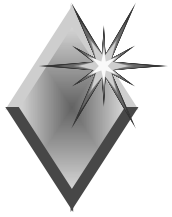
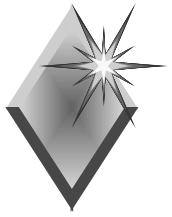


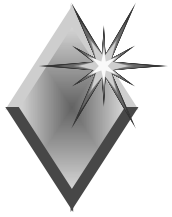
Course Overview

- Introduction and History
- Regulatory Issues
- Fundamentals of Cellular Systems
- AMPS and CDPD (Cellular Digital Packet Data)
- GSM (Global System for Mobile communication)
- Mobile IP
- TCP over Wireless Link
- Issues in Mobile Application Design
- Outlook and Conclusions



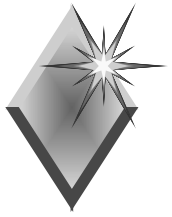
European R&D Programs

- 1985-1995: RACE (Research into Advanced Communications in Europe)
  - Phase I: concentrated on system engineering, outlining specifications and key technologies
  - Phase II: concentrated on systems integration, prototyping of new services and applications
- since 1995: ACTS (Advanced Communications Technologies and Services):
  - integrate the building blocks identified during RACE into one single system
  - major research effort into following three network platforms:
    - **UMTS** (Universal Mobile Telecommunications Systems)
    - MBS (Mobile Broadband Systems)
    - **WLAN** (Wireless Local Area Networks)



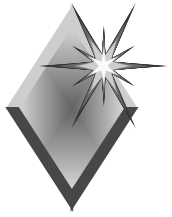
3rd Generation Cellular Systems

- next generation mobile communication systems under development at ITU and ETSI (one of GSM study groups)
- European project is Universal Mobile Telecommunication System (UMTS), while ITU project is called Future Public Land Mobile Telecommunication System (FPLMTS)
- time horizon: basic standards by 2000, commercialization by 2005, “life” expectancy beyond 2025
- mobile access part of future Broadband ISDN network
- service objectives
  - broad range of customizable telecommunication services up to 2 Mbps, subset of B-ISDN
  - support Universal Personal Telecommunications (UPT), fixed network service for personal mobility, allowing registration and deregistration at any terminal
  - support wide range of terminal types



3rd Generation Cellular Systems

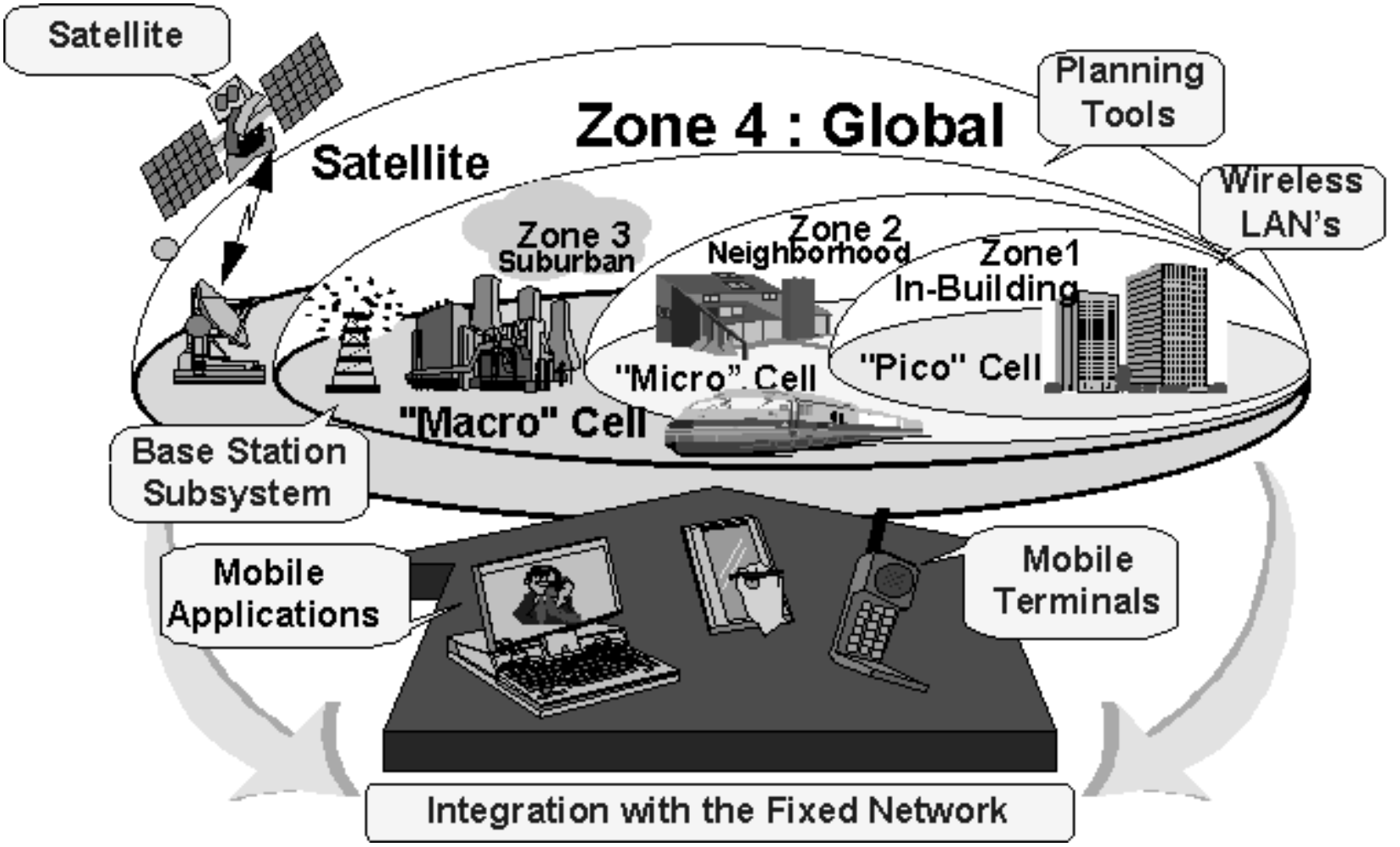
- support public and private environments
- operation in, and roaming between, different operating environments
  - sparse, rural, suburban, urban
  - indoor/outdoor
  - residential/business
  - pedestrian/vehicular
- provide integrated satellite component
- combine range of existing wireless systems (cellular, cordless, mobile data, paging) to share infrastructure costs and harmonize services
- allow flexible and rapid creation of new services
- efficient usage of spectrum resources
- enable provision of wireless local loop

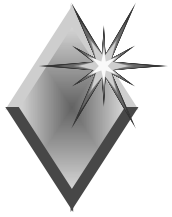


3rd Generation Cellular Systems

- FDMA, TDMA, CDMA and hybrid schemes are being studied as radio access techniques
- one major distinction of 3rd generation cellular systems relative to 2nd generation cellular systems is support for hierarchical cell structure
  - 2nd generation: one-layer cell structure, each cell basically inde-pendent, increasing traffic leads to costly cell reconfigurations
  - 3rd generation: overlaying pico- and microcells over the macrocell structure for wide area coverage - complicates system management, leads to heterogeneous environment (high bit rates in picocell, low bit rates in macrocell)
- UMTS Forum: provides ongoing high-level strategic steering of future developments, heavy industry involvement
  - advise EC on policy lines with respect to UMTS standardization
  - assist EC in carrying out review of ETSI work plans for consis-tency with “commonly agreed-upon” industry views re UMTS

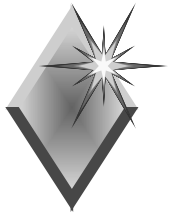
UMTS: The Vision





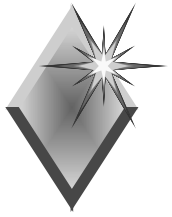
Mobile Broadband Systems

- mobile cellular extension to B-ISDN
  - incorporates transport of ATM cells
  - uses same connection admission strategies as B-ISDN
- MBSs are 3rd generation system whose development and ability is “harmonious” with UMTS, but is able to support services requiring much higher data rates
  - envisioned data rate exceeds 100 Mbps
  - original demonstrator prototype works at 62 GHz range
- applications for MBS-type systems:
  - electronic news gathering
  - outdoor television broadcasts
  - studio operations
  - program planning or editing meetings



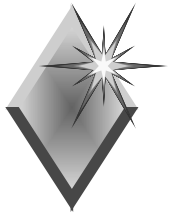
Wireless LAN

- wireless local area networks one of the most prominent applications envisioned by rule makers in the FCC
- research started in late 1970s:
  - IBM Laboratories in Rueschlikon
  - Hewlett-Packard Laboratories
  - Motorola
  - GTE Laboratories
- by 1990, wireless LAN products using direct sequence spread spectrum in the ISM band, licensed radio at 18-19 GHz and IR technology appeared in the market
  - original motivation was to save wiring costs, but these costs are not that high for new buildings
  - now mostly marketed as LAN extensions: use where wiring is impossible or just too expensive



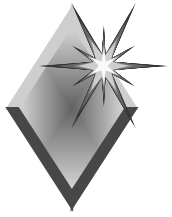
Wireless LAN

- wireless LANs operate in regulated environment:
  - need large bandwidth for high-speed transmission, no deep market penetration yet
  - new technology with “revolutionary” new applications, great market potential
  - regulators: how to justify assignment of adequate (and scarce) bands to wireless LANs, against more traditional and better established technologies (such as voice-oriented services)
- two potential solutions:
  - move to higher frequencies
    - increases size and power consumption
    - limits coverage of signal in indoor environments
  - release unlicensed bands as “unregulated playground” to explore different technologies



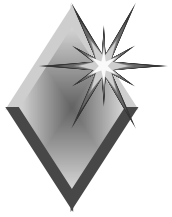
Wireless LAN

- access in unlicensed bands uses spread spectrum
  - FCC specifies max. signal strength and minimal spreading factors for direct sequence and frequency hopping
- CDMA requires power control for proper operation
  - requires communication among all terminals and central unit
  - impossible to implement in multi-vendor environment
- use of spread spectrum without CDMA seems to sacrifice maximum supportable data rate to gain transmission reliability
- data rate is most important feature of LAN, so other access techniques are under consideration (sectored antennas, multi-carrier transmission)



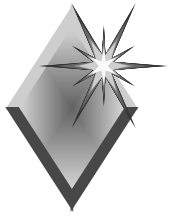
Wireless LAN

- three major activities related to wireless LANs:
  - IEEE 802.11
    - standard for DSSS, FHSS, and DFIR (diffused Infrared) technologies
    - uses 80MHz in 2.4 GHz ISM band (widely available, not just North America) as a radio channel
    - supported data rates: 1 Mbps with all three technologies, 2 Mbps with DSSS and FHSS
    - DSSS: frequency band split into five overlapping 26 MHz subbands to improve transmission reliability in the presence of interference or severe frequency selective multipath fading
    - FHSS: channel divided into 79 subbands, 1 MHz wide each. Three patterns of 22 hops, minimum hop rate of 2.5 hops/s (basically: retransmission of destroyed packet on another channel with hopefully better conditions)



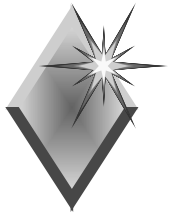
Wireless LAN

- HIPERLAN(High Performance Radio Local Area Networks)
  - idea: establish standard first, then develop products based on standard (see GSM)
  - developed by Sub-Technical Committee RES10 of ETSI
  - operates in 5.2 and 17.1 GHz bands released in Europe
  - will probably adopt non-spread spectrum modulation techniques to achieve high data rates (specifications call for minimum useful bit rate of 20 Mbps for point-to-point communication with range of 50 m).
- WINFORUM (industry alliance)
  - initiated by Apple Computer, has more than 40 members
  - objective: obtain and effectively employ radio spectrum for unlicensed user-provided personal communication services
  - one achievement: unlicensed 20 MHz in 1.9 GHz PCS band
  - develops a “spectrum etiquette”: fair access to widely different applications and devices



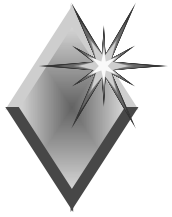
Wireless LAN

- WINFORUM "spectrum etiquette":
  - listen-before-talk (e.g.,: do not transmit if the spectrum you intend to use is already occupied)
  - power limitations to keep ranges short
  - relate power and connection time to the occupied bandwidth to equalize interference and provide fair access to frequency-time resources
  - WINFORUM identifies to classes of information type:
    - asynchronous transmissions: bursty, short, high power, link released quickly, operates in 50kHz-10MHz subbands
    - isochronous transmissions: long holding times, periodic transmissions, flexible link access times, operate in 1.25 MHz subbands
    - those two types are technically contrasting and cannot share same spectrum



3rd Generation Wireless LAN

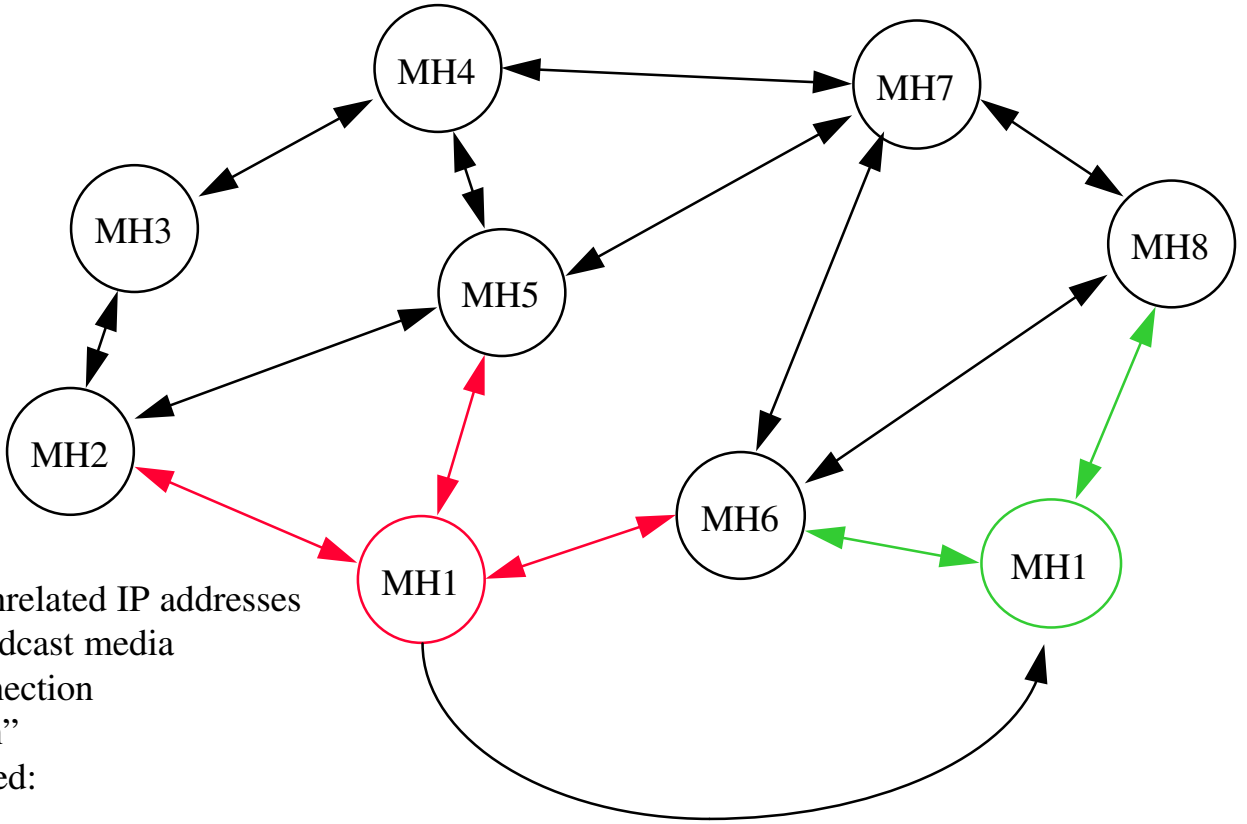
- two ACTS projects to explore future wireless LAN
  - MEDIAN
    - evaluate and implement a high-speed WLAN pilot system for multi-media applications and demonstrate it in real-user trials
    - relies on multi-carrier modulation scheme at 60 GHz, which is adaptive to the transmitted data rates and channel characteristics
    - features wireless ATM network extensions
  - WAND
    - wireless ATM transmission facility at 17 GHz
    - data rates > 20 Mbps at controlled service levels, research into rates of up to 155 Mbps
  - difference to emerging standards in WLAN:
    - two relatively unexplored frequency bands
    - novel radio access schemes
    - focus on close integration with fixed-wire B-ISDN and ATM



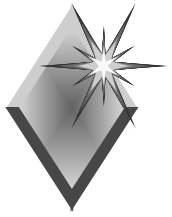
Ad-Hoc Networking

- idea: allow an arbitrary collection of mobiles to create a network on demand, without support from any “base” station or user administration:
  - create a network of all people attending a working group meeting to exchange e-mail or to run groupware applications
  - digital battlefield communications
  - disaster relief efforts
  - one host might have special capabilities (such as an Internet connection) and all other machines might want to route through it
- solution should coexist with existing protocols, such as mobile IP

Ad-Hoc Networking

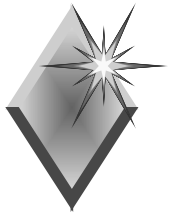


- computers have unrelated IP addresses
- limited range broadcast media
- dynamic interconnection
- no “administration”
- issues not addressed:
  - sleep mode
  - are links symmetric?
  - quality of service issues



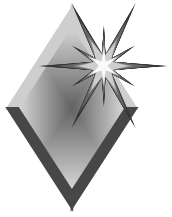
Ad-Hoc Networking: DSDV

- DSDV: Destination-Sequenced Distance Vector protocol
- basic idea: destination provides freshness indication, not intermediate nodes
  - each mobile host is a router
  - periodic broadcasts with sequence numbers
  - significant new information triggers broadcast updates
  - link breakages (metric ∞) are significant
  - two criteria for route selection:
    - sequence number guarantee maximal freshness (top priority)
    - metric comparison for lowest cost
  - protocol supports incremental and full updates
  - some routes in forwarding table might not be advertised



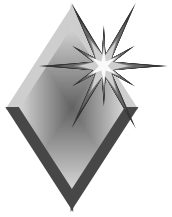
Ad-hoc Networking: DSDV

- claimed properties of the DSDV protocol:
  - loop-free at all instants
  - dynamic, multi-hop, self-starting
  - low memory requirements
  - quick convergence via triggered updates
  - routes available for all destinations
  - fast processing time
  - reasonable network load
  - minimal route trashing
  - intended for operation with 100 mobile nodes, depending on "mobility factor"



Ad-hoc Networking

- DSDV supports reasonably-sized ad-hoc networks
- destination timestamping provides useful freshness
- incoming route updates selected based upon two metrics
- dynamic topology is supported by maximizing the number of routers (e.g., each host is a router)
- much more analysis is needed
- many more protocols are emerging:
  - Dynamic Source Routing (D. Johnson, CMU)
  - WINGs (J. Garcia, UC Santa Cruz)
  - WAMIS (M. Gerla, UCLA)
  - Link-Reversal (S. Corson, University of Maryland)



Conclusions

- wireless communication is clearly here to stay
- wireless communication is difficult to achieve efficiently
  - limited spectrum in a regulated environment
  - technologies not mature, constantly evolving and changing
  - particular challenge: high-speed wireless links
- wireless communication and portable devices enable vision of mobile computing (ubiquitous computing, nomadic computing, etc)
  - raises many interesting research problems in all areas of networking and distributed computing
  - infrastructure costs to make visions come true immense, so what is “migration path”?