15-744: Computer Networking

L-8 Mobile Routing

Mobile Routing

- Mobile IP
- Ad-hoc network routing
- Assigned reading
  - [Joh96] Scalable Support for Transparent Mobile Host Internetworking
  - [BMJ+98] Performance Comparison of Multi-Hop Wireless Ad Hoc Routing Protocols

Overview

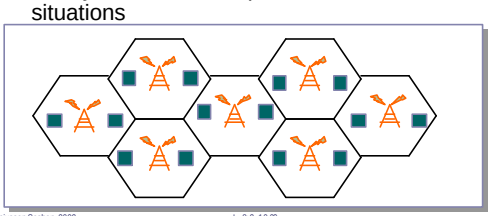
- Link layer challenges
- Internet mobility
- Ad-hoc routing

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

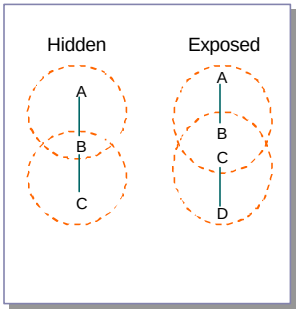
Cellular Reuse

- 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



CSMA/CD Does Not Work

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



RTS/CTS Approach

- Before sending data, send Ready-to-Send (RTS)
- Target responds with Clear-to-Send (CTS)
- Others who hear defer transmission
  - Packet length in RTS and CTS messages
- If CTS is not heard, or RTS collides
  - Retransmit RTS after binary exponential backoff

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How to Handle Mobile Nodes?

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

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

Handling Mobile Node

- 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
- 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!

Handling Mobile Nodes (Routing)

- Allow mobile node to keep same address and name
- How do we deliver IP packets when the endpoint moves?
  - Why can't we 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

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)

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

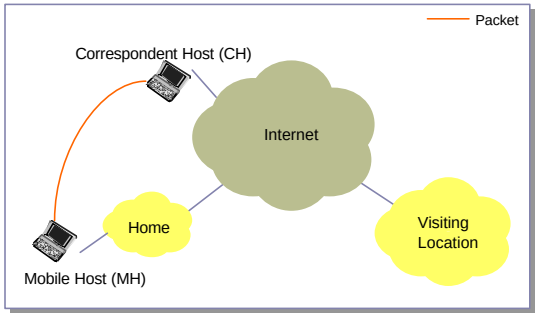
Delivery

- 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?

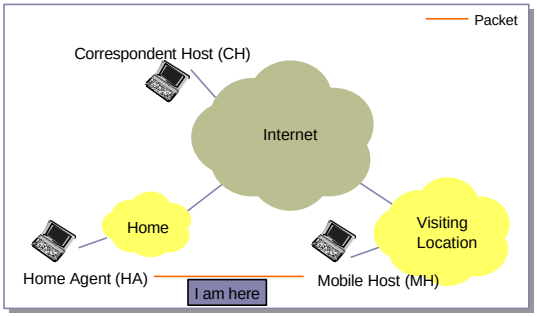
Mobile IP (RFC 2290)

- Interception
  - Typically home agent – hosts 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

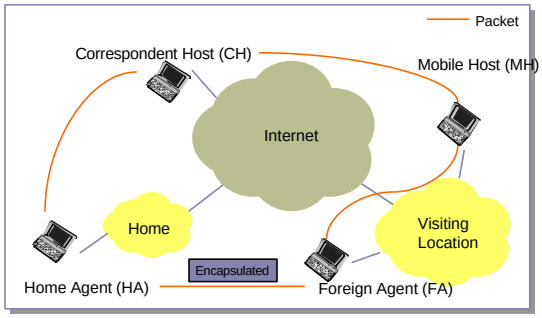
Mobile IP (MH at Home)



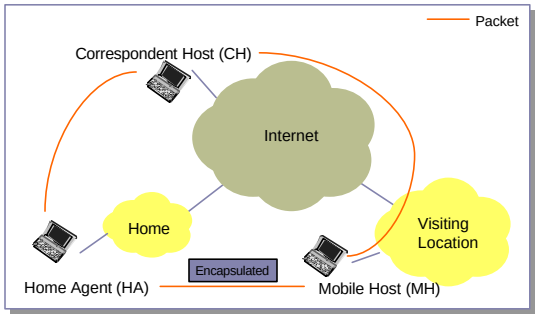
Mobile IP (MH Moving)



Mobile IP (MH Away – Foreign Agent)



Mobile IP (MH Away - Collocated)



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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Ad Hoc Routing

- Create multi-hop connectivity among set of wireless, possibly moving, nodes
- Mobile, wireless hosts act as forwarding nodes as well as end systems
- Need routing protocol to find multi-hop paths
  - Needs to be dynamic to adapt to new routes, movement
  - Interesting challenges related to interference and power limitations
  - Low consumption of memory, bandwidth, power
  - Scalable with numbers of nodes
  - Localized effects of link failure

Problems Using DV or LS

- DV protocols may form loops
  - Very wasteful in wireless: bandwidth, power
  - Loop avoidance sometimes complex
- LS protocols: high storage and communication overhead
- More links in wireless (e.g., clusters) - may be redundant → higher protocol overhead

Problems Using DV or LS

- Periodic updates waste power
  - Tx sends portion of battery power into air
  - Reception requires less power, but periodic updates prevent mobile from “sleeping”
- Convergence may be slower in conventional networks but must be fast in ad-hoc networks and be done without frequent updates

Proposed Protocols

- Destination-Sequenced Distance Vector (DSDV)
  - hbh, DV protocol, destinations advertise sequence number to avoid loops, not on demand
- Temporally-Ordered Routing Algorithm (TORA)
  - On demand creation of hbh routes based on link-reversal
- Dynamic Source Routing (DSR)
  - On demand source route discovery
- Ad Hoc On-Demand Distance Vector (AODV)
  - Combination of DSR and DSDV: on demand route discovery with hbh routing

DSR Concepts

- Source routing
  - No need to maintain up-to-date info at intermediate nodes
- On-demand route discovery
  - No need for periodic route advertisements

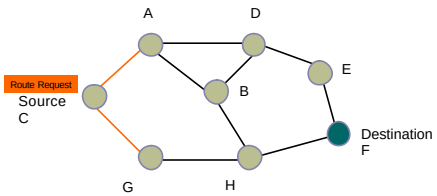
DSR Components

- Route discovery
  - The mechanism by which a sending node obtains a route to destination
- Route maintenance
  - The mechanism by which a sending node detects that the network topology has changed and its route to destination is no longer valid

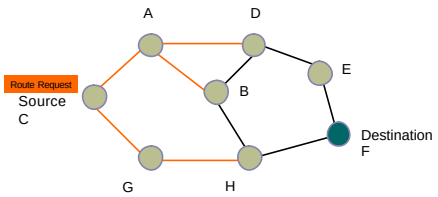
DSR Route Discovery

- Route discovery - basic idea
  - **Source** broadcasts route-request to **Destination**
  - Each node forwards request by adding own address and re-broadcasting
  - Requests propagate outward until:
    - Target is found, or
    - A node that has a route to Destination is found

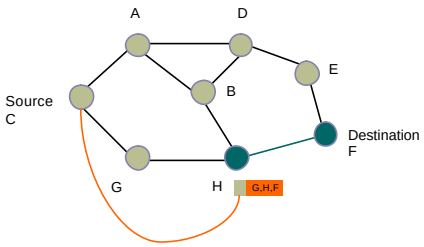
C Broadcasts Route Request to F



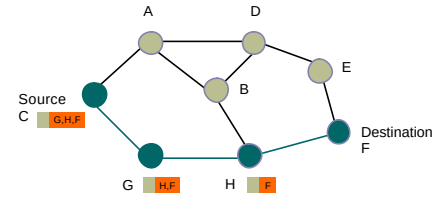
C Broadcasts Route Request to F



H Responds to Route Request



C Transmits a Packet to F



Forwarding Route Requests

- A request is forwarded if:
  - Node is not the destination
  - Node not already listed in recorded source route
  - Node has not seen request with same sequence number
  - IP TTL field may be used to limit scope
- Destination copies route into a Route-reply packet and sends it back to **Source**

Route Cache

- All source routes learned by a node are kept in Route Cache
  - Reduces cost of route discovery
- If intermediate node receives RR for destination and has entry for destination in route cache, it responds to RR and does not propagate RR further
- Nodes overhearing RR/RP may insert routes in cache

Sending Data

- Check cache for route to destination
- If route exists then
  - If reachable in one hop
    - Send packet
  - Else insert routing header to destination and send
- If route does not exist, buffer packet and initiate route discovery

Discussion

- Source routing is good for on demand routes instead of a priori distribution
- Route discovery protocol used to obtain routes on demand
  - Caching used to minimize use of discovery
- Periodic messages avoided
- But need to buffer packets

Next Lecture: TCP Basics

- TCP reliability
- Assigned reading
  - [FF96] Simulation-based Comparisons of Tahoe, Reno, and SACK TCP

Key Things You Should Know Already

- Port numbers
- TCP/UDP checksum
- Sliding window flow control
  - Sequence numbers
- TCP connection setup