Last Lecture: Data Link Layer

1. Design goals and issues
2. (More on) Error Control and Detection
3. Multiple Access Control (MAC)
4. Ethernet, LAN Addresses and ARP
5. Hubs, Bridges, Switches
6. Wireless LANs ✔
7. Mobile Networking
8. WLAN Security
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   o Credits: some slides from Jennifer Rexford @ Princeton
8. WLAN Security
Varying Degrees of User Mobility

- Moves only within same access network
  - Single access point: mobility is irrelevant
  - Multiple access points: only link-link layer changes
  - Either way, users is not mobile at the network layer

- Shuts down between changes access networks
  - Host gets new IP address at the new access network
  - No need to support any ongoing transfers
  - Applications have become good at supporting this

- Maintains connections while changing networks
  - Surfing the ‘net while driving in a car or flying a plane
  - Need to ensure traffic continues to reach the host
Maintaining Ongoing Transfers

- Seamless transmission to a mobile host
**E.g., Keep Track of Friends on the Move**

- Sending a letter to a friend who moves often
  - How do you know where to reach him?
- Option #1: have him update you
  - Friend contacts you on each move
  - So you can mail him directly
  - E.g., *Boeing Connexion service*
- Option #2: ask his parents when needed
  - Parents serve as “permanent address”
  - So they can forward your letter to him
  - E.g., Mobile IP
Option #1: Let Routing Protocol Handle It

- Mobile node has a single, persistent address
- Address injected into routing protocol (e.g., OSPF)

Mobile host with IP address 12.34.45.7

A 12.34.45.0/24

B 12.34.45.7/32

Mobile host with IP address 12.34.45.7
Example: Boeing Connexion Service

- Example: Boeing Connexion service
  - Mobile Internet access provider
  - WiFi “hot spot” at 35,000 feet moving 600 mph

- Communication technology
  - Antenna on the plane to leased satellite transponders
  - Ground stations serve as Internet gateways

- Using BGP for mobility
  - IP address block per airplane
  - Ground station advertises into BGP
Example: Boeing Connexion Service

12.78.3.0/24

Internet
In-Flight Wi-Fi Access

- **Boeing Connexion Service**
  - Cost structure horrible: installation took weeks, gears too heavy (800 pounds) $\Rightarrow$ Cost > benefit
  - Worked well! Went out of business in December 2006 ...

- **2009: other in-flight ISPs started to “take off”**
  - PDAs, Laptops, Social Networking more popular $\Rightarrow$ no one users “need” Internet access in-flight
  - Better cost structures
  - **AirCell & Row 44** in the US
  - **OnAir** in Europe and the Middle East
Some restrictions

- No US airline allows VoIP calling, voice chats, video chats, or any variant thereof
  - People prefer quiet flights
  - Aircell blocks well-known ports
  - If you use VPN, you can do it anyhow!
AirCell

- In a 2006 auction, AirCell won
  - 3 MHz in the 800 MHz band
  - Split into 1.5 MHz for uplink and 1.5 MHz for downlink

- AirCell uses 3G-cellular technology
  - Qualcomm's *EVDO Rev. A* service
  - Few Mbps to the plane, few hundred Mbps from the plane
  - Built a network of ground stations that have antennas that point up

- Example service: gogo Inflight Internet
AirCell’s Antennas (under the Jet planes)
Similar to Connexion: use satellites
- Ku-band satellites
- 4 to 20 Mbps to a single plane
- Can cover larger areas (than that of AirCell)

Satellites are geostationary, orbiting above the equator
- Flights near the poles can’t have service

BTW, OnAir uses satellites too (Inmarsat fourth-generation BGAN)
Summary: Letting Routing Handle It

- **Advantages**
  - No changes to the end host
  - Traffic follows an efficient path to new location

- **Disadvantages**
  - Does not scale to large number of mobile hosts
    - Large number of routing-protocol messages
    - Larger routing tables to store smaller address blocks

- **Alternative**
  - Mobile IP
Option #2: Home Network and Home Agent

**Home network:** permanent “home” of mobile (e.g., 128.119.40/24)

**Home agent:** entity that will perform mobility functions on behalf of mobile, when mobile is remote

**Permanent address:** address in home network, *can always* be used to reach mobile e.g., 128.119.40.186

**Correspondent:** wants to communicate with mobile

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**Visited Network and Care-of Address**

- **Permanent address**: remains constant (e.g., 128.119.40.186)
- **Care-of-address**: address in visited network. (e.g., 79.129.13.2)
- **Visited network**: network in which mobile currently resides (e.g., 79.129.13/24)
- **Home agent**: entity in visited network that performs mobility functions on behalf of mobile.
- **Correspondent**: wants to communicate with mobile.
- Foreign agent knows about mobile
- Home agent knows location of mobile
Mobility via Indirect Routing

1. Correspondent addresses packets using home address of mobile.
2. Home agent intercepts packets, forwards to foreign agent.
3. Foreign agent receives packets, forwards to mobile.
4. Mobile replies directly to correspondent.
Indirect Routing: Efficiency Issues

- Mobile uses two addresses
  - Permanent address: used by correspondent (making mobile’s location is transparent to correspondent)
  - Care-of-address: used by the home agent to forward datagrams to the mobile
- Mobile may perform the foreign agent functions
- Triangle routing is inefficient
  - E.g., correspondent and mobile in the same network
Mobility via Direct Routing

1. Correspondent requests, receives foreign address of mobile
2. Correspondent forwards to foreign agent
3. Foreign agent receives packets, forwards to mobile
4. Mobile replies directly to correspondent

No longer transparent to the correspondent
Mobility Today

- **Limited support for mobility**
  - E.g., among base stations on a campus

- **Applications increasingly robust under mobility**
  - Robust to changes in IP address, and disconnections
  - E.g., e-mail client contacting the e-mail server
  - ... and allowing reading/writing while disconnected
  - New Google Gears for offline Web applications

- **Increasing demand for seamless IP mobility**
  - E.g., continue a VoIP call while on the train

- **Increasing integration of WiFi and cellular**
  - E.g., dual-mode cell phones that can use both networks
  - Called Unlicensed Mobile Access (UMA)
Impact on Higher-Layer Protocols

- Wireless and mobility change path properties
  - Wireless: higher packet loss, not from congestion
  - Mobility: transient disruptions, and changes in RTT
- Logically, impact should be minimal ...
  - Best-effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- But, performance definitely is affected
  - TCP treats packet loss as a sign of congestion
  - TCP tries to estimate the RTT to drive retransmissions
  - TCP does not perform well under out-of-order packets
- Internet not designed with these issues in mind