networks

- n Bluetooth = IEEE802.15.1

- n Sensor Networks:

- n ZigBee = IEEE802.15.4



# Some Trends in Wireless Networks

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- n Service architectures:

- n IEEE802.11b/a/g leading to hotspots
- n Cellular for full coverage, voice, and mobility
- n Hybrid wireless networks: multihop and infrastructure

- n Recent hot physical layer technologies research:

- n Ultra Wide Band (UWB) derived from radar technology for low interference-low power communication

- n All IP cellular networks:

- n Flarion, Airvana (CDMA 2000 1xEV-DO), etc.

- n Coexistence of technologies:

- n Software Defined Radio, single chip multiple radio technologies (Qualcomm)