Wireless Network Technology and Applications

Sunil Kumar, Ph.D.
Associate Professor
Thomas G. Pine Faculty Fellow
Electrical & Computer Engineering Dept
San Diego State University
URL: http://attila.sdsu.edu/~kumar
Email: skumar@mail.sdsu.edu

Outline

- Research group
- Multimedia over Wireless Networks
- Wireless Networks – technology and applications

Research Group

- **Director, Multimedia & Wireless Networks Research Group**
  - **2 Postdoc, 3 Ph.D., 10 M.S. thesis students**
  - **Lab equipped with: 8 workstations, 4 laptops, Cognitive radio testbed, ZigBee and Wireless Sensor Network testbed**
- **External funding** (>$1M):
  - **NSF MRI and CCLI, Air Force, AFRL Information Institute, Dept. of Energy, Sprint, Cisco, ASEE, NYSERDA, CITeR**
- **Publications:** 24 journal articles, 70 conference papers/presentations, 2 book/book chapters

Research Areas (1)

- **Efficient and Flexible Multimedia Representation:** *Network-friendly and adaptive to channel impairments*
  - Image and video compression, including H.264, MPEG-4 and JPEG2000 standards
  - **Scalable Compression** for dynamically varying wireless networks
  - **Network-friendly and adaptive to channel impairments**
    - **e.g., Adaptive NALU size in H.264 AVC**
  - **Error Resilient** schemes for high error rates in wireless
    - e.g., RVLC, Bitstream Packetization and Metadata
    - Data partitioning, Resynchronization, Slices, Interleaving/FMO

Research Areas (2)

- **Multimedia delivery** *over heterogeneous networks*:
  - **MM QoS-aware** wireless MANET, Sensor, WiMax and Cellular network protocols
    - Consider application, network and user QoS requirements
    - Consider compressed bitstream characteristics to maximize user experience
  - **Cross layer protocols – MAC, Routing, Application layers**
    - Network adaptation and Adaptive resource management to guarantee the desired QoS
    - Use of multiple channels
    - Adaptive packet fragmentation at MAC

Wireless Multimedia Communication

Wireless Multimedia Communication (1)

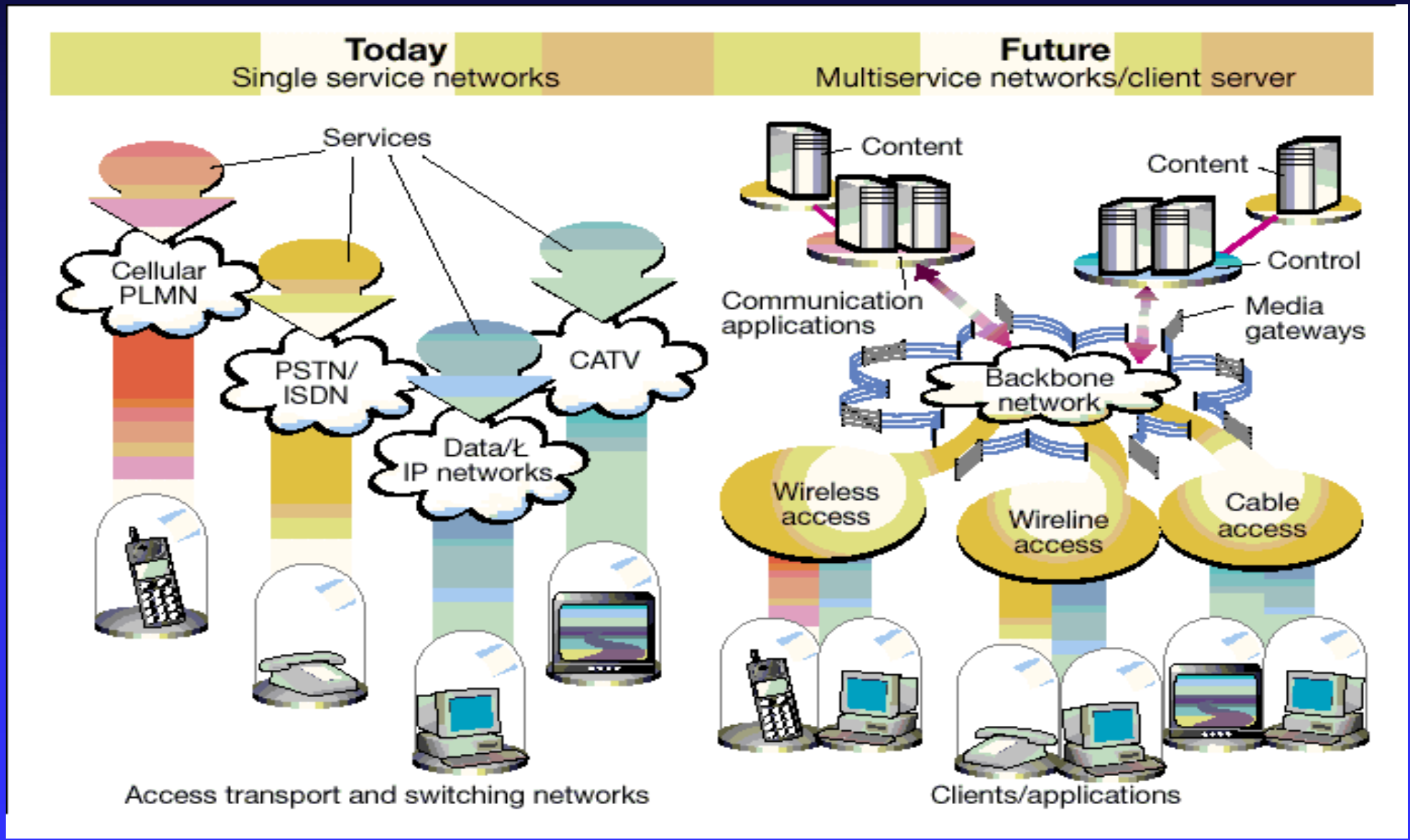
- Vision: Being able to communicate from anywhere at any time with any type of data
- Mobile communications and Multimedia communications have seen unequaled rapid growth and commercial success
- Builds on advances in network infrastructure, low-power integrated circuits, and powerful signal processing/compression algorithms

Wireless Multimedia Communication (2)

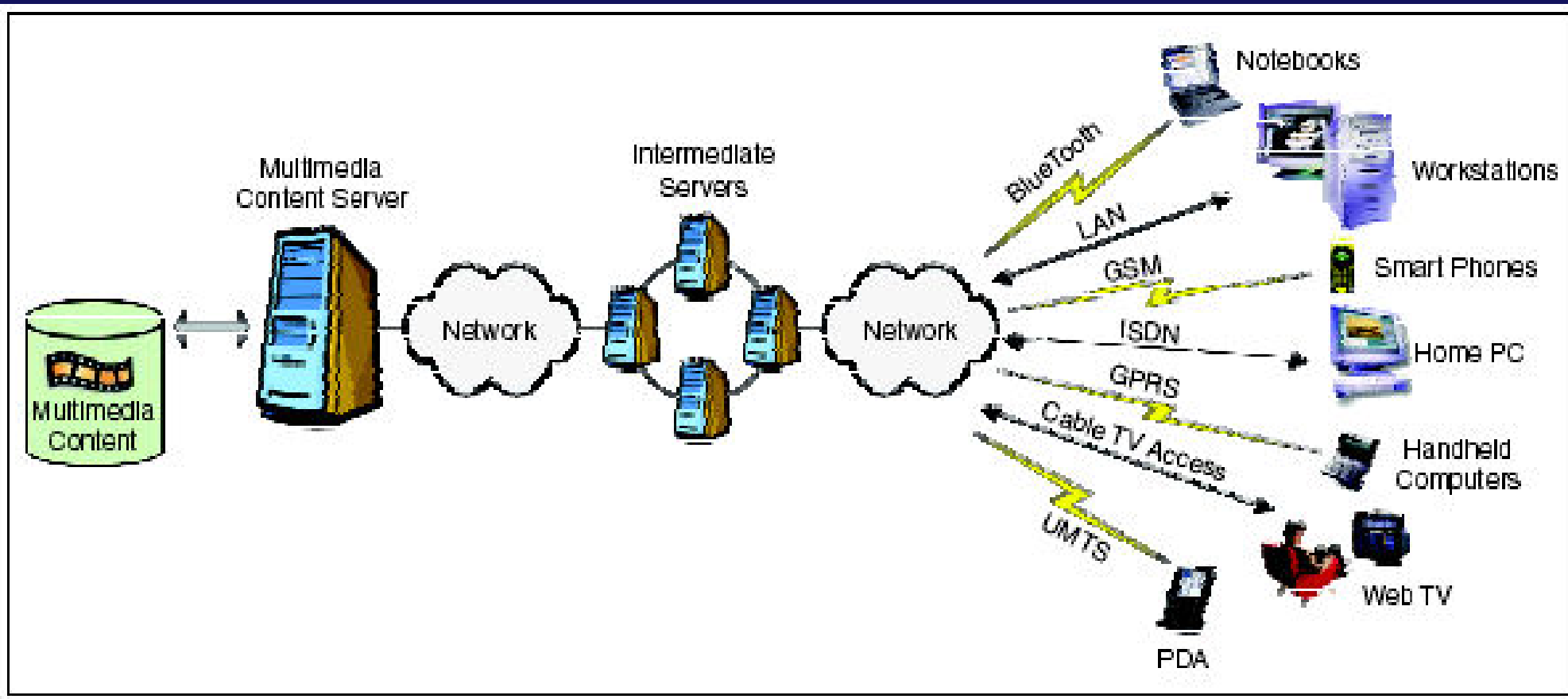
- 3G systems (e.g., IMT2000, WCDMA, CDMA2000) support ubiquitous access and integrated multimedia services
  - Significantly higher data rate
    - 384 kbps for full area coverage
    - 2 Mbps for local coverage
  - Use of hand-held user devices

- 4G systems – WiMAX, LTE

Integrated Multimedia Networks: Evolution



Multimedia Delivery



Challenges in WMM Networks

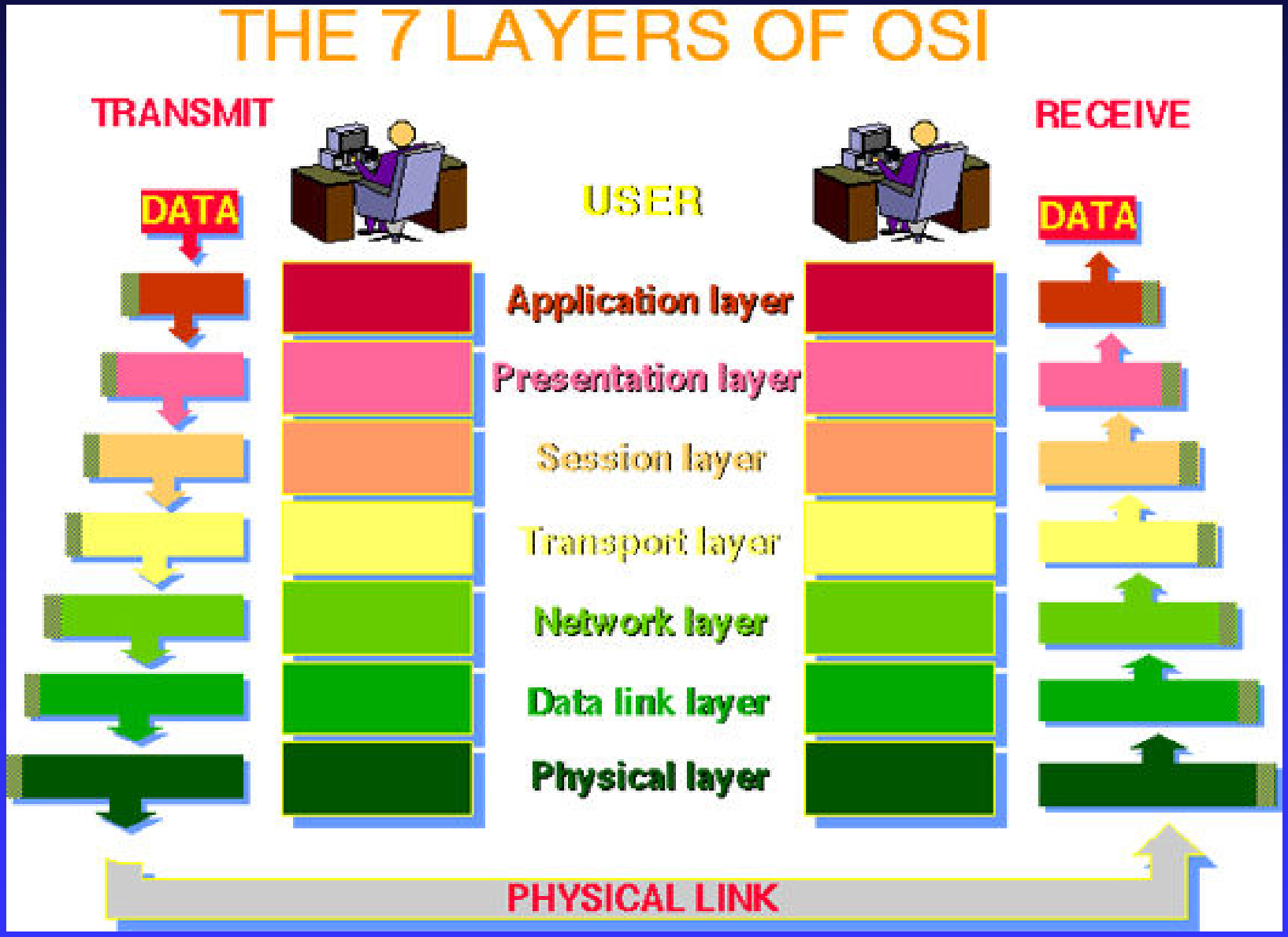
- **Multimedia service characteristics:**
  - Various media types: Video, Audio, Voice, Data
  - **Very high data-rates** (especially Video/Audio applications require higher bandwidth)
  - Interactive applications require **Low delay**
- **Wireless network characteristics:**
  - **Limited bandwidth** (i.e., available radio spectrum)
  - **Highly variable environment** (variations in channel bandwidth, channel errors and network resources)
  - **Seamless service** desired

Wireless Network Technology

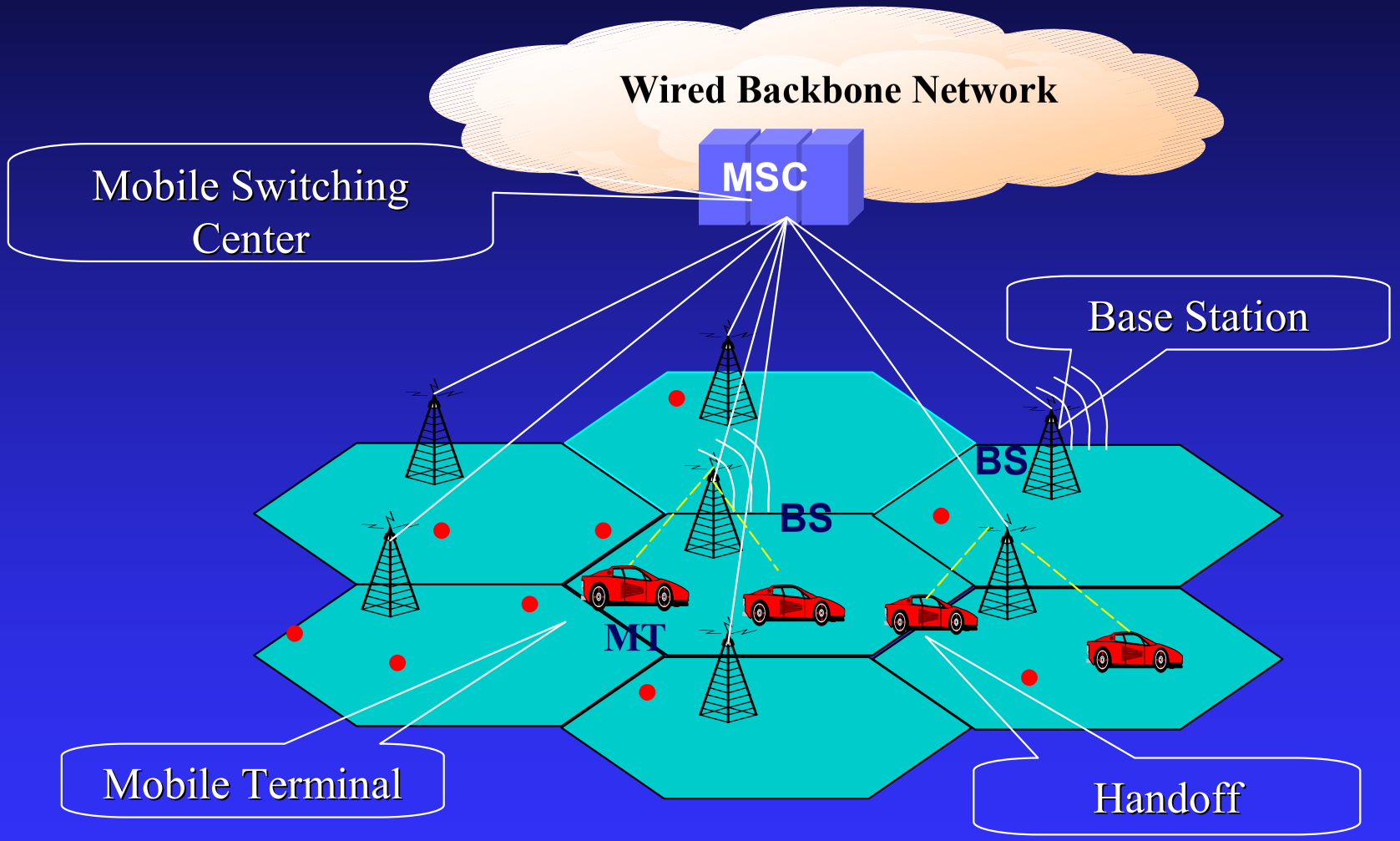
Types of Wireless Networks

- Cellular networks: 3G, UMTS, EV-DO
- Wireless LAN: IEEE 802.11 a/b/g/e
- Wireless Ad hoc networks
- Wireless Sensor networks
- Cognitive networks

OSI – (Open Systems Interconnection) Model



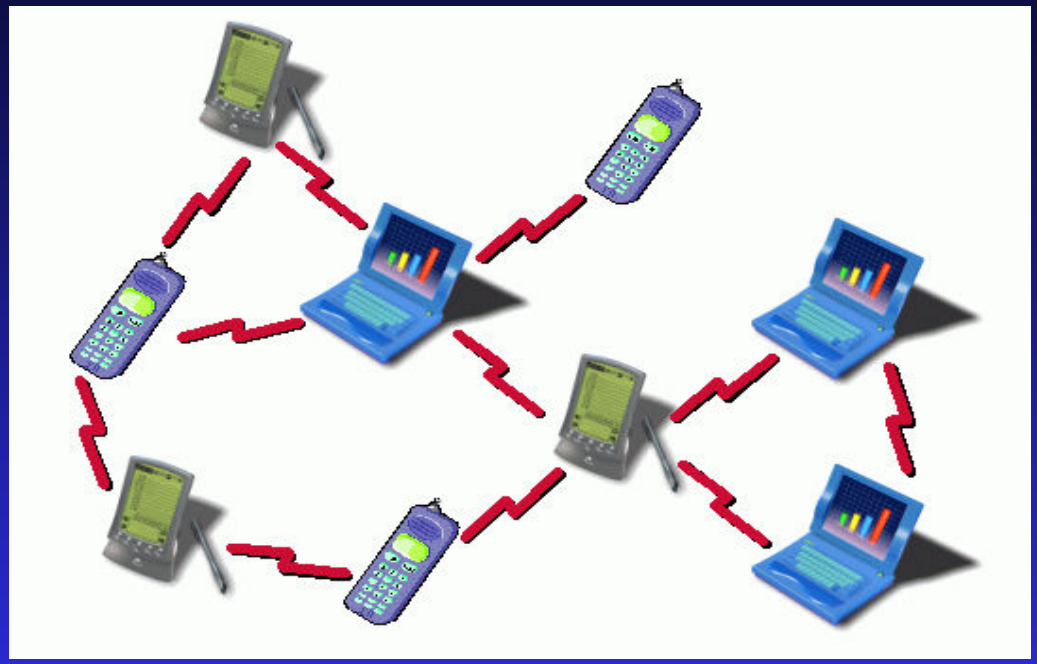
Cellular Network Infrastructure



Wireless LANs

- Base stations are deployed before the network can be used
- Base station controls communications in a network
- Node<->BS<->Node

Wireless Ad-Hoc Networks



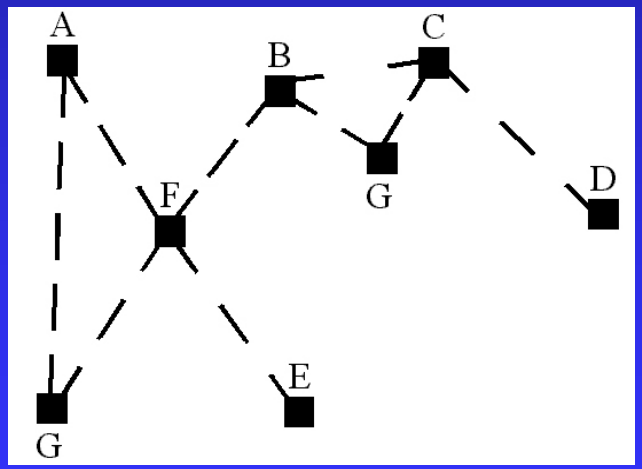
- Ad-hoc networks are spontaneously formed among a group of wireless nodes
- Require no existing infrastructure
- Nodes communicate in peer-to-peer mode

What is an Ad Hoc Network?

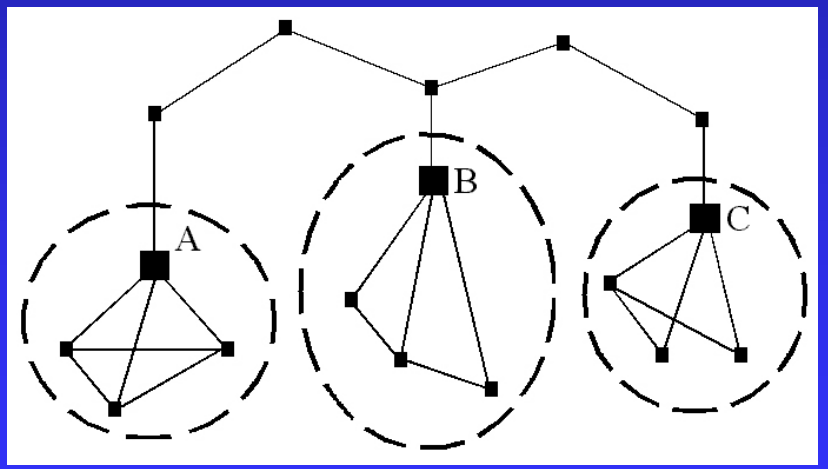
- Collection of multiple nodes, each of which is a terminal as well as a repeater
- Node has transceiver, antenna and power supply
- Self-initializing, self-configuring
- No need for centralized control
- Mobile ad hoc network (MANET)
- Multi-hop route should be found in order to establish a link between two nodes out of range to each other

Architecture Types in Ad-hoc Networks

- Flat networks
- All nodes equal



- Clustered networks
- Some special nodes – cluster heads



Applications of Ad Hoc Networks

- Emergency communications
- Virtual navigation
- Workplace data synchronization
- Context sensitive/location aware
- Battlefield scenarios

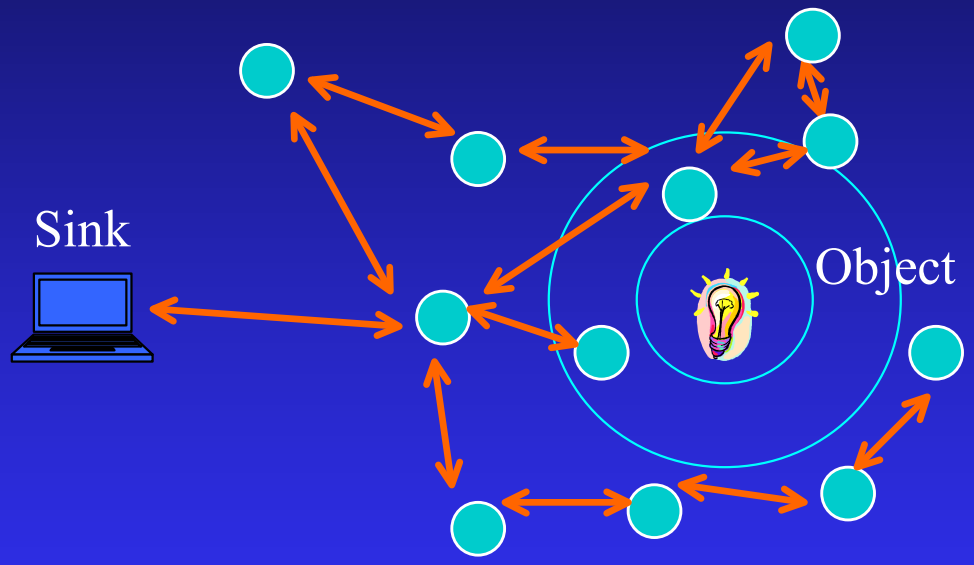
Issues in Wireless Ad-Hoc Networks

- Limited bandwidth and channel errors
- Mobile nodes
- Limited battery power
- Multi-hop topology
- Asynchronous with time
- Security
- Quality of service

Wireless Channel

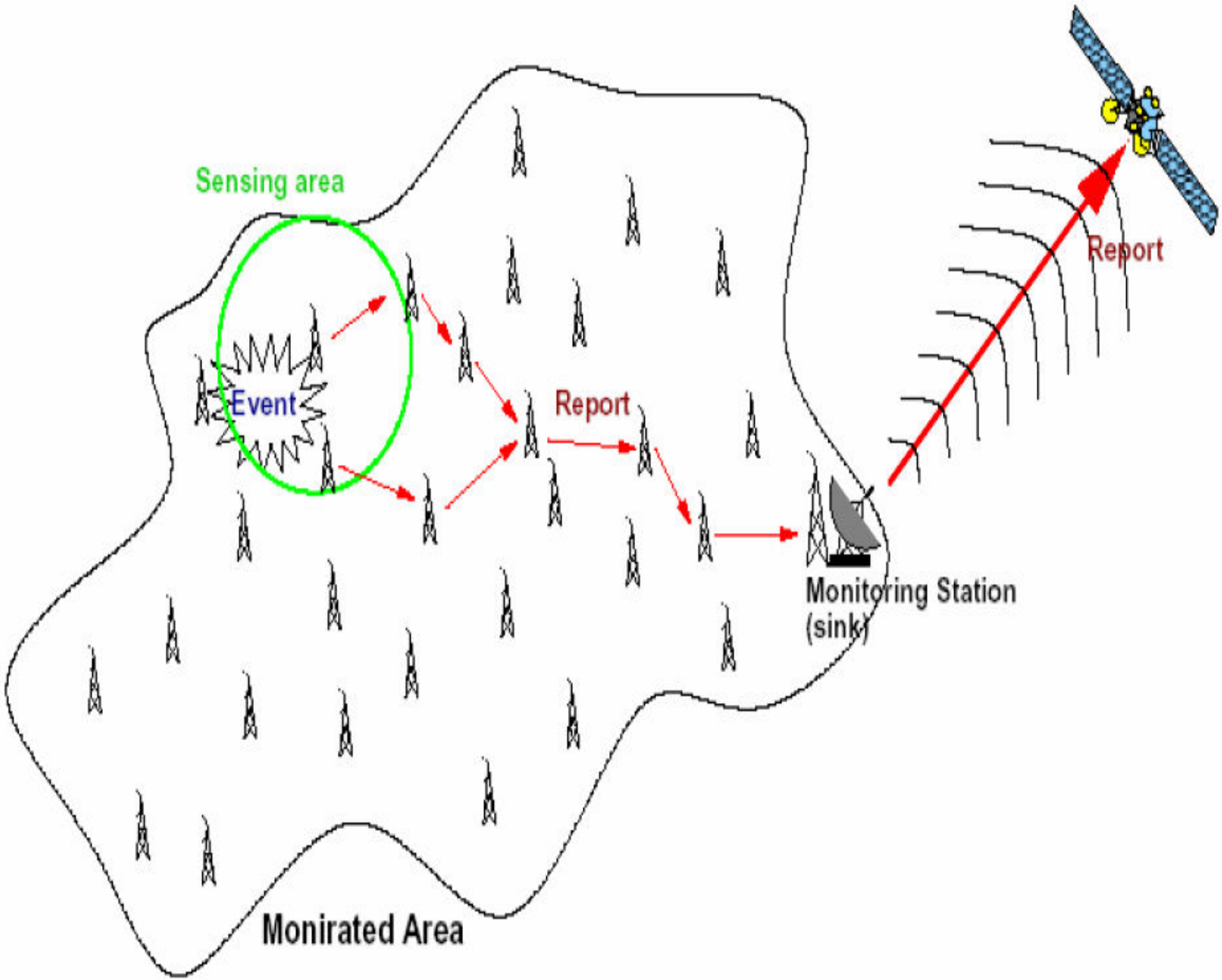
- Free ISM (Industrial, Scientific and Medical) radio bands: 2.4000~2.4835 GHz
  - IEEE802.11b/g LAN, data rate: up to 11Mbps
  - Bluetooth
  - Zigbee
- UNII (Unlicensed National Information Infrastructure) bands: 5.15~5.35 GHz, 5.725~5.825 GHz
  - IEEE802.11a LAN, higher data rate: up to 54Mbps

Wireless Sensor Network



- Sensor network is close to object
- Sensors coordinate to make observation
- Tells host about result of observation

WSN


Sensing area
Event
Report
Report
Monitoring Station
(sink)
Monirated Area

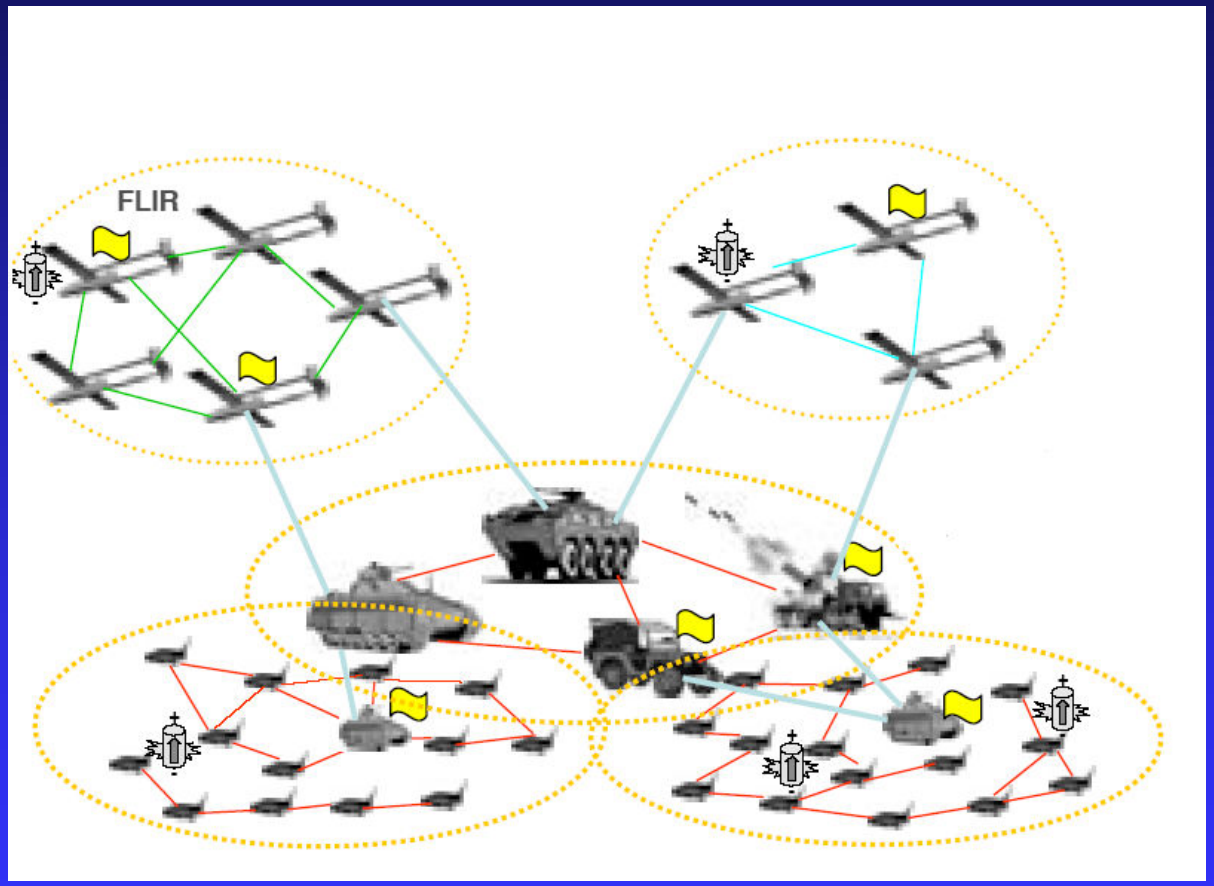
Wireless Sensor Networks

- Sensor nodes based on MEMS
  - Sensing hardware
  - Radio frequency transceiver/antenna
  - Power supply
  - Low cost
  - Often used only once

Applications of Wireless Sensor Network

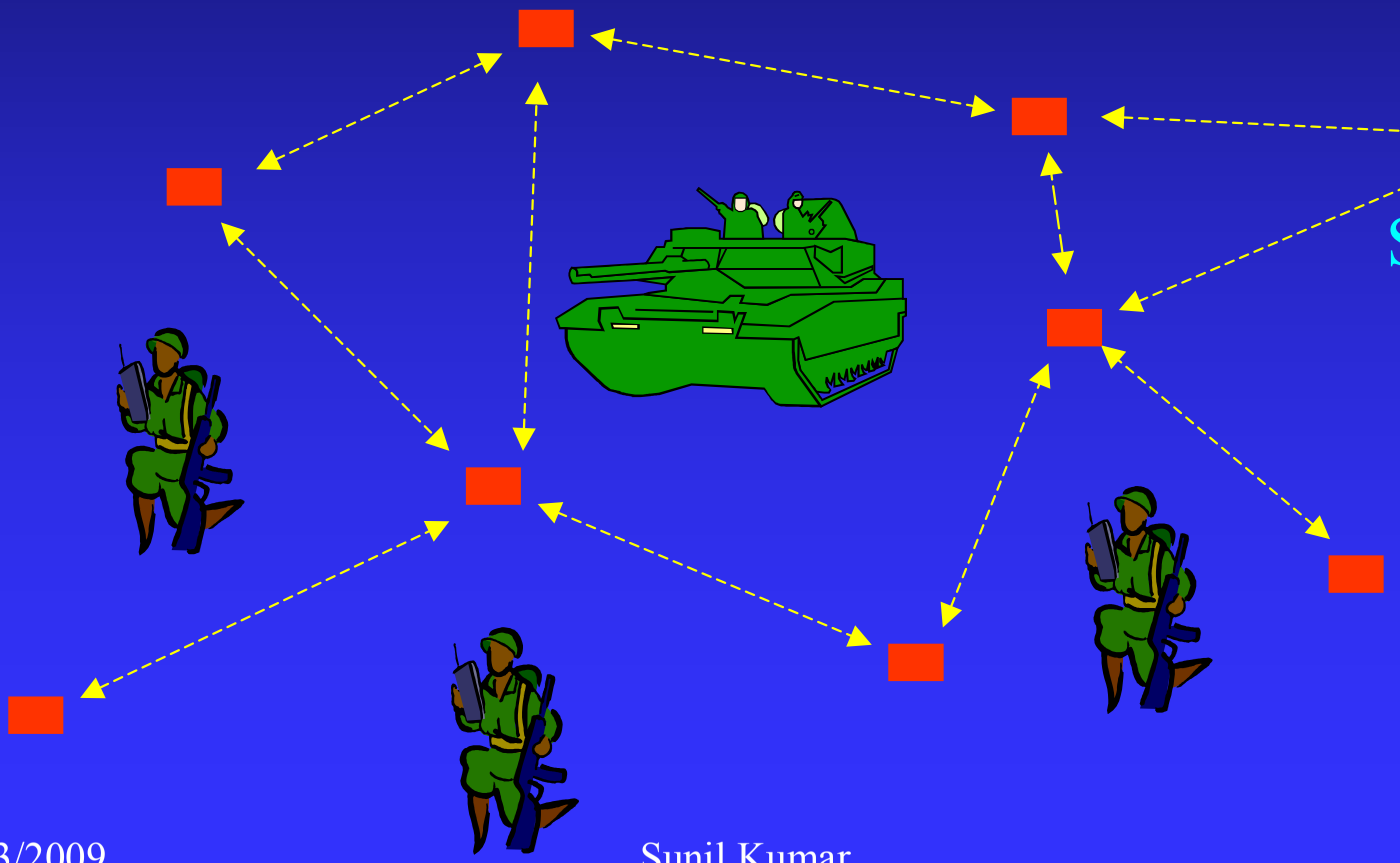
- Military applications
- Environmental applications
- Health applications
- Home applications
- Industrial monitoring and control
- Surveillance
- Many more…

WSN: Military Applications



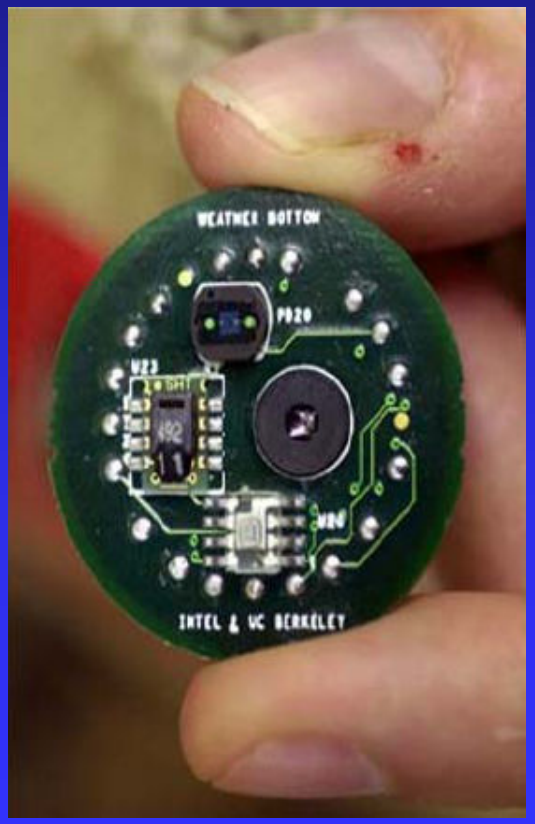
- Detecting mine fields, firing locations
- Targeting, target tracking
- Chemical and biological attack detection

Battlefield Application



WSN Applications

- In UC Berkeley Botanical garden, 50 “micromotes”sensors are dangled like earrings from the branches of 3 redwood trees to monitor their growth



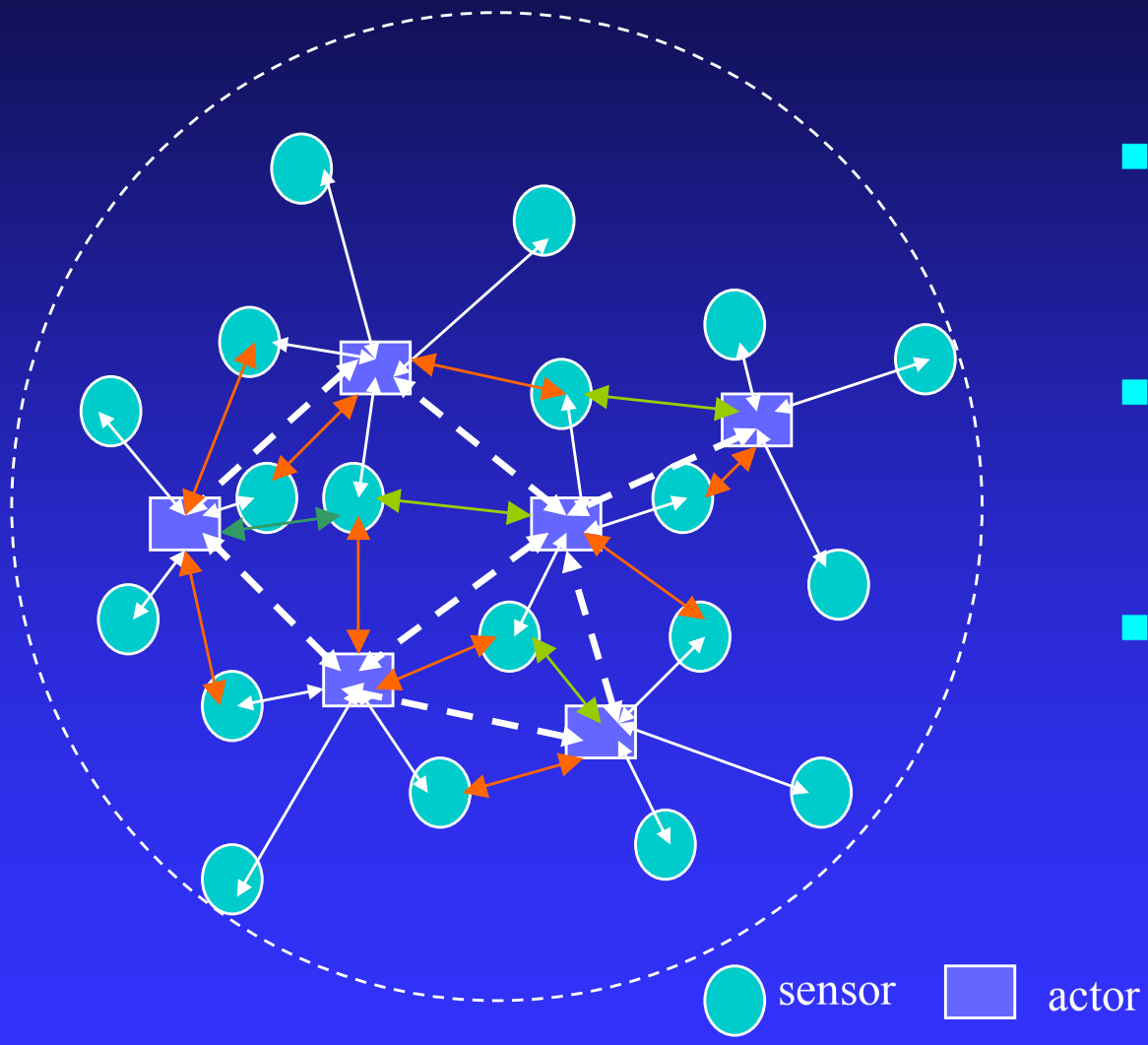
WSN Constraints (1)

- Sensor Node Constraints
  - Battery Power/Energy
  - Rechargeability
  - Transmission Range
  - Memory
  - Location Sensing
  - Tamper Protection
  - Unattended Operations

WSN Constraints (2)

- Networking Constraints
  - Ad hoc Networking
  - Limited Pre-Configuration
  - Data Rate/Packet Size
  - Channel error rate
  - Frequent Routing Changes
  - Population Density
  - Unknown Recipients

Wireless Sensor and Actor Network

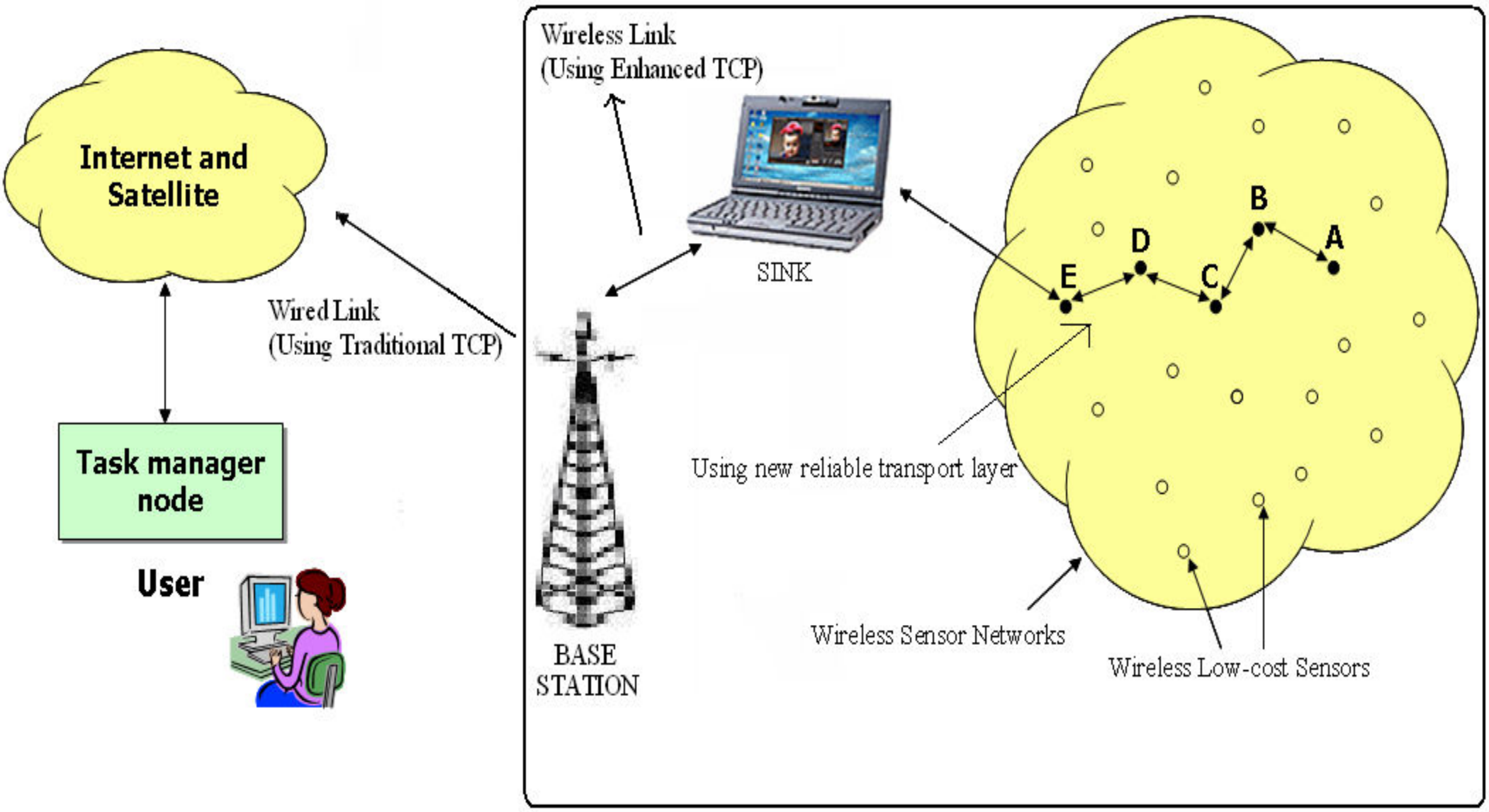


- Actors are more powerful nodes
- Number of actors is much less than that of sensors
- A distributed local coordination mechanism is necessary among sensors and actors

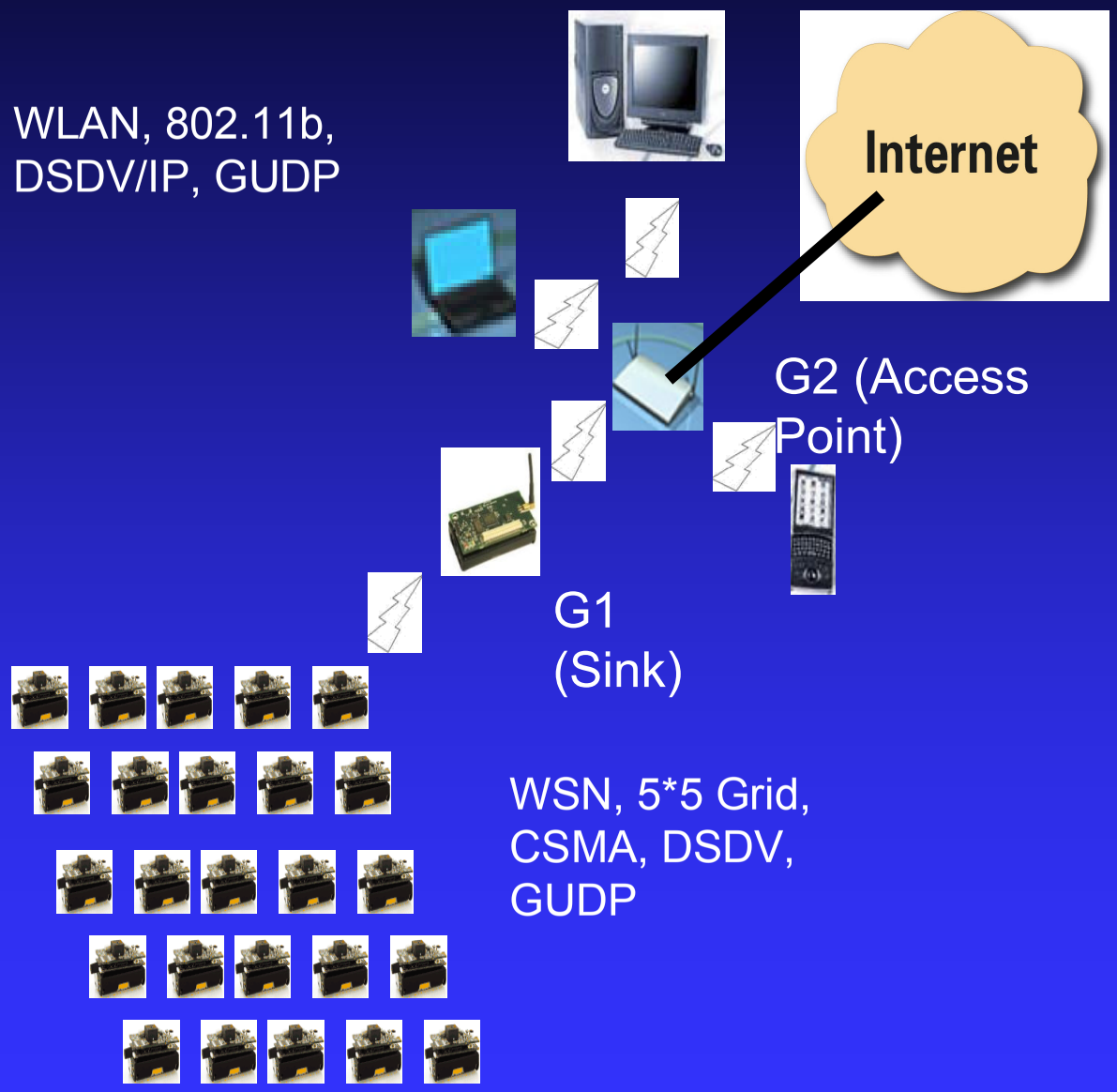
Wireless Ad Hoc Vs. Sensor Networks

- Size and density
- Probability of node failure
- Priorities of QoS and power conservation
- Topological changes
- Nature/rate of data transmission
- Data aggregation

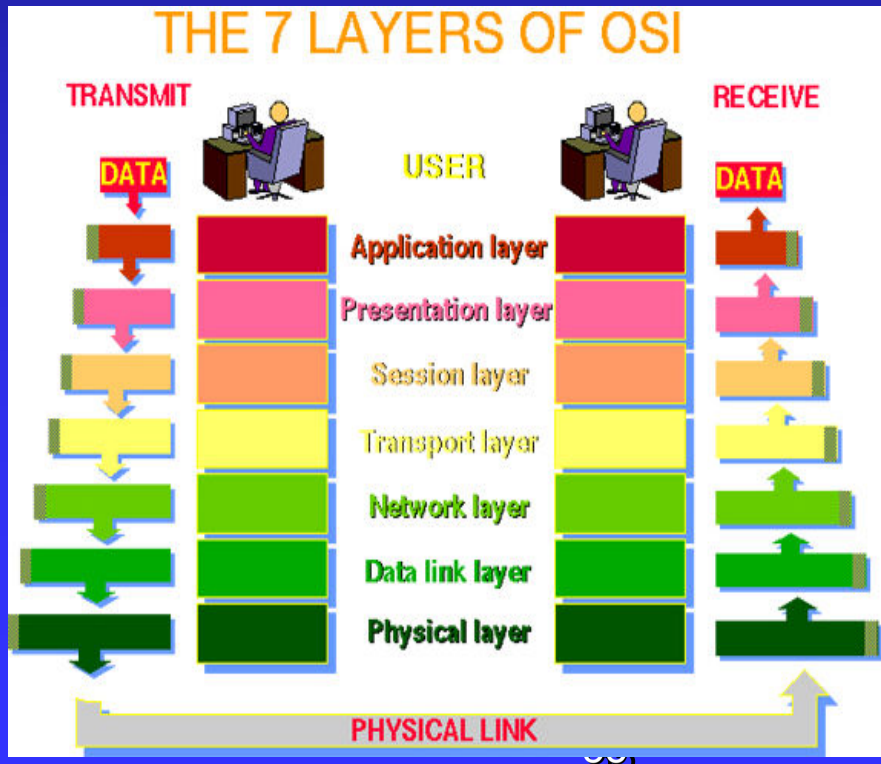
Hybrid 4G WSN Scenario



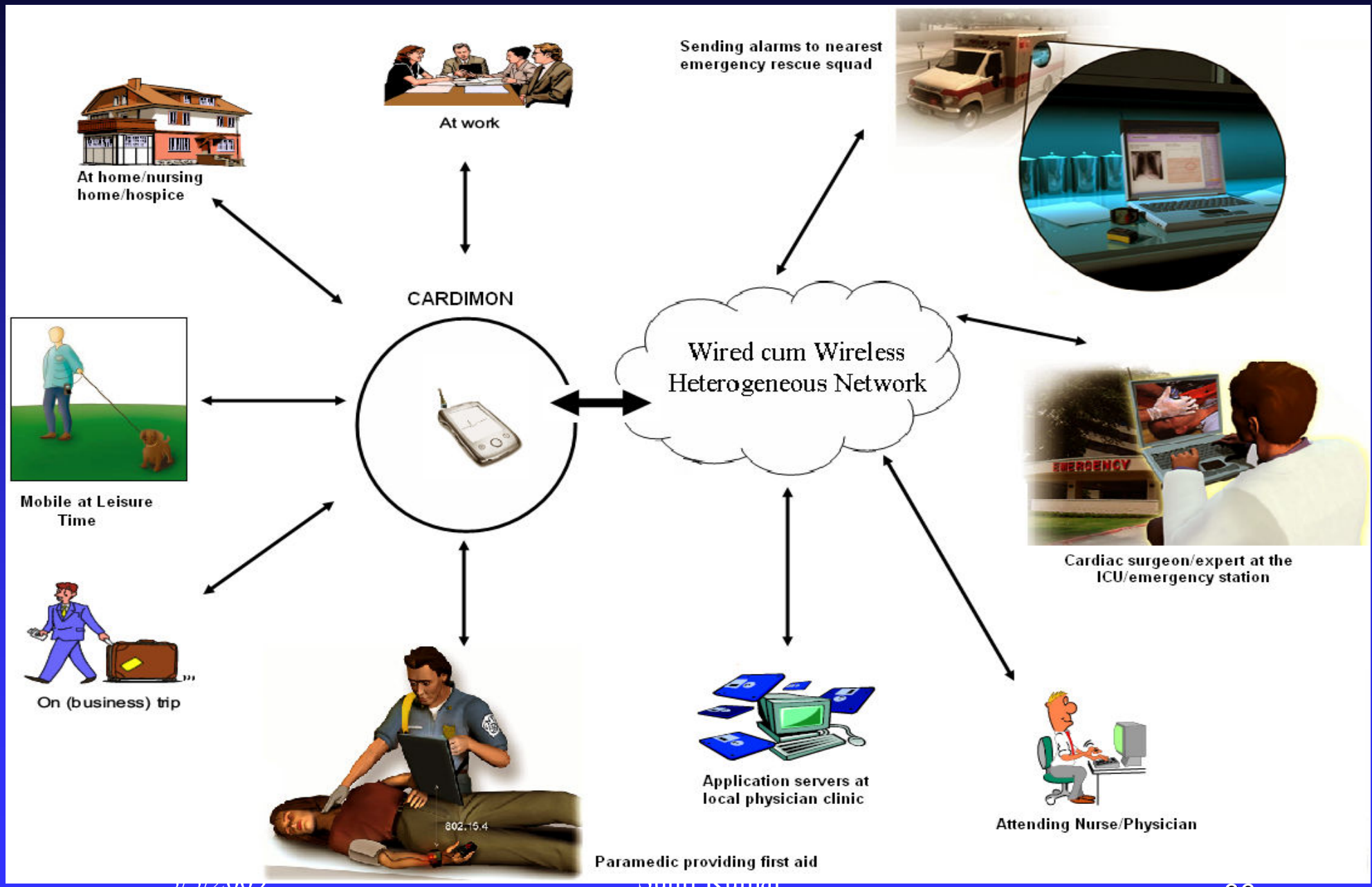
Gateway UDP System Structure



- GUDP system include designs both in the network and transport layer.
- GUDP also refers to the transport protocol we designed for GUDP system

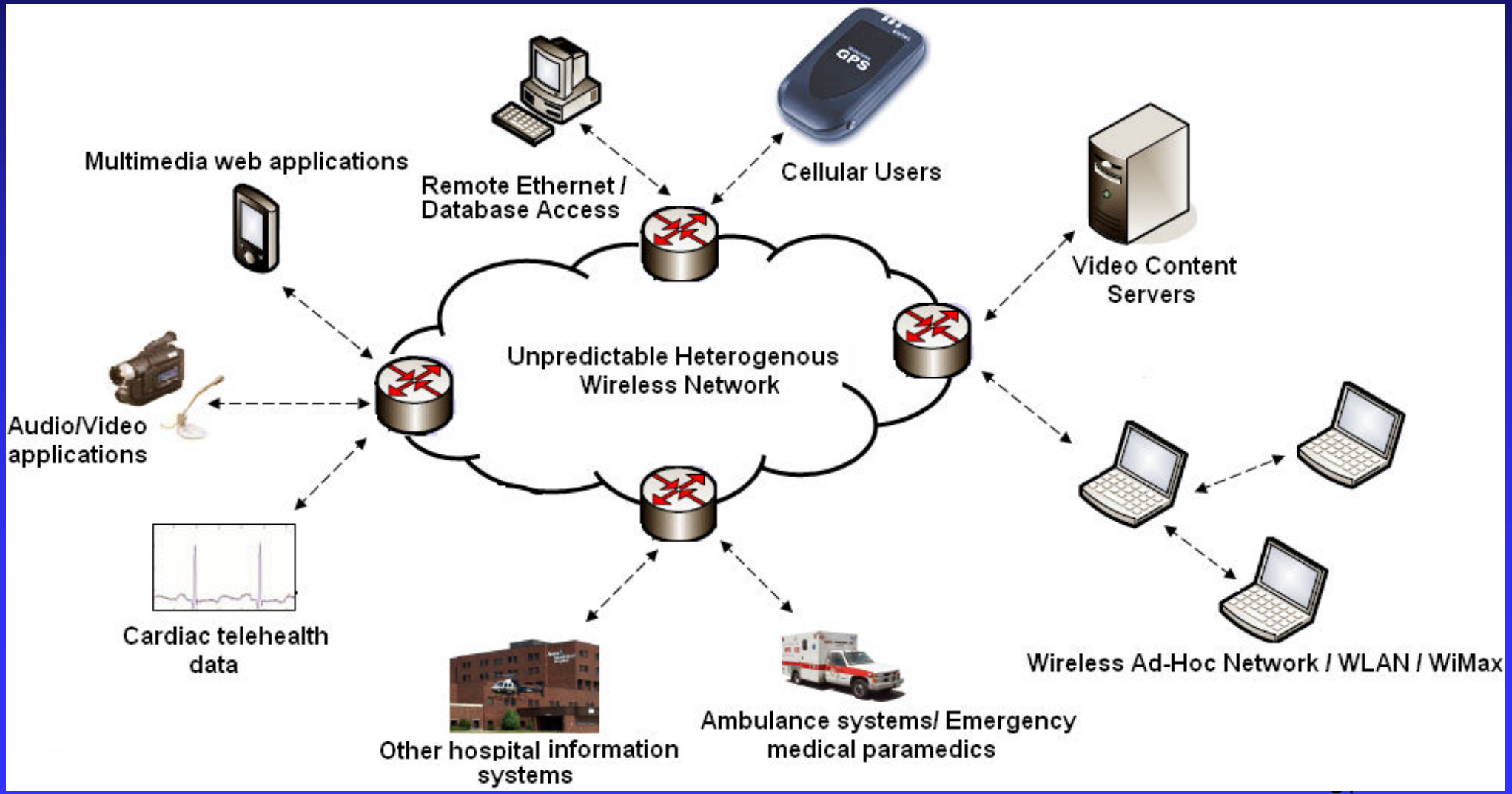


Ubiquitous Telemedicine Application

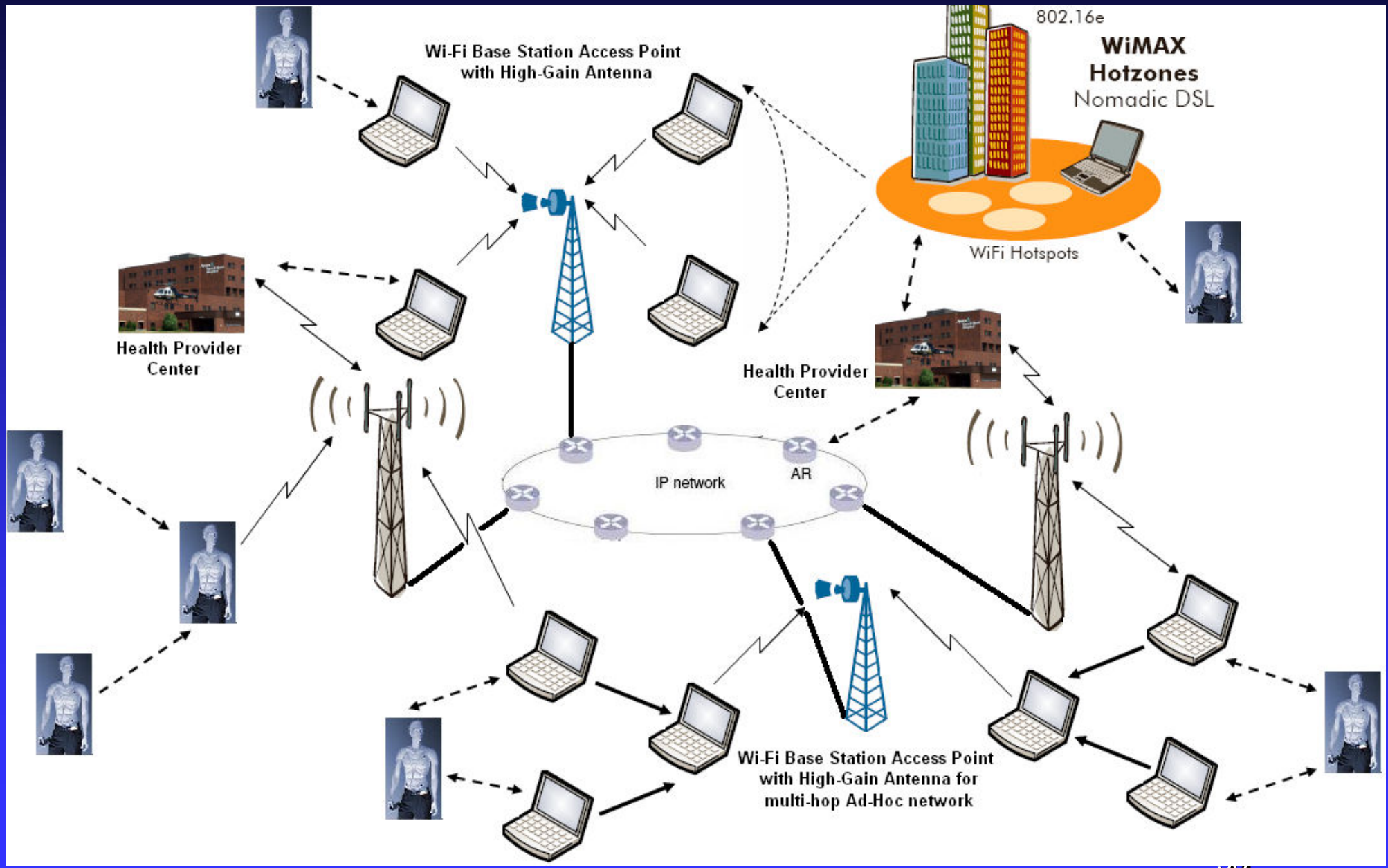


Telemedicine: Different Network Applications

- Disparate Services, Heterogeneous networks, Reliable data transport



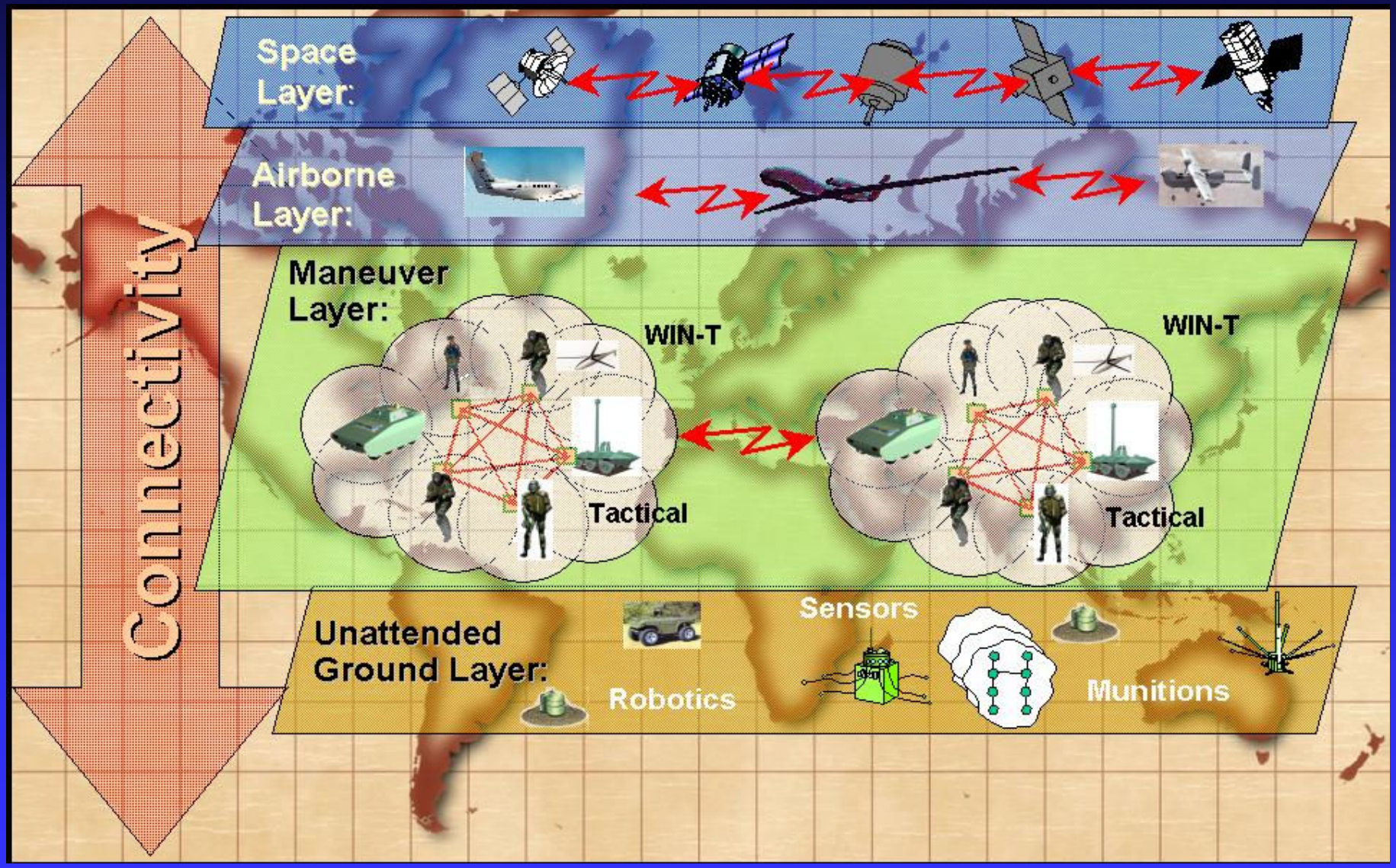
Telemedicine: Heterogeneous Architecture



Airborne Networks Design Challenges

Military Operational Environment

Net-Centric Warfare Vision: Information Anywhere, Anytime



Source: Airborne Network Workshop, Utica, NY, Aug. 1-3 2006

Airborne Networks: Characteristics and Challenges

Mission: Acquire, deploy and sustain a secure and robust Airborne Information Communication infrastructure

Seamless connectivity between Air, Ground & Space

Why Dynamic Spectrum Access (DSA) ?

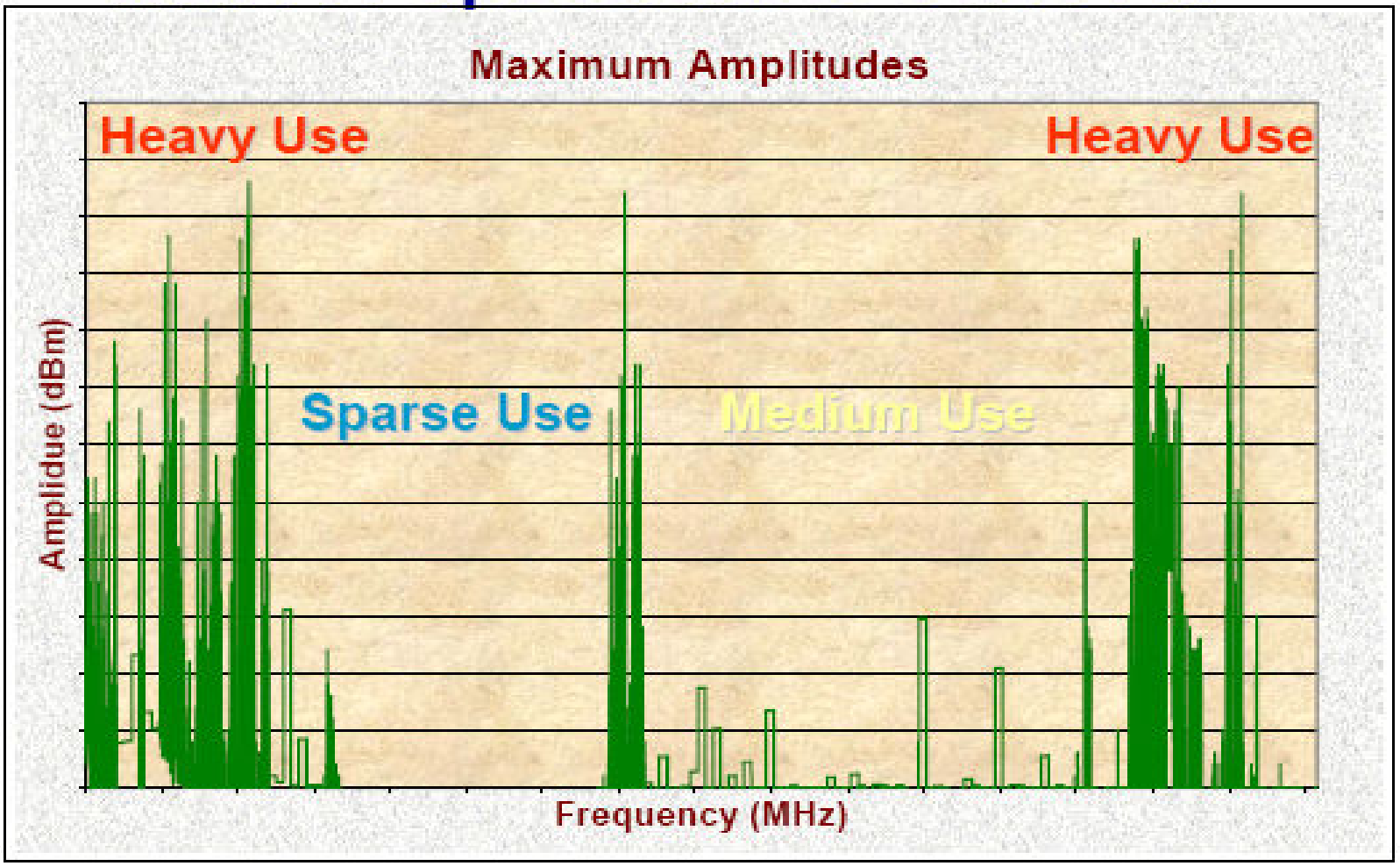
Cognitive Radio: *The capability of seeing and opportunistically utilizing radio resources – in time, frequency and space domains – on a real time basis.*

Advantages of DSAN

- Radio can sense available channel bands (i.e., spectrum holes) and choose the best one
- Makes available many unused channels to mobile users via heterogeneous architectures
- Reduced interference/jamming from other users

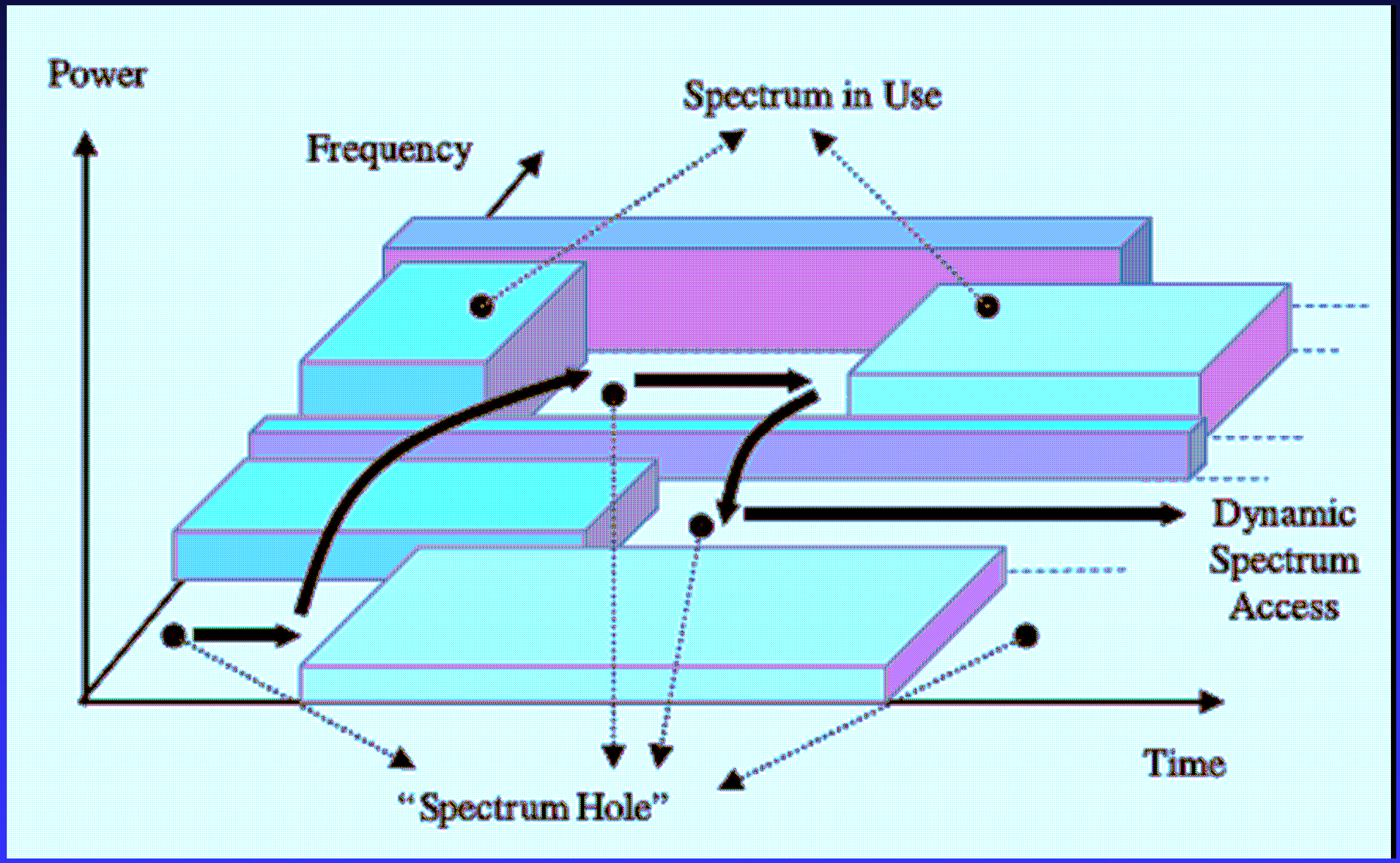
Current Spectrum Utilization

…Most Spectrum Is Unused!



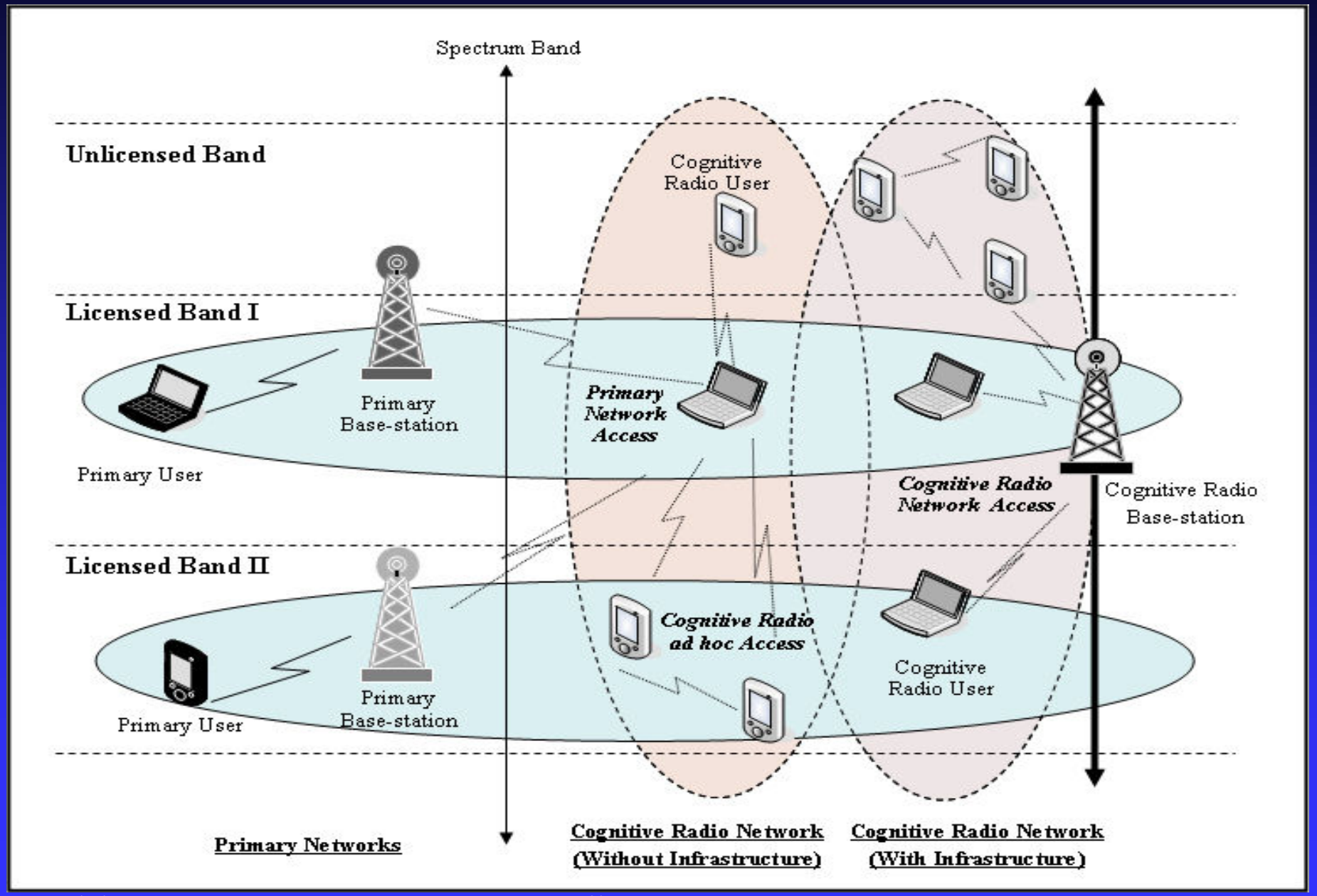
Source: FCC, Dec. 2003

Can dynamically use "Spectrum Holes"



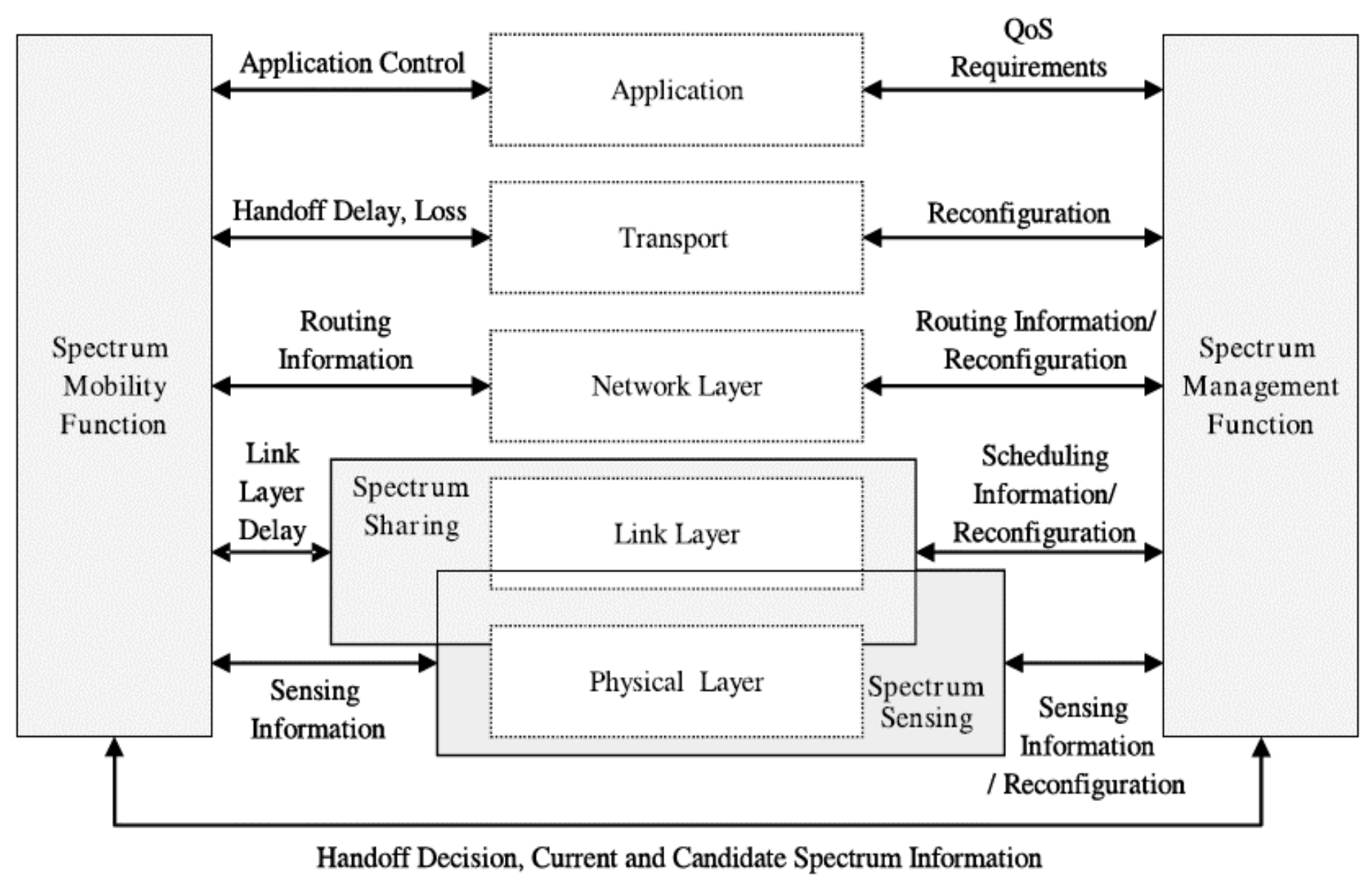
Akyildiz et al., Computer Networks, Sept. 2006

DSA Network Architecture



Akyildiz et al., Computer Networks, Sept. 2006

DSA Cross-layer Design Issues



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