CS 755 – System and Network Architectures and Implementation

Module 5 – Naming and Mobility

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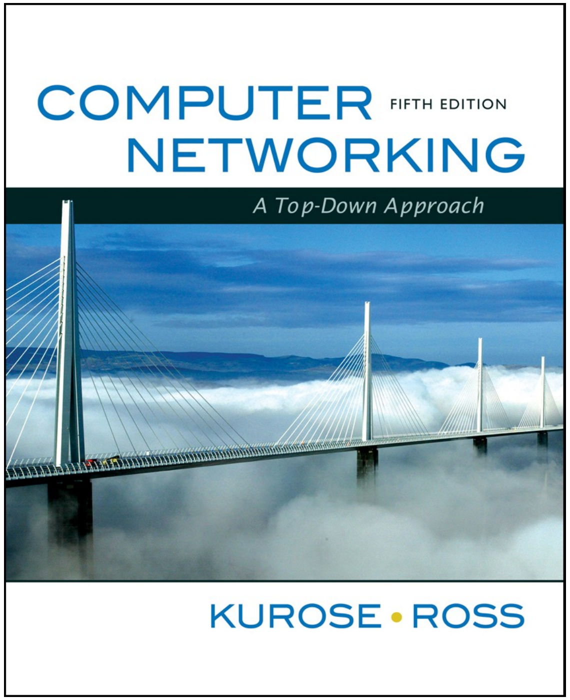

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Computer Networking: A Top Down Approach
5th edition.
Jim Kurose, Keith Ross
Addison-Wesley, April 2009.

Overview

- naming
  - manage and find entities and services
  - examples: DNS, DHT
- mobility
  - naming + maintain connectivity
  - example: Mobile IP

Services – Review

- messaging middleware
  - persistent communication
  - asynchrounous communication
- remote procedure call
  - transparency
- security
  - privacy, integrity, authentication

Naming

“Of what one cannot speak,
one must pass over in silence.”

Ludwig Wittgenstein, *Tractatus*

Naming

- names in (distributed) computer systems
  - identification, (permanent) uniqueness – *scope*
  - facilitate communication / access – *resolution*
  - description of entity – *context*
- static vs. dynamic naming
  - online vs. offline *agreement*
  - online: distributed vs. centralized
  - manual configuration

Name Resolution

- access named object / entity
- direct access
  - forward message to destination
- indirect access
  - map name to other name using database (*lookup*)
  - might be a distributed database

  -> forwarding within distributed database?

Definition Attempt

- a *name* is a handle/reference, valid and unique in a *scope*, that can be used to access a (group of) object(s) via a *resolution* mechanism

- try your own...

Everything is a Name

- memory address
- file system inode / name, socket handle
- MAC address, IP address, port, DNS name
- URL
- email address, Skype ID, Twitter ID
- phone number
- service identifier: WSDL, WSIL, UDDI
- “plumbing contractor kitchener ontario”

Conflicting Goals

- uniqueness, permanence - *identifier*
  - numbering scheme, large range
- access / communication - *locator*
  - location-dependent name (distance metric?)
  - efficient processing for forwarding
- description - *descriptor*
  - precision
  - processing overhead

Discovery

- human-oriented description
  - expressive vs. concise

  vs. machine processing, efficiency
  - basic semantic schism: human vs. machine

- essential mechanism: search
  - range queries
  - typos, unclear intent
  - multiple results

Name Processing

- At any point during name processing:
  scope, resolution, and context are implicit!

- if explicit, they are described by a label
  ... which is mapped into something else
  ... therefore the label is a name
  ... which needs scope, resolution, and context
  => recursive contradiction!

Abstract Names

- role name
  - 'mkarsten' vs. 'root'
  - 'joe@email.com' vs. 'admin@isp.com'

- service name
  - print.cs.uwaterloo.ca
  - ipp://print.cs.uwaterloo.ca:631/printers/color

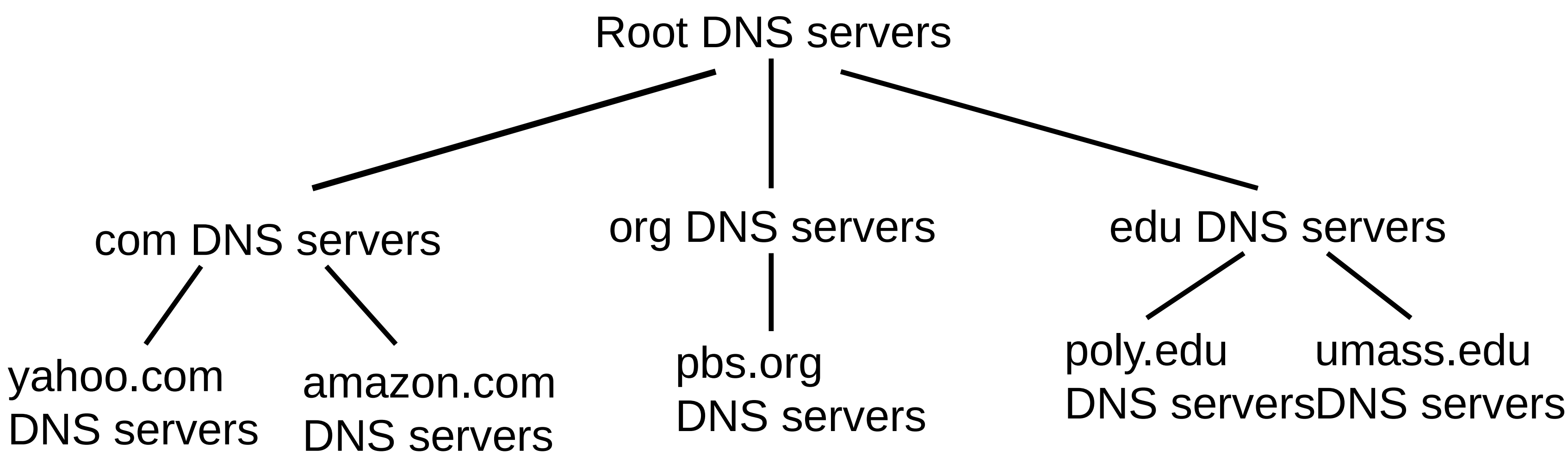
Distributed Naming System

- name assignment
  - alias support
- name resolution
  - resolution overhead
  - storage overhead
  - scalability, caching
    - size of name space, number of managed entities
    - frequency of updates and lookups
  - relative vs. absolute names

Example: DNS

- <u>D</u>omain <u>N</u>ame <u>S</u>ystem
- hierarchical host names in the Internet
  - example: `cpu08.student.cs.uwaterloo.ca`
    - sequence of labels, written with separator
    - cf. file system name: /home/mkarsten/cs755/network.pdf
  - naming conventions
    - top level domain: country code or orga-type code
    - 2nd level: organizational name
    - etc. - local conventions (org units, depts, ...)
    - lowest level: role-based name (www, print, cpu, ...)

DNS Database



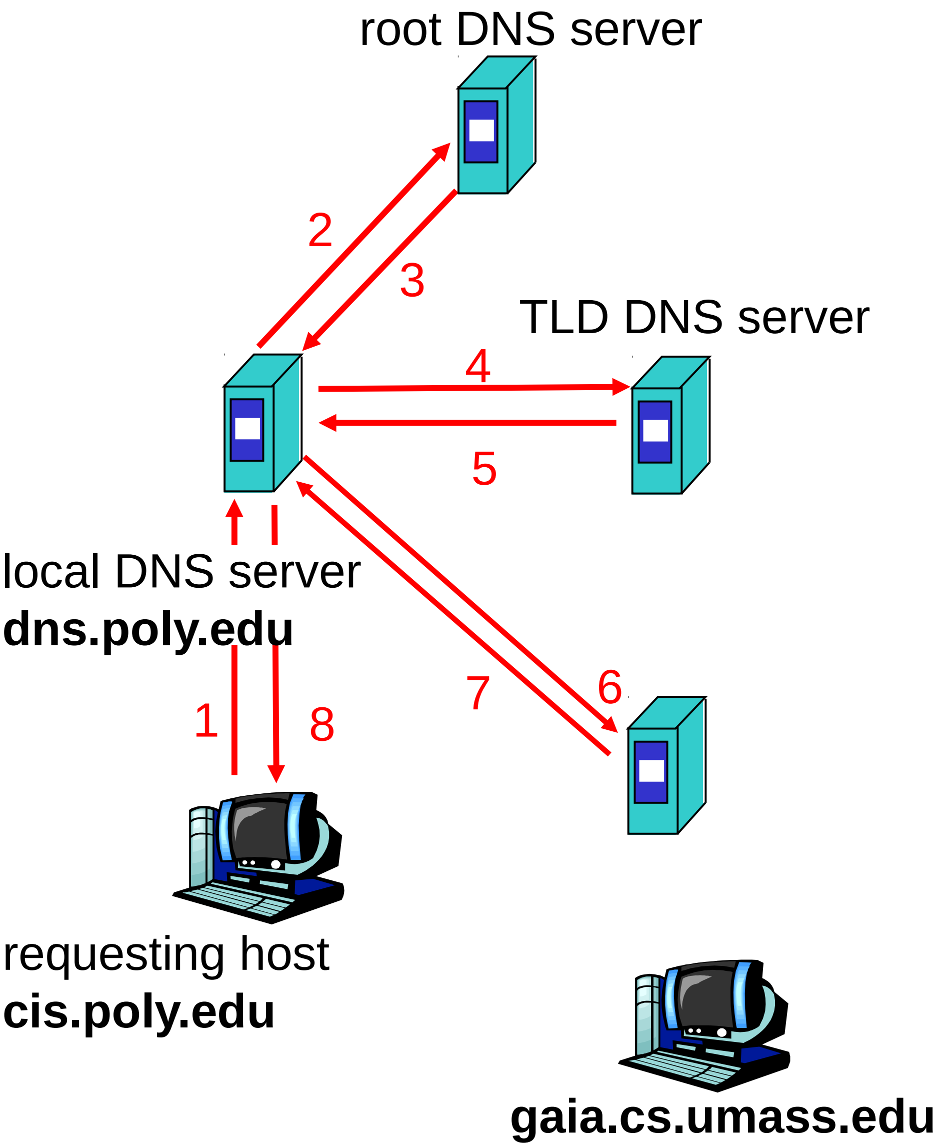
- distributed database - entry point: root server(s)
  - hierarchy (mostly) follows naming hierarchy
  - resolution requests traverse hierarchy
- local caching

Caching

- local DNS server
  - not part of authoritative hierarchy
  - caching proxy for DNS requests
  - often co-located with regular DNS server
  - “default name server”
- hierarchy of caching servers
- DNS updates are not frequent
  - and not expected to propagate fast

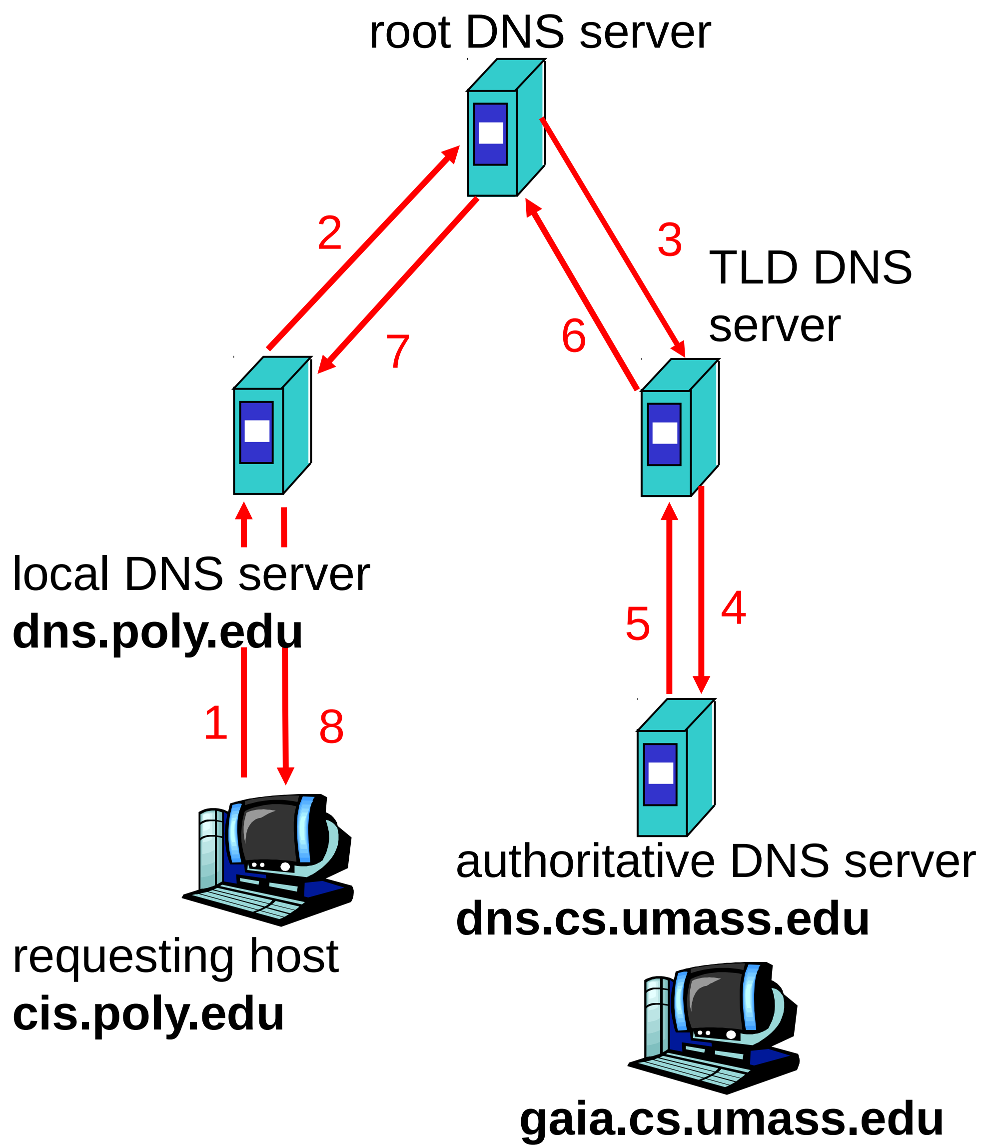
DNS Lookup

- iterative resolution
  - server replies with name/address of next server to contact
  - resolver can cache multiple intermediate results



DNS Lookup

- recursive resolution
  - server forwards request and replies with ultimate response
  - high-level servers can cache lots of results
  - load on high-level servers?
- recursive vs. iterative? => mix & match!



DNS Records

- DNS resource records (RR)

  name, value, type, ttl
- Type A: hostname -> IP address
- Type NS: domain name -> name server name
- Type CNAME: hostname -> hostname (alias)
- Type MX: email domain -> mail server name
- etc.

DNS – Notes

- simple request/reply protocol using UDP
  - retransmission, message identifiers
  - recursion optional
- ownership & regulation
  - IP address has technical meaning
  - DNS name has business value
- security & authentication
  - 'www.personalbank.com' redirected to bad party?

DNS – Notes

- replicated root servers
- relative names?
  - difficult, because resolution logically starts at root
- special functionality
  - multiple entries for name
    - return random value -> basic load balancing
    - server location -> geographical load balancing
- relevance in the age of Google?
  - how important is it to own www.mycompany.com?

Example: Distributed Hash Table

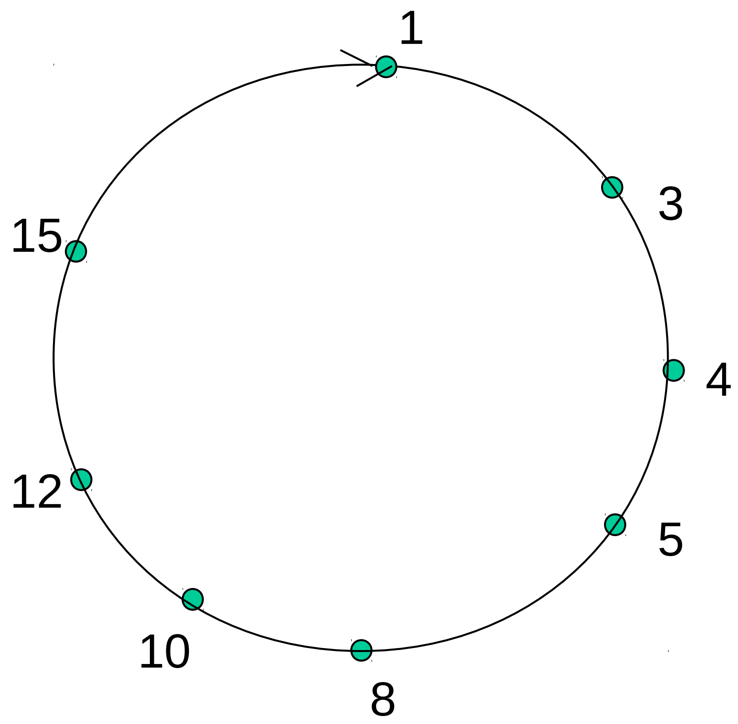
- flat identifier space for peer-to-peer applications
- DHT: distributed database for (key,value) pairs
- peers can insert (key,value) pairs
- peers query with key
  - DB returns with value that matches key
- identifier for each peer in [0...2^n-1]
- keys are taken from the same range
  - e.g., use hashing

Location of Values

- assign (key,value) to immediate successor peer of key, i.e., peer with smallest larger ID
- example: n = 4, peers: 1, 3, 4, 5, 8, 10, 12, 14
  - key = 14, successor peer = 14
  - key = 15, successor peer = 1

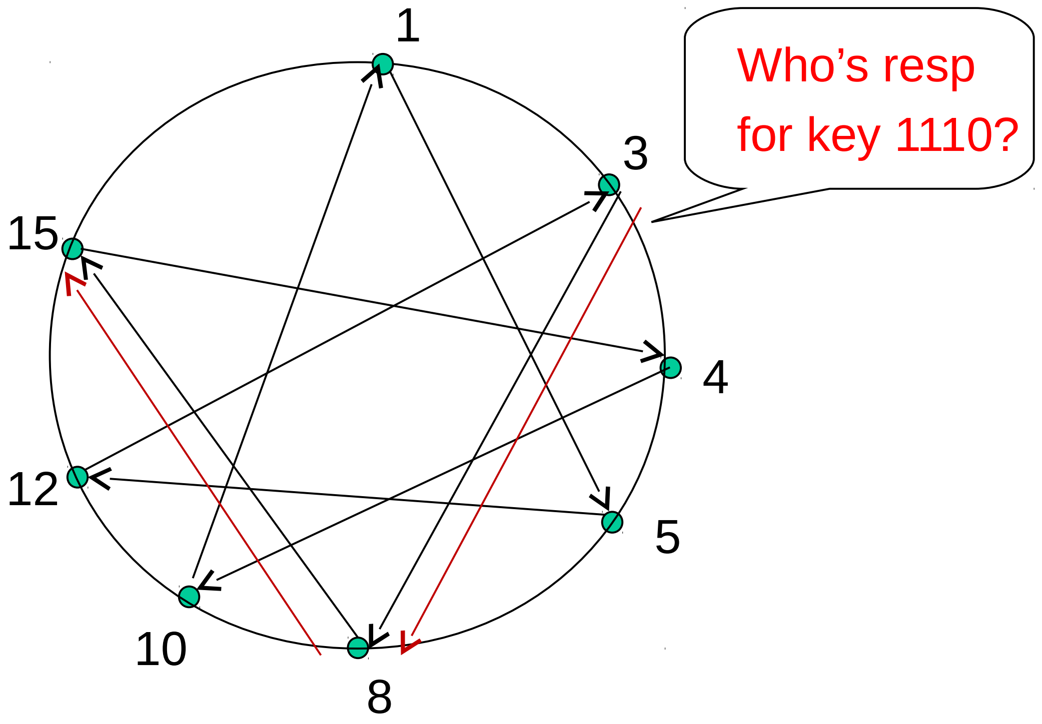
=> logical ring

Logical Ring Structure



- virtual network ("overlay")
- linear search?

Circular DHT with Shortcuts



- each peer has shortcuts to O(logN) peers
  - average distance 1, 2, 4, 8, 16, etc. (randomized)
- expected lookup in O(logN) steps

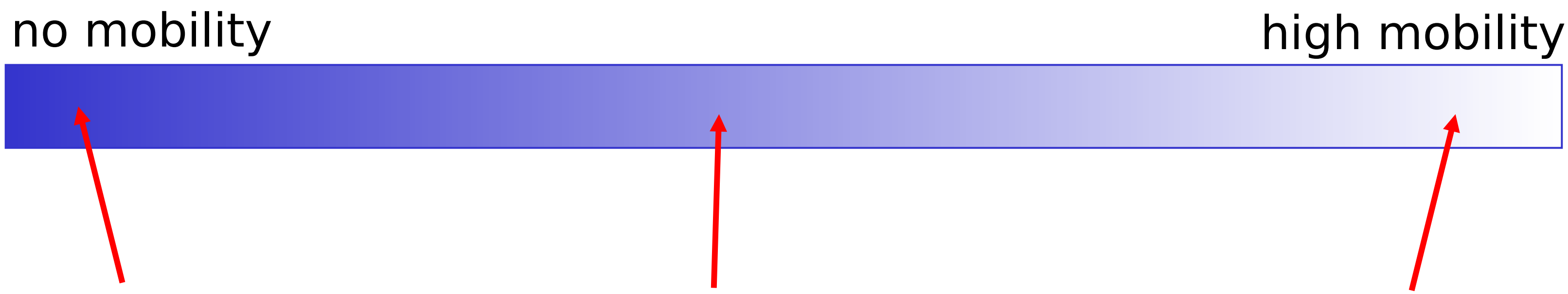
DHT Challenges

- decentralized management
- join / leave operations
  - periodic ping of successors
  - eliminate peers that have left from structure
  - join needs starting point and hook into the structure

- security?
- overhead with high churn?

Mobility

- spectrum of mobility, from network perspective



stationary wireless user, using same access point

mobile user, connecting/ disconnecting from network using DHCP.

mobile user, passing through multiple access point with ongoing sessions (cell phone)

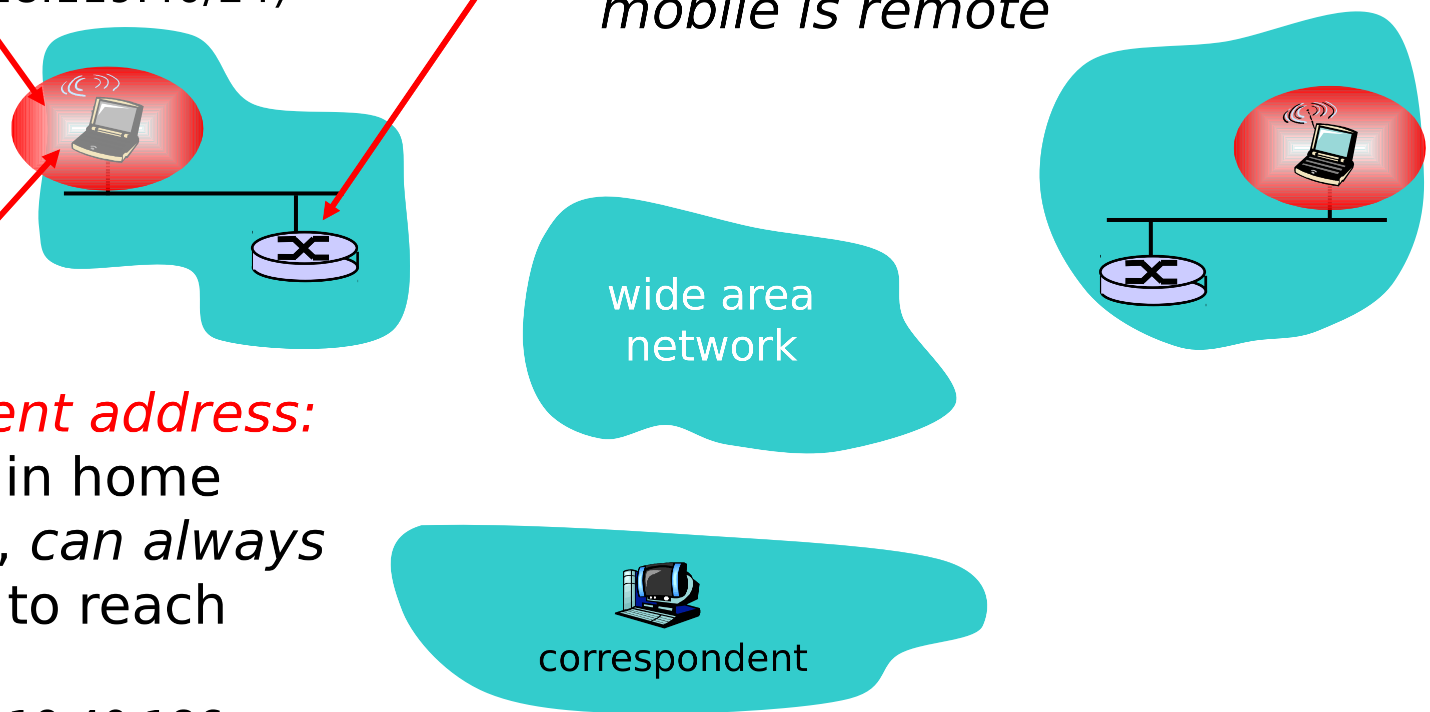
Mobility

- network access point
  - nearest network-level stationary router
  - might or might not be wireless access point
- challenges
  - initial lookup of responder
    - needs some form of registry
  - ongoing connectivity with movements
    - needs some form of update/redirection
  - similar, but different: time scale – session vs. packet

Example: Mobile IP

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



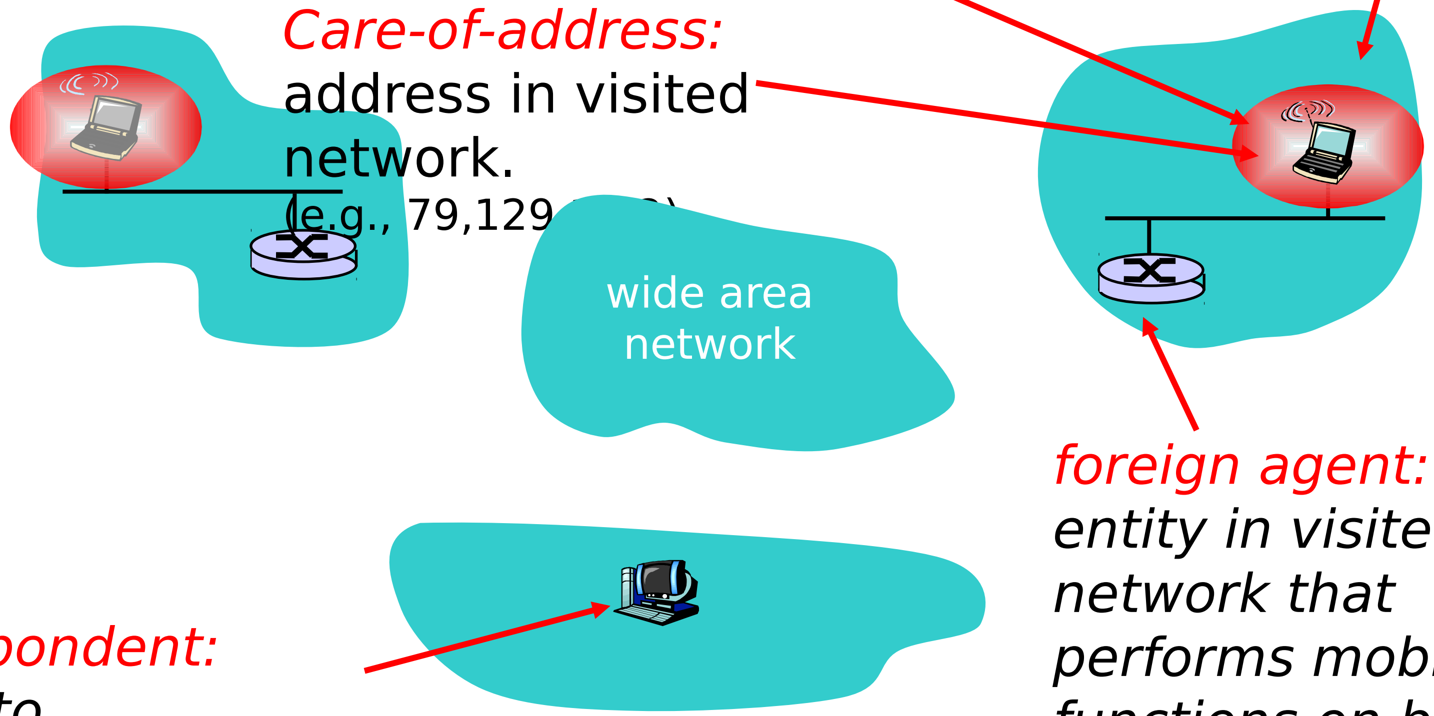
Permanent address: address in home network, *can always* be used to reach mobile
e.g., 128.119.40.186

Mobile IP

Permanent address: remains constant (e.g., 128.119.40.186)

visited network: network in which mobile currently resides (e.g., 79.129.13/24)

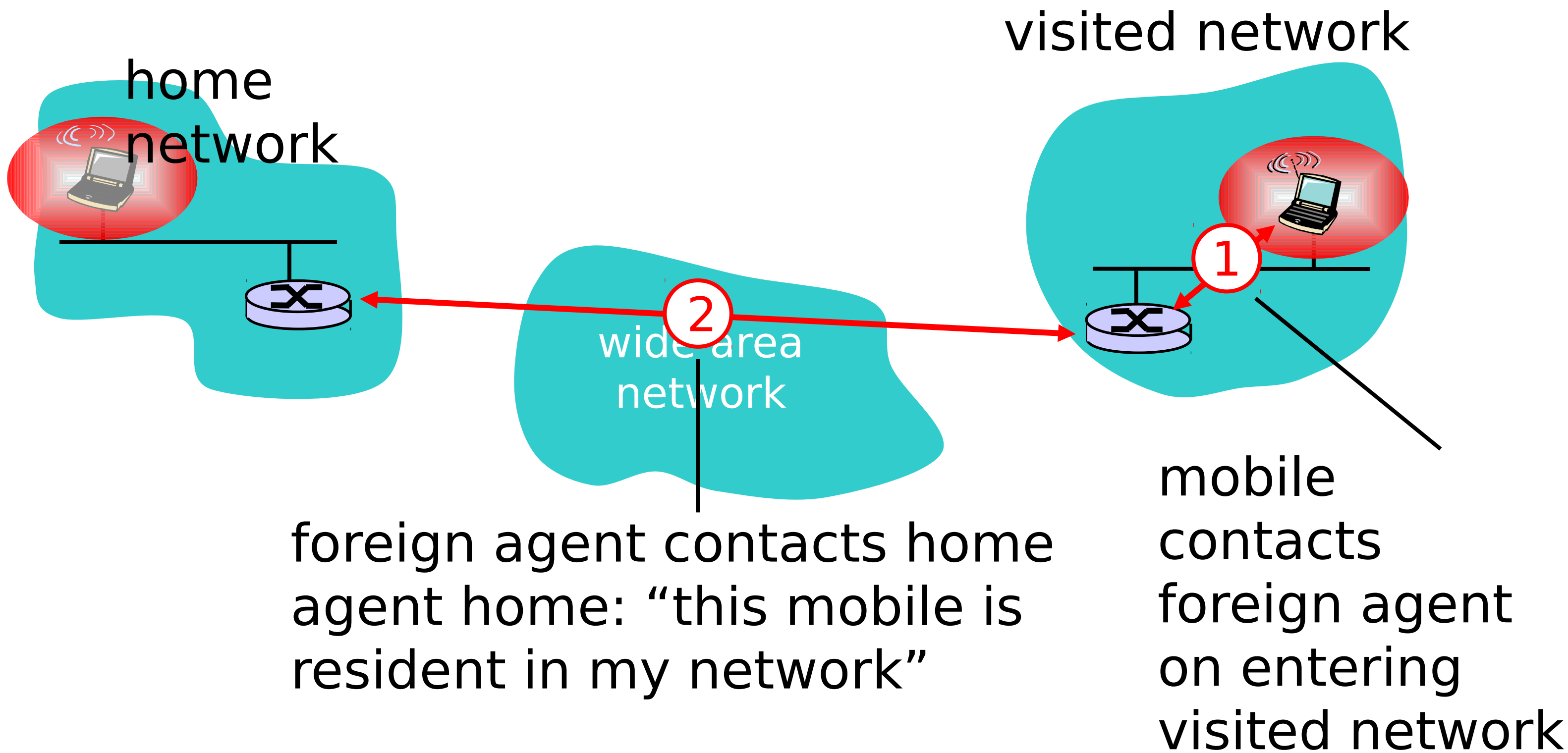
Care-of-address: address in visited network. (e.g., 79,129



foreign agent: entity in visited network that performs mobility functions on behalf of mobile.

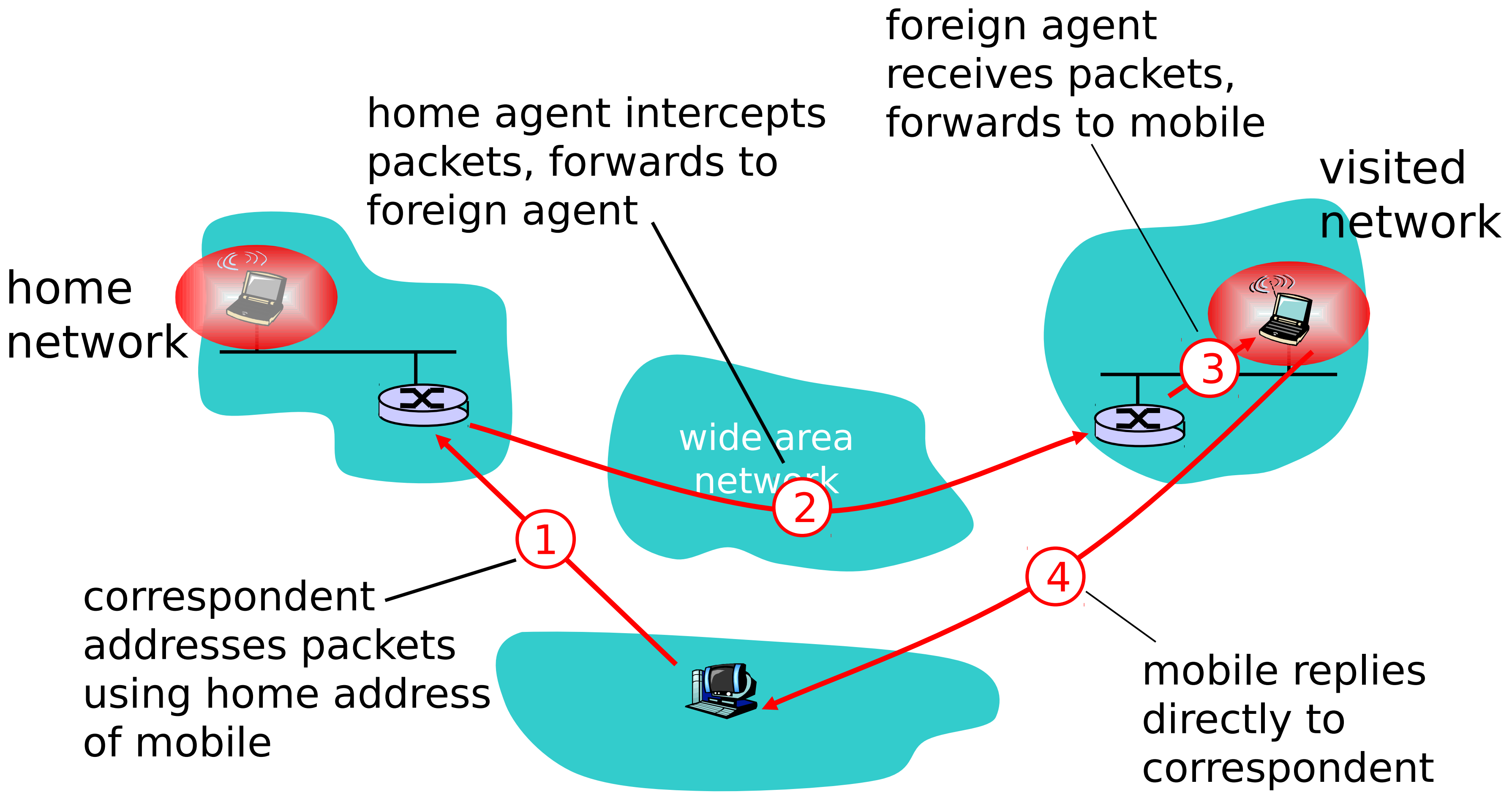
correspondent: wants to communicate with mobile

Mobile IP – Registration

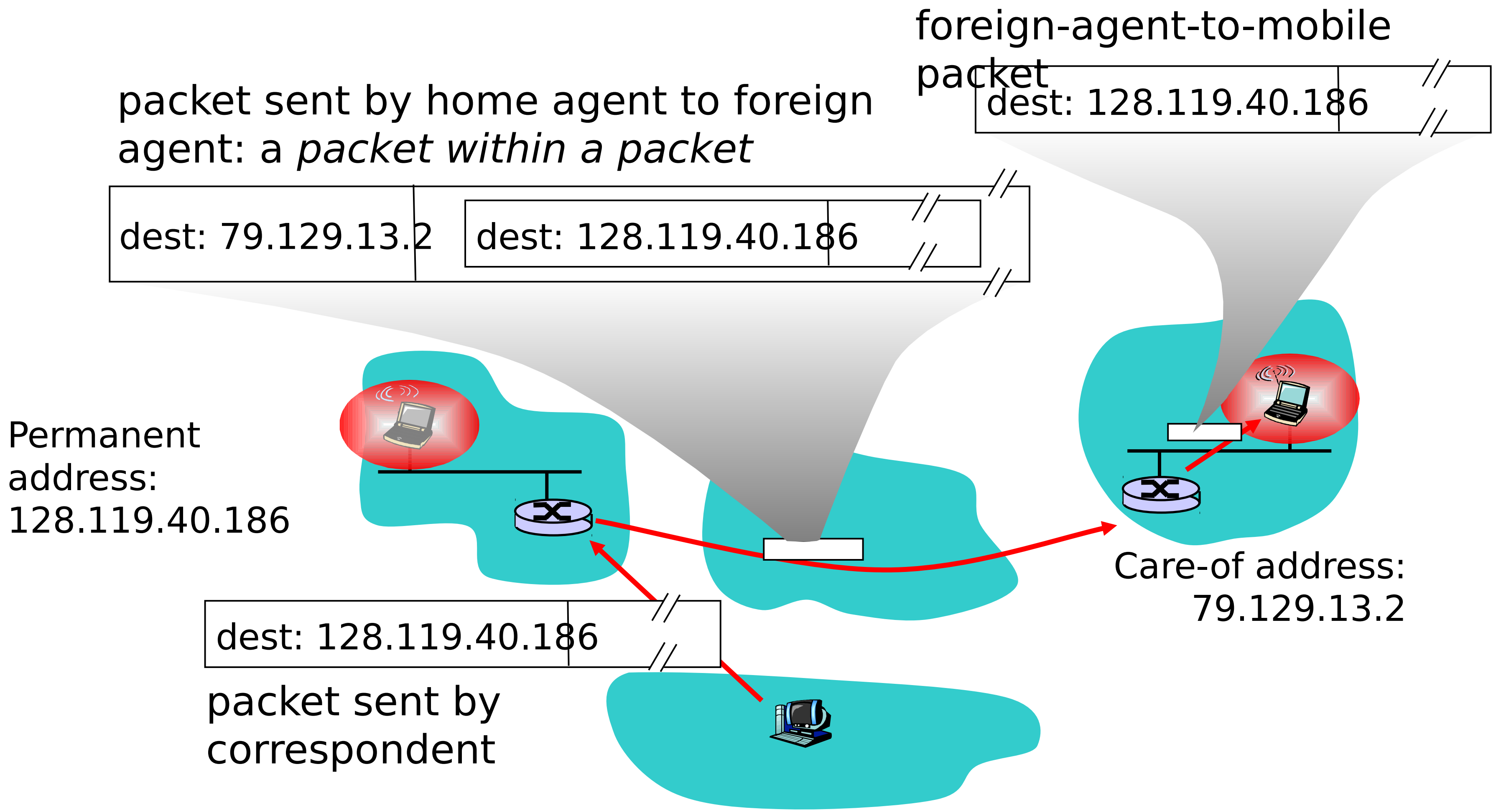


- foreign agent knows about mobile
- home agent knows location of mobile

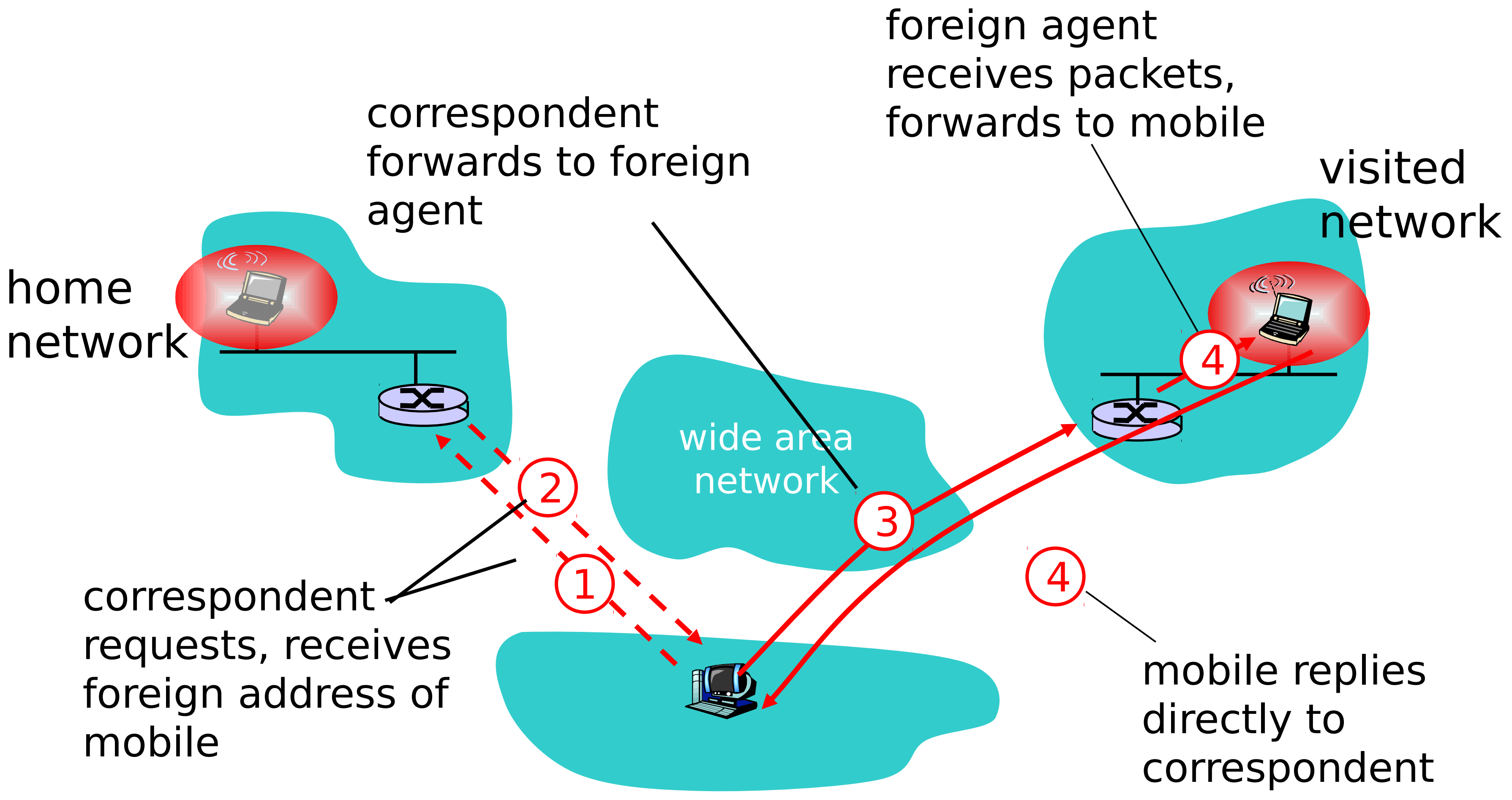
Mobile IP – Indirect Routing



Mobile IP – Indirect Routing

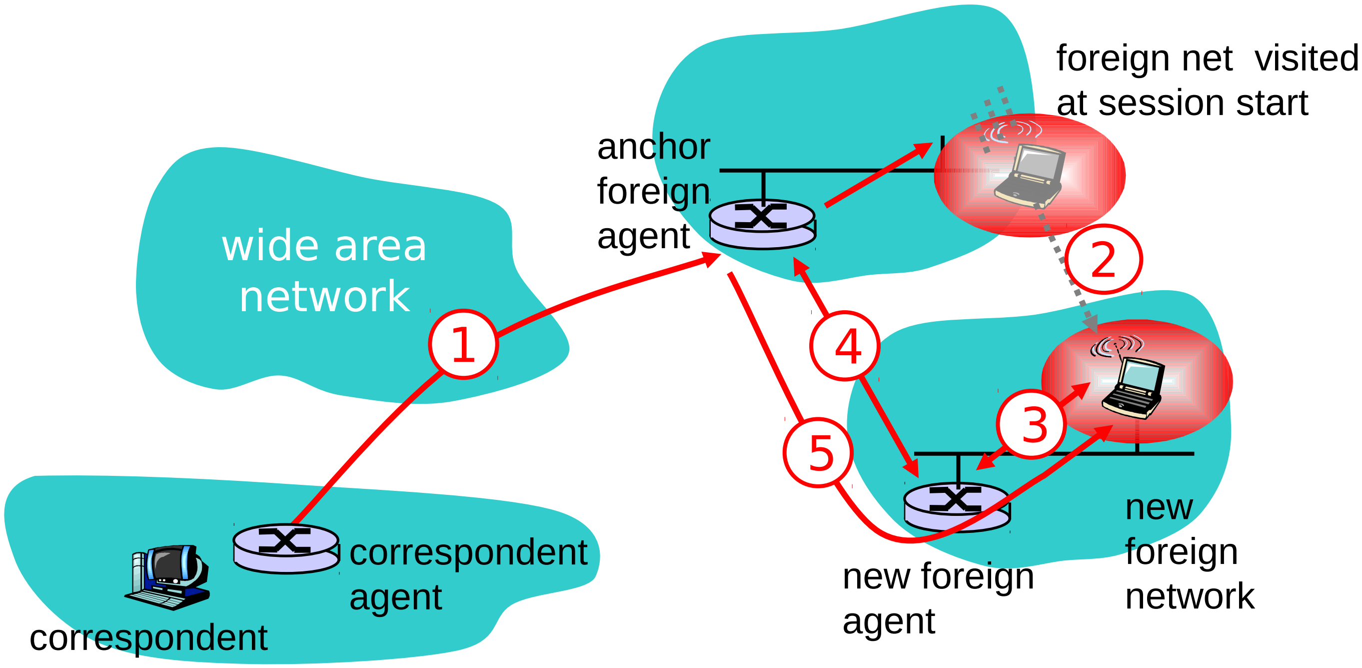


Mobile IP – Direct Routing



Mobile IP – Hierarchical Agents

- fast handover support – avoid end-to-end delay
- can be extended arbitrarily



Mobile IP – Discussion

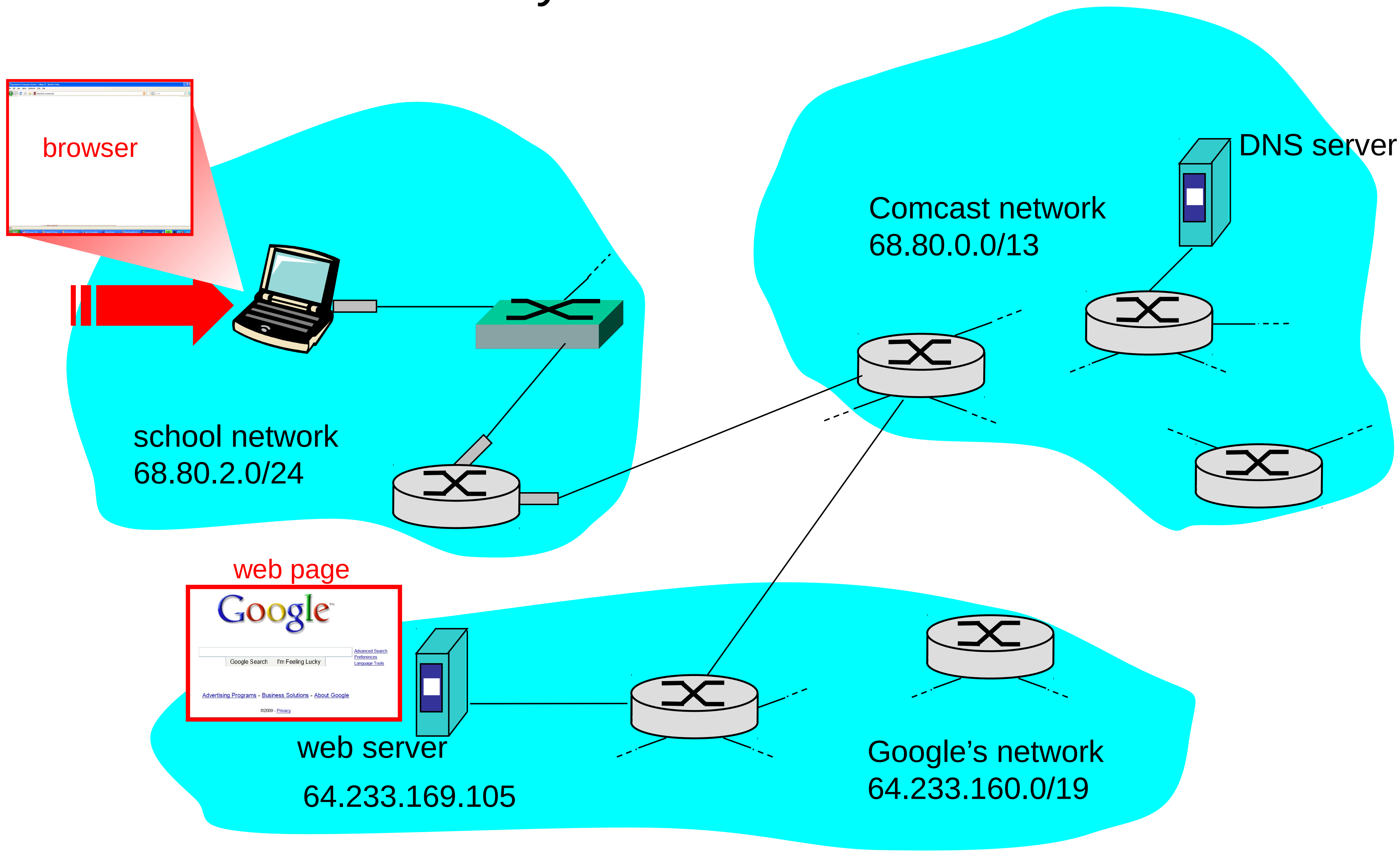
- overarching design consideration
  - transparency, backward-compatibility
  - triangle routing direct reply – source addr checks?
- foreign agent functionality can be with mobile
  - e.g., with address allocation via DHCP
- Mobile IP uses IP tunneling
  - could use direct forwarding with address rewriting
  - ... similar to reverse NAT
  - ... similar to virtual circuit -> similar to GSM

A Day in the Life of a Web Request

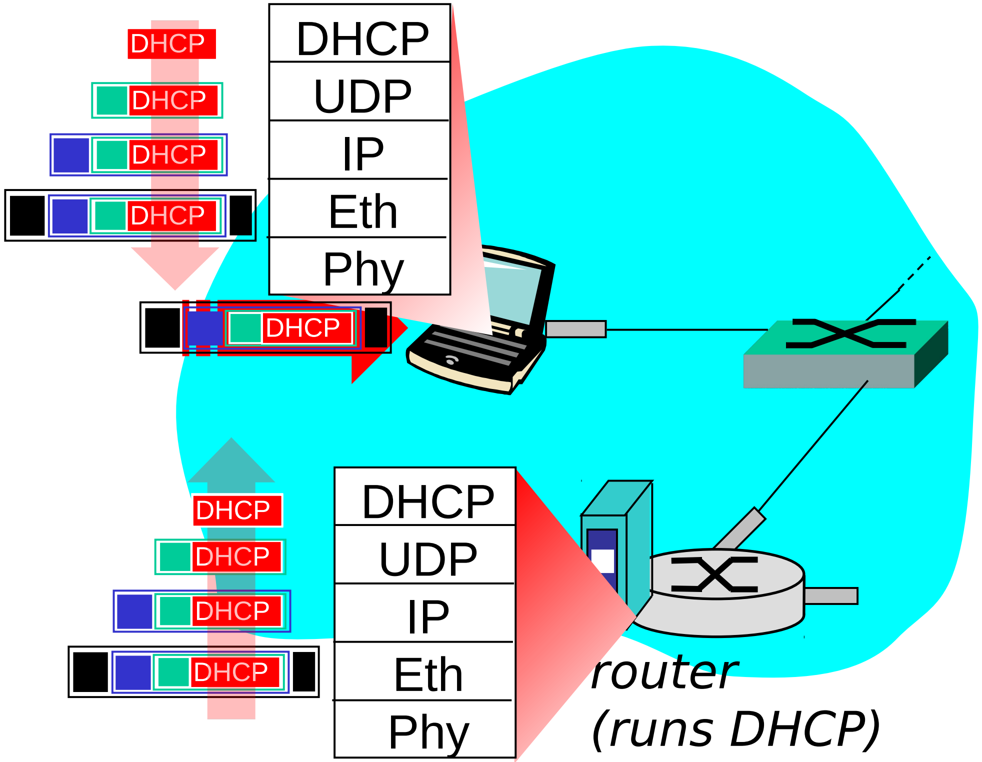
- journey through basic functionality complete!
  - channel, network, transport, naming

- putting-it-all-together: synthesis!
  - *goal:* identify, review, understand protocols (at all layers) involved in seemingly simple scenario: requesting www page
  - *scenario:* student attaches laptop to campus network, requests/receives www.google.com

A day in the life: scenario



A day in the life… connecting to the Internet

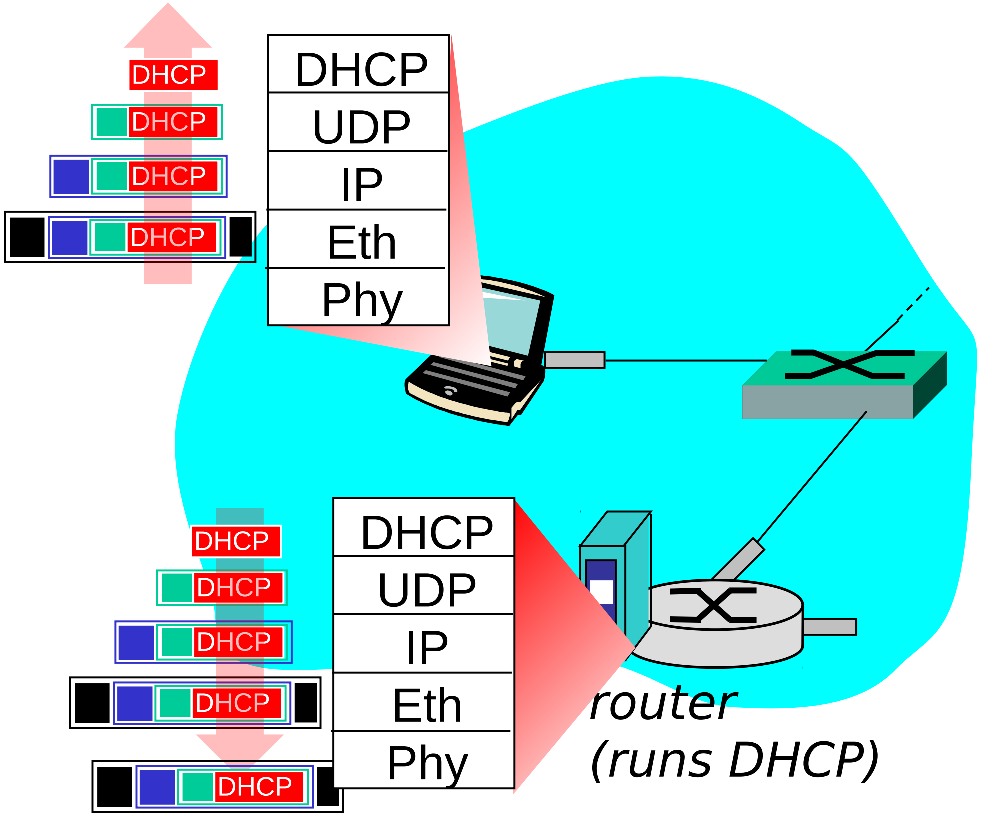


- connecting laptop needs to get its own IP address, addr of first-hop router, addr of DNS server: use ***DHCP***

- DHCP request ***encapsulated*** in ***UDP***, encapsulated in ***IP***, encapsulated in ***802.1*** Ethernet
- Ethernet frame ***broadcast*** (dest: FFFFFFFFFFFF) on LAN, received at router running ***DHCP*** server

- Ethernet ***demux'ed*** to IP demux'ed, UDP demux'ed to DHCP

A day in the life… connecting to the Internet

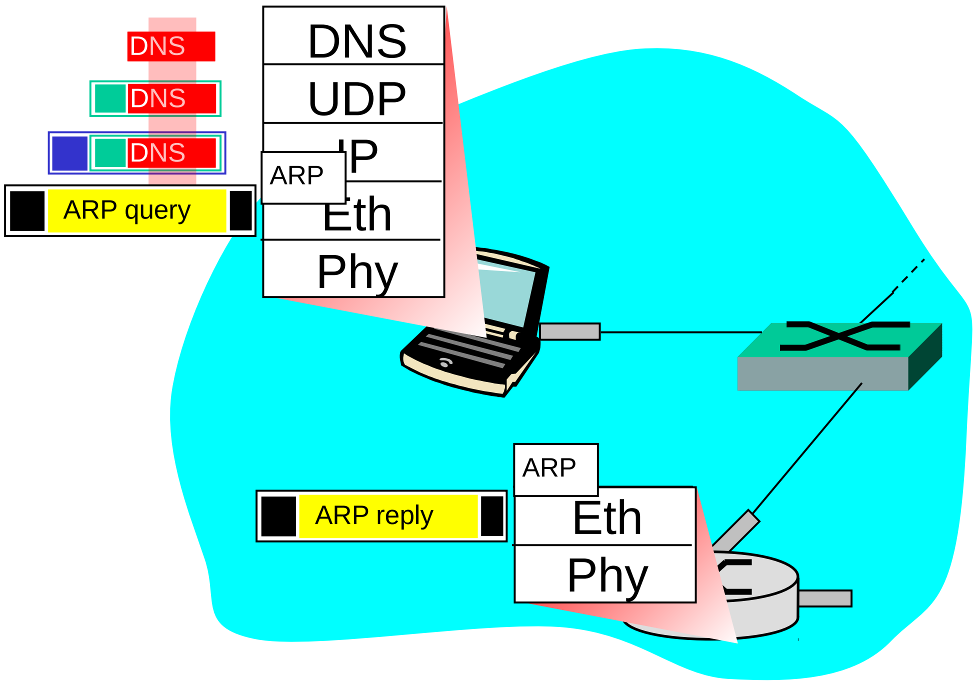


- DHCP server formulates ***DHCP ACK*** containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server

- encapsulation at DHCP server, frame forwarded (***switch learning***) through LAN, demultiplexing at client
- DHCP client receives DHCP ACK reply

Client now has IP address, knows name & addr of DNS server, IP address of its first-hop router

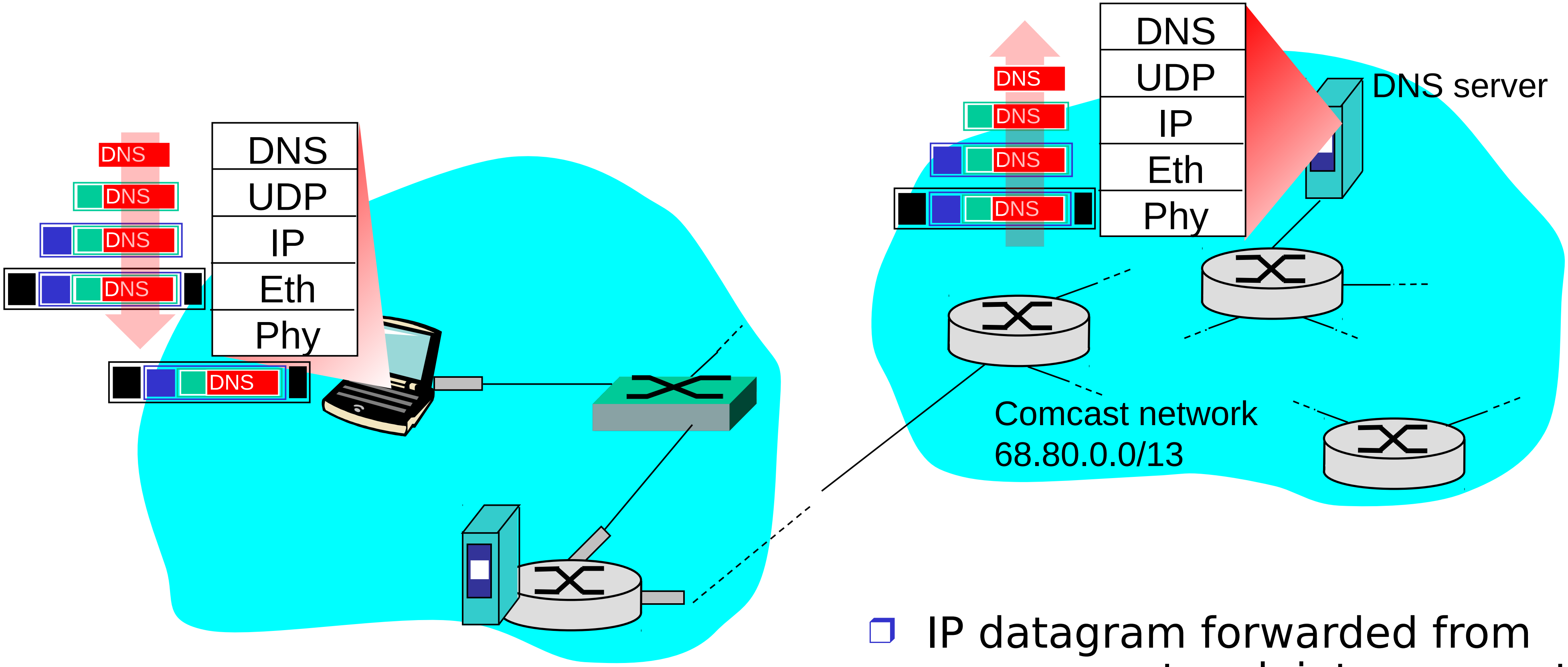
A day in the life… ARP (before DNS, before HTTP)



- before sending ***HTTP*** request, need IP address of www.google.com: ***DNS***

- DNS query created, encapsulated in UDP, encapsulated in IP, encasulated in Eth. In order to send frame to router, need MAC address of router interface: ***ARP***
- ***ARP query*** broadcast, received by router, which replies with ***ARP reply*** giving MAC address of router interface
- client now knows MAC address of first hop router, so can now send frame containing DNS query

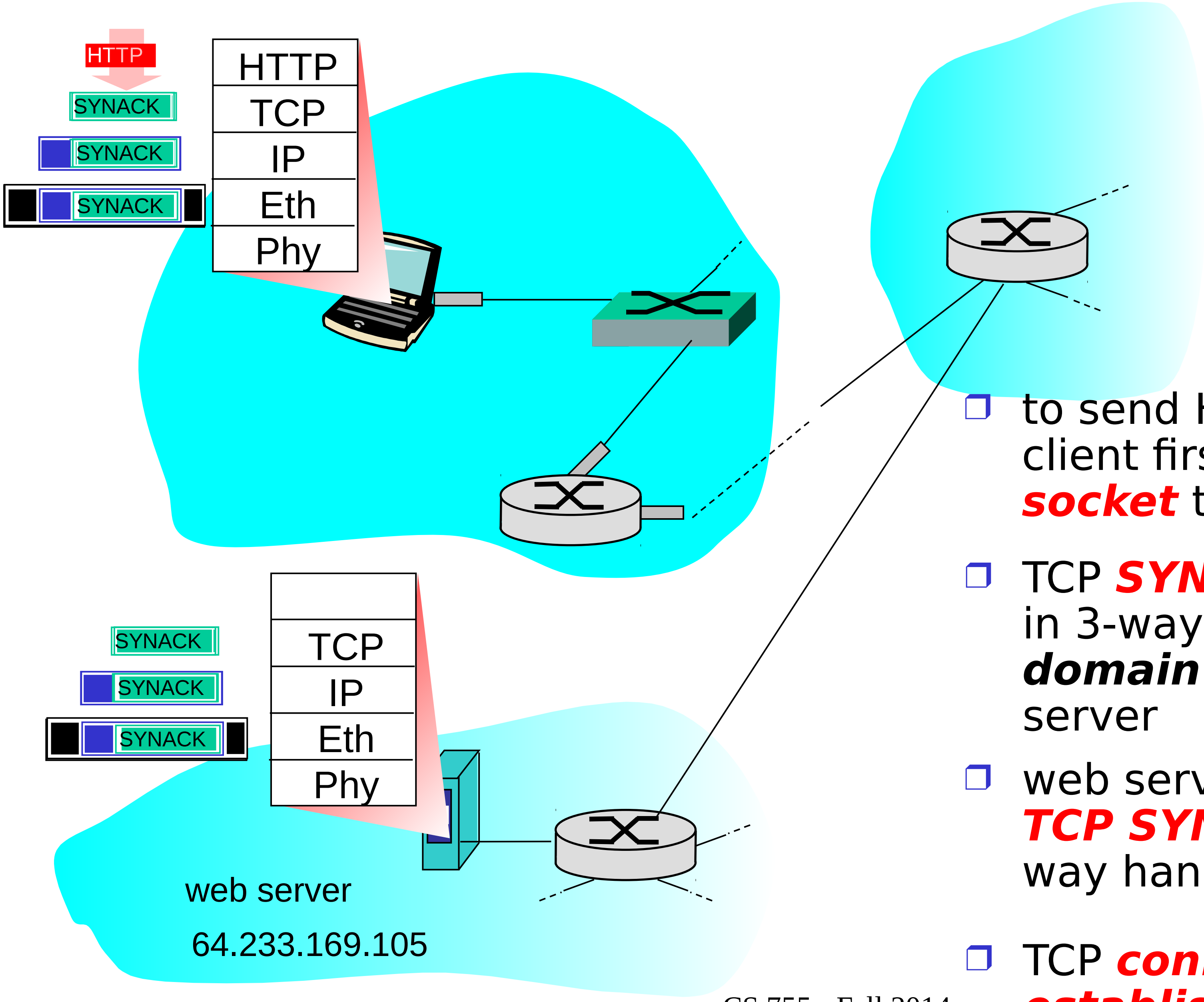
A day in the life… using DNS



- IP datagram containing DNS query forwarded via LAN switch from client to 1st hop router

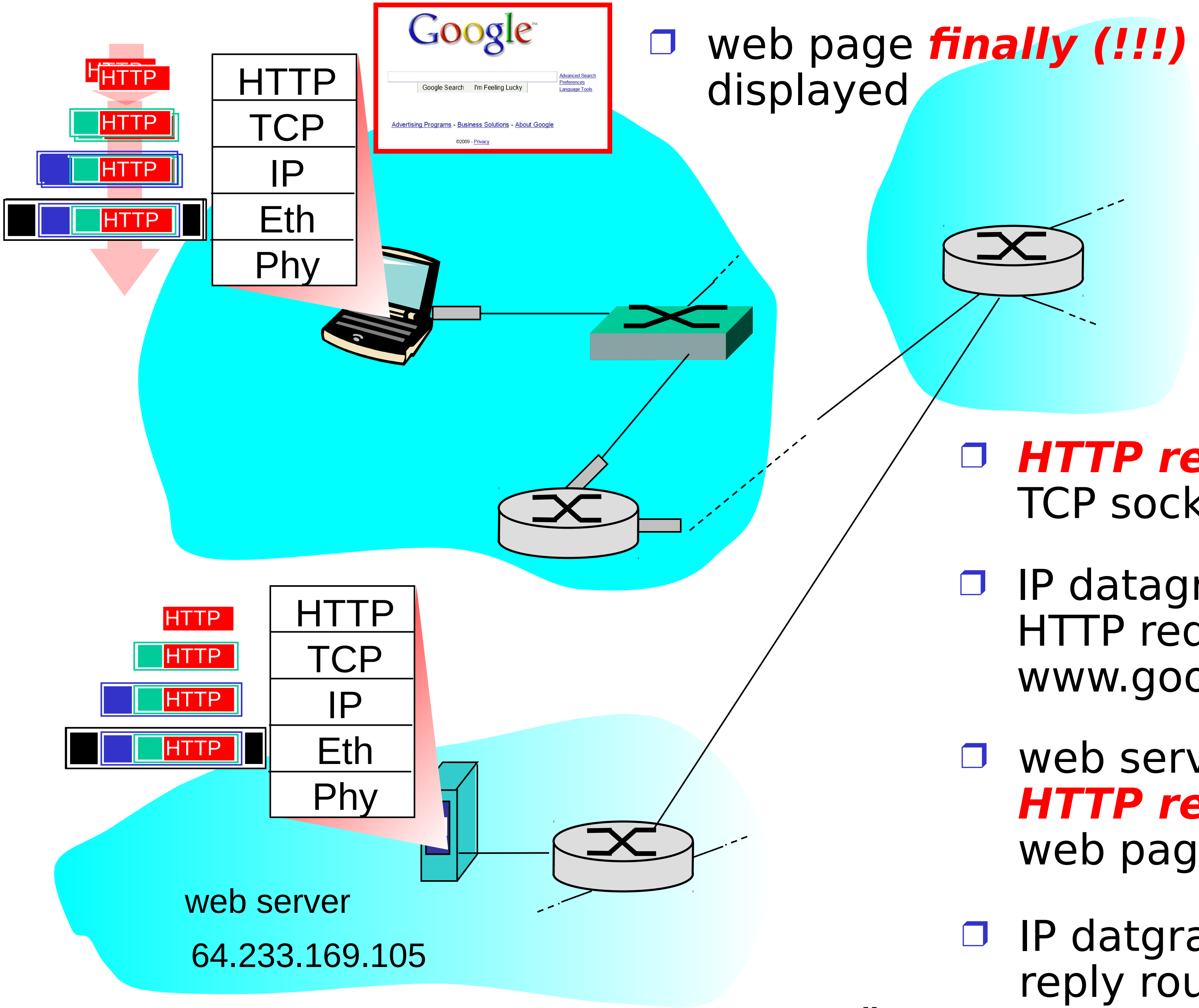
- IP datagram forwarded from campus network into comcast network, routed (tables created by ***RIP, OSPF, IS-IS*** and/or ***BGP*** routing protocols) to DNS server
- demux'ed to DNS server
- DNS server replies to client with IP address of www.google.com

A day in the life… TCP connection carrying HTTP



- to send HTTP request, client first opens ***TCP socket*** to web server
- TCP ***SYN segment*** (step 1 in 3-way handshake) ***inter-domain routed*** to web server
- web server responds with ***TCP SYNACK*** (step 2 in 3-way handshake)
- TCP ***connection established!***

A day in the life… HTTP request/reply



- web page ***finally (!!!)*** displayed
- ***HTTP request*** sent into TCP socket
- IP datagram containing HTTP request routed to www.google.com
- web server responds with ***HTTP reply*** (containing web page)
- IP datgram containing HTTP reply routed back to client