

Wireless and Mobile Networks

Reading: Sections 2.8 and 4.2.5

CS-375: Computer Networks

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Goals of Today's Lecture

- Wireless links: unique channel characteristics
  - High, time-varying bit-error rate
  - Broadcast where some nodes can't hear each other
- Mobile hosts: addressing and routing challenges
  - Keeping track of the host's changing attachment point
  - Maintaining a data transfer as the host moves
- Some specific examples
  - Wireless: 802.11 wireless LAN (aka "WiFi")
  - Mobility: Boeing Connexion and Mobile IP

Many slides adapted from Jim Kurose's lectures at UMass-Amherst

Widespread Deployment

- Worldwide cellular subscribers
  - 1993: 34 million
  - 2005: more than 2 billion
  - Now more than landline subscribers

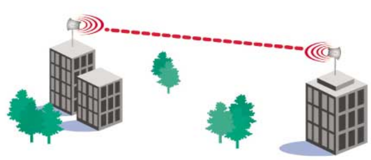



- Wireless local area networks
  - Wireless adapters built in to most laptops, and even PDAs
  - More than 220,000 known WiFi locations in 134 countries
  - Probably many, many more (e.g., home networks, corporate networks, …)

Wireless Links and Wireless Networks

Wireless Links: High Bit Error Rate

- Decreasing signal strength
  - –Disperses as it travels greater distance
  - –Attenuates as it passes through matter

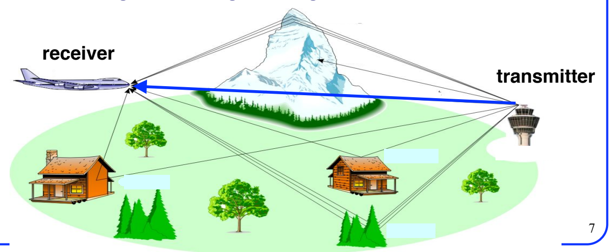


Wireless Links: High Bit Error Rate

- Interference from other sources
  - –Radio sources in same frequency band
  - –E.g., 2.4 GHz wireless phone interferes with 802.11b wireless LAN
  - –Electromagnetic noise (e.g., microwave oven)

Wireless Links: High Bit Error Rate

- Multi-path propagation
  - –Electromagnetic waves reflect off objects
  - –Taking many paths of different lengths
  - –Causing blurring of signal at the receiver

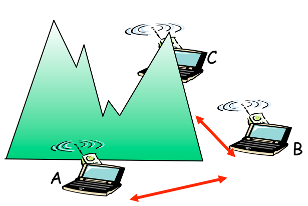


Dealing With Bit Errors

- Wireless vs. wired links
  - –Wired: most loss is due to congestion
  - –Wireless: higher, time-varying bit-error ate
- Dealing with high bit-error rates
  - –Sender could increase transmission power
    - Requires more energy (bad for battery-powered hosts)
    - Creates more interference with other senders
  - –Stronger error detection and recovery
    - More powerful error detection codes
    - Link-layer retransmission of corrupted frames

Wireless Links: Broadcast Limitations

- Wired broadcast links
  - – E.g., Ethernet bridging, in wired LANs
  - – All nodes receive transmissions from all other nodes
- Wireless broadcast: hidden terminal problem



•A and B hear each other
•B and C hear each other
•But, A and C do not

So, A and C are unaware of their interference at B.

Wireless Links: Broadcast Limitations

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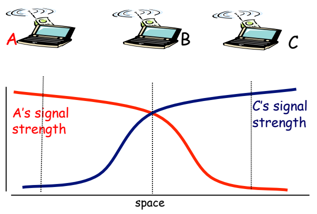
  - All nodes receive transmissions from all other nodes
- Wireless broadcast: fading over distance



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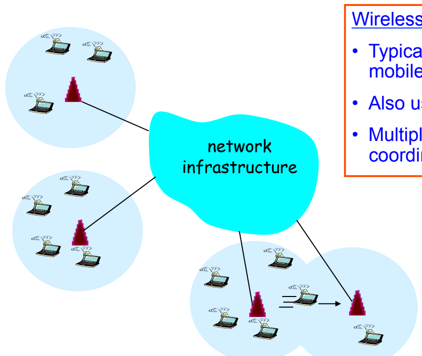
Example Wireless Link Technologies

- Data networks
  - Indoor (10-30 meters)
    - 802.11n: 200 Mbps
    - 802.11a and g: 54 Mbps
    - 802.11b: 5-11 Mbps
    - 802.15.1: 1 Mbps
  - Outdoor (50 meters to 20 kmeters)
    - 802.11 and g point-to-point: 54 Mbps
    - WiMax: 5-11 Mbps
- Cellular networks, outdoors
  - 3G enhanced: 4 Mbps
  - 3G: 384 Kbps
  - 2G: 56 Kbps

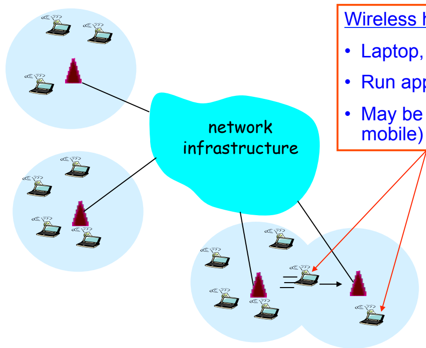
Wireless Network: Wireless Link



Wireless link

- Typically used to connect mobile(s) to base station
- Also used as backbone link
- Multiple access protocol coordinates link access

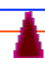
Wireless Network: Wireless Hosts

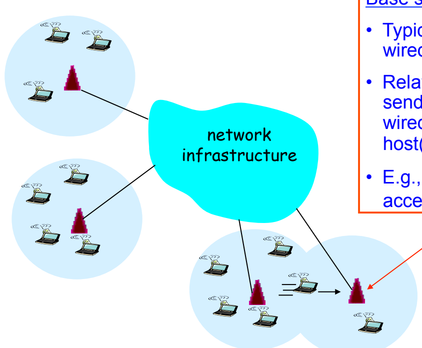


Wireless host

- Laptop, PDA, IP phone
- Run applications
- May be stationary (non-mobile) or mobile

Wireless Network: Base Station

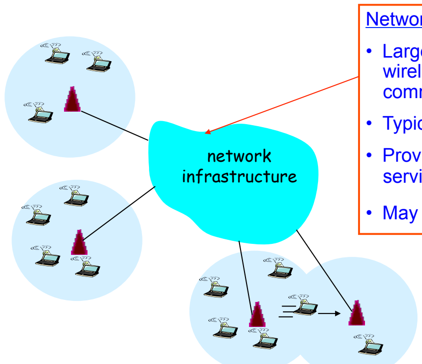




Base station

- 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

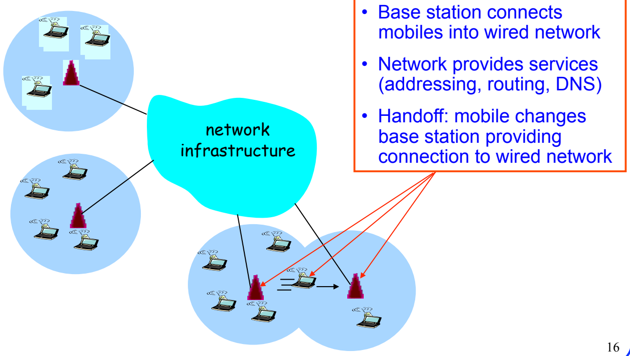
Wireless Network: Infrastructure



Network infrastructure

- Larger network with which a wireless host wants to communicate
- Typically a wired network
- Provides traditional network services
- May not always exist

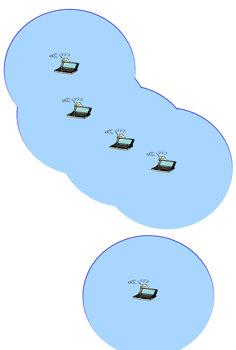
Scenario #1: Infrastructure Mode



Infrastructure mode

- Base station connects mobiles into wired network
- Network provides services (addressing, routing, DNS)
- Handoff: mobile changes base station providing connection to wired network

Scenario #2: Ad Hoc Networks



Ad hoc mode

- No base stations
- Nodes can only transmit to other nodes within link coverage
- Nodes self-organize and route among themselves

Infrastructure vs. Ad Hoc

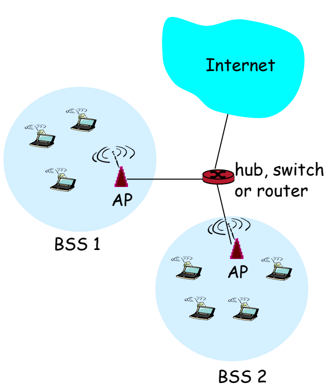
- Infrastructure mode
  - Wireless hosts are associated with a base station
  - Traditional services provided by the connected network
  - E.g., address assignment, routing, and DNS resolution
- Ad hoc networks
  - Wireless hosts have no infrastructure to connect to
  - Hosts themselves must provide network services
- Similar in spirit to the difference between
  - Client-server communication
  - Peer-to-peer communication

Different Types of Wireless Networks

	Infrastructure-based	Infrastructure-less
Single hop	Base station connected to larger wired network (e.g., WiFi wireless LAN, and cellular telephony networks)	No wired network; one node coordinates the transmissions of the others (e.g., Bluetooth, and ad hoc 802.11)
Multi-hop	Base station exists, but some nodes must relay through other nodes (e.g., wireless sensor networks, and wireless mesh networks)	No base station exists, and some nodes must relay through others (e.g., mobile ad hoc networks, like vehicular ad hoc networks)

WiFi: 802.11 Wireless LANs

802.11 LAN Architecture

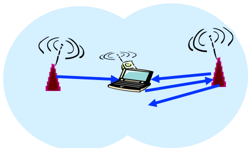


- Access Point (AP)
  - Base station that communicates with the wireless hosts
- Basic Service Set (BSS)
  - Coverage of one AP
  - AP acts as the master
  - Identified by an "network name" known as an SSID

SSID: Service Set Identifier

Channels and Association

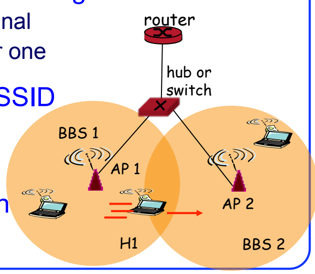
- Multiple channels at different frequencies
  - Network administrator chooses frequency for AP
  - Interference if channel is same as neighboring AP
- Access points send periodic beacon frames
  - Containing AP's name (SSID) and MAC address
  - Host scans channels, listening for beacon frames
  - Host selects an access point to associate with



- Beacon frames from APs
- Associate request from host
- Association response from AP

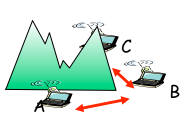
Mobility Within the Same Subnet

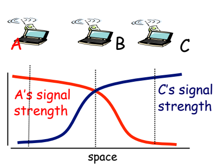
- H1 remains in same IP subnet
  - IP address of the host can remain same
  - Ongoing data transfers can continue uninterrupted
- H1 recognizes the need to change
  - H1 detects a weakening signal
  - Starts scanning for stronger one
- Changes APs with same SSID
  - H1 disassociates from one
  - And associates with other
- Switch learns new location
  - Self-learning mechanism



CSMA: Carrier Sense, Multiple Access

- Multiple access: channel is shared medium
  - Station: wireless host or access point
  - Multiple stations may want to transmit at same time
- Carrier sense: sense channel before sending
  - Station doesn't send when channel is busy
  - To prevent collisions with ongoing transfers
  - But, detecting ongoing transfers isn't always possible





CA: Collision Avoidance, Not Detection

- Collision detection in wired Ethernet
  - Station listens while transmitting
  - Detects collision with other transmission
  - Aborts transmission and tries sending again
- Problem #1: cannot detect all collisions
  - Hidden terminal problem
  - Fading
- Problem #2: listening while sending
  - Strength of received signal is much smaller
  - Expensive to build hardware that detects collisions
- So, 802.11 does *not* do collision detection

Medium Access Control in 802.11

- Collision avoidance, not detection
  - Once a station starts transmitting, send in its entirety
  - More aggressive collision-avoidance techniques
  - E.g., waiting a little after sensing an idle channel
  - To reduce likelihood two stations transmit at once
- Link-layer acknowledgment and retransmission
  - CRC to detect errors
  - Receiving station sends an acknowledgment
  - Sending station retransmits if no ACK is received
  - Giving up after a few failed transmissions

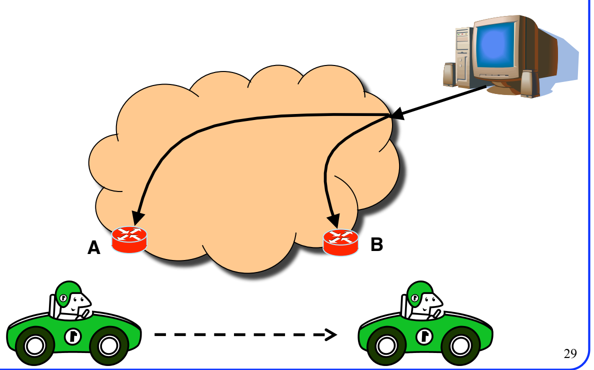
Host Mobility

Varying Degrees of User Mobility

- Moves only within same access network
  - Single access point: mobility is irrelevant
  - Multiple access points: only link-link layer changes
  - Either way, user is not mobile at the network layer
- Shuts down between changes access networks
  - Host gets new IP address at the new access network
  - No need to support any ongoing transfers
  - Applications have become good at supporting this
- Maintains connections while changing networks
  - Surfing the 'net while driving in a car or flying a plane
  - Need to ensure traffic continues to reach the host

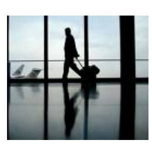
Maintaining Ongoing Transfers

- Seamless transmission to a mobile host



E.g., Keep Track of Friends on the Move

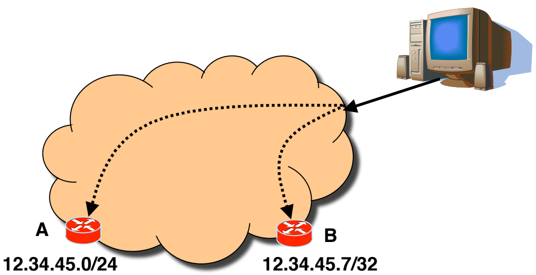
- Sending a letter to a friend who moves often
  - How do you know where to reach him?
- Option #1: have him update you
  - Friend contacts you on each move
  - So you can mail him directly
  - E.g., Boeing Connexion service



- Option #2: ask his parents when needed
  - Parents serve as "permanent address"
  - So they can forward your letter to him
  - E.g., Mobile IP

Option #1: Let Routing Protocol Handle It

- Mobile node has a single, persistent address
- Address injected into routing protocol (e.g., OSPF)

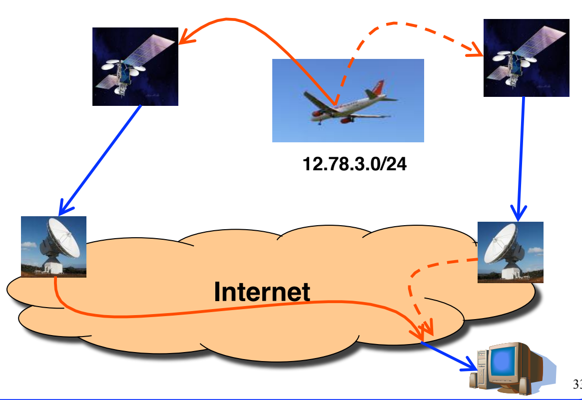


Mobile host with IP address 12.34.45.7

Example: Boeing Connexion Service

- Boeing Connexion service
  - Mobile Internet access provider
  - WiFi "hot spot" at 35,000 feet moving 600 mph
  - Went out of business in December 2006… ☹
- Communication technology
  - Antenna on the plane to leased satellite transponders
  - Ground stations serve as Internet gateways
- Using BGP for mobility
  - IP address block per airplane
  - Ground station advertises into BGP
  - http://www.nanog.org/mtg-0405/abarbanel.html

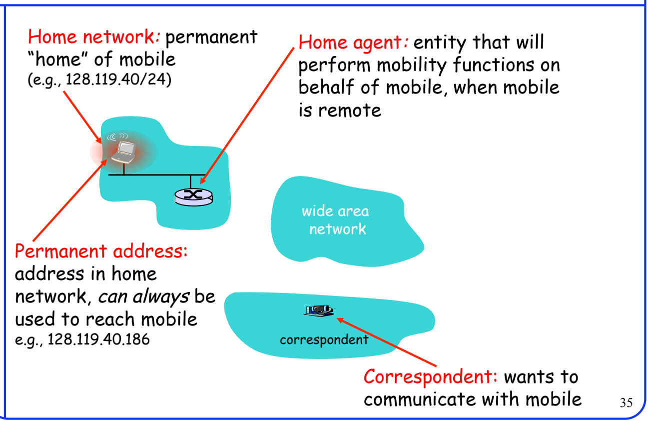
Example: Boeing Connexion Service



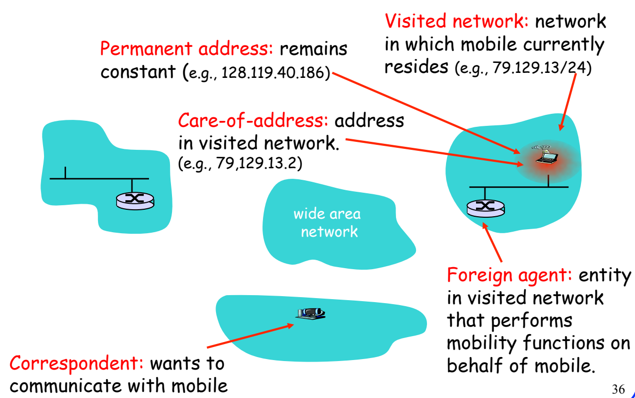
Summary: Letting Routing Handle It

- Advantages
  - No changes to the end host
  - Traffic follows an efficient path to new location
- Disadvantages
  - Does not scale to large number of mobile hosts
    - Large number of routing-protocol messages
    - Larger routing tables to store smaller address blocks
- Alternative
  - Mobile IP

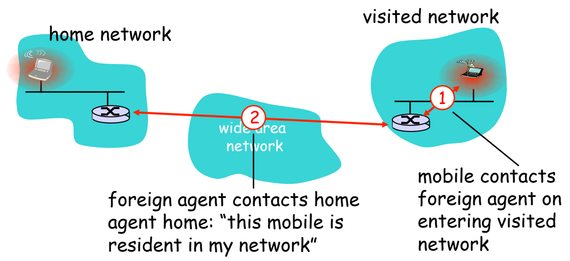
Option #2: Home Network and Home Agent



Visited Network and Care-of Address

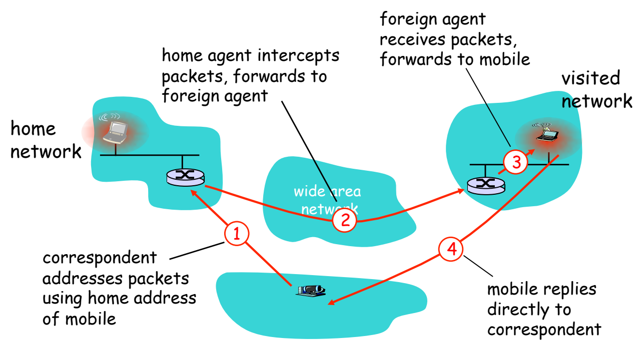


Mobility: Registration



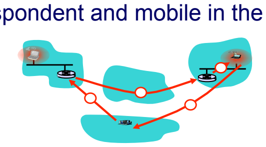
- Foreign agent knows about mobile
- Home agent knows location of mobile

Mobility via Indirect Routing

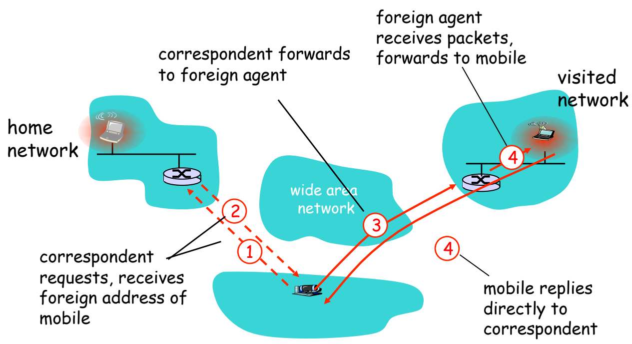


Indirect Routing: Efficiency Issues

- Mobile uses two addresses
  - Permanent address: used by correspondent (making mobile's location is transparent to correspondent)
  - Care-of-address: used by the home agent to forward datagrams to the mobile
- Mobile may perform the foreign agent functions
- Triangle routing is inefficient
  - E.g., correspondent and mobile in the same network



Mobility via Direct Routing



No longer transparent to the correspondent

Mobility Today

- Limited support for mobility
  - E.g., among base stations on a campus
- Applications increasingly robust under mobility
  - Robust to changes in IP address, and disconnections
  - E.g., e-mail client contacting the e-mail server
  - … and allowing reading/writing while disconnected
  - New Google Gears for offline Web applications
- Increasing demand for seamless IP mobility
  - E.g., continue a VoIP call while on the train
- Increasing integration of WiFi and cellular
  - E.g., dual-mode cell phones that can use both networks
  - Called Unlicensed Mobile Access (UMA)

Impact on Higher-Layer Protocols

- Wireless and mobility change path properties
  - Wireless: higher packet loss, not from congestion
  - Mobility: transient disruptions, and changes in RTT
- Logically, impact should be minimal …
  - Best-effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- But, performance definitely *is* affected
  - TCP treats packet loss as a sign of congestion
  - TCP tries to estimate the RTT to drive retransmissions
  - TCP does not perform well under out-of-order packets
- Internet not designed with these issues in mind

Conclusions

- Wireless
  - Already a major way people connect to the Internet
  - Gradually becoming more than just an access network
- Mobility
  - Today's users tolerate disruptions as they move
  - … and applications try to hide the effects
  - Tomorrow's users expect seamless mobility
- Challenges the design of network protocols
  - Wireless breaks the abstraction of a link, and the assumption that packet loss implies congestion
  - Mobility breaks association of address and location
  - Higher-layer protocols don't perform as well