



## 15-441: Computer Networking

### Lecture 23: Mobile and Wireless Networking

## Wireless Challenges



- Force us to rethink many assumptions
- Need to share airwaves rather than wire
  - Don't know what hosts are involved
  - Host may not be using same link technology
- Mobility
- Other characteristics of wireless
  - Noisy → lots of losses
  - Slow
  - Interaction of multiple transmitters at receiver
    - Collisions, capture, interference
  - Multipath interference

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## Overview



- Link layer challenges
- Internet mobility
- TCP Over Noisy Links

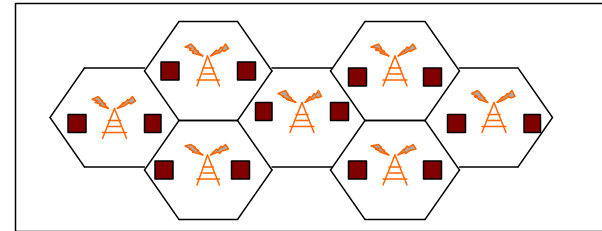
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## Cellular Reuse



- Transmissions decay over distance
  - Spectrum can be reused in different areas
  - Different "LANs"
  - Decay is  $1/R^2$  in free space,  $1/R^4$  in some situations



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## IEEE 802.11 Wireless LAN



- **802.11b**
  - 2.4-5 GHz unlicensed radio spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code
  - widely deployed, using base stations
- **802.11a**
  - 5-6 GHz range
  - up to 54 Mbps
- **802.11g**
  - 2.4-5 GHz range
  - up to 54 Mbps
- All use CSMA/CA for multiple access
- All have base-station and ad-hoc network versions

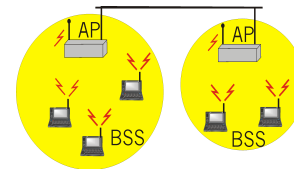
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## IEEE 802.11 Wireless LAN



- Wireless host communicates with a base station
  - Base station = access point (AP)
- **Basic Service Set (BSS)** (a.k.a. “cell”) contains:
  - **Wireless hosts**
  - **Access point (AP): base station**
- **BSS's combined to form distribution system (DS)**



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## Ad Hoc Networks



- **Ad hoc network:** IEEE 802.11 stations can dynamically form network *without* AP
- Applications:
  - Laptops meeting in conference room, car
  - Interconnection of “personal” devices



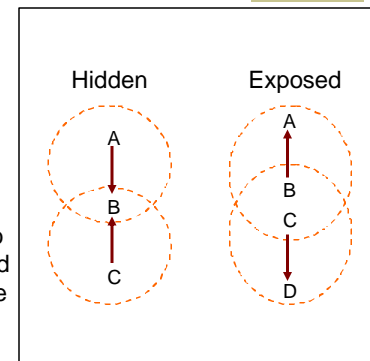
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## CSMA/CD Does Not Work



- Collision detection problems
  - Relevant contention at the **receiver**, not sender
    - Hidden terminal
    - Exposed terminal
  - Hard to build a radio that can transmit and receive at same time



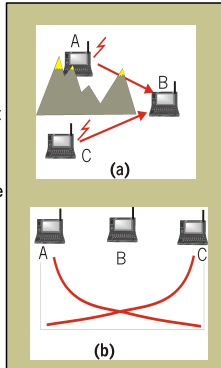
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## Hidden Terminal Effect



- **Hidden terminals:** A, C cannot hear each other
  - Obstacles, signal attenuation
  - Collisions at B
  - Collision if 2 or more nodes transmit at same time
- CSMA makes sense:
  - Get all the bandwidth if you're the only one transmitting
  - Shouldn't cause a collision if you sense another transmission
- Collision detection doesn't work
- **CSMA/CA: CSMA with Collision Avoidance**



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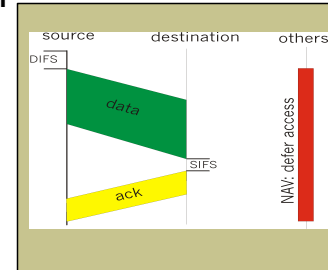
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## IEEE 802.11 MAC Protocol: CSMA/CA



- 802.11 CSMA: sender**
- If sense channel idle for **DIFS (Distributed Inter Frame Space)** then transmit entire frame (no collision detection)
  - If sense channel busy then binary backoff

- 802.11 CSMA receiver:**
- If received OK return ACK after **SIFS (Short IFS)** (ACK is needed due to hidden terminal problem)



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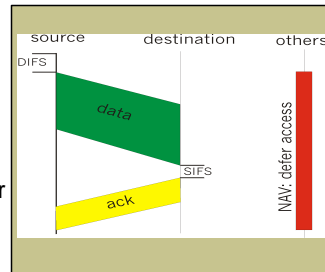
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## IEEE 802.11 MAC Protocol



### 802.11 CSMA Protocol: others

- **NAV:** Network Allocation Vector
- 802.11 frame has transmission time field
- Others (hearing data) defer access for NAV time units



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## Collision Avoidance Mechanisms



- **Problem:**
  - Two nodes, hidden from each other, transmit complete frames to base station
  - Wasted bandwidth for long duration !
- **Solution:**
  - Small reservation packets
  - Nodes track reservation interval with internal "network allocation vector" (NAV)

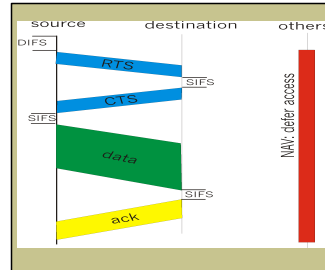
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## Collision Avoidance: RTS-CTS Exchange



- Explicit channel reservation
  - Sender: send short RTS: request to send
  - Receiver: reply with short CTS: clear to send
  - CTS reserves channel for sender, notifying (possibly hidden) stations
- RTS and CTS short:
  - collisions less likely, of shorter duration
  - end result similar to collision detection
- Avoid hidden station collisions



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## Overview



- Link layer challenges
- **Internet mobility**
- TCP Over Noisy Links

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## Routing to Mobile Nodes



- Obvious solution: have mobile nodes advertise route to mobile address/32
  - Should work!!!
- Why is this bad?
  - Consider forwarding tables on backbone routers
    - Would have an entry for each mobile host
    - Not very scalable

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## How to Handle Mobile Nodes? (Addressing)



- Dynamic Host Configuration (DHCP)
  - Host gets new IP address in new locations
  - Problems
    - Host does not have constant name/address → how do others contact host
    - What happens to active transport connections?

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## How to Handle Mobile Nodes? (Naming)



- Naming
  - Use DHCP and update name-address mapping whenever host changes address
  - Fixes contact problem but not broken transport connections

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## How to Handle Mobile Nodes? (Transport)



- TCP currently uses 4 tuple to describe connection
  - <Src Addr, Src port, Dst addr, Dst port>
- Modify TCP to allow peer's address to be changed during connection
- Security issues
  - Can someone easily hijack connection?
- Difficult deployment → both ends must support mobility

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## How to Handle Mobile Nodes? (Link Layer)



- Link layer mobility
  - Learning bridges can handle mobility → this is how it is handled at CMU
  - Encapsulated PPP (PPTP) → Have mobile host act like he is connected to original LAN
    - Works for IP AND other network protocols

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## How to Handle Mobile Nodes? (Routing 1)



- Multicast
  - Solves similar problem → how to route packets to different sets of hosts at different times
  - Can't we just reuse same solutions?
    - Don't really have solution for multicast either!

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## How to Handle Mobile Nodes? (Routing 2)



- Allow mobile node to keep same address and name
- How do we deliver IP packets when the endpoint moves?
  - Can't just have nodes advertise route to their address
- What about packets from the mobile host?
  - Routing not a problem
  - What source address on packet?
- Key design considerations
  - Scale
  - Incremental deployment

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## Basic Solution to Mobile Routing



- Same as other problems in Computer Science
  - Add a level of indirection
- Keep some part of the network informed about current location
  - Need technique to route packets through this location (interception)
- Need to forward packets from this location to mobile host (delivery)

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## Interception



- Somewhere along normal forwarding path
  - At source
  - Any router along path
  - Router to home network
  - Machine on home network (masquerading as mobile host)
- Clever tricks to force packet to particular destination
  - "Mobile subnet" – assign mobiles a special address range and have special node advertise route

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## Delivery



- Need to get packet to mobile's current location
- Tunnels
  - Tunnel endpoint = current location
  - Tunnel contents = original packets
- Source routing
  - Loose source route through mobile current location
- Network address translation (NAT)
  - What about packets from the mobile host?

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## Mobile IP (RFC 2290)

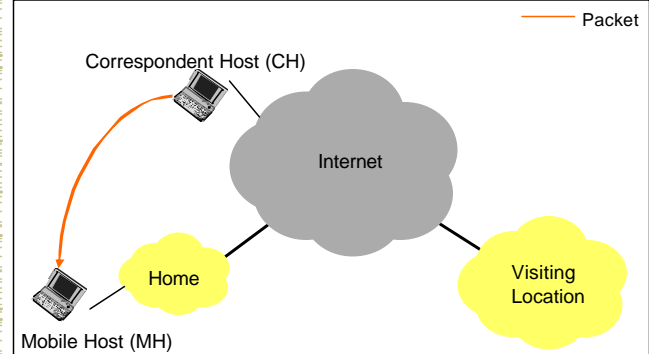


- Interception
  - Typically home agent – a host on home network
- Delivery
  - Typically IP-in-IP tunneling
  - Endpoint – either temporary mobile address or foreign agent
- Terminology
  - Mobile host (MH), correspondent host (CH), home agent (HA), foreign agent (FA)
  - Care-of-address, home address

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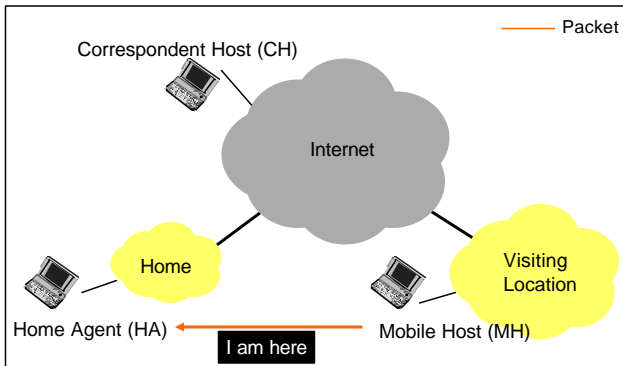
## Mobile IP (MH at Home)



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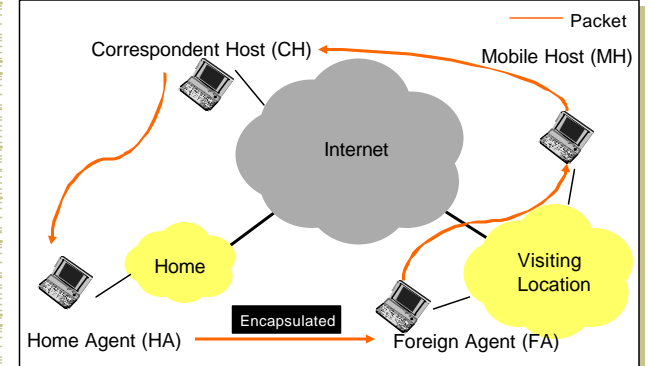
## Mobile IP (MH Moving)



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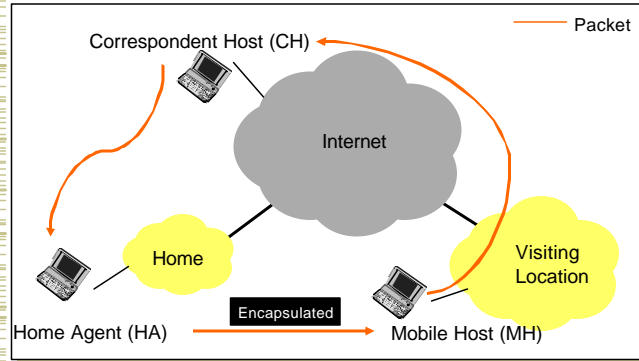
## Mobile IP (MH Away – Foreign Agent)



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## Mobile IP (MH Away - Collocated)



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## Other Mobile IP Issues



- Route optimality
  - Resulting paths can be sub-optimal
  - Can be improved with route optimization
    - Unsolicited binding cache update to sender
- Authentication
  - Registration messages
  - Binding cache updates
- Must send updates across network
  - Handoffs can be slow
- Problems with basic solution
  - Triangle routing
  - Reverse path check for security

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## Overview



- Link layer challenges
- Internet mobility
- **TCP Over Noisy Links**

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## TCP Problems Over Noisy Links



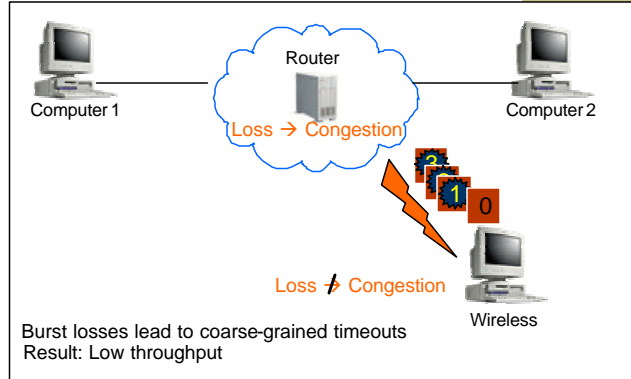
- Wireless links are inherently error-prone
  - Fades, interference, attenuation
  - Errors often happen in bursts
- TCP cannot distinguish between corruption and congestion
  - TCP unnecessarily reduces window, resulting in low throughput and high latency
- Burst losses often result in timeouts
- Sender retransmission is the only option
  - Inefficient use of bandwidth

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## Wireless Bit-Errors



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## Constraints & Requirements

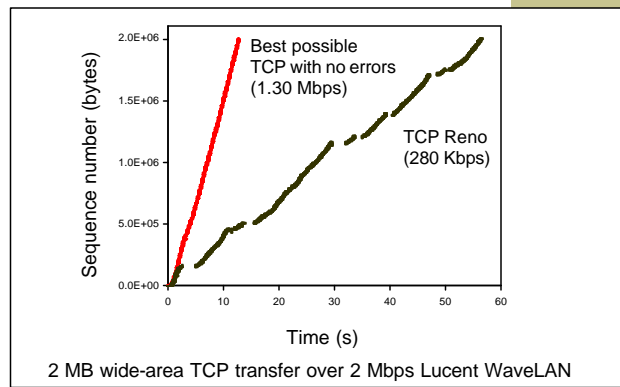


- Incremental deployment
  - Solution should not require modifications to fixed hosts
  - If possible, avoid modifying mobile hosts

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## Performance Degradation



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## Proposed Solutions



- End-to-end protocols
  - Selective ACKs, Explicit loss notification
- Split-connection protocols
  - Separate connections for wired path and wireless hop
- Reliable link-layer protocols
  - Error-correcting codes
  - Local retransmission

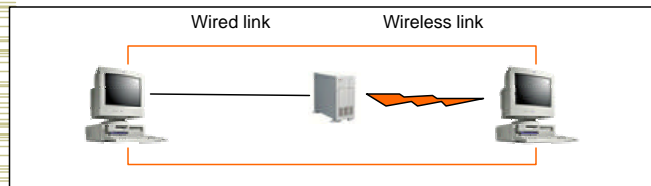
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## Approach Styles (End-to-End)



- Improve TCP implementations
  - Not incrementally deployable
  - Improve loss recovery (SACK, NewReno)
  - Help it identify congestion (ELN, ECN)
    - ACKs include flag indicating wireless loss
  - Trick TCP into doing right thing → E.g. send extra dupacks



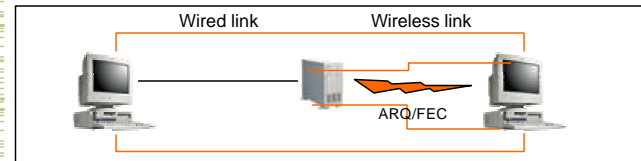
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## Approach Styles (Link Layer)



- More aggressive local retransmit than TCP
  - Bandwidth not wasted on wired links
- Possible adverse interactions with transport layer
  - Timer interactions
  - Interactions with fast retransmissions
  - Large end-to-end round-trip time variation
- FEC does not work well with burst losses



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## Overview



- Adapting Applications to Slow Links

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## Adapting Applications



- Applications make key assumptions
  - Hardware variation
    - E.g. how big is screen?
  - Software variation
    - E.g. is there a postscript decoder?
  - Network variation
    - E.g. how fast is the network?
    - Reason why we are discussing in this class ☺
- Basic idea – distillation
  - Transcode object to meet needs of mobile host

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## Transcoding Example



- Generate reduced quality variant of Web page at proxy
  - Must predict how much size reduction will result from transcoding
  - How long to transcode?
- Send appropriate reduced-size variant
  - Target response time?

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## Source Adaptation



- Can also just have source provide different versions
  - Common solution today
  - No waiting for transcoding
  - Full version not sent across network
  - Can't handle fine grain adaptation

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