Course Overview

- Introduction and History
- Data in Wireless Cellular Systems
- Data in Wireless Local Area Networks
- Internet Protocols
- Routing and Ad-Hoc Networks
- TCP over Wireless Link
- Services and Service Discovery
- System Support for Mobile Applications

What is TCP/IP ?

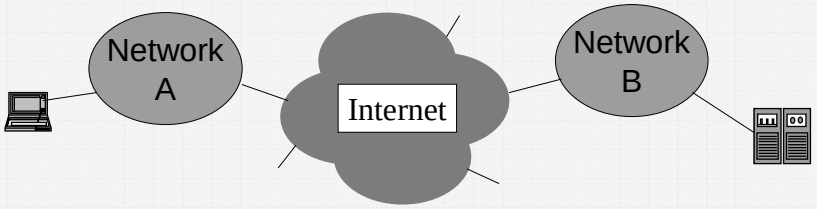
- TCP/IP is a collection of protocols that facilitates communications among servers and terminals that are hooked to different networks

TCP → Transport Control Protocol

IP → Internet Protocol

What is TCP/IP ? (continue)

- The TCP and IP are only two of several protocols, but the name stuck !!
- They are the most important ones



The Big Picture of TCP/IP

Application	Ping	Telnet	FTP	SMTP	SNMP	Trace Route
(Host-to-Host)	DNS	TFTP	BOOTP	RIP	OSPF	others
Transport	TCP		UDP		ICMP	
Network	IP					
Data Link	LLC		HDLC		PPP	
	Ethernet	802.3t	X.25	Token Ring	Frame Relay	ATM	SMDS	Etc.
Physical	Fiber Optics		UTP	Coaxial		Satellite	STP	

- The most familiar Internet applications are
  - File Transfer (e.g. FTP)
  - Interactive request/response applications (e.g. Telnet)
  - Electronic mail (e.g. SMTP)

IETF: Internet Engineering Task Force

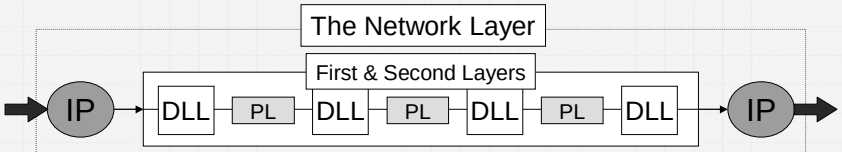
- Who develops protocols such as TCP/IP, Mobile IP, ...?
  - "standardized" by action of IETF
- IETF has over 70 *working groups* considering a broad range of protocol proposals for the Internet, tries to identify protocol needs in advance (?)
- IETF works with Internet Assigned Number Authority (IANA) 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

Protocol Layers

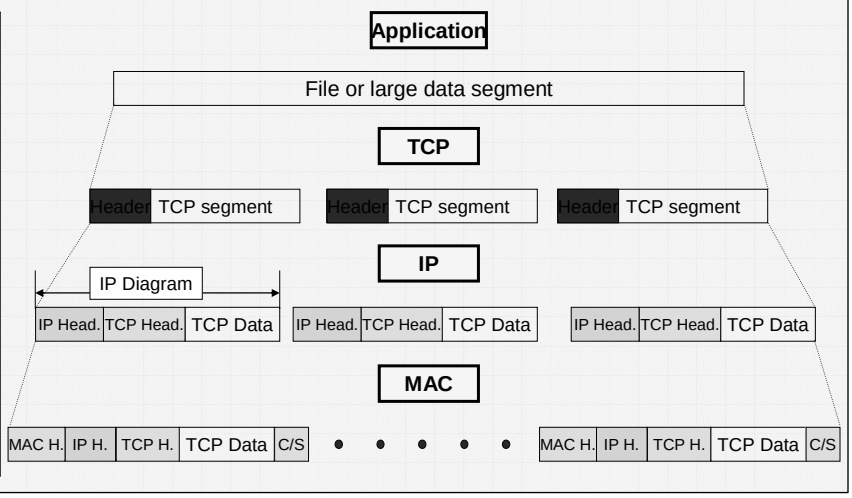
- Layers are logical steps with well-defined purposes: OSI reference model
- We are mainly interested in lower 4 layers: (1) Physical, (2) Link, (3) Network, (4) Transport

The Network Layer

- The network layer is the domain of the Internet Protocol (IP)
- The IP guides user's datagrams across several networks
- The IP is "connectionless". The data is guided by addresses rather than fixed pre-determine connections

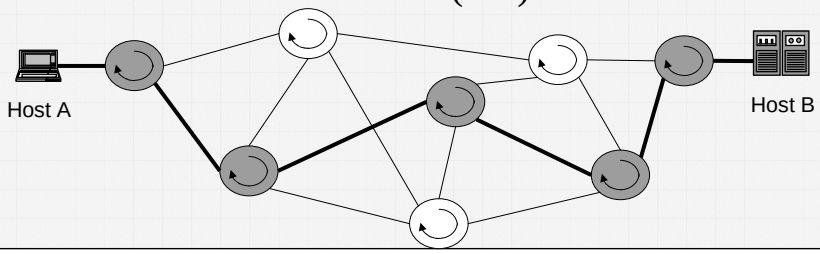


Data Fragmentation

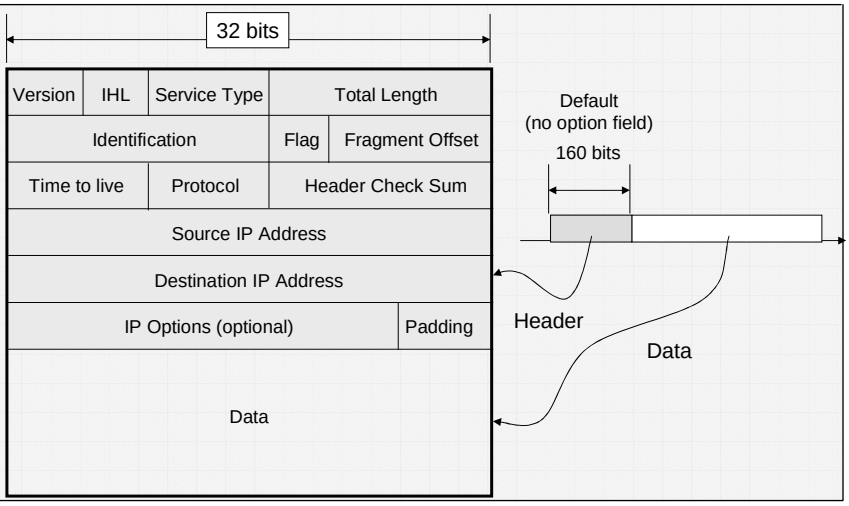


Overview of IP Routing

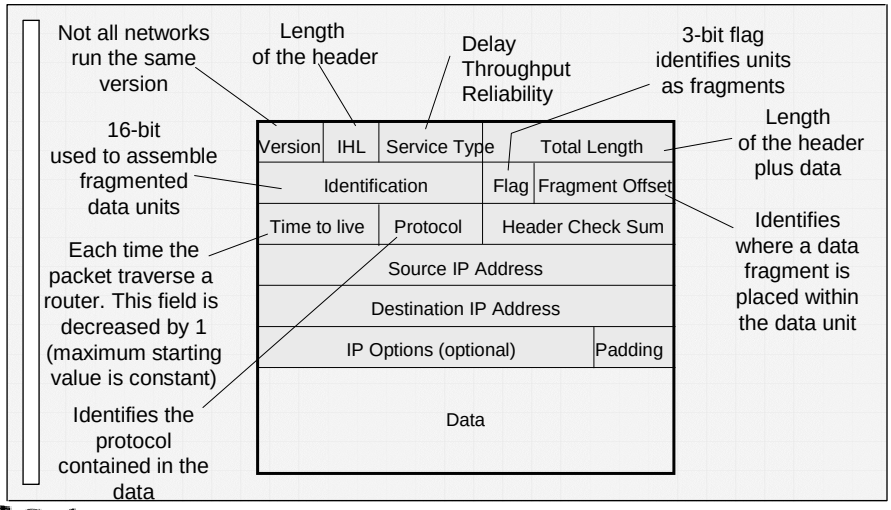
- The lines in the figure represent separate networks.
- The circles represent IP routing points.
- The Hosts are connected to their own LAN's or Internet Service Providers (ISP)



Structure of the IP Packet



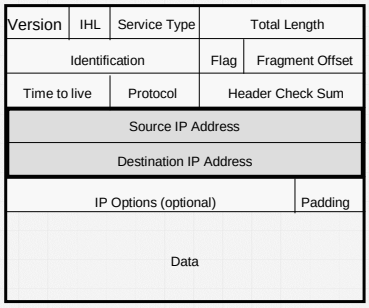
The IP Header

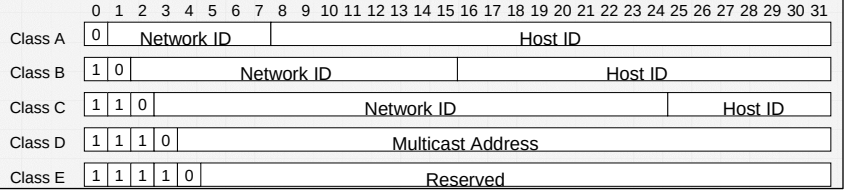


The Address Fields

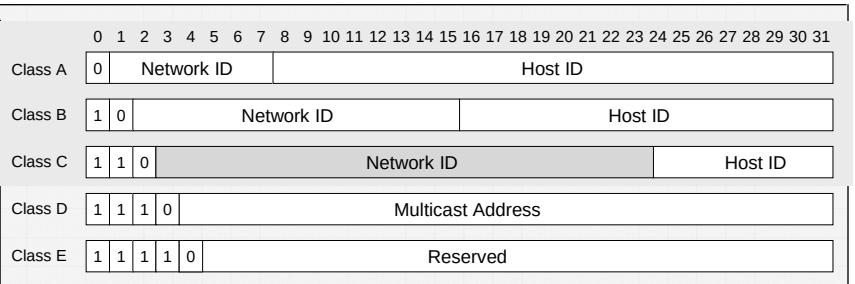
- The address field of IPv4 is 32-bit long
- It consists of three parts:
  - <class> <network ID> <host ID>

The source & destination IP addresses belong to one of these classes





IP Addresses



class	# of Nets	# of hosts
A	127	16,777,214
B	16,384	66,534
C	1,097,152	254

IP Addresses and Physical Addresses

- Map IP addresses into physical addresses
  - destination host
  - next hop router
- Techniques
  - encode physical address in host part of IP address
  - table-based
- ARP
  - table of IP to physical address bindings
  - broadcast request if IP address not in table
  - target machine responds with its physical address
  - table entries are discarded if not refreshed

ARP: Address Translation

- Notes on ARP table management:
  - table entries time out in about 10 minutes
  - update table with source when you are the target (reverse learning)
  - update table entry timeout if table already has an entry
  - do not refresh table entries upon reference

ICMP

- There are number of tasks that IP does not perform. These tasks are done by a helper protocol called: Internet Control Message Protocol (ICMP)
- The primary task of ICMP is to report routing errors and anomalies back to the source
- ICMP also tests the reachability of a node across the internet
- It also provide ways to increase routing efficiency
- It also informs the source that a given datagram has exceeded its allocated time

IPv6

- Extended addressing capabilities: 128-bit address field and other improvements.
- Simplified header format: Some fields of IPv4 are dropped or turned into options
- Improved support for extensions and options: flexibility and ability to introduce new options
- Flow labeling
- Authentication and privacy

Why Worry About Mobility?

- mobile computing is on the rise
  - wireless communications technologies widely available
    - IEEE 802.11 finally 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 or Proxim
  - 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 Worry about Mobility?

- 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

Where to Solve Mobility Problem

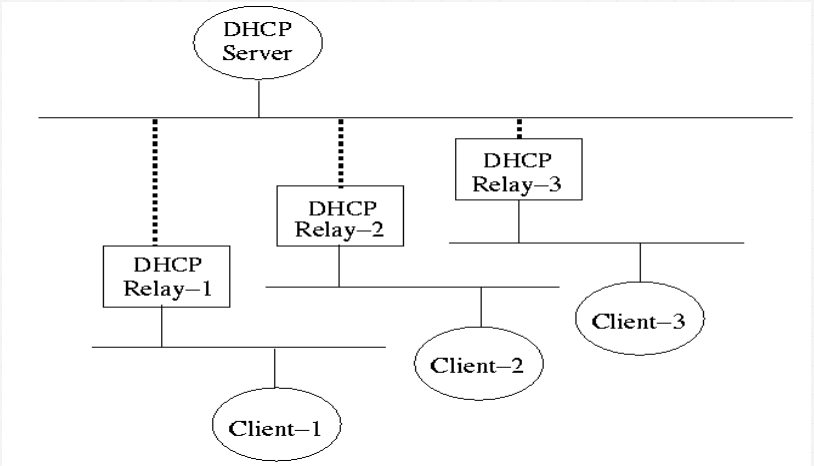
- What model of mobility
  - "nomadic clients": DHCP or similar solutions enough
  - Truly mobile: need to keep connections alive WHILE moving
- Where in the protocol stack
  - IP is common glue, solve it once and for all at IP layer
  - BUT: may be in contradiction to end-to-end argument
  - Other solutions/proposals exits, such as TCP connection migration

DHCP: Dynamic Host Configuration Protocol

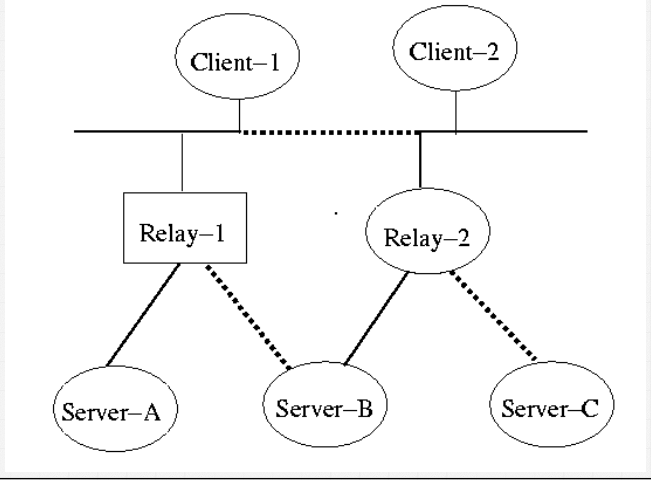
(http://www.ietf.org/html.charters/dhc-charter.html)

- automated allocation, configuration and management of IP addresses and TCP/IP protocol stack parameters:
  - automated allocation and recovery of IP addresses
  - automated configuration of all TCP/IP stack parameters, as described in the Host Requirements documents
  - automated configuration of other host parameters such as application layer services
  - inter-server communication for coordination of multiple servers
  - mechanisms for the authentication of clients and servers
- A specification for IPv4 has been entered into the IETF standards track (RFC 2131)
- currently developing a specification for DHCP for IPv6 (DHCPv6), which is available as an Internet Draft.

DHCP Architecture



DHCP: Multiple Servers



DHCP Messages

DHCPDISCOVER: Client broadcast to locate available servers.

DHCPOFFER: Server to client in response to DHCPDISCOVER with offer of configuration parameters.

DHCPREQUEST: Client message to servers either (a) requesting offered parameters from one server and implicitly declining offers from all others, (b) confirming correctness of previously allocated address after, e.g., system reboot, or (c) extending the lease on a particular network address.

DHCPACK: Server to client with configuration parameters, including committed network address.

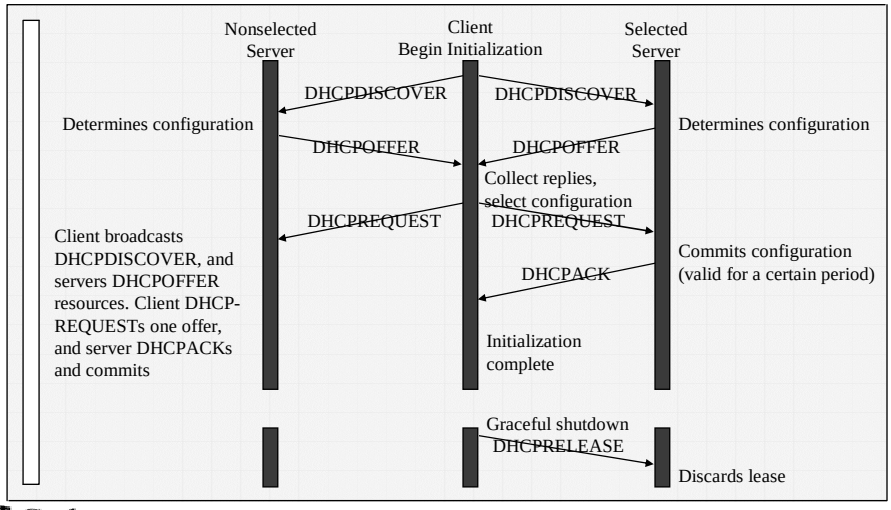
DHCPNAK: Server to client indicating client's notion of network address is incorrect (e.g., client has moved to new subnet) or client's lease as expired

DHCPDECLINE: Client to server indicating network address is already in use.

DHCPRELEASE: Client to server relinquishing network address and cancelling remaining lease.

DHCPINFORM: Client to server, asking only for local configuration parameters; client already has externally configured network address.

DHCP: Initialization of Client



DHCP Address Assignment

- If an address is available, the new address SHOULD be chosen as follows:
  - The client's current address as recorded in the client's current binding, ELSE
  - The client's previous address as recorded in the client's (now expired or released) binding, if that address is in the server's pool of available addresses and not already allocated, ELSE
  - The address requested in the 'Requested IP Address' option, if that address is valid and not already allocated, ELSE
  - A new address allocated from the server's pool of available addresses; the address is selected based on the subnet from which the message was received (if 'giaddr' is 0) or on the address of the relay agent that forwarded the message ('giaddr' when not 0).

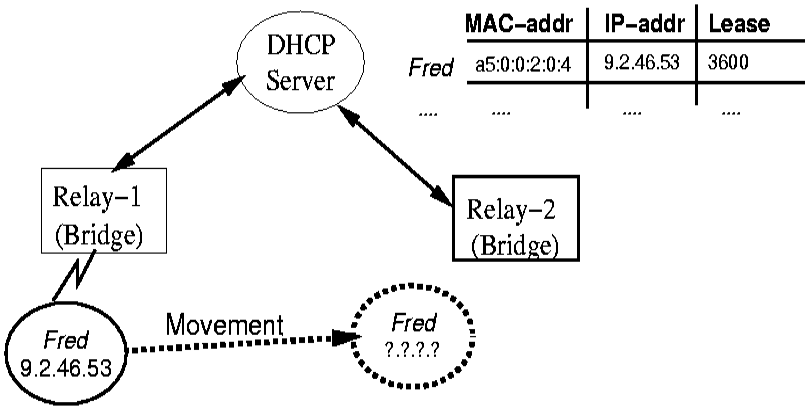
DHCP Lease Period

- The server must choose an expiration time for the lease, as follows:
  - IF the client has not requested a specific lease in the DHCPDISCOVER message and the client already has an assigned network address, the server returns the lease expiration time previously assigned to that address (note that the client must explicitly request a specific lease to extend the expiration time on a previously assigned address), ELSE
  - IF the client has not requested a specific lease in the DHCPDISCOVER message and the client does not have an assigned network address, the server assigns a locally configured default lease time, ELSE
  - IF the client has requested a specific lease in the DHCPDISCOVER message (regardless of whether the client has an assigned network address), the server may choose either to return the requested lease (if the lease is acceptable to local policy) or select another lease.

DHCP

- leases expire, so have to renew configuration from time to time
- renewing similar to initialization, but no discovery step needed
- renewal with either server that issued configuration in the first place, or all servers
- in latter case, pick configuration that is ack-ed first, ignore later DHCPACKs
- when done, release configuration

DHCP: Portability



DHCP: Portability

- Initiate connectivity to Internet by DHCP request
- Once initial IP address has been obtained, start all servers/demons, etc.
- Suppose host detects movement: re-issue new DHCP request to validate current IP address
  - if okay, proceed
  - if new address needed, we have a problem
    - new IP address will not work with existing connections
      - shut down and reboot machine
    - since no other node knows new IP address, MH has to initiate all requests
      - alternative: allow DNS updates, which takes time and introduces new security problem

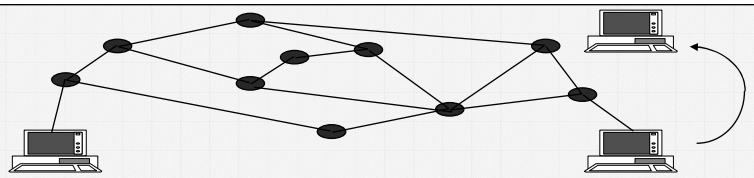
Mobile IP

- Mobile IP: support true mobility, transparent to higher protocol layers
- 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.

Routing in the Internet (Review)

- 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

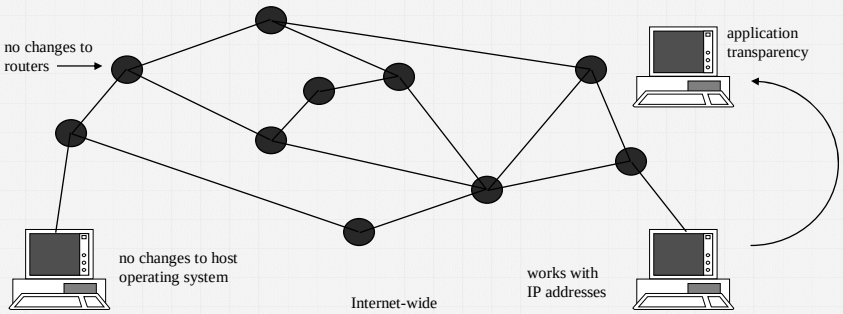


rouge.uwaterloo.ca
(129.97.40.25)

hp4.iti.informatik.th-darmstadt.de
(130.83.27.4)

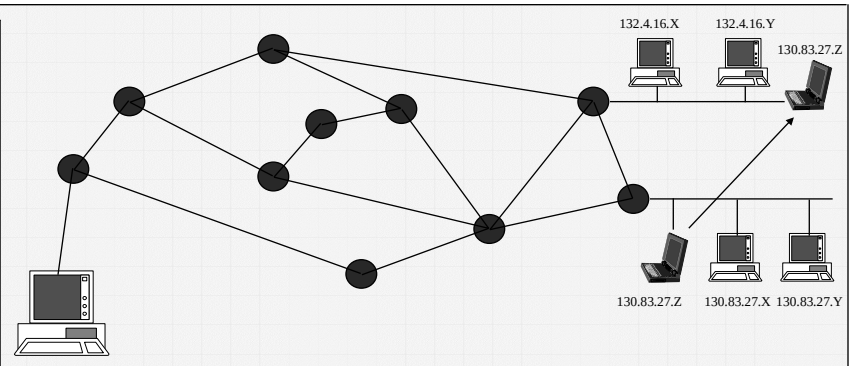
- TCP connections are defined by source and destination IP addresses and port numbers:
  - Connection := <129.97.40.25, port#, 130.83.27.4, port#>
- mobile computers violate the assumption that IP addresses define the topological relationship
  - change host address: connection breaks
  - do not change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

Characteristics of Desired Solutions



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

Internet Routing revisited



rouge.uwaterloo.ca
(129.97.40.25)

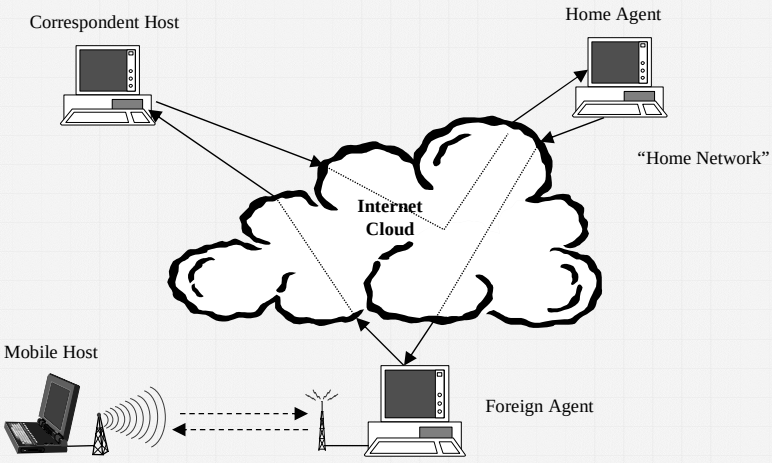
routing based on subnetwork (addresses have hierarchical structure)

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

Mobile IP Overview

- Mobile IP basically transforms the mobility problem to a routing problem, using **two** IP addresses
  - static IP address: connection establishment, packet delivery
  - care-of IP address: changes with host mobility
- **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
- 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 Overview



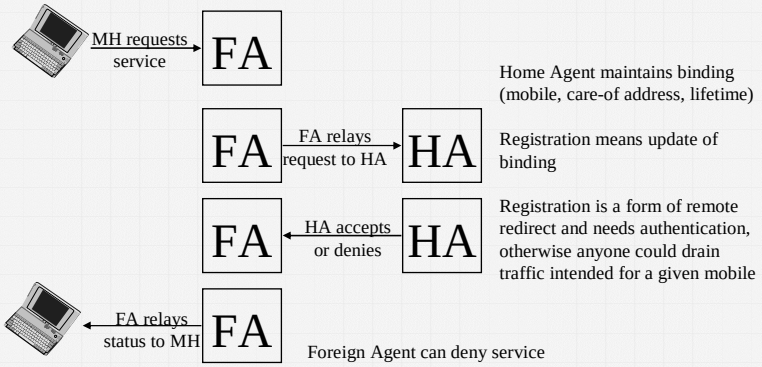
Mobile IP Components

- 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

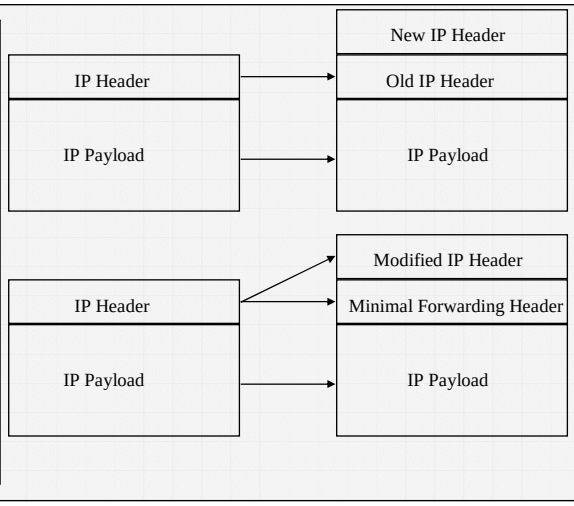
Mobile IP: Service Advertisement

- 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



Mobile IP: Encapsulation



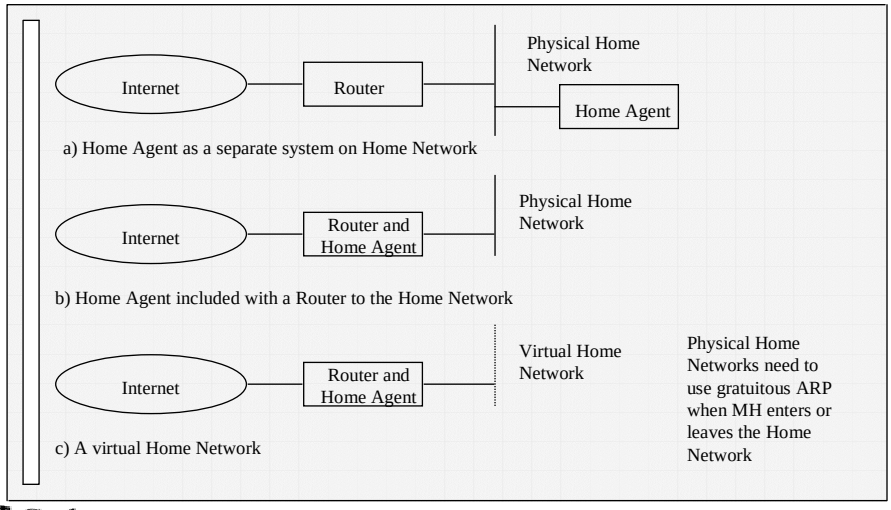
IP-within-IP: (RFC 2003)
- handle incoming fragmentation
- new IP Header uses protocol number 4

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

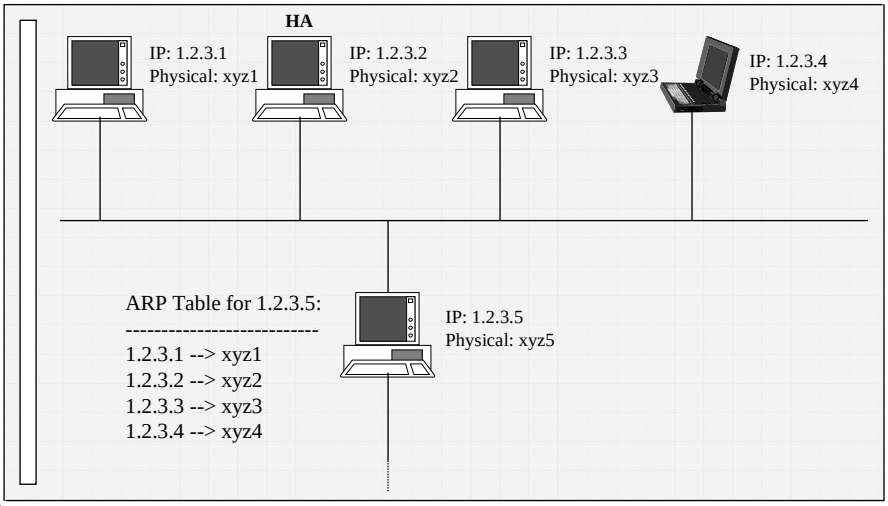
Mobile IP: Motion Detection

- 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

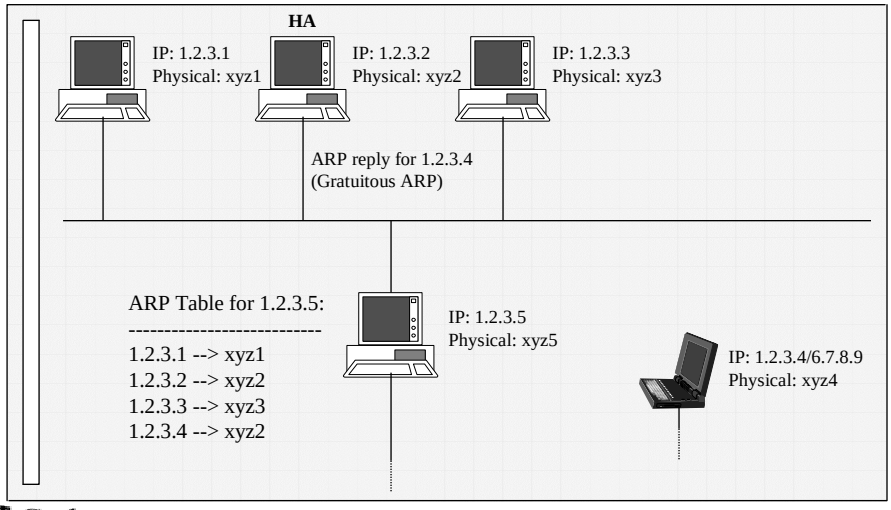
Mobile IP: Home Networks



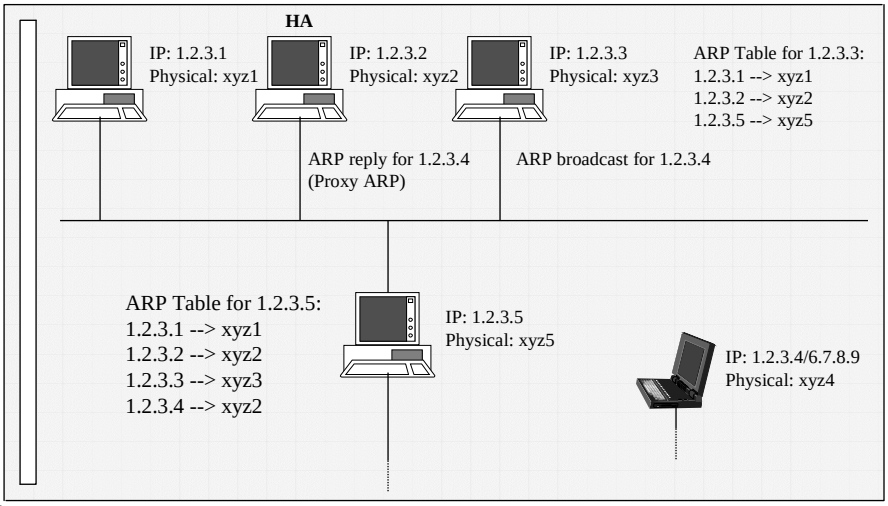
Mobile IP and ARP



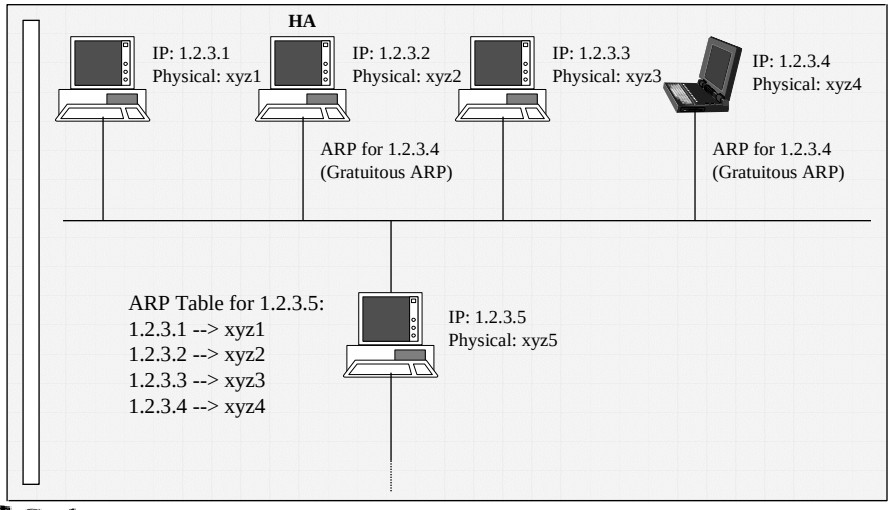
Mobile IP and ARP: Gratuitous ARP



Mobile IP and ARP: Proxy ARP



Mobile IP and ARP: Gratuitous ARP



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
- 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
- newer version of proposal also supports “soft handover” between two FAs

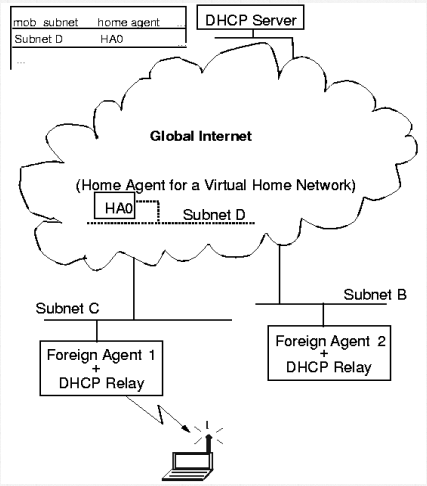
Mobile IP: Route Optimization

- four UDP message types:
  - 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 smooth handoffs
- 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?

DHCP: Mobility



DHCP: Mobility

- Use dynamic IP address as co-located care-of-address
  - no need to reboot machine or to restart demons
  - MH known under home IP address
    - others can initiate connections to it
    - no need to allow updates to DNS servers
- obtain IP address from DHCP server prior to registration request
  - should set D bit in registration request, especially if MH needs to get broadcasts or multicasts sent by home agent
  - required to register care-of-address by way of a foreign agent if agent advertisements with R bit set are being received from local foreign agents

DHCP and Mobile IP

- Two address expirations
  - DHCP lease (IP addresses are leased for a limited time, need to be renewed periodically)
  - Home Agent binding will expire
  - Ideally: make DHCP lease and binding lifetime same (usually means that DHCP lease will be shortened, since leases are usually rather long-lived for desktops and other stationary devices)
- Dual-mode operation: FA or DHCP?
  - Less address maintenance is required when using FA care-of-address (no DHCP lease renewal)
  - FA may be equipped to handle decapsulation efficiently
  - FAs may cooperate to provide smooth handoffs
  - packets for MH decapsulated before wireless link, reducing bandwidth

DHCP Mobile Home Address Option

- Problem: completely auto-configure a MH, even with information about home address/home agents
- existing DHCP options do not allow MH to specify that they request an appropriate home address
- new option (68): DHCP server returns home address plus zero or more home agent addresses
- as part of DISCOVER and REQUEST message, MH requests return of option 68, use information in reply to register its care-of-address (obtained by whatever means) for its (new) home address with one home agent (maybe returned as part of reply)

Mobile IP: Future Work

- Is location transparency really wanted/needed?
- Is seamless connectivity really wanted/needed?
- As cells shrink and bandwidth increases:
  - reconfigurations have to be automatic
  - reduce minimal time between registrations, minimal time between successive solicitations for FA service
  - make better decisions about cell changes to avoid unnecessary packet losses
- How does MobileIP interact with QoS reservation protocols such as RSVP
- home IP address will not always be important/necessary (POP, anonymous FTP)
  - if home address is NOT important, use care-of-address to avoid problems associated with use of home address
- co-existence MobileIP and AdHoc Networks?