CS640: Introduction to Computer Networks

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Lecture 22 -
Wireless Networking

Wireless Challenges

- Force us to rethink many assumptions
- Need to share airwaves rather than wire
- 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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The Road Ahead

- Internet mobility
- TCP over noisy links
- Link layer challenges

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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 routing tables on backbone routers
    - Would have an entry for each mobile host
      - No aggregation
    - Not very scalable
- What are some possible solutions?

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Handling 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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Handling 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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Handling 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

Handle Mobile Nodes: Link Layer

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

Handling Mobile Nodes: Routing

- 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? → this can cause problems
- Key design considerations
  - Scale
  - Incremental deployment

Basic Solution to Mobile Routing

- Same as other problems in computer science
  - Add a level of indirection
- Keep some part of the network fixed, and informed about current location of mobile node
  - 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

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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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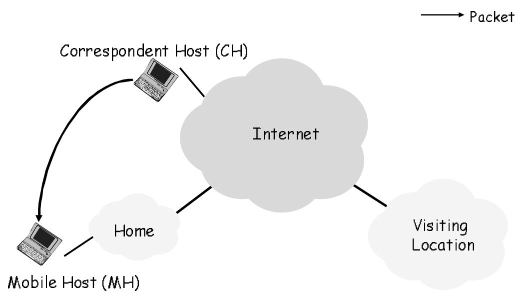
Mobile IP (MH at Home)



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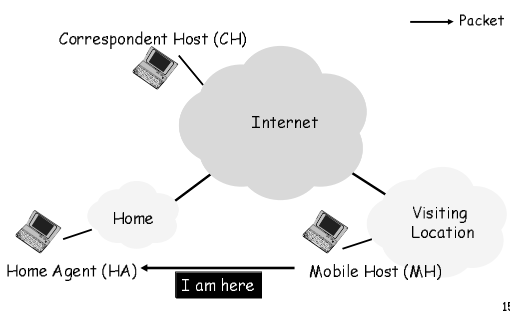
Mobile IP (MH Moving)



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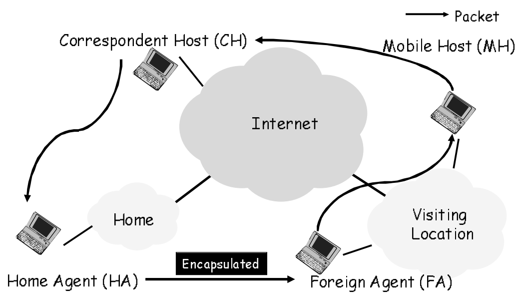
Mobile IP (MH Away – FA)



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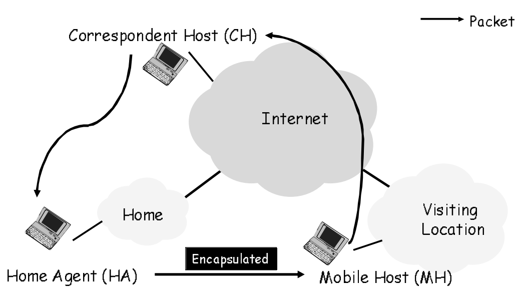
Mobile IP (MH Away - Collocated)



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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 (direct routing)
- Authentication
  - Registration messages
- Must send updates across network
  - Handoffs can be slow
- Problems with basic solution
  - Triangle routing
  - Reverse path check for security

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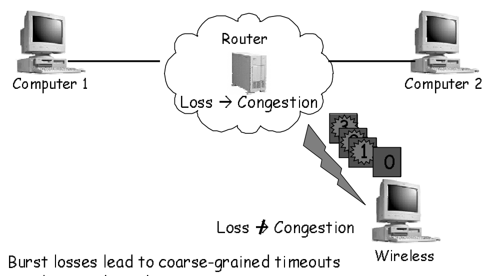
Wireless Bit-Errors



Burst losses lead to coarse-grained timeouts
Result: Low throughput

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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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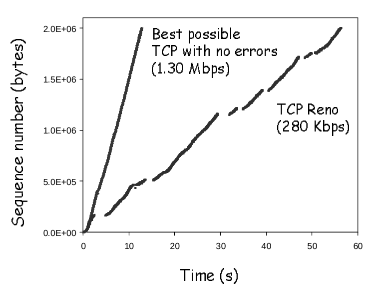
Performance Degradation



2 MB wide-area TCP transfer over 2 Mbps Lucent WaveLAN

Proposed Solutions

- Incremental deployment
  - Solution should not require modifications to fixed hosts
  - If possible, avoid modifying mobile hosts
- 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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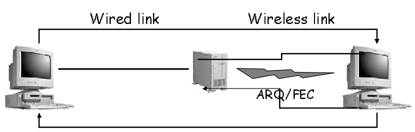
Approach Styles (Link Layer)

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



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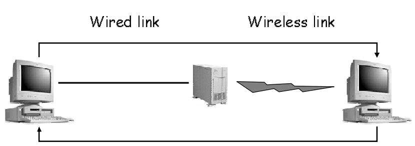
Approach Styles (End-to-End)

- 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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IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-2.5 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
  - 2.4-2.5 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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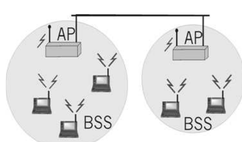
IEEE 802.11 Wireless LAN

- 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



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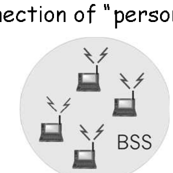
Ad Hoc Networks

- 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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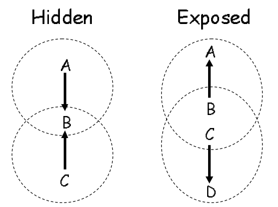
CSMA/CD Does Not Work

- 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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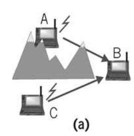
Hidden Terminal Effect

- 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 C**ollision **A**voidance



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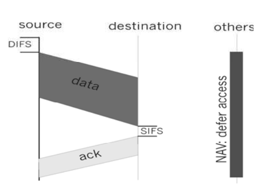
IEEE 802.11 MAC Protocol: CSMA/CA

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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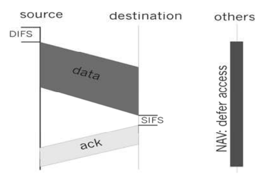
IEEE 802.11 MAC Protocol

802.11 CSMA Protocol: others

- NAV: Network Allocation Vector; maintained by each node
- 802.11 RTS frame has transmission time field
- Others (hearing CTS) defer access for NAV time units
- Reserve bandwidth for NAV time units

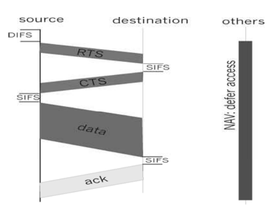


Collision Avoidance Mechanisms

- 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)

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
- Not widely used/implemented
  - Consider typical traffic patterns



Summary

- Many assumptions built into Internet design
  - Wireless forces reconsideration of issues
- Link-layer
  - Spatial reuse (cellular) vs wires
  - Hidden/exposed terminal
  - CSMA/CA (why CA?) and RTS/CTS
- Network
  - Mobile endpoints – how to route with fixed identifier?
  - Link layer, naming, addressing and routing solutions
    - What are the +/- of each?
- Transport
  - Losses can occur due to corruption as well as congestion
    - Impact on TCP?
  - How to fix this → hide it from TCP or change TCP

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