Course Overview

- Introduction and History
- Regulatory Issues
- Fundamentals of Cellular Systems
- 1st Generation: AMPS and CDPD
- 2nd Generation: GSM
- 3rd Generation: IMT-2000
- Mobile IP
- TCP over Wireless Link

Why Mobile IP?

- mobile computing is on the rise
  - wireless communications technologies widely available
    - IEEE 802.11 finally getting standardized
      - MAC layer protocol with lots of features: power saving, ad-hoc networking support, maybe even isochronous communication
    - cellular telephony everywhere
      - AMPS and CDPD
      - GSM
    - wireless indoor equipment (IR and RF) such as Lucent (formerly AT & T) WaveLAN
  - people expect the same from both desktop and laptop
    - high-resolution color display
    - 200 MHz processor
    - multi-gigabyte disk
    - with a docking station, the laptop **is** the desktop

Why Mobile IP?

- wireless communication and powerful portable devices lead to new computing paradigms:
  - mobile computing
  - ubiquitous computing
  - nomadic computing
- at the same time, the Internet and in particular the Web, are growing exponentially
  - timely news (and lots of it), user-friendly(?), lots of pretty pictures (70%-80% of Internet traffic is WWW traffic)
  - the "Information Superhighway" is where people want to be
  - certainly strong support by national governments to build and maintain this infrastructure
  - mobile computing seen as "on-ramp" to this infrastructure

Mobile IP

- addressing mobility at network layer has following advantages:
  - wireless network access
  - location-independent access to computing resources
  - continuous connectivity (even when physical media changes)
  - software reusability, application transparency
  - economy and ease of operation
- Mobile IP can make it seem that a (possibly virtual) *home network* extends over the entire Internet, allowing for seamless roaming.

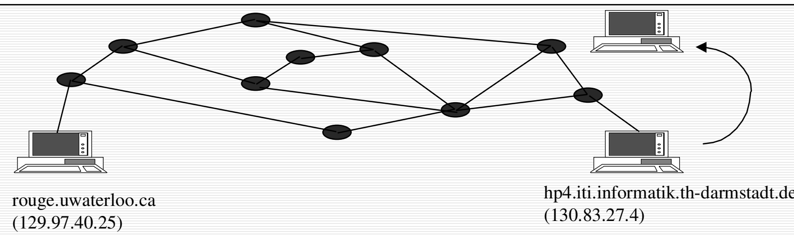
IETF: Internet Engineering Task Force

- Who develops protocols such as TCP/IP, Mobile IP, ...?
  - "standardized" by action of IETF
- IETF has over 70 *working groups* considering a broad range of protocol proposals for the Internet, tries to identify protocol needs in advance (?)
- IETF works with Internet Assigned Number Authority (IANA) to keep track of protocol number assignments and address allocations as required by various Internet protocols
- each protocol specified by a "Request for Comments"
  - working groups develop new RFCs by publishing Internet Drafts, building prototypes, and encouraging public debate
  - operational model: rough consensus and running code

Routing in the Internet

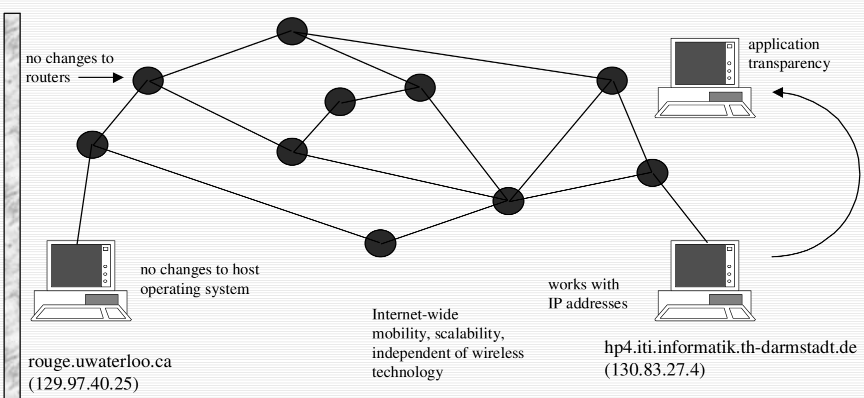
- datagrams in Internet flow from on link to another via routers
- computers send and receive datagrams based on their IP (Internet Protocol) address
- Domain Name Service (DNS) translates machine names into IP address
- Internet routing is dynamic, unpredictable, subject to congestion, and performed on a best-effort basis. IP does not guarantee that datagrams will be delivered (current loss rate 2%-5%, expected to grow due to congestion)

Routing in the Internet



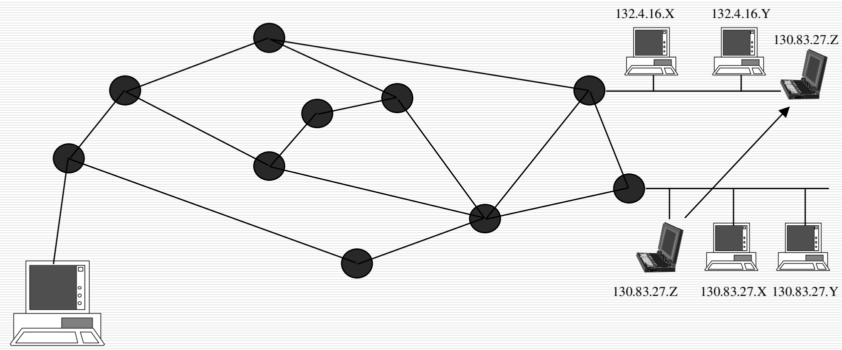
- TCP connections are defined by source and destination IP addresses and port numbers:
  - Connection := <129.97.40.25, port#, 130.83.27.4, port#>
- mobile computers violate the assumption that IP addresses define the topological relationship
  - change host address: connection breaks
  - do not change host address: routing fails

Characteristics of Desired Solutions



compatibility (in all respects) with existing Internet routers, computers, apps

Internet Routing revisited



routing based on subnetwork (addresses have hierarchical structure)

as mobile computers move from one IP subnetwork to another, they have the wrong "subnet prefix" for the destination subnet

Mobile IP Overview

- *home agent* is the router for the home network
- *foreign agent*, located within the range of a mobile computer, delivers packets to it after receiving them from the home agent
- Mobile IP basically transforms the mobility problem to a routing problem
- no special routing is needed to send packets from a mobile computer to a non-mobile computer
- routing from stationary computer to mobile computer is not necessarily optimal (triangular routing), proposals exist for route optimization

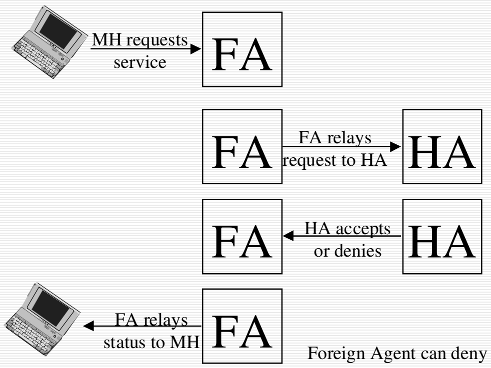
Mobile IP Components

- standardized by RFC 2002: “IP Mobility Support”
- service advertisements: let mobiles know of existence of mobility agent (home agent or foreign agent)
- registration: mobile computer “camps on” an IP subnet and informs its home agent about its current location
- tunneling: process of forwarding IP packets from home agent to foreign agent, for delivery to the mobile
- motion detection: mobile detects that it moved on to a new cell/IP subnet
- route optimization: avoid problem of triangle routing, not part of standard but under discussion

Mobile IP: Service Advertisement

- agent advertisements transmitted every second by mobility agents (extension of ICMP router advertisement), serves as a “beacon” for cell selection
- alternatively, mobile can issue agent solicitation (extension of ICMP router solicitation) when no advertisements received
- foreign agents can:
  - be too busy for more clients (but still send out advertisements)
  - describe what encapsulation they offer
  - require registration via an advertised care-of address (even if mobile has co-located care-of address)
- service advertisements not authenticated

Mobile IP: Registration



Home Agent maintains binding (mobile, care-of address, lifetime)

Registration means update of binding

Registration is a form of remote redirect and needs authentication, otherwise anyone could drain traffic intended for a given mobile

Foreign Agent can deny service (ignore request) if
- too busy
- service request is for too long

Home Agent always replies

Mobile IP: Registration Messages

– all messages are exchanged using UDP (User Datagram Protocol):
  - simpler than ICMP for user processes (such as mobility agents)
  - TCP unnecessary (explicit acks)
  - all messages sent to well-known port 434 used by FA and HA
  - port numbers used by MH variable and unauthenticated

Registration Message Format (after UDP header):

Type	Flags	Lifetime
Home Address		
Home Agent		
Care-of Address		
Identification		

Type: 1
Lifetime: requested binding lifetime
Home Address: permanent IP address of MH
Home Agent: IP address of home agent
Care-of Address: IP address for end of IP tunnel
Identification: 64-bit identification and replay protection
Flags: SDBMGV (MGV as before)
S: simultaneous registrations (e.g., multiple care-of addresses)
B: broadcasts requested (forward broadcasts through tunnel too)
D: dynamic/co-located care-of address

Mobile IP: Registration Messages

Registration Reply Message Format (after UDP header):

Type	Code	Lifetime
Home Address		
Home Agent		
Identification		

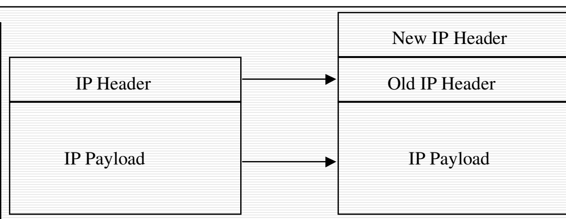
Type: 3
Code: status of the registration request
Lifetime: lifetime of binding, could be smaller then request lifetime
Home Address: permanent IP address of MH
Home Agent: IP address of Home Agent
Identification: as in registration request

Registration status codes

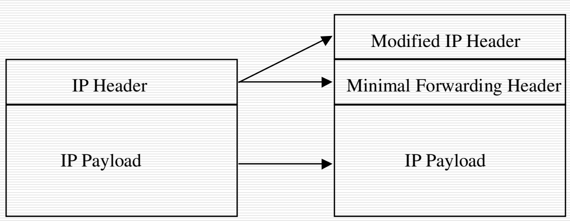
0: registration accepted
1: registration accepted, simultaneous mobility bindings unsupported
64-88: service denied by FA (maybe because problem contacting HA)
128-136: service denied by HA

Up-to-date values of the Code field are specified in the most recent "Assigned Numbers" (RFC 1700)

Mobile IP: Encapsulation



IP-within-IP: (RFC 2003)
- handle incoming fragmentation
- new IP Header uses protocol number 4

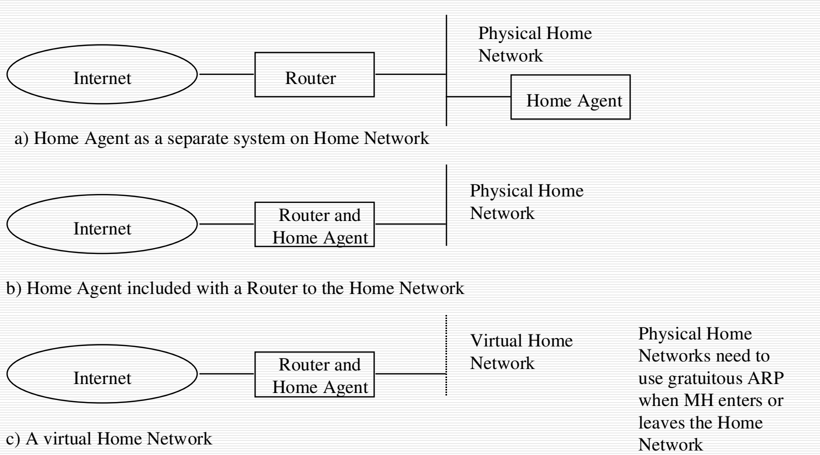


Minimal IP Encapsulation: (RFC 2004)
- insert minimal forwarding header that basically consists of only the information not derivable from tunnel IP header (original protocol number, original destination address), plus optionally original source address.
- modified IP Header uses protocol number 55

Mobile IP: Motion Detection

- detect when MH moved to new IP subnet, triggers new registration
- two primary mechanisms, others MAY be used:
  - algorithm 1 based on lifetime in agent advertisement:
    - MH records lifetime, updates it with every advertisement
    - upon expiration, assume that contact with agent is lost
    - register with an agent for which advertisement was received and whose lifetime is not yet expired
  - algorithm 2 uses network prefixes
    - compare newly received agent advertisements with network prefix of currently used care-of address
    - if prefixes differ, assume that MH moved
    - upon expiration of current registration, MH MAY choose to register with new FA

Mobile IP: Home Networks



a) Home Agent as a separate system on Home Network

b) Home Agent included with a Router to the Home Network

c) A virtual Home Network

Mobile IP: Route Optimization

- triangle routing is best you can do with no modifications to fixed hosts
- route optimization under discussion, not part of mobile IP standard ("draft-ietf-mobileip-optim-05.txt")
- current solution allows correspondent host to know care-of address of the mobile node (get binding update)
- bindings kept in location cache, part of routing table
- again, authentication is necessary to prevent traffic hijacking

Mobile IP: Route Optimization

- four UDP message types (sent to port 434):
  - binding warning
  - binding request
  - binding update
  - binding acknowledge
- when mobility agent sees that a correspondent host has a stale location cache, it issues a **binding warning**
  - message rate is limited, preferably with exponential backoff
- correspondent makes **binding request** to elicit **binding update** (for example, as result of **binding warning)**
- **binding update** may be acknowledged with a **binding acknowledge**

Mobile IP: Miscellaneous Topics

- support for multiple home agents
- nonces vs. timestamps in authentication
  - timestamps require clock synchronization, open to attack
- TCP congestion control vs. error-prone media
- discovering home agent addresses
- simultaneous registrations
  - replicate each IP packet, send over different wireless links for improved reliability
- specify broadcast and multicast preferences
- organize foreign agents hierarchically to limit reporting requirements back to HA
  - use ideas from location management in cellular systems?

Mobile IP and IPv6

- mobility in IPv6 (“draft-ietf-mobileip-ipv6-02.txt”):
  - MH may notify its correspondents when it moves (no triangle routing)
  - correspondents put care-of address in routing header
  - home agent encapsulates packets if it gets them (e.g., from correspondents having no current care-of address)
  - binding updates are carried in a destination option
  - acknowledgments (usually only sent by a HA) in another destination option, with status code
  - MH creates his care-of address using link-local address and automatic address configuration
  - MH should be able to receive packets at multiple addresses

Mobile IP and IPv6

- all IPv6 nodes need to support:
  - routing headers (they are supposed to anyways)
  - mobility cache
  - binding update processing
- IPv6 mobile nodes:
  - motion detection
  - care-of address construction
  - decapsulation
  - sending binding updates to correspondent hosts and mobility agents
- Mobility Agents (Routers)
  - encapsulation
  - binding update and acknowledgment