Data Wireless Networking

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These slides are available at
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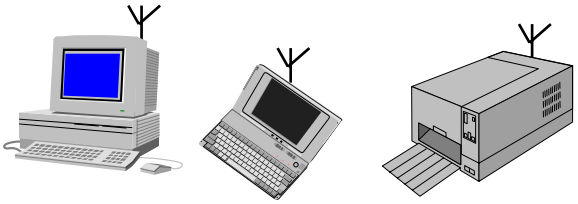
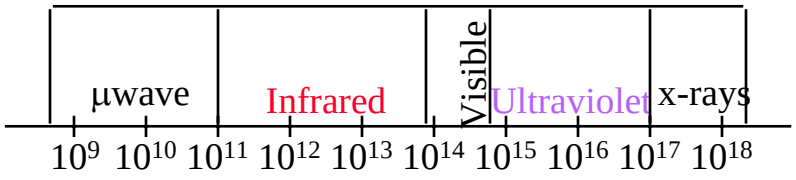
Overview

- Wireless local area networks
- Wireless LAN standard: IEEE 802.11, Hiperlan, Bluetooth
- WAP - Wireless Application Protocol

Wireless LANs



- IR ⇒ Line of sight, short range, indoors
- RF ⇒ Need license
- Spread-Spectrum: Resistance to interference



Wireless LANs

- Wireless LANs transmit data through the air using radio frequency transmissions.
- Several standards for WLANs have recently emerged facilitating market to take off.
- Currently the three principal WLAN technologies are: 802.11b (low speed), 802.11a (higher speed protocol) and Bluetooth.
- An emerging WLAN standard that may prove more important in the future is 802.11g.

Characteristics of wireless LANs

- Advantages
  - very flexible within the reception area
  - Ad-hoc networks without previous planning possible
  - (almost) no wiring difficulties (e.g. historic buildings, firewalls)
  - more robust against disasters like, e.g., earthquakes, fire - or users pulling a plug...
- Disadvantages
  - typically very low bandwidth compared to wired networks (1-10 Mbit/s)
  - many proprietary solutions, especially for higher bit-rates, standards take their time (e.g. IEEE 802.11)
  - products have to follow many national restrictions if working wireless, it takes a vary long time to establish global solutions like, e.g., IMT-2000

Design goals for wireless LANs

- global, seamless operation
- low power for battery use
- no special permissions or licenses needed to use the LAN
- robust transmission technology
- simplified spontaneous cooperation at meetings
- easy to use for everyone, simple management
- protection of investment in wired networks
- security (no one should be able to read my data), privacy (no one should be able to collect user profiles), safety (low radiation)
- transparency concerning applications and higher layer protocols, but also location awareness if necessary

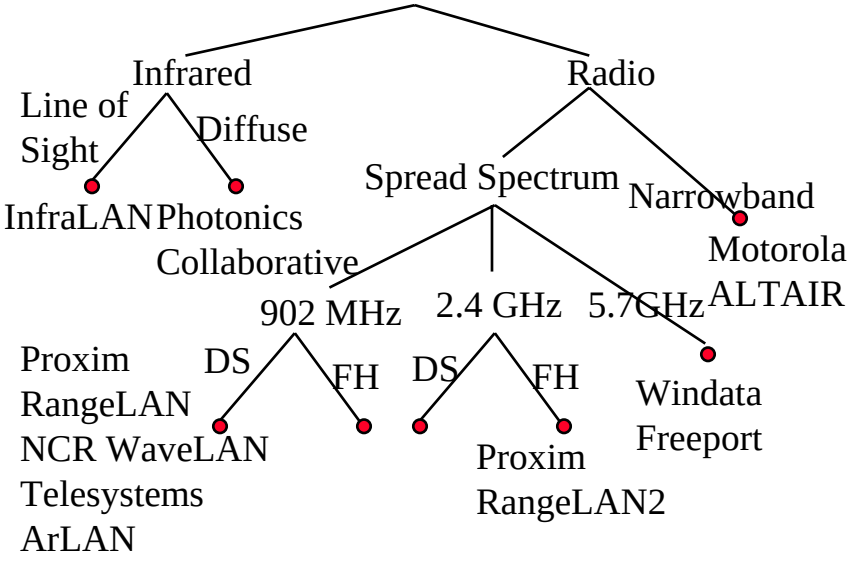
Wireless LANs

- Wireless LANs have never been as fast or as reliable as their wired equivalents and still suffer from competing standards
- Initially not as fast as long range mobile systems
- The industry has learned from infrared failure
- Public access wireless LANs could provide a shortcut to 4G mobile systems – data rate in the multimegabit range.

WLAN in the workplace

- WLANs are popular because they:
  - Eliminate cabling and make network access possible from a variety of locations
  - Facilitate computing for mobile workers at different office locations or as those workers move around the office.
  - Are increasingly used in hospitals because they enable doctors and nurses access patient records.
  - Are becoming popular in airports because they enable business travelers to access the Internet while waiting for their flights to leave

Wireless LANs



Comparison: infrared vs. radio transmission

- Infrared
  - uses IR diodes, diffuse light, multiple reflections (walls, furniture etc.)
- Advantages
  - simple, cheap, available in many mobile devices
  - no licenses needed
  - simple shielding possible
- Disadvantages
  - interference by sunlight, heat sources etc.
  - many things shield or absorb IR light
  - low bandwidth
- Example
  - IrDA (Infrared Data Association) interface available everywhere

- Radio
  - typically using the license free ISM band at 2.4 GHz
- Advantages
  - experience from wireless WAN and mobile phones can be used
  - coverage of larger areas possible (radio can penetrate walls, furniture etc.)
- Disadvantages
  - very limited license free frequency bands
  - shielding more difficult, interference with other electrical devices
- Example
  - WaveLAN, HIPERLAN, Bluetooth

Unlicensed Spectrum

- Regulators have set aside special frequency bands for which no license is required
- To minimize interference and protect users' safety, the transmission power of devices is limited to far less than that of cell phones, restricting their range to at most few hundreds meters
- ITU has designed several bands for Industrial, Scientific and Medical (ISM) purposes, three of which are within microwave region used by wireless devices

Band Name	FCC Frequencies	ETSI Frequencies	Main use
ISM-900	902-928MHz	890-906MHz	Food processing
ISM-2.4	2.4-2.4835MHz	2.4-2.5MHz	Microwave ovens
ISM-5.8	5.725-5.850GHz	5.725-5.870GHz	Medical scanners

Wireless Ethernet (IEEE 802.11b)

- The IEEE 802.11b, also called wireless Ethernet, is now the dominant WLAN standard.
- Two version of IEEE 802.11b exist:
  - ***Frequency-hopping spread-spectrum (FHSS)*** with data rates of 1 and 2 Mbps and
  - ***Direct-sequence spread-spectrum (DHSS)*** with data rates of 1, 2, 5.5 and 11Mbps, which dominates the market due to its higher speed

IEEE 802.11 Features

- 1 and 2 Mbps
- Supports both Ad-hoc and base-stations
- Spread Spectrum ⇒ No licensing required.
  Three Phys: Direct Sequence, Frequency Hopping, 915-MHz, **2.4 GHz** (Worldwide ISM), 5.2 GHz, and Diffused Infrared (850-900 nm) bands.
- Supports multiple priorities
- Supports time-critical and data traffic
- Power management allows a node to doze off

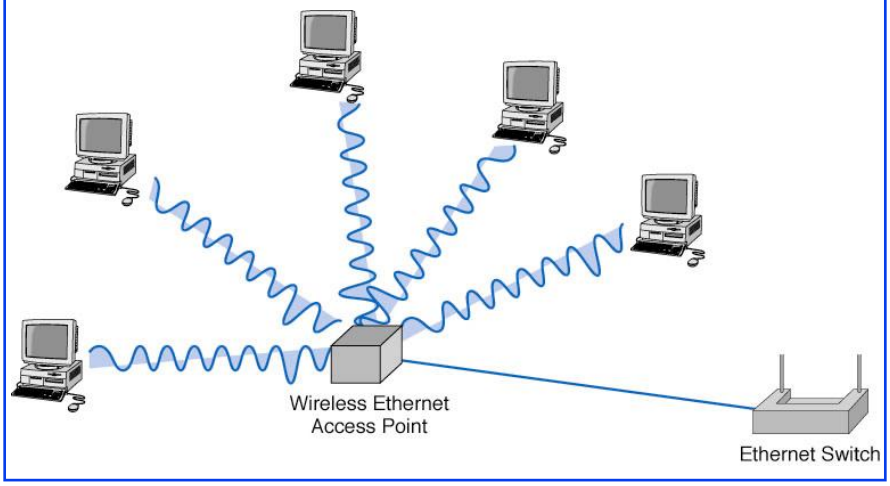
Types of Wireless Ethernet

- Two forms of the IEEE 802.11b standard currently exist:
- ***Direct Sequence Spread Spectrum*** (**DSSS**) uses the entire 2.4 GHz WLAN frequency band to transmit information. DSSS is capable of data rates of up to 11 Mbps with fallback rates of 5.5, 2 and 1 Mbps. Lower rates are used whenever interference or congestion occurs.
- ***Frequency Hopping Spread Spectrum*** (**FHSS**) divides the frequency band into a series of channels and then changes its frequency channel about every half a second, using a pseudorandom sequence. FHSS is more secure, but is only capable of data rates of 1 or 2 Mbps, since the frequency band gets divided up into a number of channels.
- ***IEEE 802.11a*** is another Wireless LAN standard. It operates in the 5 GHz band and be capable of data rates of up to 54 Mbps, but averages about 20 Mbps in practice.

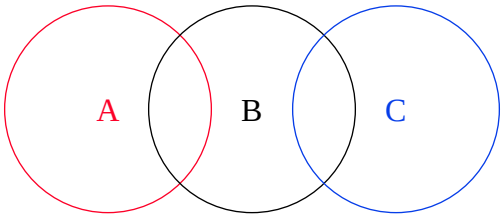
IEEE 802.11b Wireless LAN Topology

- WLANs use a ***physical star, logical bus topology.***
- Each WLAN computer uses a ***wireless NIC*** that transmits radio signals to the AP.
- WLAN network access is through devices called ***access points*** (**APs**), which have a maximum transmission range of about 100-500 feet.
- AP also connect into the wired LAN. The AP acts as a repeater by retransmitting frames from client computers over the wired network.
- Multiple APs are needed to make wireless access possible in most areas of a building.
- IEEE 802.11 also uses 3 separate radio channels, allowing APs with overlapping ranges to be set up without interfering with each other's signals.

IEEE 802.11b Wireless LAN Topology

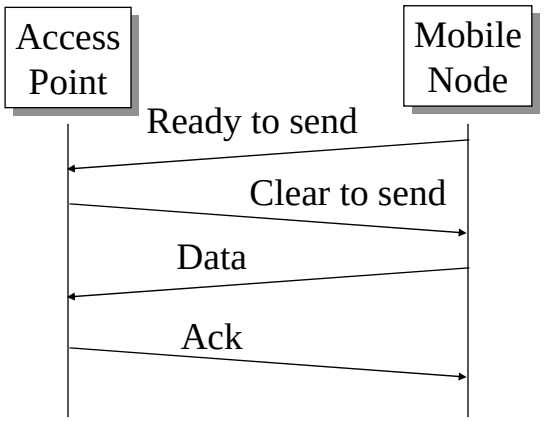


Hidden Node Problem



- C cannot hear A.
  It may start transmitting while A is also transmitting
  $\Rightarrow$ A and C can't detect collision.
- Only the receiver can help avoid collisions

4-Way Handshake



IEEE 802.11 MAC

- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- Listen before you talk. If the medium is busy, the transmitter backs off for a random period.
- Two WLAN MAC techniques are now in use:
  - ***Distributed Coordination Function (DCF)***
  - ***Point Coordination Function (PCF)***.
- PCF: Avoids collision by sending a short message:
  Ready to send (RTS)
  RTS contains dest. address and duration of message.
  Tells everyone to backoff for the duration.
- Destination sends: Clear to send (CTS)
- Can not detect collision ⇒ Each packet is acked.
- MAC level retransmission if not acked.

Distributed Coordination Function (DCF)

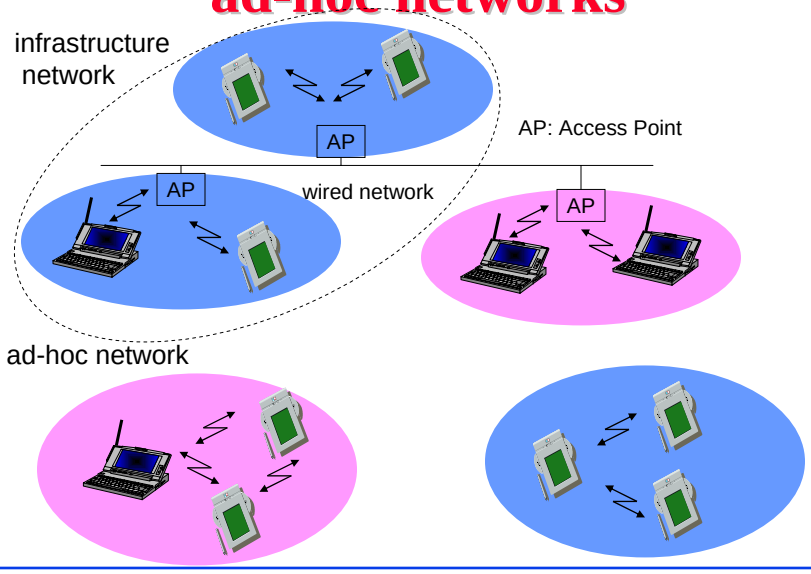
- With DCF, also known as ***physical sense carrier method***, a node that wants to send first listens to make sure that the transmitting node has finished, then waits a random period of time longer.
- During transmission, each frame is sent using the Stop and Wait ARQ, so by waiting, the listening node can detect that the sending node has finished and can then begin sending its transmission.
- With Wireless LANs, ACK/NAK signals are sent a short time after a frame is received.
- Stations wishing to send a frame wait a somewhat longer time, ensuring that no collision will occur.

Point Coordination Function (PCF)

- When a computer on a Wireless LAN is near the transmission limits of the AP at one end and another computer is near the transmission limits at the other end of the AP's range, both computers may be able to transmit to the AP, but can not detect each other's signals.
- This is known as the ***hidden node problem***. When it occurs, the ***physical carrier sense method*** will not work.
- The ***virtual carrier sense method*** solves this problem by having a transmitting station first send a ***request to send*** (**RTS**) signal to the AP. If the AP responds with a ***clear to send*** (**CTS**) signal, the computer wishing to send a frame can then begin transmitting.

Ad-Hoc vs Infrastructure

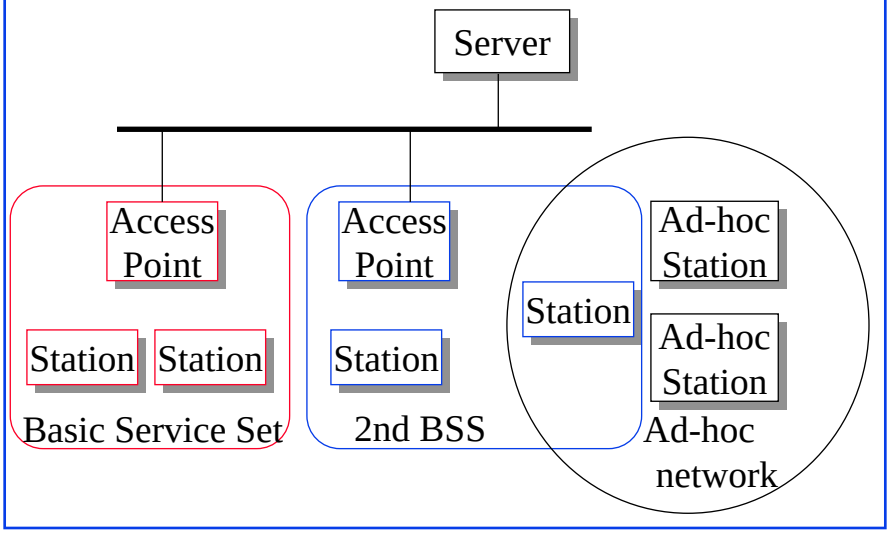
Comparison: infrastructure vs. ad-hoc networks



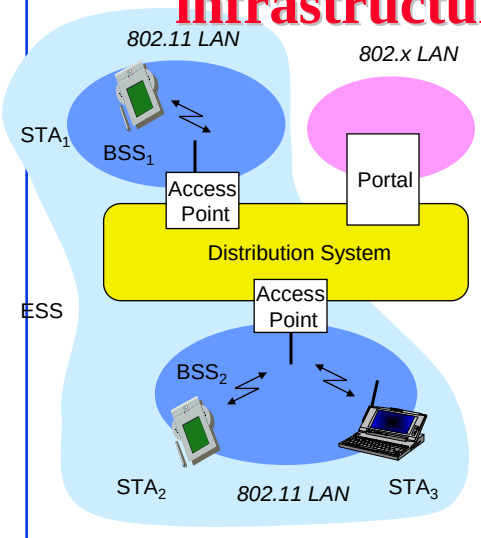
Peer-to-Peer or Base Stations?

- Ad-hoc (Autonomous) Group:
  - Two stations can communicate
  - All stations have the same logic
  - No infrastructure, Suitable for small area
- Infrastructure Based: Access points (base units)
  - Stations can be simpler than bases.
  - Base provide connection for off-network traffic
  - Base provides location tracking, directory, authentication ⇒ Scalable to large networks
- IEEE 802.11 provides both.

IEEE 802.11 Architecture

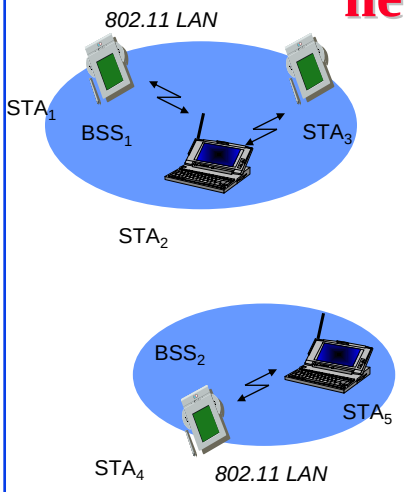


802.11 - Architecture of an infrastructure network



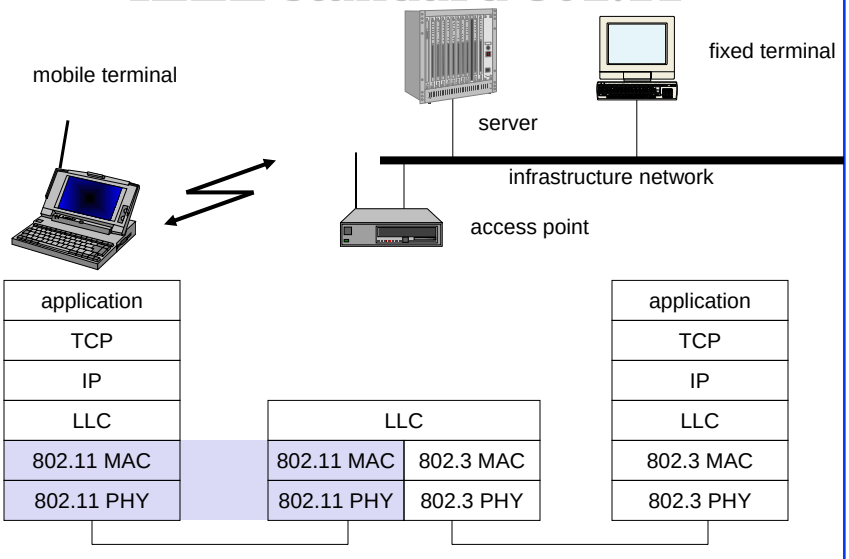
- Station (STA)
  - terminal with access mechanisms to the wireless medium and radio contact to the access point
- Basic Service Set (BSS)
  - group of stations using the same radio frequency
- Access Point
  - station integrated into the wireless LAN and the distribution system
- Portal
  - bridge to other (wired) networks
- Distribution System
  - interconnection network to form one logical network (EES: Extended Service Set) based on several BSS

802.11 - Architecture of an ad-hoc network



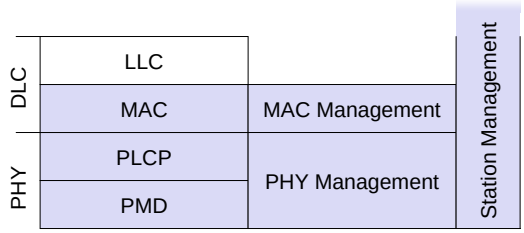
- Direct communication within a limited range
  - Station (STA): terminal with access mechanisms to the wireless medium
  - Basic Service Set (BSS): group of stations using the same radio frequency

IEEE standard 802.11

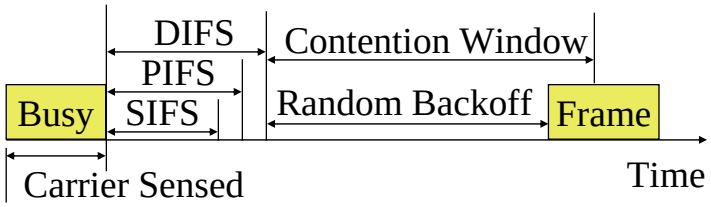


802.11 - Layers and functions

- MAC
  - access mechanisms, fragmentation, encryption
- MAC Management
  - synchronization, roaming, MIB, power management
- PLCP Physical Layer Convergence Protocol
  - clear channel assessment signal (carrier sense)
- PMD Physical Medium Dependent
  - modulation, coding
- PHY Management
  - channel selection, MIB
- Station Management
  - coordination of all management functions

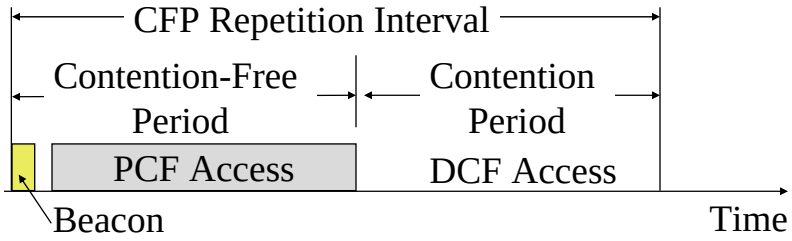


IEEE 802.11 Priorities



- Initial interframe space (IFS)
- Highest priority frames, e.g., Acks, use short IFS (SIFS)
- Medium priority time-critical frames use “Point Coordination Function IFS” (PIFS)
- Asynchronous data frames use “Distributed coordination function IFS” (DIFS)

Time Critical Services



- Timer critical services use Point Coordination Function
- The point coordinator allows only one station to access
- Coordinator sends a beacon frame to all stations. Then uses a polling frame to allow a particular station to have contention-free access
- Contention Free Period (CFP) varies with the load.

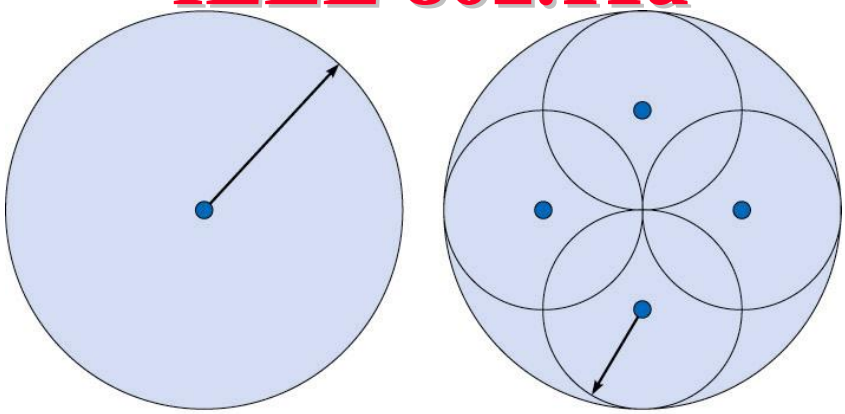
Power Management

- A station can be in one of three states:
  - Transmitter on
  - Receiver only on
  - Dozing: Both transmitter and receivers off.
- Access point (AP) buffers traffic for dozing stations.
- AP announces which stations have frames buffered. Traffic indication map included in each beacon. All multicasts/broadcasts are buffered.
- Dozing stations wake up to listen to the beacon. If there is data waiting for it, the station sends a poll frame to get the data.

New developments

- IEEE 802.11a
- 802.11a uses the same topology as 802.11b, transmitting data rates of up to 54 Mbps using frequencies in the 5 GHz range, with a total available bandwidth of 300 MHz.
- The signal range for 802.11a is also reduced to only 50m, for 12-24 Mbps and to only 15m for 54 Mbps.
- This means that more APs are needed to cover the same area as for 802.11b.
- 802.11a uses 12 channels instead of the 3 802.11b uses, making AP co-location possible. Higher data rates are then possible by having multiple APs co-located and assigning each to a different frequency
- Close cooperation with BRAN (ETSI Broadband Radio Access Network)

IEEE 802.11a



It takes more 802.11a APs to provide the same coverage as one 802.11b access point.

New developments

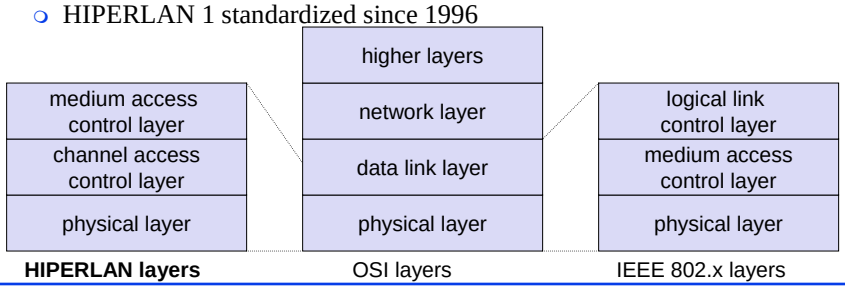
- IEEE 802.11b
  - higher data rates at 2.4 GHz
  - proprietary solutions already offer 10 Mbit/s
- IEEE WPAN (Wireless Personal Area Networks)
  - market potential
  - compatibility
  - low cost/power, small form factor
  - technical/economic feasibility
    ➔ Bluetooth

HIPERLAN

- High Performance Radio LAN
- European Telecom Standards Institute (ETSI)'s subtechnical committee RES10.
- 5.12-5.30 GHz and 17.1-17.3 GHz bands
- Phy: 23.5 Mbps on 23.5 MHz, non-spread spectrum (GMSK)
- MAC: CSMA/CA but different from IEEE 802.11
- Peer-to-peer only.
- Power management: Nodes announce their wakeup cycle. Other nodes send according to the cycle. A low-bit rate header allows nodes to keep most ckts off.
- HIPERLAN2

ETSI - HIPERLAN

- ETSI standard
  - European standard, cf. GSM, DECT, ...
  - Enhancement of local Networks and interworking with fixed networks
  - integration of time-sensitive services from the early beginning
- HIPERLAN family
  - one standard cannot satisfy all requirements
    - range, bandwidth, QoS support
    - commercial constraints
  - HIPERLAN 1 standardized since 1996



Bluetooth

- Consortium: Ericsson, Intel, IBM, Nokia, Toshiba - many members
- Scenarios
  - connection of peripheral devices
    - loudspeaker, joystick, headset
  - support of ad-hoc networking
    - small devices, low-cost
  - bridging of networks
    - e.g., GSM via mobile phone - Bluetooth - laptop
- Simple, cheap, replacement of IrDA, low range, lower data rates
  - 2.4 GHz, FHSS, TDD, CDMA

Bluetooth

- Bluetooth, standardized as ***IEEE 802.15***, provides networking for small personal networks.
- Bluetooth's basic data rate is 1 Mbps.
- Devices are small and cheap and have been designed to eliminate cabling between keyboards, mice, telephone handsets and PDAs.
- Bluetooth is not compatible with the other IEEE 802.11 WLAN standards.

Bluetooth Media Access Control

- Bluetooth network is called a ***piconet***.
- All communications is between the master devices and the slave devices. Slaves do not communicate directly.
- Bluetooth uses a controlled MAC technique and ***frequency-hopping spread spectrum (FHSS)*** using 79 channels.
- During communications the signal makes about 1,600 channel changes per second (called ***hops***).
- Data is encoded using 2-level frequency modulation, with one frequency encoding a binary 0 and another for binary 1.

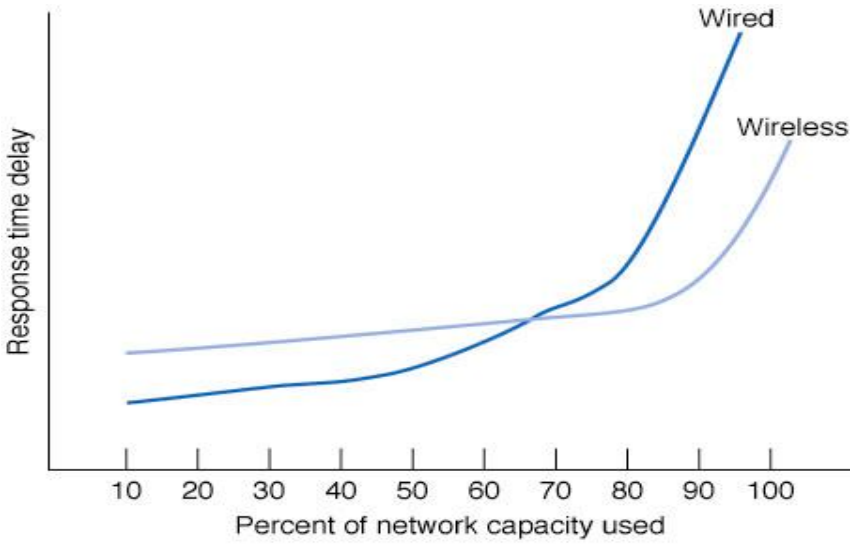
Wireless LAN Standards

System	Theoretical Capacity	Real Max. Throughput	Spectrum	Air Interface	Status as of 2002
802.11	1Mbps	0.5Mbps	2.4 GHz	FHSS	Obsolete
802.11	2Mbps	1Mbps	2.4 GHz	DSSS	Obsolete
802.11b	11Mbps	6Mbps	2.4 GHz	DSSS	Popular
802.11g	54Mbps	31Mbps	2.4 GHz	OFDM	Near future
802.11a	54Mbps	31Mbps	5 GHz	OFDM	New
HiperLan1	23.5Mbps	Unknown	5 GHz	TDMA	Abandoned
HiperLan2	54Mbps	31Mbps	5 GHz	OFDM	Near future
5-WING/5-UP	104Mbps	72Mbps	5 GHz	OFDM	Future

802.11b - present, 802.11a - next, 5-WING or 5-UP - future as convergence of 802.11a and HiperLan2

Media Access Control Protocol Efficiency

- Unlike CSMA/CD, Wireless Ethernet's PCF controlled-access technique imposes time delays, even when traffic is low.
- Response time delays increase only slowly with increased traffic up to about 85-90 percent of nominal capacity.
- At traffic levels of about 85-90 percent of nominal capacity performance begins to fall dramatically, though it remains better than with a comparable wired network.



Performance of wireless versus wired Ethernet LANs

Effective Data Rates for WLANs

- Next figure presents effective data rates of 802.11b and 802.11a protocols under a range of conditions.
- At close range, 802.11a clearly provides superior performance to 802.11b.
- If range is a factor, however, 802.11a performs only *modestly* better than 802.11b.
- To achieve higher performance, many companies are now installing ***overlay networks***; i.e., combined networks where the wireless portions extend the reach of the wired network into areas not normally wired.

Technology	Network Traffic Conditions		
	Low	Medium	High
802.11b perfect conditions (11 Mbps)	4.8 Mbps	1.9 Mbps	960 kbps
802.11b normal conditions (5.5 Mbps)	2.4 Mbps	1 Mbps	480 kbps
802.11a perfect conditions (54 Mbps)	17.2 Mbps	6.9 Mbps	3.4 Mbps
802.11a long range (12 Mbps)	3.8 Mbps	1.5 Mbps	760 kbps
802.11b perfect conditions w/ 4 APs (54 Mbps)	34.4 Mbps	27.5 Mbps	13.7 Mbps

Assumes: 1500 byte frames, no transmission errors
(No. of active users: Low traffic = 2, moderate = 5, high = 10)

Effective data rate estimates for Wireless Ethernet

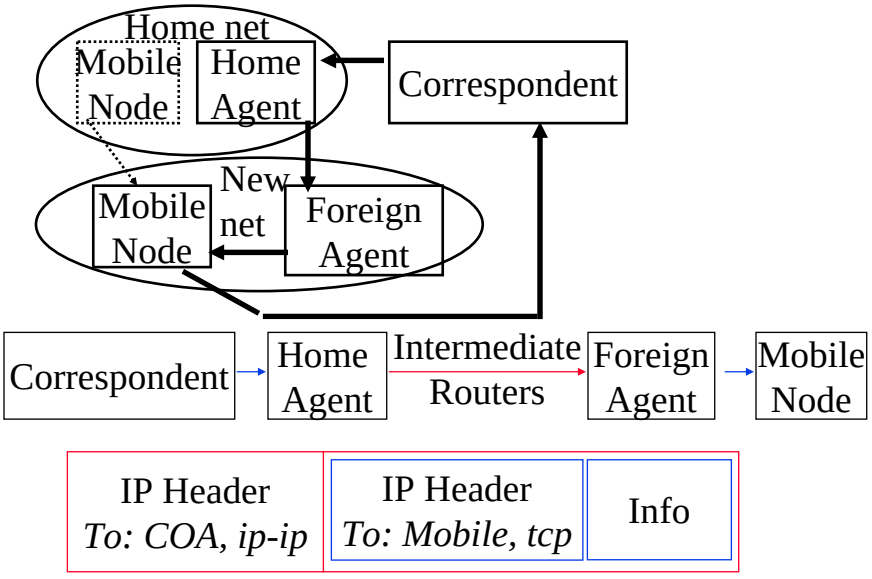
Recommendations

- For new construction, WLANs are only modestly more expensive than wired LANs.
- WLANs have the advantage of mobility, linking indoor to outdoor areas as well as areas without wired access.
- Given its lower price, longer track record and ability to operate over greater distances 802.11b is the more attractive of the two WLAN protocols,
- If high capacity is critical, then 802.11a becomes more attractive.
- Over time, as 802.11a technology should drop in price. As experience with the technology increases, its popularity should increase as well.

Mobile IP: Features

- You can take you notebook to any location
- Finds nearby IP routers and connects *automatically.* You don't even have to find a phone jack.
- Only "Mobility Aware" routers and mobile units need new s/w. Other routers and hosts can use current IP
- No new IP addresses or address formats
- Secure: Allows authentication
- Also supports mobile networks (whole airplane/car load of mobile units)

Mobile IP: Mechanisms



Mechanism (Cont)

- Mobile node finds foreign agents via solicitation or advertising
- Mobile registers with the foreign agents and informs the home agent
- Home agent intercepts mobile node's datagrams and forwards them to the care-of-address
- Care-of-address (COA): Address of the end-of-tunnel towards the mobile node. May or may not be foreign agent
- At COA, datagram is extracted and sent to mobile

WAP - Wireless Application Protocol

- Goals
  - deliver Internet content and enhanced services to mobile devices and users (mobile phones, PDAs)
  - independence from wireless network standards
  - open for everyone to participate, protocol specifications will be proposed to standardization bodies
  - applications should scale well beyond current transport media and device types and should also be applicable to future developments
- Platforms
  - e.g., GSM (900, 1800, 1900), CDMA IS-95, TDMA IS-136, 3rd generation systems (IMT-2000, UMTS, W-CDMA)
- Forum
  - WAP Forum, co-founded by Ericsson, Motorola, Nokia, Unwired Planet
  - further information http://www.wapforum.org

WAP - scope of standardization

- Browser
  - "micro browser", similar to existing, well-known browsers in the Internet
- Script language
  - similar to Java script, adapted to the mobile environment
- WTA/WTAI
  - Wireless Telephony Application (Interface): access to all telephone functions
- Content formats
  - e.g., business cards (vCard), calendar events (vCalender)
- Protocol layers – a new stack of protocols
  - transport layer, security layer, session layer etc.
- Working Groups
  - WAP Architecture Working Group, WAP Wireless Protocol Working Group, WAP Wireless Security Working Group, WAP Wireless Application Working Group

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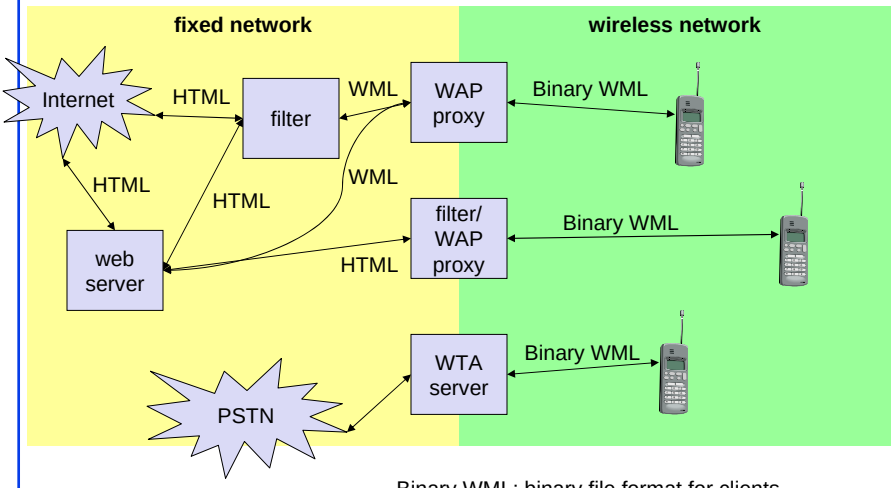
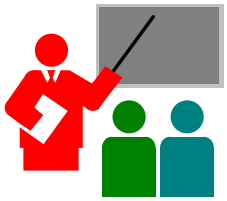
WAP - network elements



Binary WML: binary file format for clients

Summary



- Spread spectrum: Frequency hopping or direct sequence
- WANs: Ardis, RAM, Cellular, CDPD, Metricom
- Proprietary LANs: Photonics, RangeLan, ALTAIR
- LAN Standards: IEEE 802.11, Hiperlan, Bluetooth
- WAP