Home Area Networks

CS 687

University of Kentucky

Fall 2015

Outline

- Home Area Networks
- Access Technologies
- Home Area Network Architecture for Smart Grid
- IEEE 802.11
- IEEE 802.15.4 (Zigbee)
- 6LoWPAN
- ITU G.hn

Home Area Networks

- Home-based networks for Internet access to run multimedia applications that integrate voice, video and data communications
  - view television and movies
  - voice over IP (VoIP)
  - broadband Internet access
- Home networking to implement demand-side management (DSM) programs for Smart Grid
  - In-home display of energy use
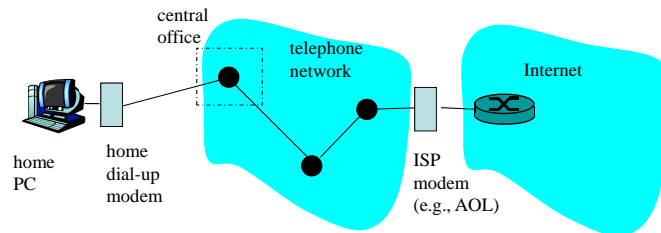 - Demand response
  - Gateway to field area networks

Access Technologies

Q: How to connect to the outside world from home?

- Wired
  - Dial-up
  - DSL
  - Cable
  - Fiber, Powerline
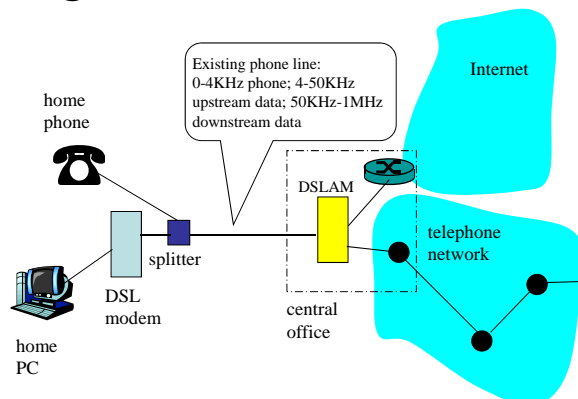- Wireless
  - Cellular, WiMAX, LTE
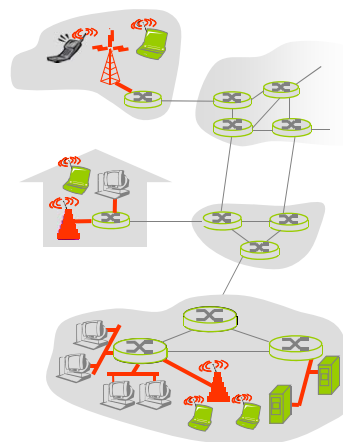
Dial-up Modem

* ❖ Uses existing telephony infrastructure
  * ❖ Home is connected to central office
* ❖ up to 56Kbps direct access to router (often less)
* ❖ Can't surf and phone at same time: not "always on"

Digital Subscriber Line (DSL)

* ❖ Also uses existing telephone infrastructure
* ❖ up to 1 Mbps upstream (today typically < 256 kbps)
* ❖ up to 8 Mbps downstream (today typically < 1 Mbps)
* ❖ dedicated physical line to telephone central office

3

Residential access: cable modems

- Does not use telephone infrastructure
    - Instead uses cable TV infrastructure
- HFC: hybrid fiber coax
    - asymmetric: up to 30Mbps downstream, 2 Mbps upstream
- network of cable and fiber attaches homes to ISP router
    - homes share access to router
    - unlike DSL, which has dedicated access
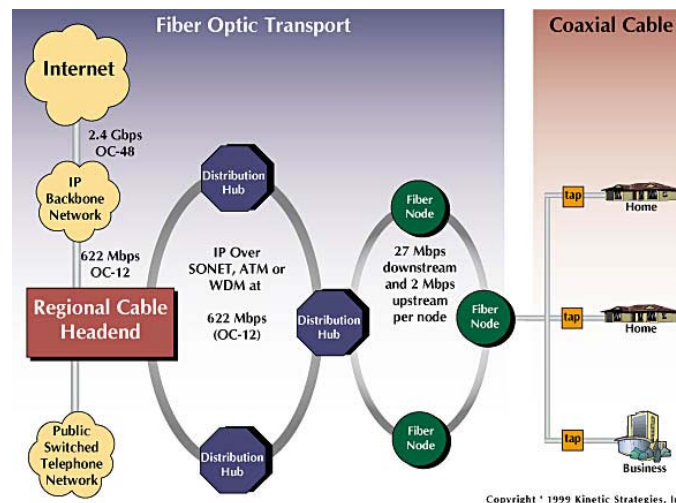
Residential access: cable modems

Diagram: http://www.cabledatacomnews.com/cmic/diagram.html
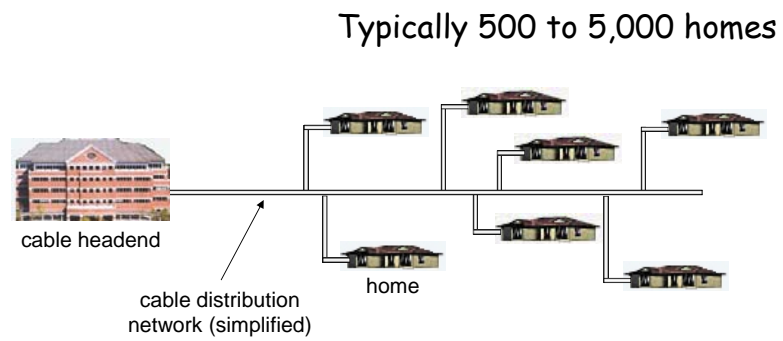
Cable Network Architecture: Overview

Typically 500 to 5,000 homes

cable headend

cable distribution
network (simplified)

home

Cable Network Architecture: Overview

server(s)

cable headend

cable distribution
network

home

Cable Network Architecture: Overview

Home Environment

Set-Top Box

TV

Cable Modem

PC

Coax

Splitter

Coax

10 Mbps Ethernet

cable headend

cable distribution
network (simplified)

home

Cable Network Architecture: Overview

FDM (more shortly):

| V I D E O 1 | V I D E O 2 | V I D E O 3 | V I D E O 4 | V I D E O 5 | V I D E O 6 | D A T A 7 | D A T A 8 | C O N T R O L 9 |

Channels

cable headend

cable distribution
network

home

6
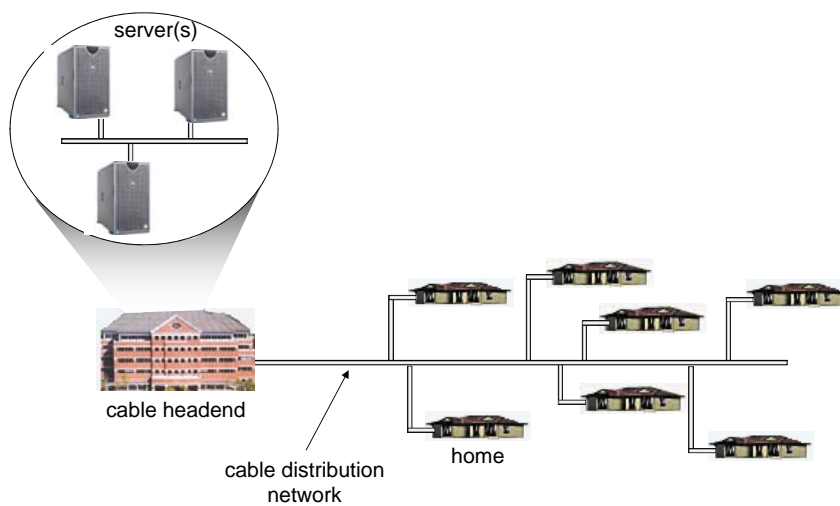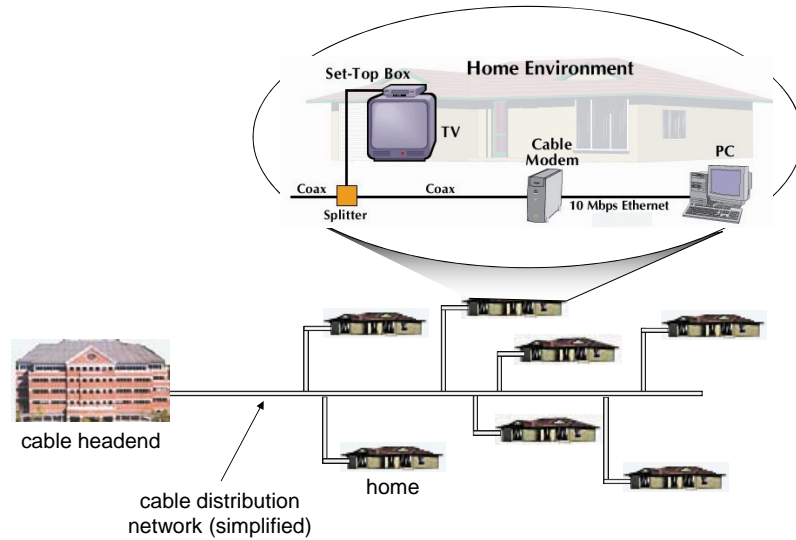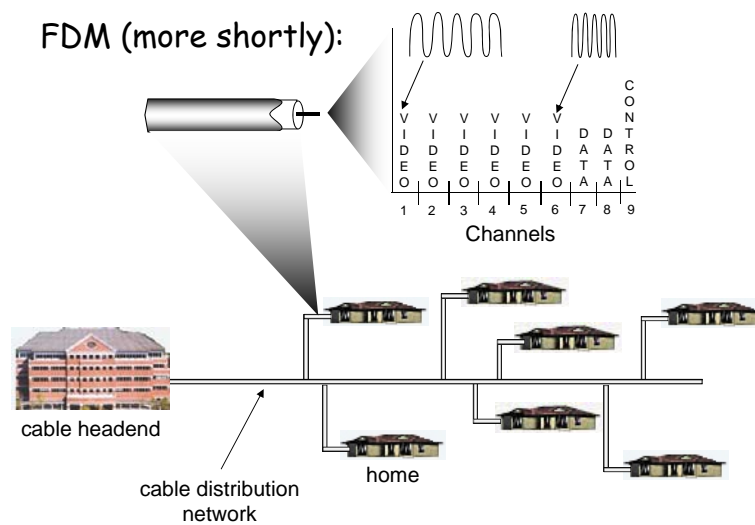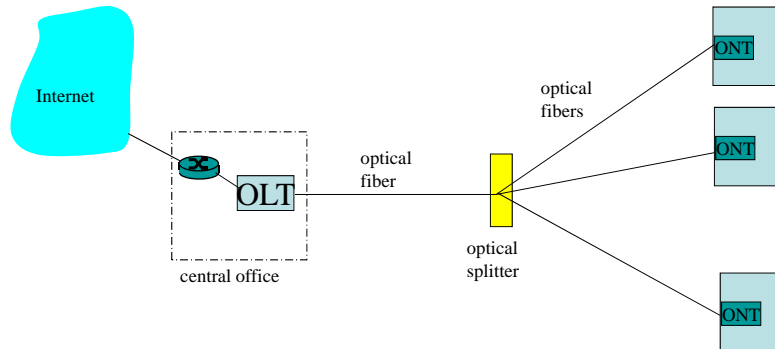
Fiber to the Home

- Optical links from central office to the home
- Two competing optical technologies:
    - Passive Optical network (PON)
    - Active Optical Network (AON)
- Much higher Internet rates; fiber also carries television and phone services

Wireless access networks

- shared *wireless* access network connects end system to router
    - via base station aka "access point"
- **wireless LANs:** (within a home)
    - 802.11b/g (WiFi): 11 or 54 Mbps
- **wider-area wireless access**
    - provided by telco operator
    - ~1Mbps over cellular system (EVDO, HSDPA)
    - next up (?): WiMAX (10's Mbps) over wide area, LTE
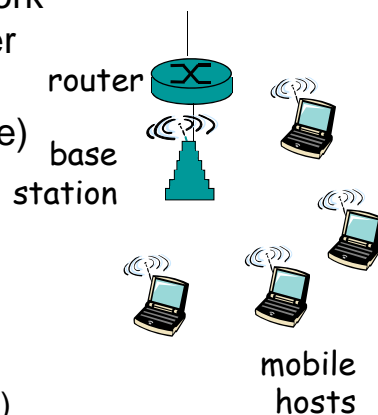
Home networks (of the first kind)

Typical home network components:

- DSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access
  point

to/from cable headend — cable modem — router/firewall — Ethernet — wireless access point — wireless laptops

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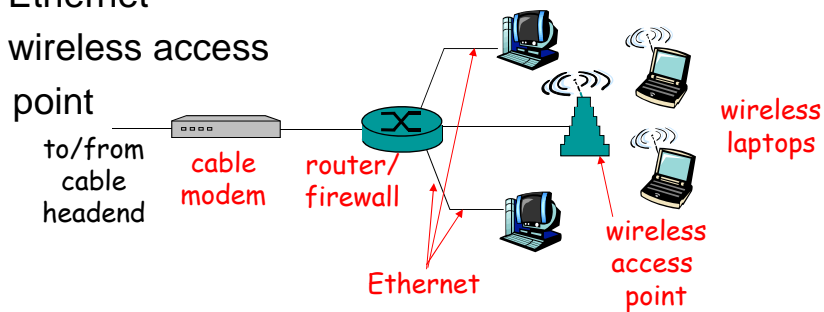
Home Area Network Architecture for Smart Grid

- Demand-side management
  - Energy efficiency
  - Demand response
  - Direct load control
- HAN architecture in existing standards
  - Zigbee Smart Energy Profile
  - Utility AMI OpenHAN Energy Services Interface

Design Considerations

- Pace of technology innovation
- Upgradability
- Consumer choice
- Device ownership
- Market diversity
- Interoperability
- Total cost
- Performance

Two Architectures --- Meter Portal

Meter Gateway

In-home display

Neighborhood Area Network (NAN/FAN)

Home Area Network (HAN)

Load control device

Thermostat

Two Architectures --- HAN Device Portal

Meter

In-home display

Neighborhood Area Network (NAN/FAN)

Home Area Network (HAN)

Gateway

Thermostat

Load control device
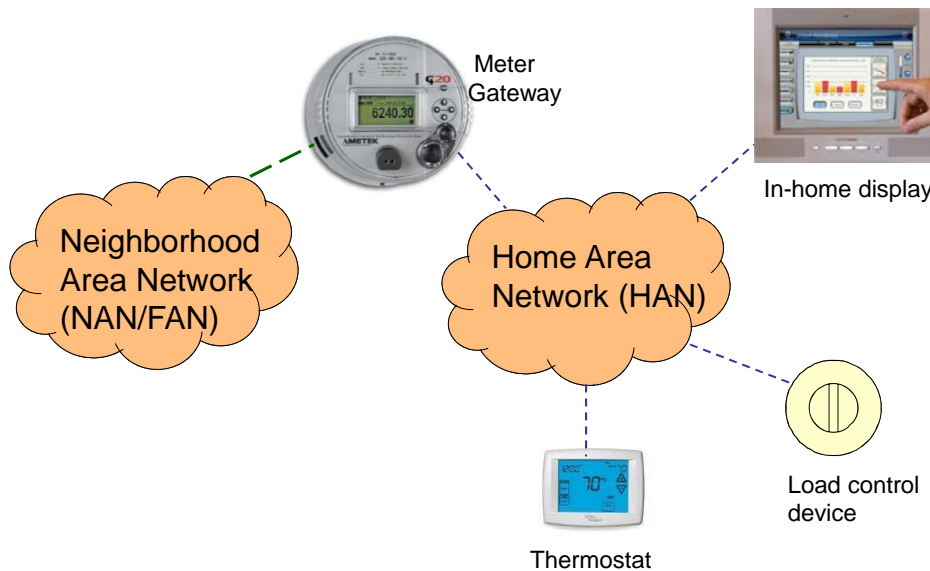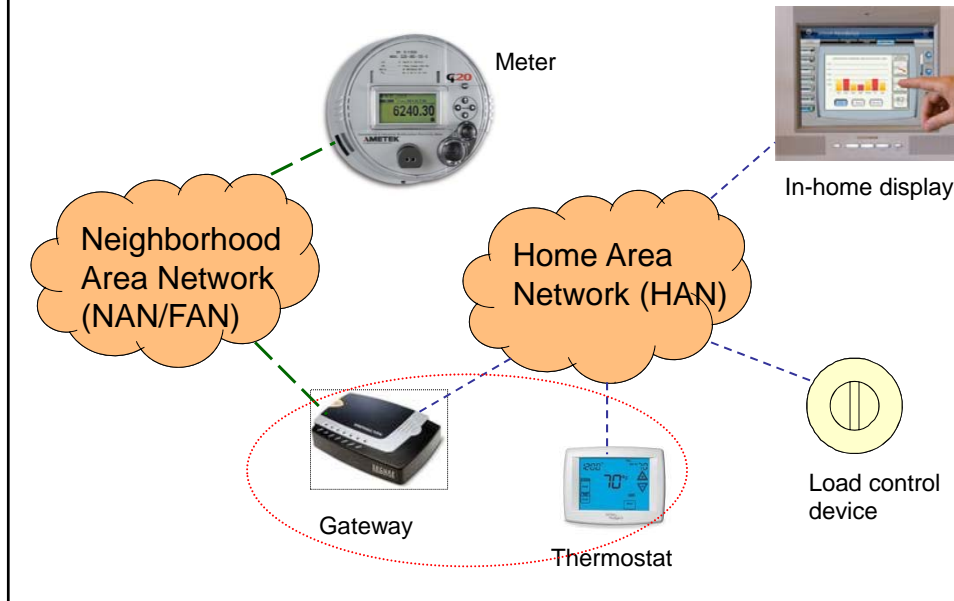
Comparisons

- Cost implications
  - Meter portal: two in the meter and one in a home device
  - HAN device portal: one in meter and two in the home device (incremental deployment)
- Communication capability
  - Meter portal may have difficulty communicating with the indoor HAN
    - Rural home (hundreds of feet from the house)
    - High-rise multi-tenant unit (meter in basement)
    - Suburban neighborhood (obstacles)
  - HAN device portal has no problem communicating with the outdoor NAN

Comparisons (cont)

- Support for Market Innovation
  - Consumers have a choice of home networks: 6LoWPAN, FlexNet, HomePlug, LonWorks, Radio Data System (RDS), WI-Fi, Z-Wave and ZigBee.
  - HAN device portal is easier to change (at least not require field replacement)
- Risk Mitigation
  - Meter portal may face the potential for obsolescence of the embedded HAN technology.
  - HAN device portal may have a user-replaceable U-SNAP HAN module.

Two Architectures --- HAN Device Portal

Meter

In-home display

Neighborhood Area Network (NAN/FAN)

Home Area Network (HAN)

?

IEEE 802.11
IEEE 802.15.4
Something else

Load control device

Gateway

Thermostat
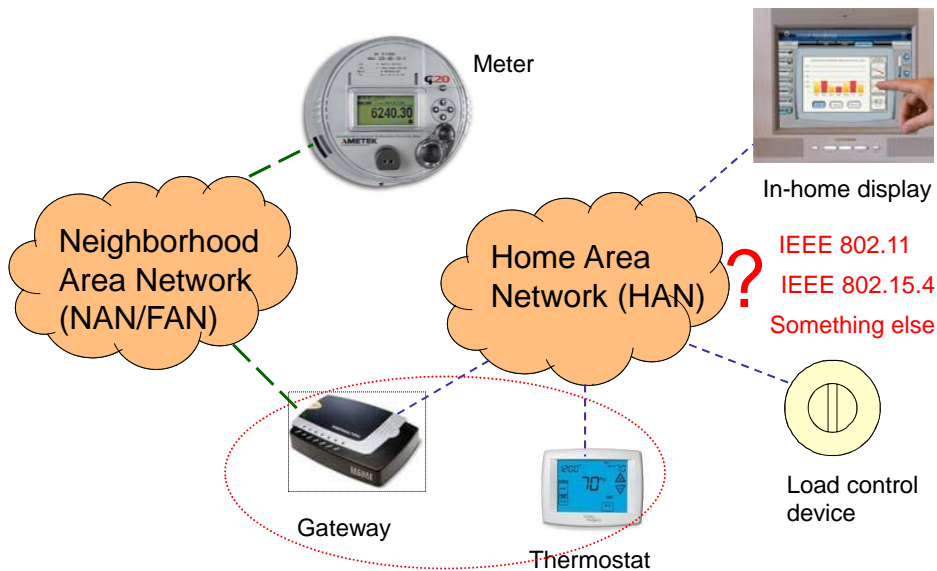
IEEE 802.11

Elements of a wireless network

wireless hosts
- laptop, PDA, IP phone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

network infrastructure

Elements of a wireless network

network infrastructure

base station
- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - e.g., cell towers, 802.11 access points

Elements of a wireless network

network infrastructure

wireless link
- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

Characteristics of selected wireless link standards

Data rate (Mbps)	Indoor 10-30m	Outdoor 50-200m	Mid-range outdoor 200m – 4 Km	Long-range outdoor 5Km – 20 Km	
200	802.11n				data
54	802.11a,g	802.11a,g point-to-point			
5-11	802.11b	802.16 (WiMAX)			
4		UMTS/WCDMA-HSPDA, CDMA2000-1xEVDO			3G cellular enhanced
1	802.15				
.384		UMTS/WCDMA, CDMA2000			3G
.056		IS-95, CDMA, GSM			2G

Elements of a wireless network

network infrastructure

infrastructure mode
- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

Elements of a wireless network
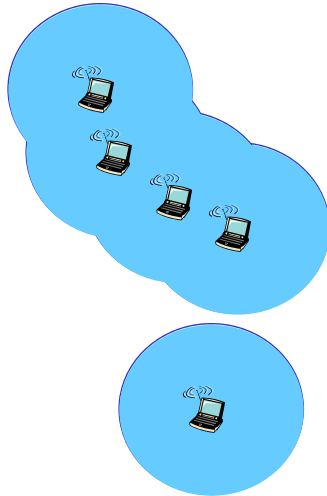
ad hoc mode
- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

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Wireless network taxonomy

|	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, WiMAX, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
no infrastructure	no base station, no connection to larger Internet (Bluetooth, ad hoc nets)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

Wireless Link Characteristics

Differences from wired link ….

- – decreased signal strength: radio signal attenuates as it propagates through matter (path loss)
- – interference from other sources: standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
- – multipath propagation: radio signal reflects off objects ground, arriving ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more "difficult"

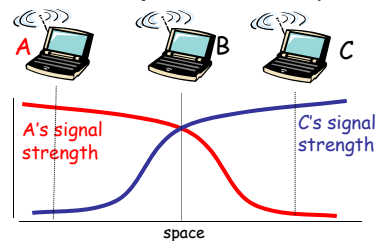# Wireless network characteristics

Multiple wireless senders and receivers create additional problems (beyond multiple access):
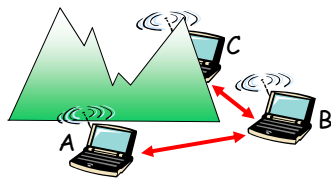
Hidden terminal problem
- B, A hear each other
- B, C hear each other
- A, C can not hear each other
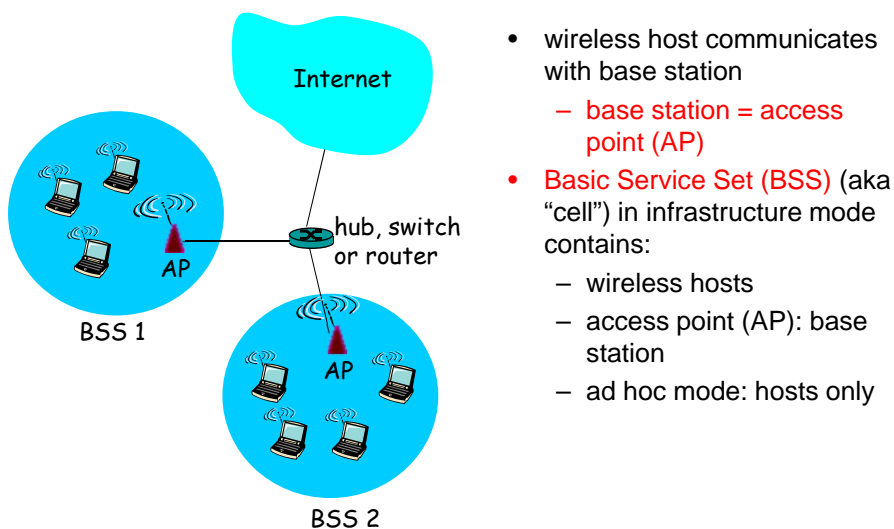
  means A, C unaware of their interference at B

Signal attenuation:
- B, A hear each other
- B, C hear each other
- A, C can not hear each other interfering at B

IEEE 802.11 Wireless LAN

- **802.11b**
  - 2.4-5 GHz unlicensed spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code

- **802.11a**
  - 5-6 GHz range
  - up to 54 Mbps
- **802.11g**
  - 2.4-5 GHz range
  - up to 54 Mbps
- **802.11n:** multiple antennae
  - 2.4-5 GHz range
  - up to 450 Mbps

- all use CSMA/CA for multiple access
- all have base-station and ad-hoc network versions

802.11 LAN architecture

Internet

hub, switch or router

AP

BSS 1

AP

BSS 2

- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

802.11: Channels, association

- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
  - selects AP to associate with
  - may perform authentication [Chapter 8]
  - will typically run DHCP to get IP address in AP's subnet

802.11: passive/active scanning
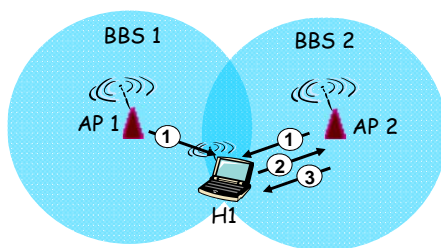
Passive Scanning:
(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent: H1 to selected AP
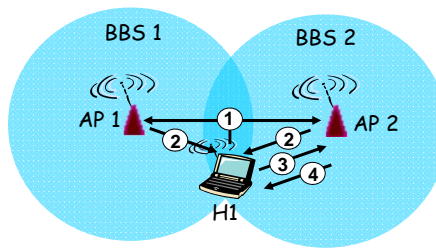
Active Scanning:
(1) Probe Request frame broadcast from H1
(2) Probes response frame sent from APs
(3) Association Request frame sent: H1 to selected AP
(4) Association Response frame sent: H1 to selected AP

IEEE 802.11: multiple access

- avoid collisions: 2+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/C(ollision)A(voidance)

C

B

A

A B C

A's signal strength

C's signal strength

space
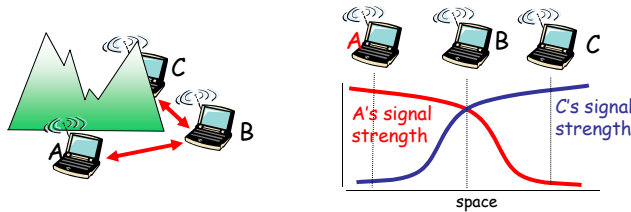
IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

1 if sense channel idle for **DIFS** then
    transmit entire frame (no CD)

2 if sense channel busy then

    start random backoff time

    timer counts down while channel idle

    transmit when timer expires

    if no ACK, increase random backoff interval, repeat 2

802.11 receiver

- if frame received OK

    return ACK after **SIFS** (ACK needed due to hidden terminal problem)

sender   receiver

DIFS {

data

SIFS

ACK
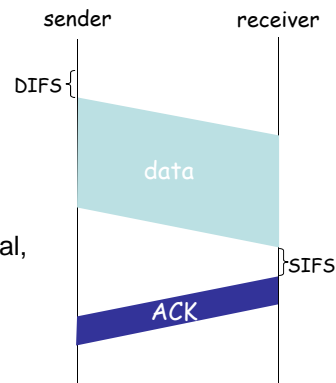
Avoiding collisions (more)

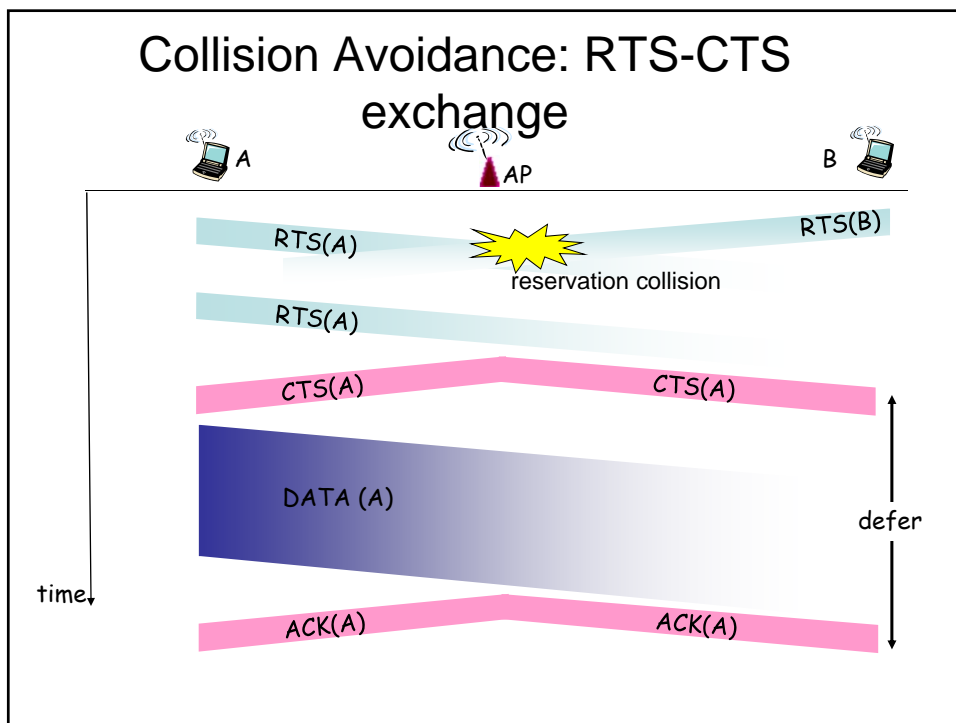*idea:* allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange

A   AP   B

RTS(A)   RTS(B)
        reservation collision

RTS(A)

CTS(A)   CTS(A)

DATA (A)   defer

time

ACK(A)   ACK(A)

802.11 frame: addressing

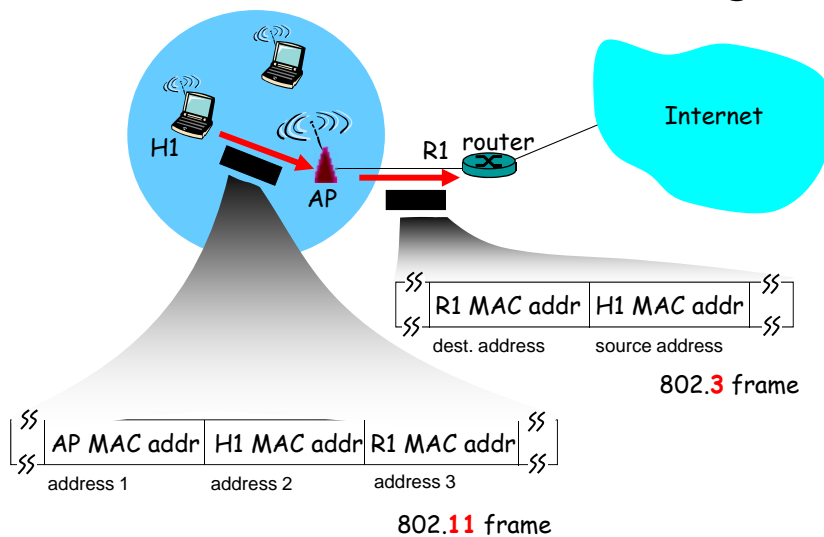| 2	2	6	6	6	2	6	0 - 2312	4
frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC
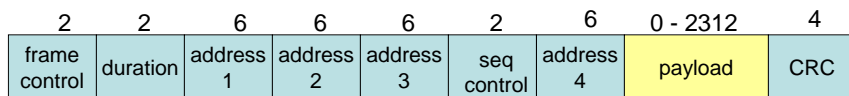
Address 1: MAC address of wireless host or AP to receive this frame

Address 2: MAC address of wireless host or AP transmitting this frame
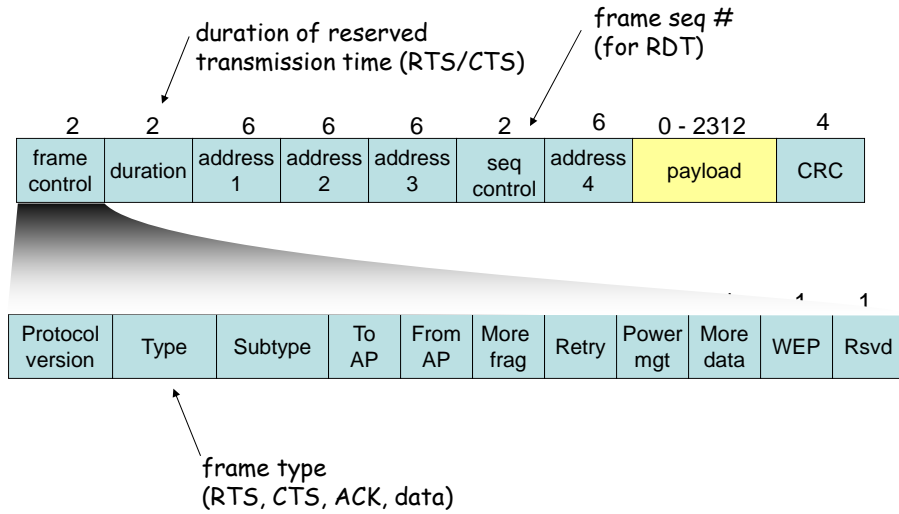
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

Internet

H1

R1 router

AP

R1 MAC addr	H1 MAC addr
dest. address	source address

802.**3** frame

AP MAC addr	H1 MAC addr	R1 MAC addr
address 1	address 2	address 3

802.**11** frame

802.11 frame: more

duration of reserved
transmission time (RTS/CTS)

frame seq #
(for RDT)

2	2	6	6	6	2	6	0 - 2312	4
frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC

Protocol version	Type	Subtype	To AP	From AP	More frag	Retry	Power mgt	More data	WEP	Rsvd

frame type
(RTS, CTS, ACK, data)

Other Contents for Home Area Networks
will be on separate sllides.