Announcements

Lectures 1-21, 23 are available.
Homework 5 is out, due last day of classes.
Are you close to finishing your projects?

ALL PROJECTS ARE DUE ON DECEMBER 10!
NO EXTENSIONS OR INCOMPLETES WILL BE GIVEN!
The Mobility Problem

• How to move hosts around the Internet and maintain connectivity.

• Remember: address is where the host is (attached to).
  – Network attachment point.

• Remember: addresses are hierarchically assigned.
  – Necessary for scaling.
  – Reflected in the routing architecture.

• To move a host to a different attachment point:
  – Change its IP address.
    or
  – Eliminate hierarchical routing.
Changing the Routing Architecture

• Propagate host routes (/32s or /128s).
  - We already have problems maintaining 100K routes.
  - 1M (or 4G) routes are unrealistic.
  - Not enough memory.
  - Not enough processing speed.
• Especially if they move rapidly.

• Routing scales because addresses are aggregated.
• We’ve already seen the problems with multihoming.
Changing the IP Address

• Just get a new address (with DHPC).
  – Works for web browsing!

• Cannot maintain established TCP connections.
  – Remember: IP address is also used as an Endpoint Identifier (EID).

• Applications sometimes have knowledge of IP address.
  – This also breaks NAT (that’s good!).

• Works if mobile only originates connections.
  – Or there exists some other location service.

• No matter what we do, something will have to change.
  – Or break!
Mobility at the Link Layer?

- Hide the fact that we changed networks.
- Works for *micromobility*:
  - Small geographical area.
  - Nearby cells.
  - Flat routing and/or bridging is economical.
- 802.11 does this.
- Moving ports on switches also does this.
- Link layer could be extended to provide this mobility.
  - L2TP?
- Different solution for each link layer type.
- Still does not give us mobility between network interfaces.
Mobility at the Transport Layer?

- Tell the transport protocol that we changed IP address.
- Remote host would also need to be informed.
- All transport protocols would have to become mobility-aware.
- Still does not address the problem of finding the mobile’s current address.
Mobility at the Application Layer?

• Tear down TCP (or whatever) connections.
• Re-open connections after you’ve moved.
• Applications that care about mobility can change.

• Who initiates the reconnection?
  – What if both hosts are moving at the same time?

• Also does not address the problem of finding the mobile’s current address.
Back to the Network Layer

- Network layer is choke-point in the network stack.

- “Hourglass” figure:

- Putting mobility in the network layer allows both higher- and lower-layer protocols to use it.
Network Layer Mobility

• Remember: Duality of IP addresses:
  – Locator (where in the topology a node is attached).
  – Name (used by protocols to identify node).

• Solution: give mobile two addresses.
  – Use one as a locator.
  – Use the other as a name.

• When locator ≠ name, use **tunneling** to get from one to the other.

• Effectively: introduce a new link-layer that is actually IP.
  – Use IP as a switching fabric for itself.
Example

- Traffic **to** mobile is routed to its **name** ("Home Address").
- The **Home Agent** (a router) picks it up.
- Tunnels it to its **locator** ("Care-of Address").
- Traffic **from** mobile may have to be **reverse-tunneled**.

```
128.59.0.0/16           128.59.22.31 (coa)
12.2.0.0/16              12.2.24.19 (ha)
```

Packet to 12.2.24.19
Location, Location, Location!

• Even if we solve the addressing/routing problem…
• … we still need to find where the mobile went.

• How to map from name to location.
  – This is a problem regardless of the routing solution.

• In network-layer mobility:
  – How to find the care-of address from the home address.
  – A: Mobile tells the Home Agent.
  – Home agent tunnels traffic to mobile.
Mobile IP

• Being designed since 1990.
• John Ioannidis, Dan Duchamp, Gerald Q. Maguire Jr.: *IP-Based Protocols for Mobile Internetworking*. ACM SIGCOMM’91, Zürich, Switzerland, September 1991.

• IETF WG since March 1992.
  – Longest-running IETF WG.

• RFC3344
• draft-ietf-mobileip-ipv6-19.txt
Assumptions/Requirements

- No constraints on IP addresses.
  - Any host can become mobile.
- Nodes don’t change addresses too frequently (<1Hz).
- Routing is still by destination address only.
- Change location regardless of distance.
- Change interface.
- Micro-mobility is still better solved in the link layer.
Architectural Components

• *Mobile Node.*
  – A host that changes Network Attachment Points without changing its IP address.
  – *Home address.*
  – *Home network.*

• *Home Agent.*
  – A router that keeps track of Mobile Nodes and tunnels traffic to and from them.

• *Foreign Agent.*
  – A router that provides services to a mobile node away from its *home network.*
  – May terminate the tunnel from the HA.
Protocol Outline

- Mobility Agents (HA or FA) advertise their presence.
  - Extension to Router Advertisement ICMP packet (RFC1256).
  - Sent to 224.0.0.1 or 255.255.255.255.
- Alt: mobile nodes solicit a Router Advertisement.
  - Extension to Router Solicitation ICMP packet.
- Mobile receives Router Advertisement and determines whether it is on Home Network or Foreign Network.
- On home network: operates without mobility extensions.
  - If returning, de-register from HA.
- On foreign network:
  - Obtain care-of address.
  - Registers COA with HA.
Care-of Addresses

• Foreign Agent Care-of Address:
  – An IP address of the FA.
  – Packets are tunneled to the FA.
  – Delivered locally using mobile’s HA.
    • Mobile has registered with the FA.
  – Preferred: many mobiles share the FA COA.

• Co-located care-of Address:
  – An (additional) IP address of the mobile.
  – Acquired through different means (e.g., DHCP).
  – Mobile serves as its own tunnel endpoint.
  – Advantage: mobile can function without FA.
Routing Inefficiencies

192.4.0.0/16
HA

192.4.13.134 (ha)
128.59.22.37 (coa)

Mobile
12.2.24.19 (ha)
128.59.22.31 (coa)

128.59.0.0/16

12.2.0.0/16
HA

128.59.0.0/16
Mobile IPv6

• Mobile IPv6: much cleaner design.
  – No installed base.
  – Still opted for network-layer mobility.

• MIPv6 supports the notion of the Binding Update.
  – A Mobile Host can tell its Correspondent Host its COA.
    • Whether mobile or stationary.
  – Still tunneling, but the tunnel does not go all over the world.

• Even more security issues (RTFIDs).
Where *is* Mobile IP?

- Cisco, Solaris now have support.
- Even less deployment than Multicast.
- Last hope: 3GPP2.