Quick announcement

- My office hours tomorrow are moved to 12pm

Last class

- Multicast communications
  - One-to-many
  - Publish and subscribe model (receiver-based)

- Routing protocols
  - Per source tree routing
    - RPF, RPB, RPM
    - Builds efficient trees
  -Shared tree
    - Unicast to rendezvous point
    - More complex, fragile, hard to manage
    - Trees inefficient by as much as 2x
  - Only requires G state on routers

Today’s issues

- What are implications of hosts that move?
  - Remember routing? It doesn’t work anymore…

- Problem review
- Design issues
- Case studies
  - Mobile IP [Johnson96]
  - TCP Migrate [Snoeren et al00]

The Mobility Problem

- Implicit assumption that Internet hosts are fixed
  - IP addresses used to name hosts; cached by higher layers
  - IP routing breaks if addresses change location. Why?
  - Unfortunately, the buying public likes mobility

Problems

- How does a mobile host get a local IP address?

- How do you know which IP address to use when sending to a mobile host?

- If a host moves during communication how do you know how to migrate state to the new IP address?

- Backwards compatibility (higher-layer state caching)
Application demands

- Geographic scope
  - Switching 802.11 LANs at UCSD vs visiting IBM in Zurich
- Rate of change
  - Cell-phone in airplane vs hotel room dial-in
- Continuity
  - State associated with session (e.g., ordering plane tickets)
- Interactivity
  - Cell-phone handoff?
- Remote accessibility
  - Client vs Server

Some simple solutions

- Datalink layer mobility
  - AP’s connected to single virtual LAN (UCSD campus solution)
  - Underlying Ethernet switches “learn” which MAC addresses
    they use and tell other switches
  - Pro: transparent to all higher layers
  - Con: Local scope only
- Dynamic Host Configuration Protocol (DHCP)
  - Request IP address dynamically (special broadcast address)
  - How do you get contacted at new IP address?
    - One solution: dynamic DNS
  - Authentication issues (who can use 802.11 in AP&M?)
  - Pro: Great over longer time scales...
  - Con: What happens during a session?

Mobile IP: Johnson96

- Current IETF proposed standard for mobility
  - Dates back to research in the early 90s
  - IPv4 (RFC 2002), IPv6 version is roughly the same
- Design constraints
  - Network layer solution
  - Only requires changes to mobile hosts
  - Stationary hosts oblivious to mobility
  - Incrementally deployable

Mobile IP Approach

- Mobile Host (MH) has two addresses
  - Home address
    - Never changes, uniquely identifies the host
    - In “home network”
  - Care-of address
    - Will change, perhaps frequently
    - In “foreign network”
    - Related to current location (IP routing gets it to the right place)

Home and Foreign Agents

- Home agent (HA) implements level of indirection between the mobile host and correspondents
  - Accepts traffic sent to home address
    - What about requests from home network?
  - Tunnels traffic to the mobile host (using care-of address)
  - And vice versa, correspondent none the wiser
- Foreign agent (FA) represents mobile in foreign network
  - Foreign agent can be care-of address
    - Mobile host does not need its own address in foreign network
    - Potential advantage: deal with local mobility locally

Mobile IP (MH at Home)
Mobile IP (MH Moving)

Visiting Location

Home

Mobile Host (MH)

Home Agent (HA)

Foreign Agent (FA)

Packet

Mobile IP (MH Away)

Visiting Location

Home

Mobile Host (MH)

Home Agent (HA)

Foreign Agent (FA)

Encapsulated Packet

Mobile IP Issues

To make all this happen, a number of issues have to be addressed:

- Discovering agents
- Registering addresses with agents (establishing bindings)
- Authentication
- Tunneling
- Performance (!)

Agent Discovery

Agent discovery enables a mobile host:

- To notice when it changes networks
- To notice when it is home again
- When home, take down the tunnel
- To find a foreign agent to register with
- Agents multicast agent advertisements locally
  - Beacons that tell the mobile who it can hear
  - Start in network A, move to network B
  - Lack of A’s beacons and presence of B’s tells mobile it has switched networks
- Mobile can also multicast an agent solicitation
- Why does multicast work here?

Registration

Mobiles must register care-of addresses with their home agents:

- So that the home agent knows where to tunnel packets
- Registration needs to be updated when location changes

Multiple steps

- Registration requests first go to foreign agent, then to home agent, which replies to foreign agent, which forwards back to the mobile
- Lifetimes
  - Registrations have TTLs

Registration Authentication

Registration requests can be used by attackers to hijack tunnels from home agent:

- Hey, send all the mobile’s traffic to me now

Need to authenticate that a registration:

- Came from mobile host (authenticity)
- Has not been altered (integrity)
- Has been sent recently (freshness)

Mechanisms:

- Shared keys (mobile and home are from same admin domain)
- MD5 digests (secure hash over the data)
- Nonces or timestamps
**Tunneling**

- Home agent and mobile communicate using a tunnel
  - IP in IP encapsulation
- Original packet
  - Correspondent address (src) → mobile home address (dest)
  - Gets sent to home agent
- Tunnel packet
  - Encapsulates original packet
  - Home agent (src) → care-of address (dest)
  - Gets sent to foreign agent (or mobile, depending on care-of)
  - Mobile can respond back directly (which source address?)
- Asides
  - Bit of overhead (20 byte header for every packet...poor telnet)

**Performance**

- The good: No overhead in local operation
  - Home agent out of picture, no longer intercepts packets
  - The common case?
- The bad: Significant overhead in remote operation
  - Triangle routing: Packets between two hosts separated by inches can travel 1000s of miles
  - Wide-area effects can determine “local” connection performance
  - The uncommon case? Even so, a steep price to pay
  - Hence: Route optimization

**Route Optimization**

- Route optimization shortcuts the triangle
  - Correspondents can learn and use mobile care-of addresses
  - Tunnel packets directly to care-of address, skip home agent
  - Requires changes to correspondents
    - Or to routers
- Issues
  - Binding cache updates (consistency)
  - Binding update authentication (more trust)
  - Yet more complexity
  - Necessary for scalability?
  - End result: Mobile IP is not widely deployed

**Alternative: Transport-level mobility [Snoeren00]**

- Same goals
  - Do not disrupt connections when network address changes
- Different approach
  - Combination of DNS naming and connection migration
  - Naming + transport (vs. network-layer w/ Mobile IP)
  - Based upon observation of how connections are made from mobile
- Three components
  - Addressing
  - Locating mobile hosts
  - Connection migration

**Addressing**

- Mobiles obtain a network-local IP address
  - No home agent, no home address
  - No foreign agent
  - No tunneling
  - Communication between correspondent and mobile uses addresses directly
- Problem: How does the correspondent learn the mobile’s address?
  - If the mobile initiates the connection, the mobile tells the correspondent its address with the SYN packet
  - What about mobile servers?

**Locating Mobiles**

- Observation: Whenever connections are established, a DNS lookup is performed (e.g. www.yahoo.com)
- Idea: Use the DNS lookup to return latest mobile address to correspondent
  - In Mobile IP, home address is used to uniquely identify mobile
  - In Transport-level mobility, DNS name is used for this purpose
  - When mobile moves and obtains a new IP address, it updates its DNS entry (e.g. myhost.ucsd.edu is now at 132.239.10.1)
Connection Migration

- Problem: What about existing open connections?
- Solution: TCP Connection Migration
  - New TCP Option: Migrate
  - Negotiated with Migrate-Permitted option in SYN
  - Requires modification to TCP stacks at both ends

Basic Idea

- We have an open connection between correspondent (src) and mobile (dest)
  - Doesn’t matter who initiated the connection
  - Connection represented by
    » <src IP, src port, dest IP, dest port>
  - Mobile moves
    » Now has new <dest IP*, dest port*>
  - Want to change connection to
    » <src IP, src port, dest IP*, dest port*>  
  - Mobile creates a new connection to the correspondent, forces correspondent to migrate old connection to new one
  - Uses token to show that connections are associated

TCP Migration example

1. Initial SYN
2. SYN/ACK
3. ACK (with data)
4. Normal data transfer
5. Migrate SYN
6. Migrate SYN/ACK
7. ACK (with data)

Issues

- Pro
  - No change to routing infrastructure
  - No triangle routes
  - Simple
- Con
  - Requires changes to both end-points
  - TCP-specific
Next time

- Midterm 😊