

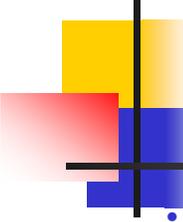
Wireless Networks

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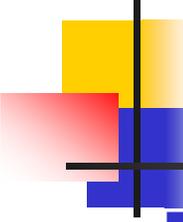
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Wireless Lectures Outline

- 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

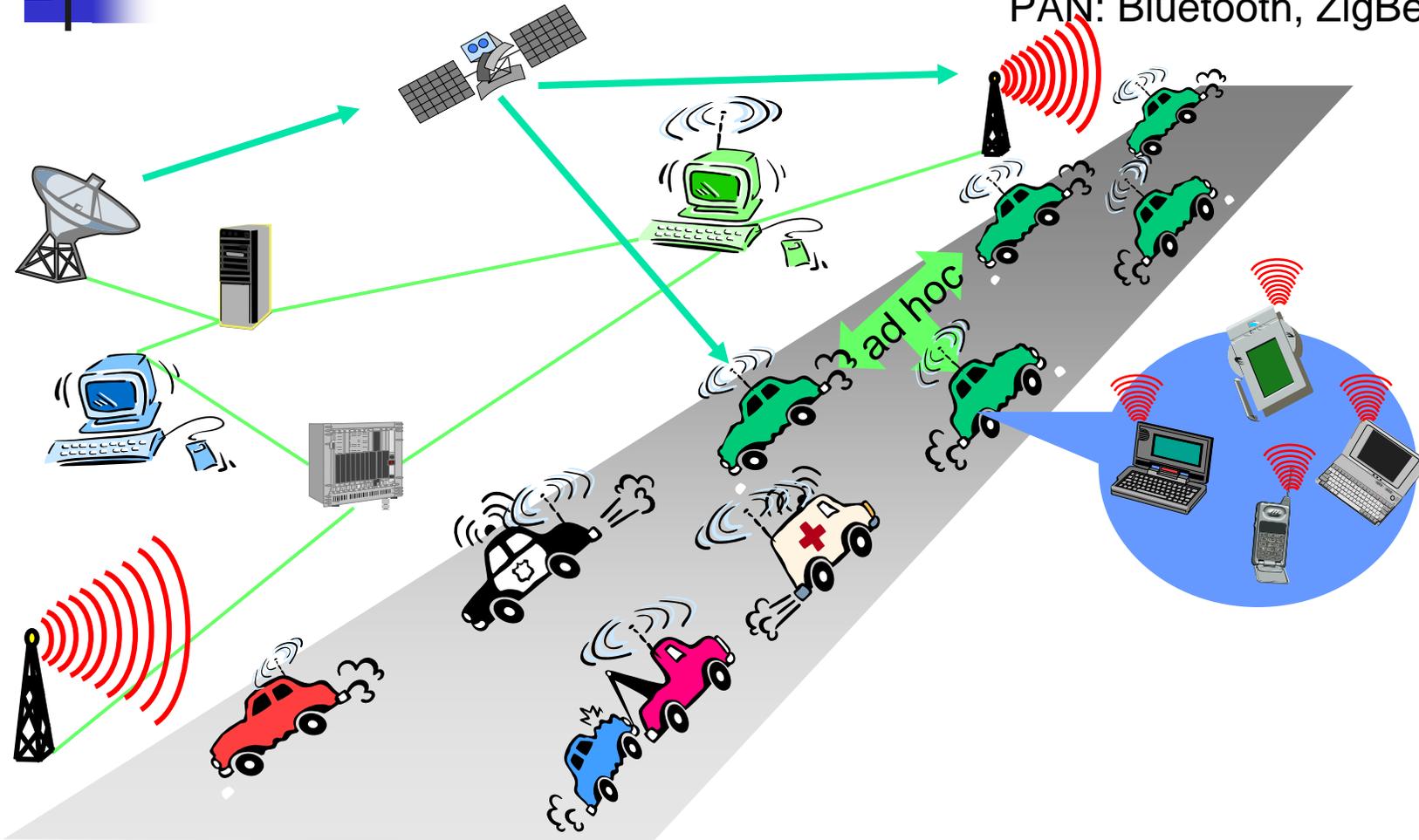


Wireless Communication Systems

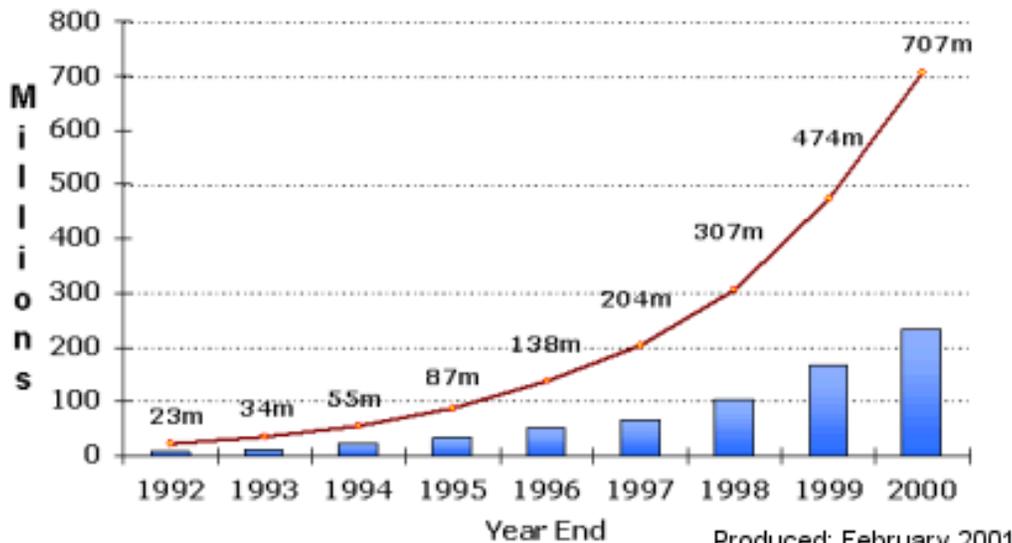
- Target Information Systems:
 - “Anytime, Anywhere, Anyform”
- Applications: Ubiquitous Computing/Information Access
- Market in continuous growth:
 - 35-60% annual growth of PCS
 - Number of subscribers:
 - 2001: over 700M wireless subscribers
 - 2003: 1.160 billion wireless subscribers
 - 2006: over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

Wireless Communication

2G: GSM/GPRS, TDMA, IS-95
2.5G: EDGE, cdmaOne,
3G: WCDMA/UMTS, 1xRTT
3.5G: HSDPA, 1xEVDO
WLAN: IEEE802.11,
WSN: ZigBee, UWB...
PAN: Bluetooth, ZigBee, UWB



Evolution of Number of Subscribers



Produced: February 2001

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

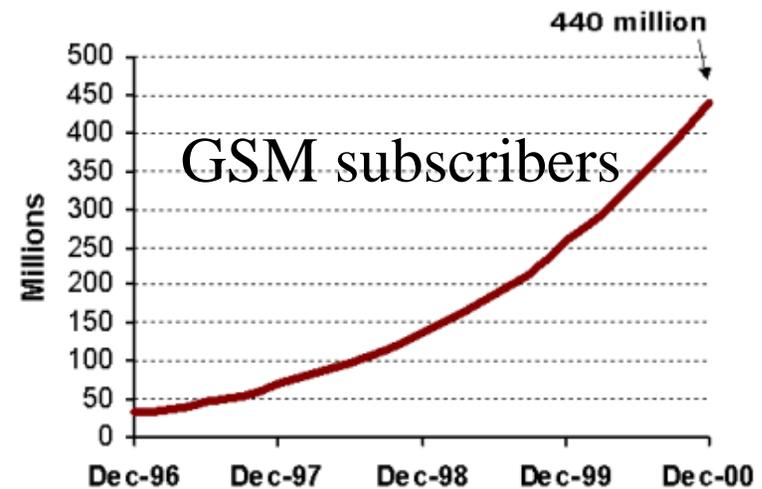
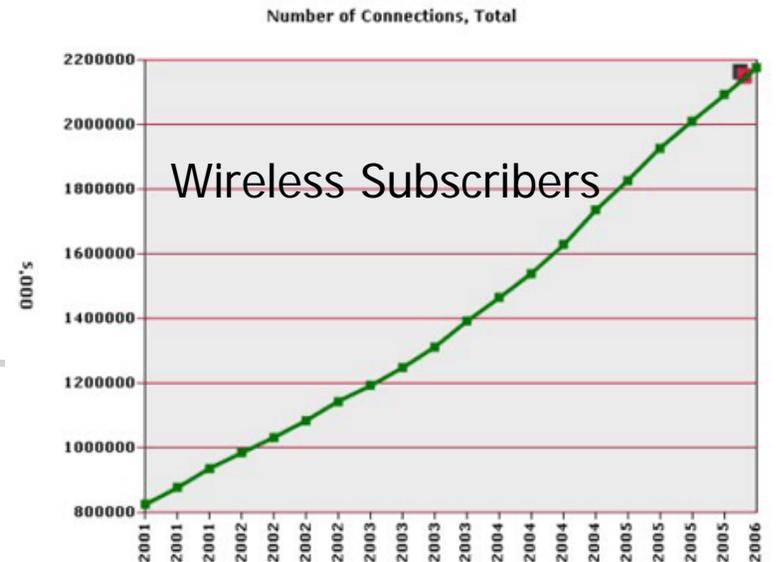
March 2003: Total(1.160B), GSM (825M),

US: Total: 140M, CDMA: 60M

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

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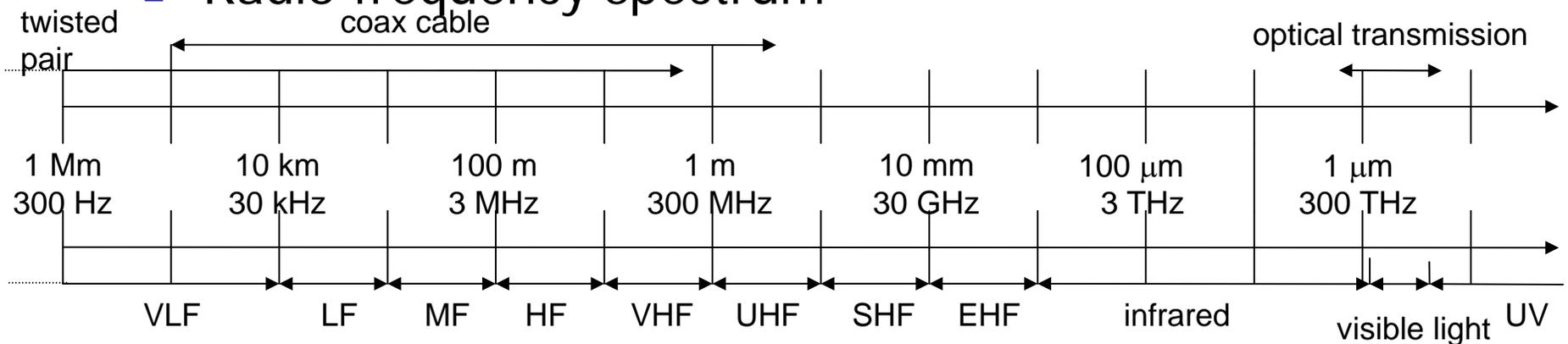
- EMC World Cellular Database (www.emc-database.com)
- GSM World Association http://www.gsmworld.com/membership/ass_sub_stats.html
- Wireless Intelligence (www.wirelessintelligence.com)



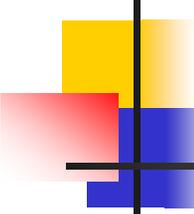
Wireless Communication

- Types of wireless communications?

- Radio frequency spectrum



- **ISM:** Industrial, Scientific and Medical frequency bands
- Wireless versus Mobile:
 - Can we have wired-mobile node or wireless-fixed node?



Attributes of Wireless & Mobile Communication Systems

- Wireless:

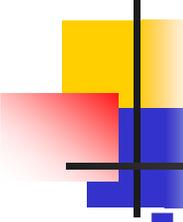
- limited bandwidth: frequencies have to be coordinated, useful frequencies are almost all occupied
- broadcast medium: requires efficient access mechanisms
- variable link quality (noise, disconnection, interference)
- high latency, higher jitter (cellular):
 - connection setup time: several hundred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

- Mobility:

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

- Portability:

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



Classification of Wireless Personal Communication

- Mobility scale:

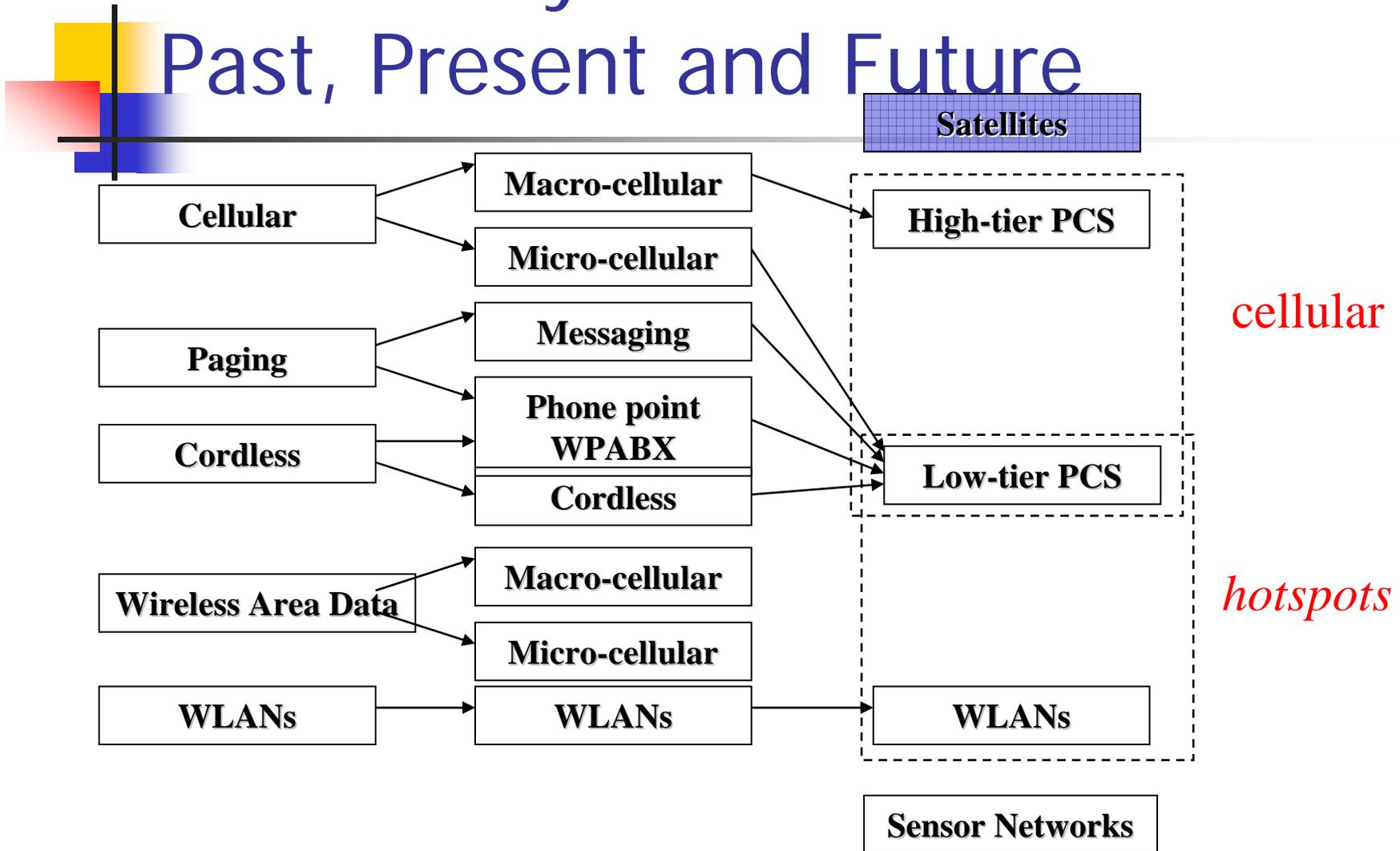
- within a house or building: cordless telephone, WLAN
- within a campus, city: (cellular radio, WLAN, wide area wireless data, radio paging, extended cordless)
- throughout the world: cellular radio, paging, satellite-based wireless

- Communication modes:

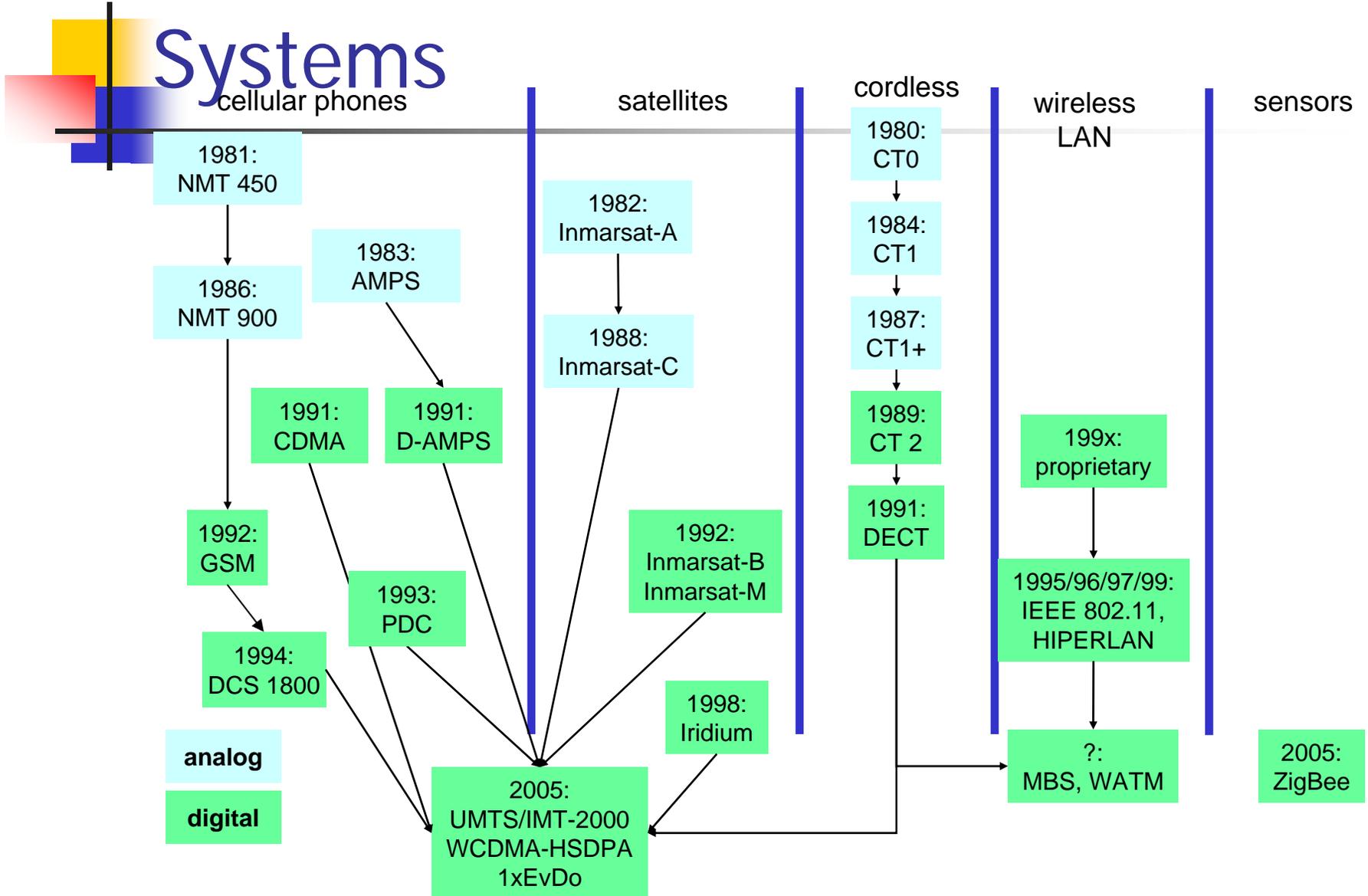
- two-way voice
- data and multimedia
- messaging

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

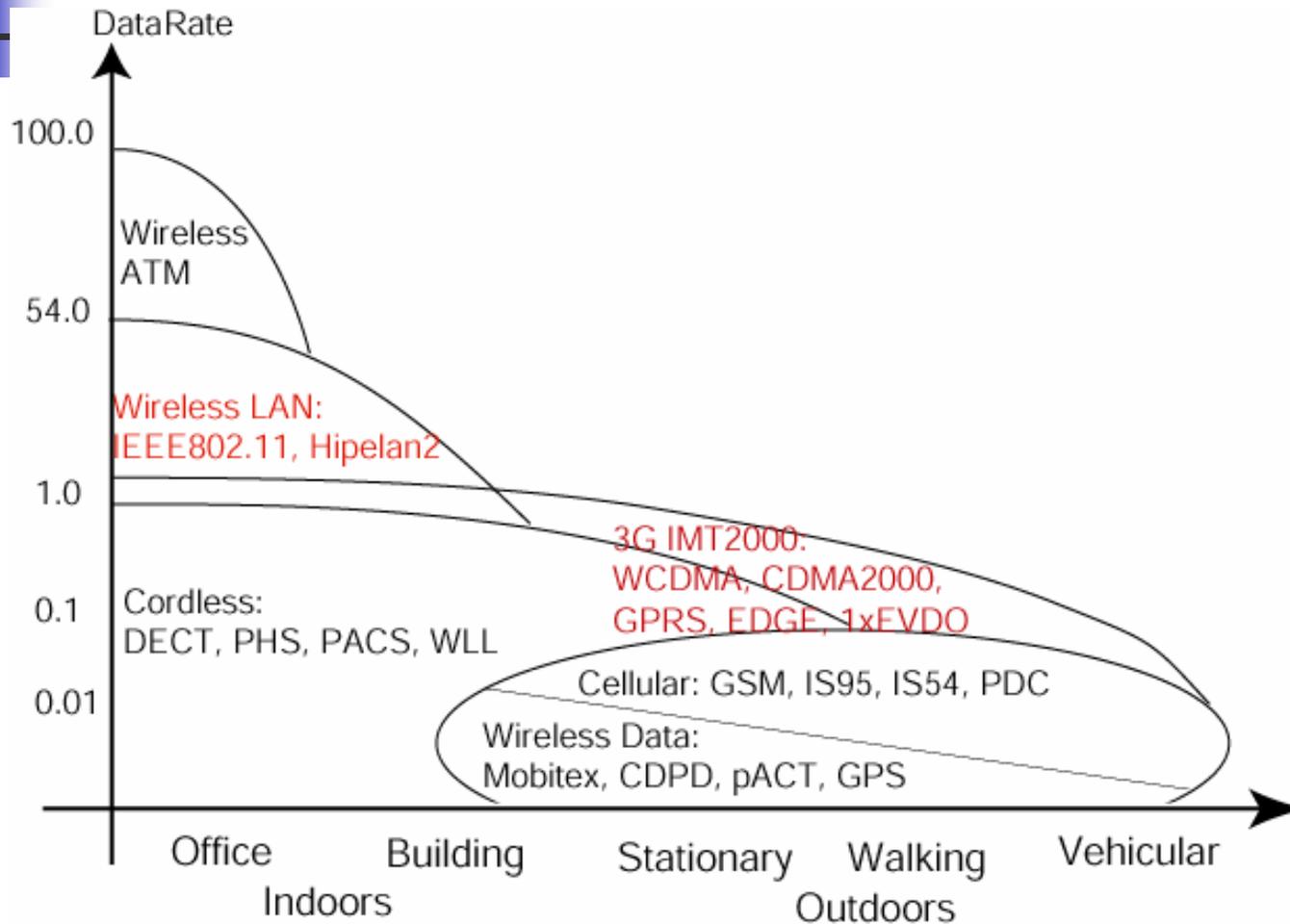
Wireless Systems: Past, Present and Future

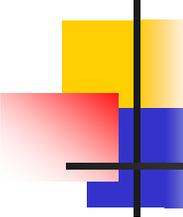


Evolution of Some Wireless Systems



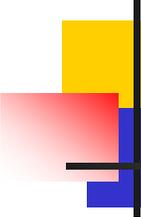
Wireless "Standards"





Cordless Telephones (1970s-)

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



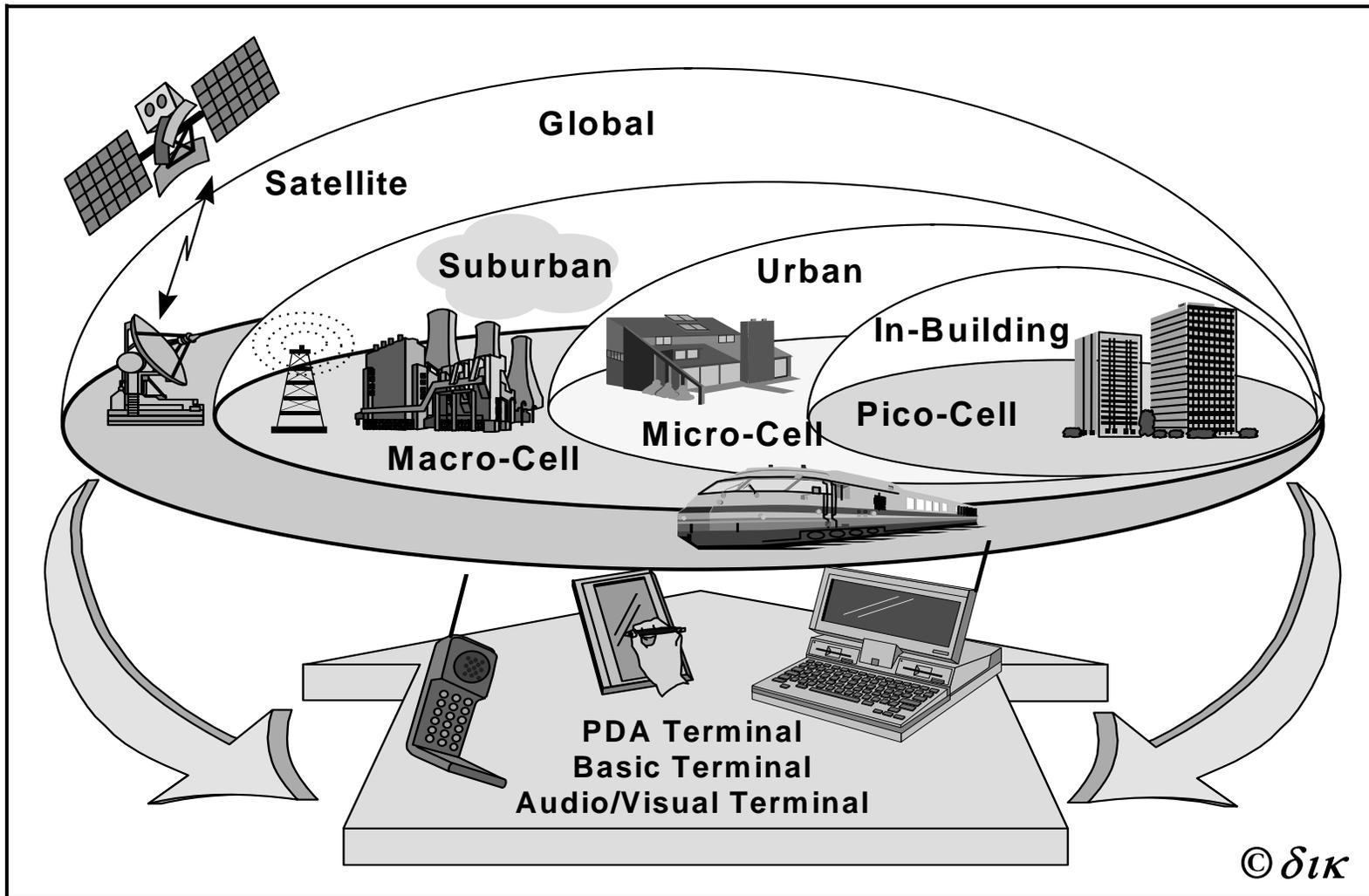
Cellular Mobile Radio Systems (Past/Present)

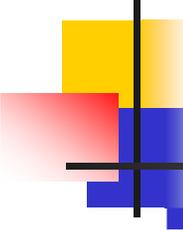
- Characteristics:
 - Two-way voice service
 - High mobility
 - Higher coverage, vehicular speed handoffs
 - Messaging
 - Mobile transmission power: ~2W
 - Low data rate: <10KBps
 - Higher RTT: ~200ms (due to interleaving, FEC etc.)
- Standards/Products:
 - Global Standard for Mobile (GSM):
 - ~825M subscribers (Europe, Asia, USA)
 - Extensions: HSCSD (in practice 28Kbps UL/28Kbps), GPRS (50Kbps)
 - Japanese of Personal Digital Cellular (JDC or PDC)
 - USA: IS-54/IS-136/DAMPS, GSM/GPRS (TDMA), IS-95/1x/1xEV-DO (CDMA)

Cellular Mobile Radio Systems

Today?

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





Wide-Area Wireless Data Systems

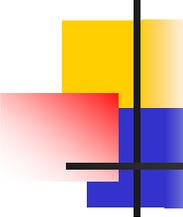
■ Characteristics:

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

■ Products:

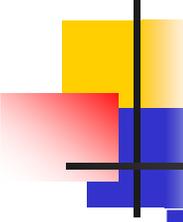
- ARDIS (USA: Motorola), RAM (Ericsson): low data rate <8Kbps
- Metricom (76Kbps):
 - large number of inexpensive base stations,
 - connected through wireless links
 - each base stations has small coverage
 - Deployed in San Francisco Bay area, Washington D.C.
 - Slow frequency hopping, Pwr <1W over 902-928MHz ISM band
- WiMax IEEE802.16 (the wireless DSL)

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



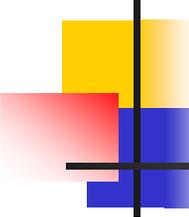
Wireless Local Area Networks

- Characteristics:
 - low-mobility
 - high data-rate: 1Mbps-54Mbps
 - campus/building coverage
- Products/standards:
 - IEEE802.11, Hiperlan 1/2, Bluetooth, HomeRF,
 - Altair Plus, AirLan, Freeport, Intersect, LAWN, WILAN, RadioPort, ArLAN, Radio Link, Range LAN 1-2, Netware, FreeLink
- Operate over ISM frequency Band:
 - 2.4GHz, 900MHz, 5GHz



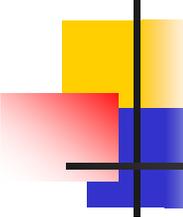
Other Wireless Systems

- Paging/Messaging:
 - Evolution: from 1 bits info, to two-way
 - Combined with CT-2 (Phone point), GSM (Short Message Service: SMS)
- Blackberry (RIM):
 - Initially proprietary basic email services now over GSM
- Satellite-Based Mobile Systems:
 - Large coverage
 - Constellation of satellites (LEO)
 - Products: *stopped*
 - Iridium (Motorola):
 - Globalstar
 - Teledesic (Lockheed Martin, Microsoft, Motorola)



Summary

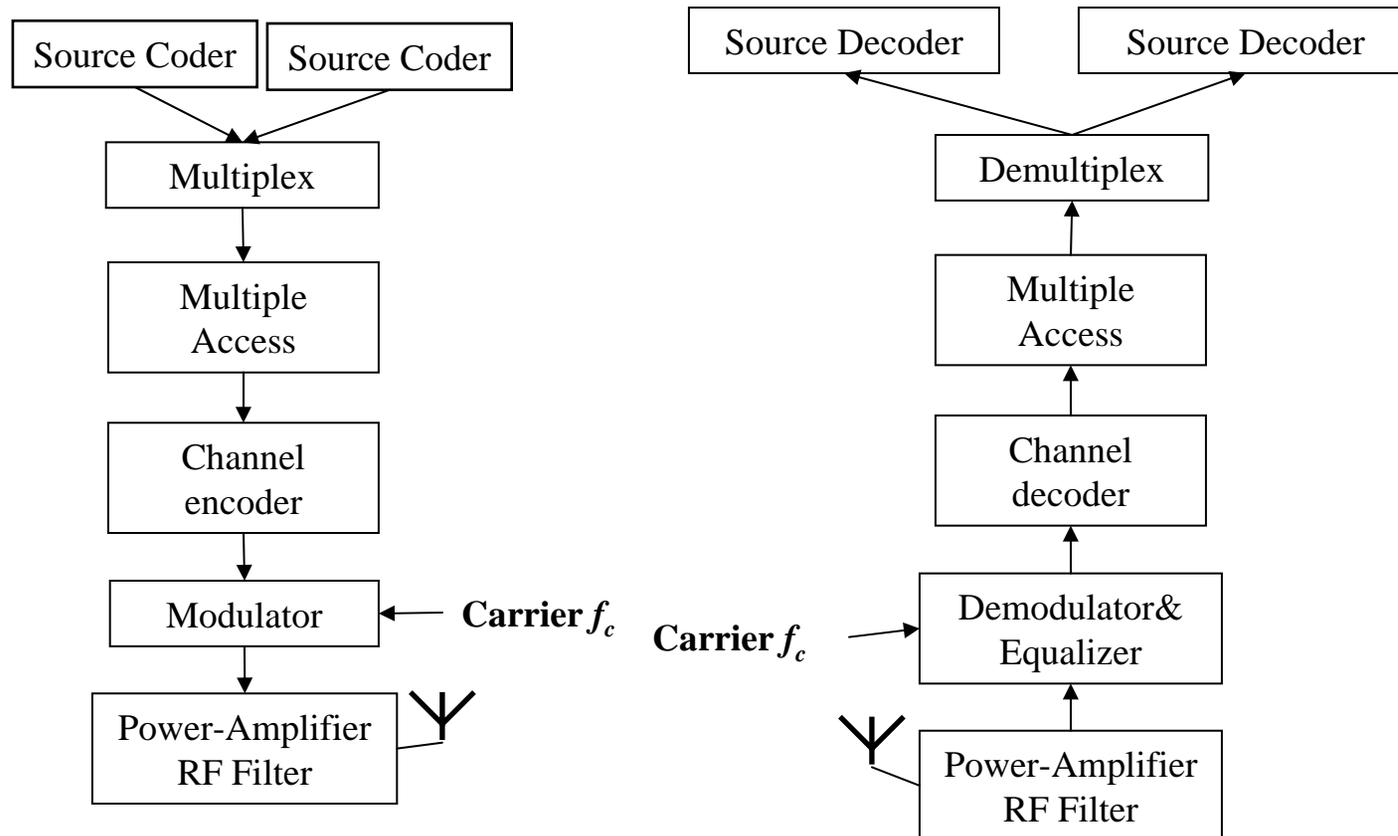
- WLAN/PAN
 - Designed for high bit-rate data transmission
 - Low-scale mobility, small area coverage
 - Use unlicensed ISM frequency bands
- PCS
 - Originally (2nd generation) designed for voice communication
 - Limited bit-rate data transmission
 - Large scale mobility and coverage (high-speed, big cells)
 - Operate over licensed frequency bands
- Wireless Metropolitan Area Networks
- Sensor Networks
 - Low data rate
 - Low power consumption
 - Low mobility
 - Over ISM



Common Components of Wireless Systems

- Antenna:
 - transducer that transforms an electric signal into an electromagnetic signal and reciprocally
- Radio-Frequency Front-End:
 - Filters
 - Power-Amplifier
 - Mixers
 - PLLs
- Base-Band:
 - Demodulation, Forward Error Correction
- Multiple-Access Scheme
 - FDMA, TDMA, CDMA, etc.

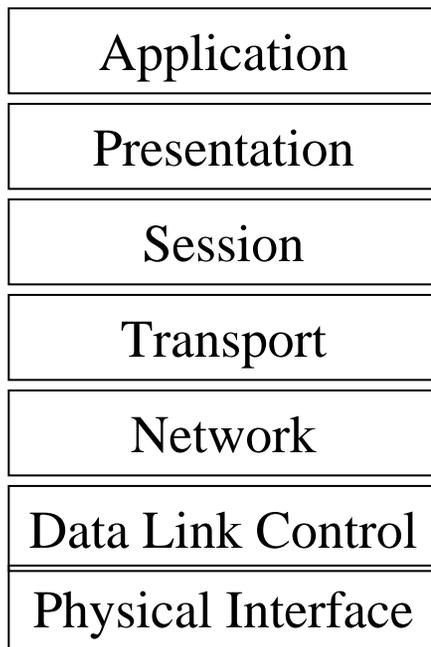
EE view vs. CS view



Electrical Engineer view:

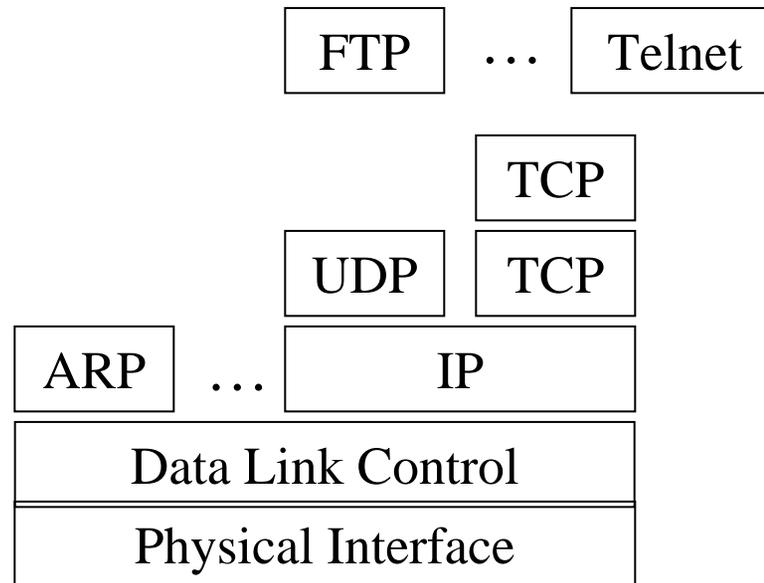
- Ignores issues of routing, reliable transport, various applications requirements

ISO view vs. IETF view

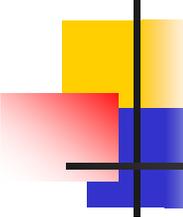


OSI stack

Computer Network Engineer view

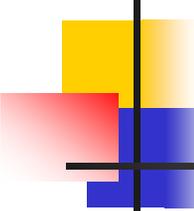


Lack of coordination between higher layers and physical layer



WLAN Architectures

- Terminology:
 - Mobile Terminal (MT) or Mobile Station (MS) to denote and mobile node
 - Access Point (AP) or Base-Station (BS) to denote the central entity that coordinates and wirelessly connects the mobiles to the wired network
- Types of WLAN:
 - Infrastructure WLAN
 - Ad Hoc WLAN:
 - Single: peer-to-peer communication
 - Multi-hop: nodes act both as terminals and routers

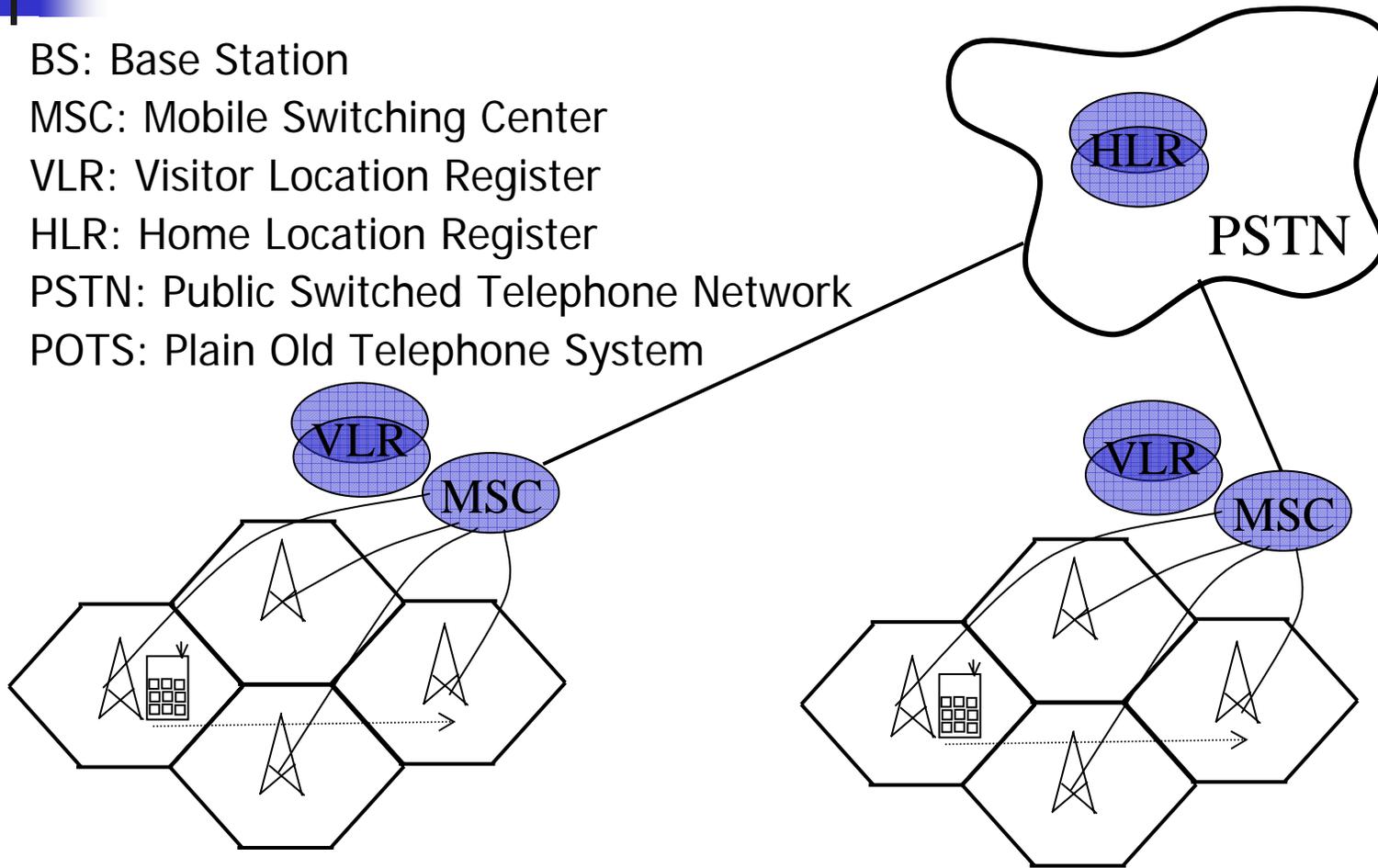


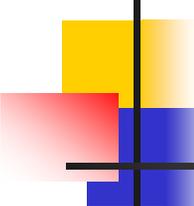
Issues in WLAN

- Physical Layer
 - How to resist to the wireless link limitations? → multiple error control coding schemes
- Medium Access Layer
 - Coordination of nodes
 - Dealing with wireless limitations (medium sensing and collisions detections)
- Network Layer
 - How to maintain the routing tables in the context of highly mobile nodes (multi-hop routing)?
- Transport Layer
 - TCP is optimized for congestion avoidance how to extend to error control
- Application Layer
 - How to satisfy the application requirements (delay, throughput)?
 - How can the application adapt to the channel?
- Resource conservation:
 - Power-consumption, bandwidth optimization
 - Planning for infrastructure networks (location identification, tele-traffic analysis)
 - Self-configuration for multi-hop ad hoc networks

PCS Architectures

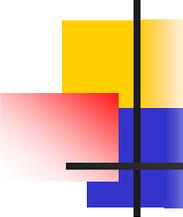
BS: Base Station
MSC: Mobile Switching Center
VLR: Visitor Location Register
HLR: Home Location Register
PSTN: Public Switched Telephone Network
POTS: Plain Old Telephone System





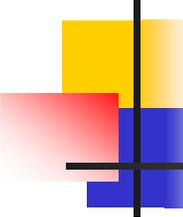
Issues in PCS

- Planning
 - Infrastructure planning:
 - Location of base stations
 - Resources planning and management:
 - Frequency, timeslots, codes
 - Fixed (FCA), Dynamic (DCA), Hybrid, etc.
- Mobility:
 - Handover (or handoff) types:
 - Soft/hard/seamless (data flow), backward/forward (control flow)
 - Mobile controlled (DECT, PACS), network controlled (AMPS, CT-2), mobile assisted (GSM, IS-95)
 - Intra-system handover, inter-system handover
 - Admission Control
 - Roaming



Summary: Main Wireless Systems

- Wireless Local Area Networks:
 - WiFi: IEEE802.11
- Cellular:
 - Today: GSM (= DCS1800, PCS1900 , GPRS), CDMA (= IS-95), DAMPS (= TDMA, IS-136, IS-54)
 - Being deployed: WCDMA (UMTS = 3GPP, HSDPA), Cdma2000 (=3GPP2: 1xEV-DO)
- Wireless Metropolitan Area Networks:
 - WiMax: IEEE802.16
- Wireless Personal Area Networks
 - Bluetooth = IEEE802.15.1, UWB = IEEE802.15.4a
- Sensor Networks:
 - ZigBee = IEEE802.15.4, UWB



Some Trends in Wireless Networks

- Service architectures:
 - IEEE802.11b/a/g leading to hotspots
 - Cellular for full coverage, voice, data, and mobility
 - Hybrid wireless networks: multihop and infrastructure
- Recent hot physical layer technologies research:
 - Ultra Wide Band (UWB) derived from radar technology for low interference-low power communication
- All IP cellular networks:
 - Flarion/Qualcomm, Airvana (CDMA 2000 1xEV-DO), etc.
- Coexistence of technologies:
 - Software Defined Radio, single chip multiple radio technologies (Qualcomm)