University of Pittsburgh

ECE 1150: Computer Networks

The Application Layer – Introduction , HTTP, Support services

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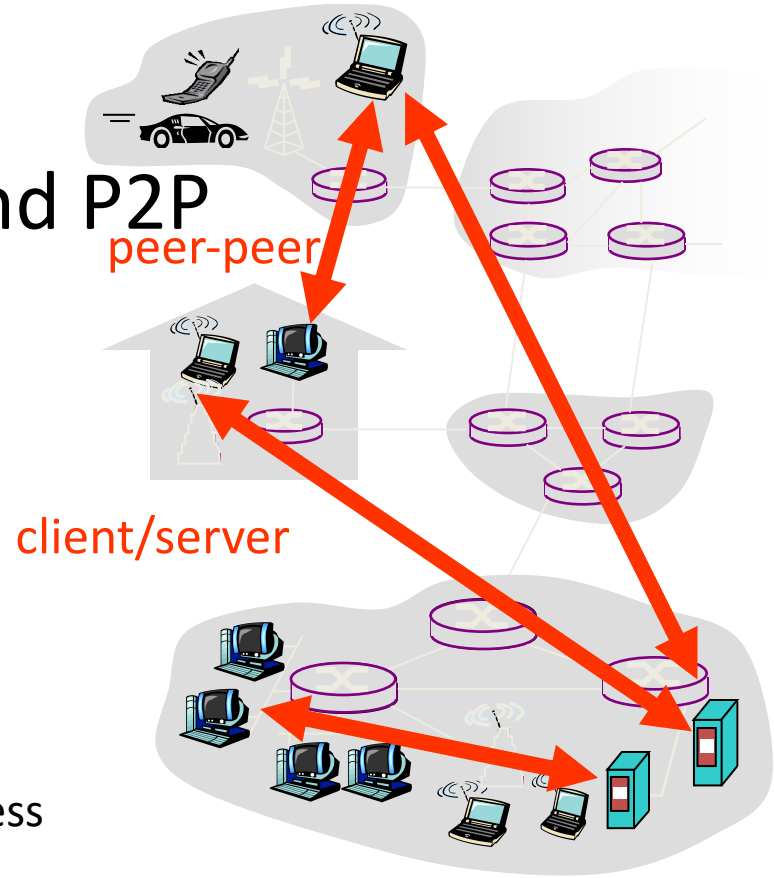
This Unit

- Intro
- Application Protocols
  - HTTP
  - Support services

Application Architectures

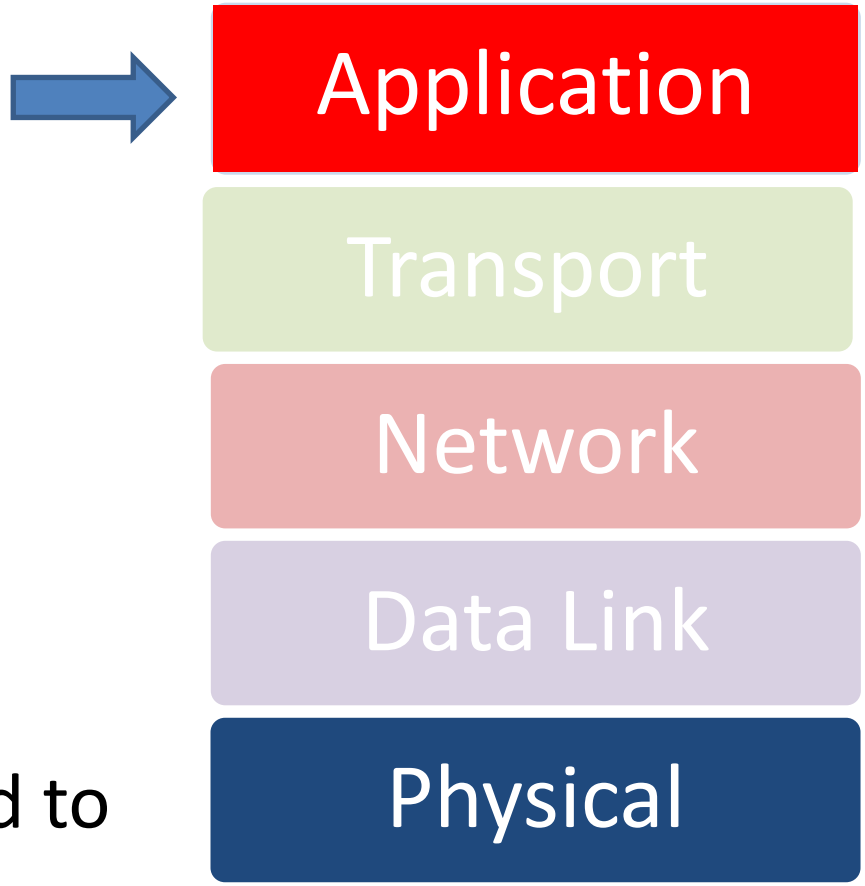
- Client-server
- Peer-to-peer (P2P)
- Hybrid of client-server and P2P



- Server:
  - Always-on host
  - Permanent IP address
- Clients:
  - May have dynamic IP addresses

Application Layer Protocol Defines

- Types of messages exchanged,
  - e.g., request, response
- **Message syntax**
  - what fields in messages
- **Message semantics**
  - meaning of information in fields
- **Rules:** when and how processes send & respond to messages



Application Layer

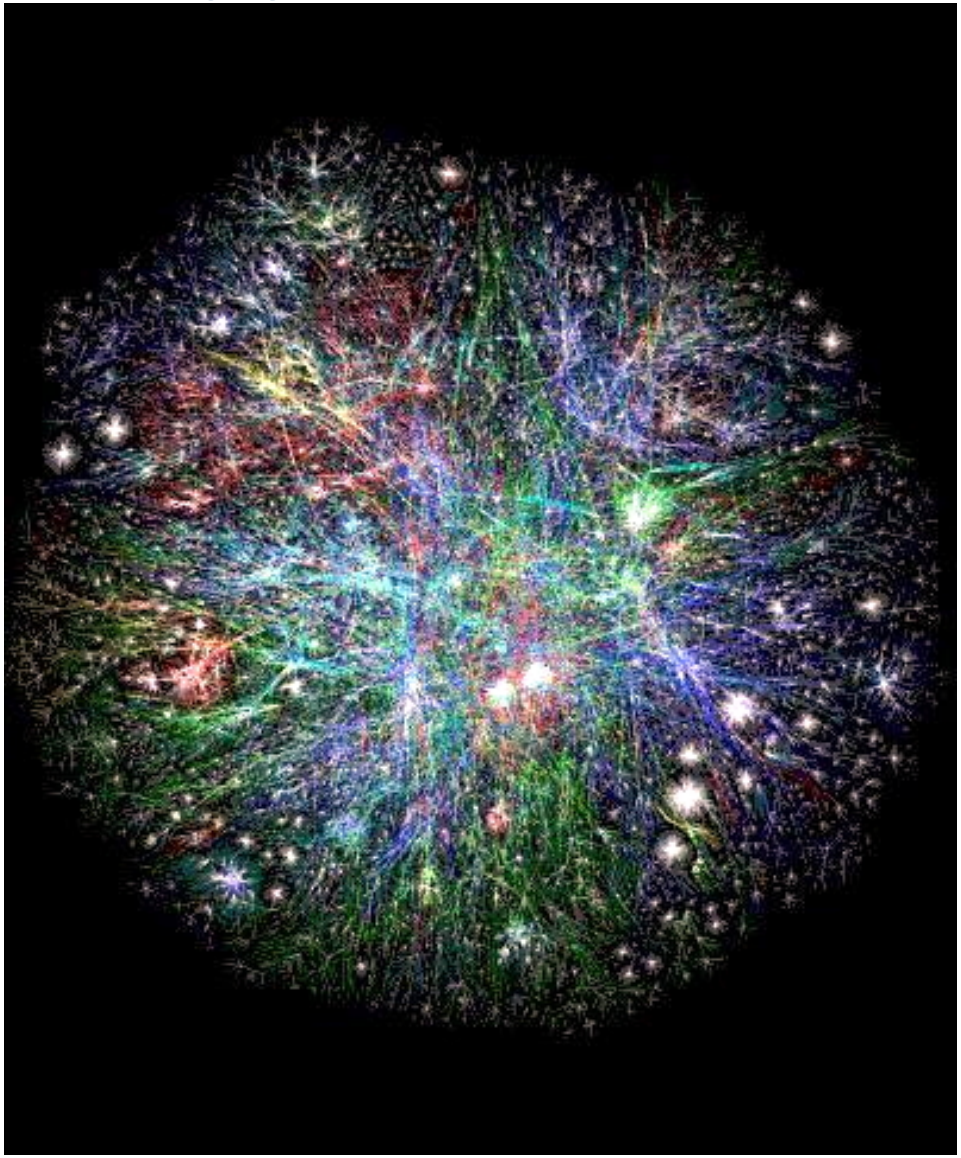
- The application layer specifies
  - Supported functions
  - Commands to accomplish these functions
- Public-domain protocols:
  - Defined in RFCs
  - Allows for interoperability
  - e.g., HTTP
- Proprietary protocols:
  - e.g., Skype

Application vs. Lower Layers

- Unlike lower layers, each supported end-user task has a different application layer protocol associated with it
  - HTTP for web
  - SMTP for email
  - FTP file sharing
  - …Many others

Example: Web Application

- The web consists of pages
- Pages are linked to each other through hyperlinks
  - Linked pages can be anywhere in the world
    - Hence the name: World Wide Web
- Web pages are written in hypertext markup language (HTML)



Web Page Example

```
<html>
   <head>
   <title>HTML 101</title>
   </head>
   <body>
   <h1>Welcome to html page at
   <a href = “www.usf.edu”>USF</a> </h1>
   <p>Please check back later</p>
   </body>
</html>
```

How the Web Works?

- Each **client** has **application software** package called **Web browser**
  - Such as Microsoft Internet Explorer
- Each **server** has an **application software** package called **Web server**
  - such as those produced by Microsoft or Apache
- For a client to get to a sever, it uses a Uniform Resource Locator (**URL**) for the page
  - The URL specified the address of the **Web server**
  - RFC 1738, 1994

How the Web Works?

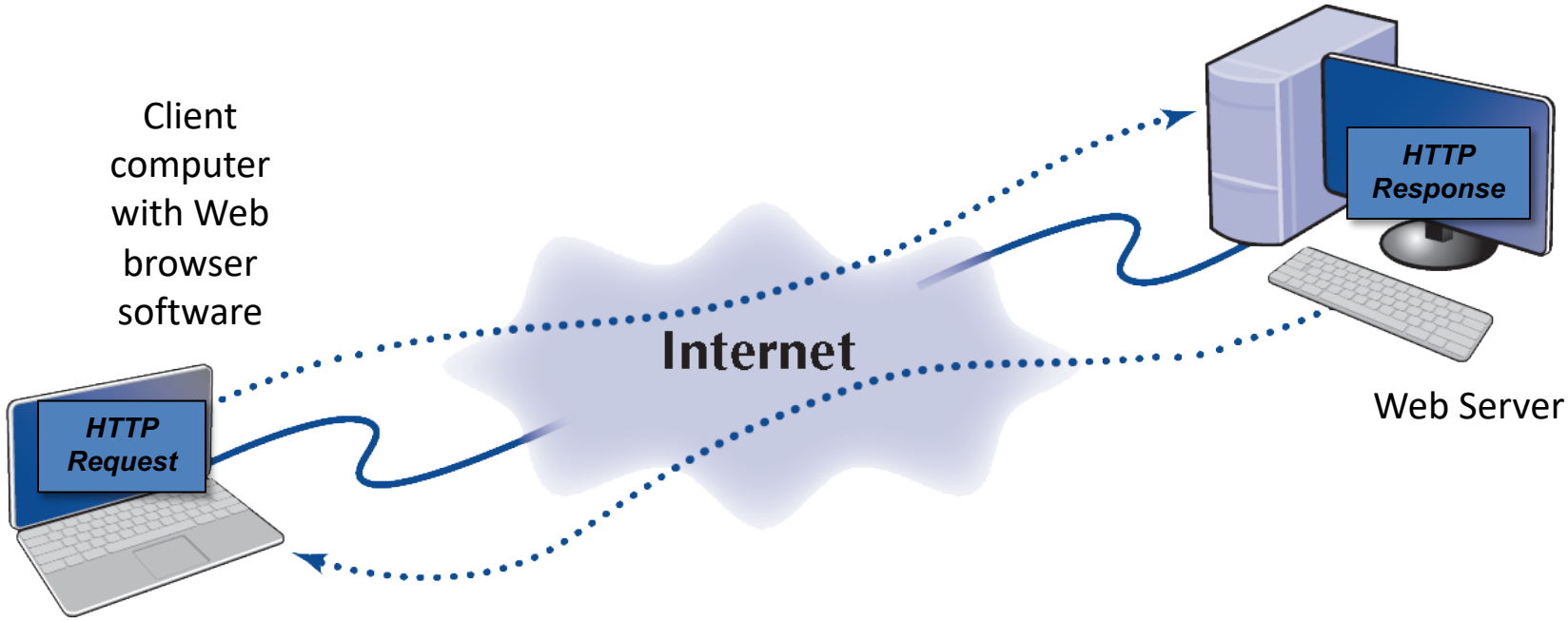
- For the request from the Web browser to be understood by the Web server, they must use the same standard **protocol** (same language)
  - If there is no standard language, it will be impossible to have Microsoft browser to communicate with Apache server
- The **standard protocol** for communication between browser and server is Hypertext Transfer Protocol (**HTTP**).

The HTTP Protocol

- Defined in RFC 2616 (1999)
- Based on **request/response**
- **Client** sends **request** to server
  - **E.g.** GET, POST , DELETE, CONNECT
- **Server responds** with **status code**, **meta-information and data**

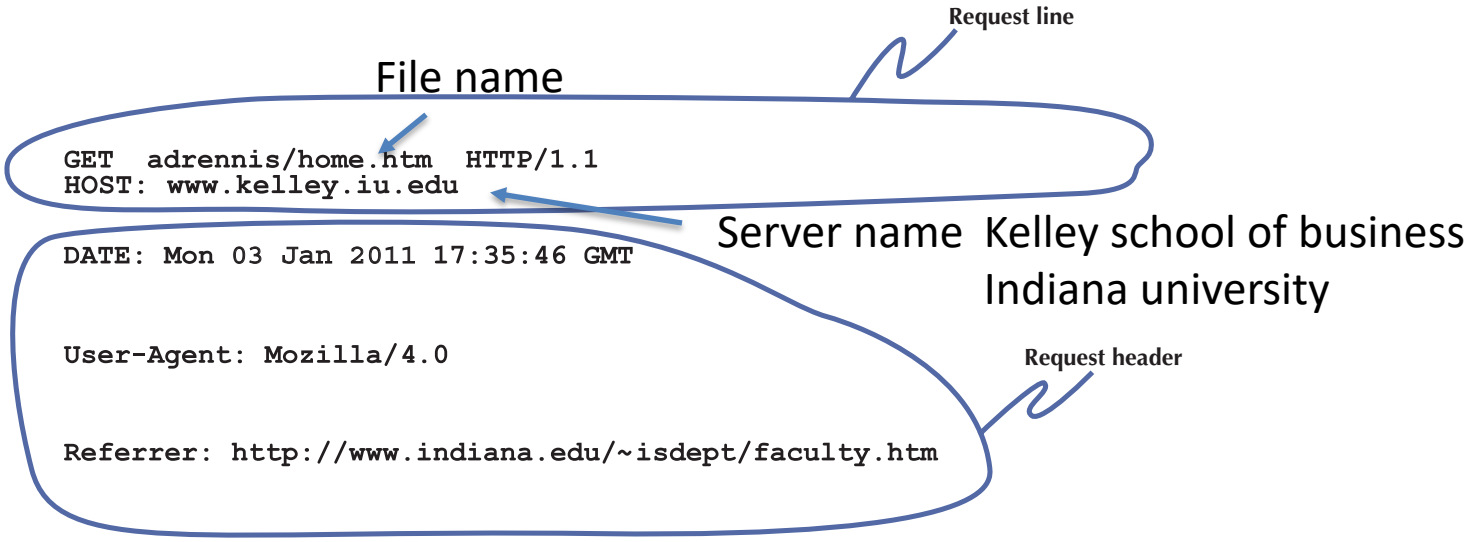
The HTTP Protocol

- Hypertext Transfer Protocol (HTTP)
- HTTP Request and Response



The HTTP Protocol

- HTTP Request



Request line: command (GET), provides web page, HTTP version number used by browser

Request header: number of optional information, such as browser used and date.
Referrer: reflects that user obtained the URL of this page by clicking on a click on another page

There could be request body if a user fill a form for example.

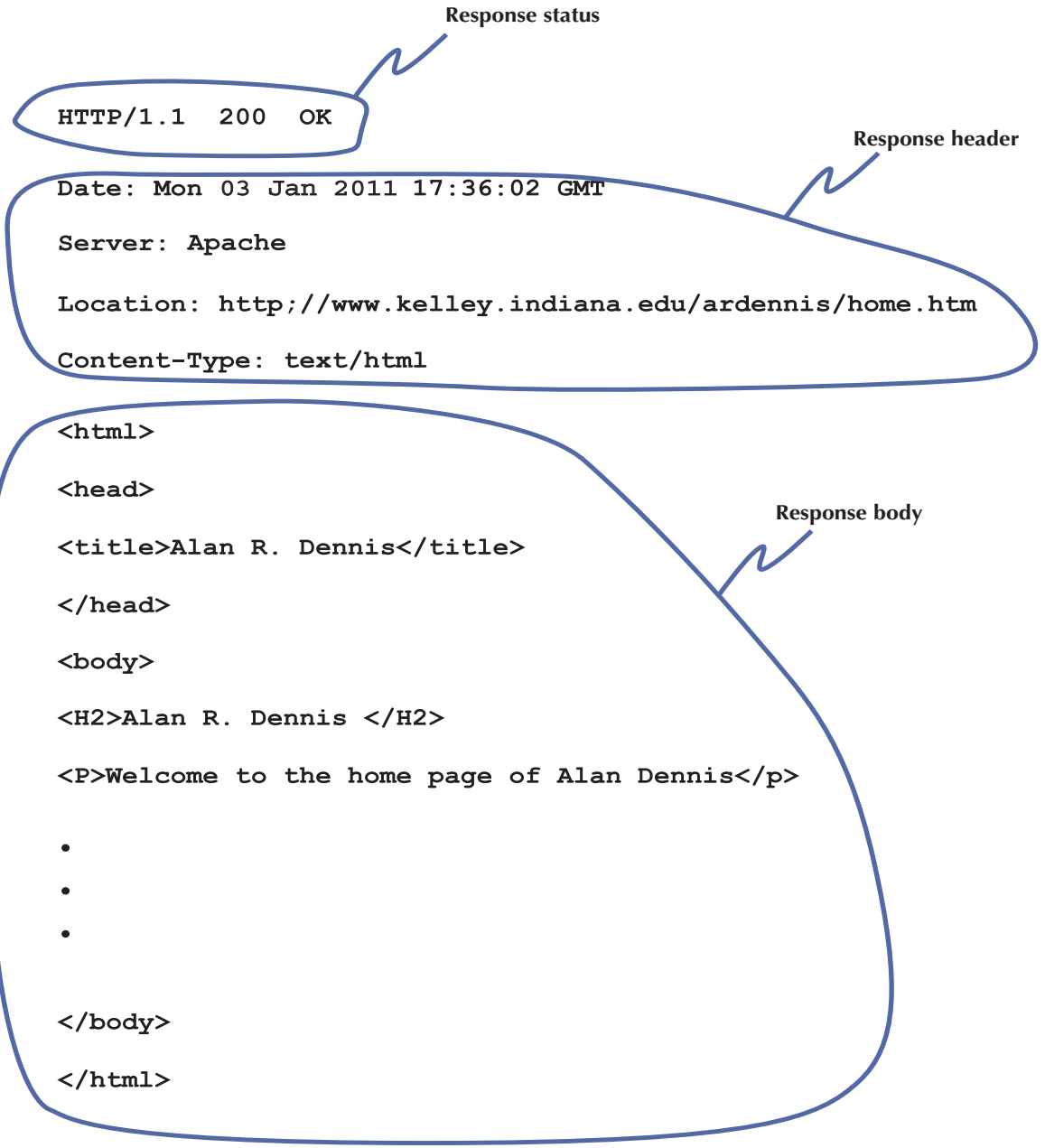
The HTTP Protocol

- HTTP Response

Status code 200 means success

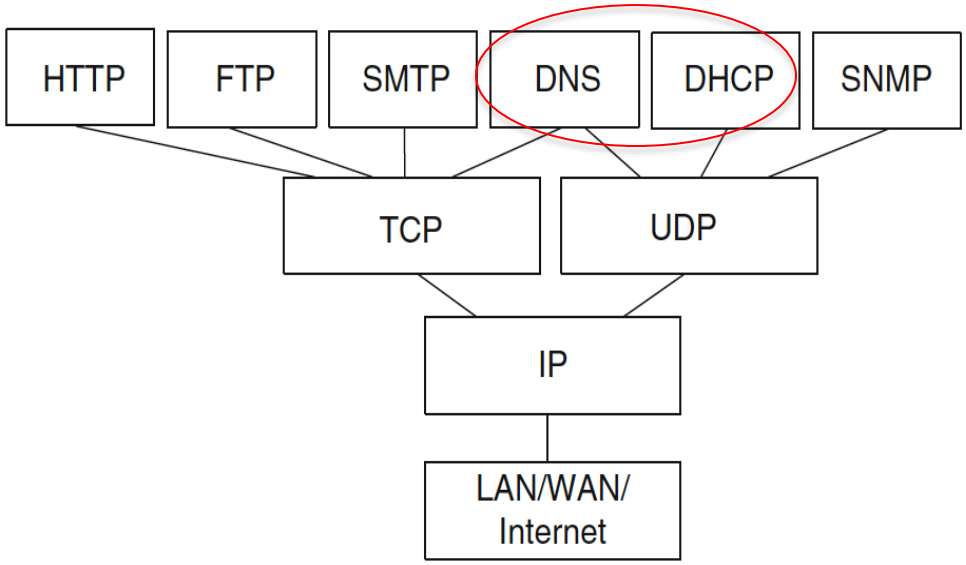
Header contains information about server

The response body is the webpage



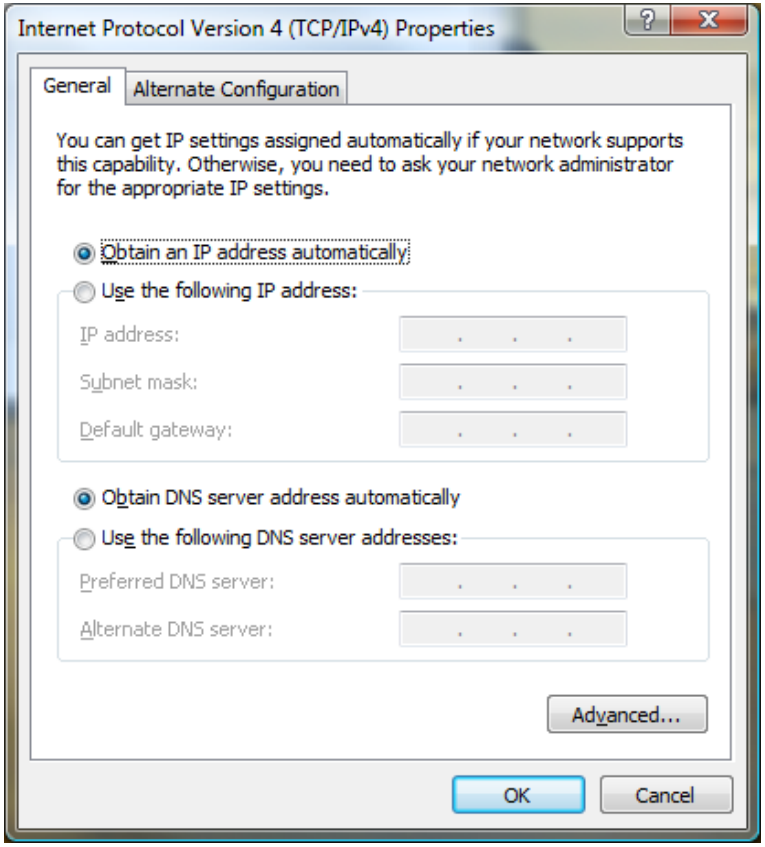
Support Services

- How does a device get an IP address when it joins a network?
  - Through DHCP application protocol
- How can a host know the IP address of the server?
  - DNS application protocol



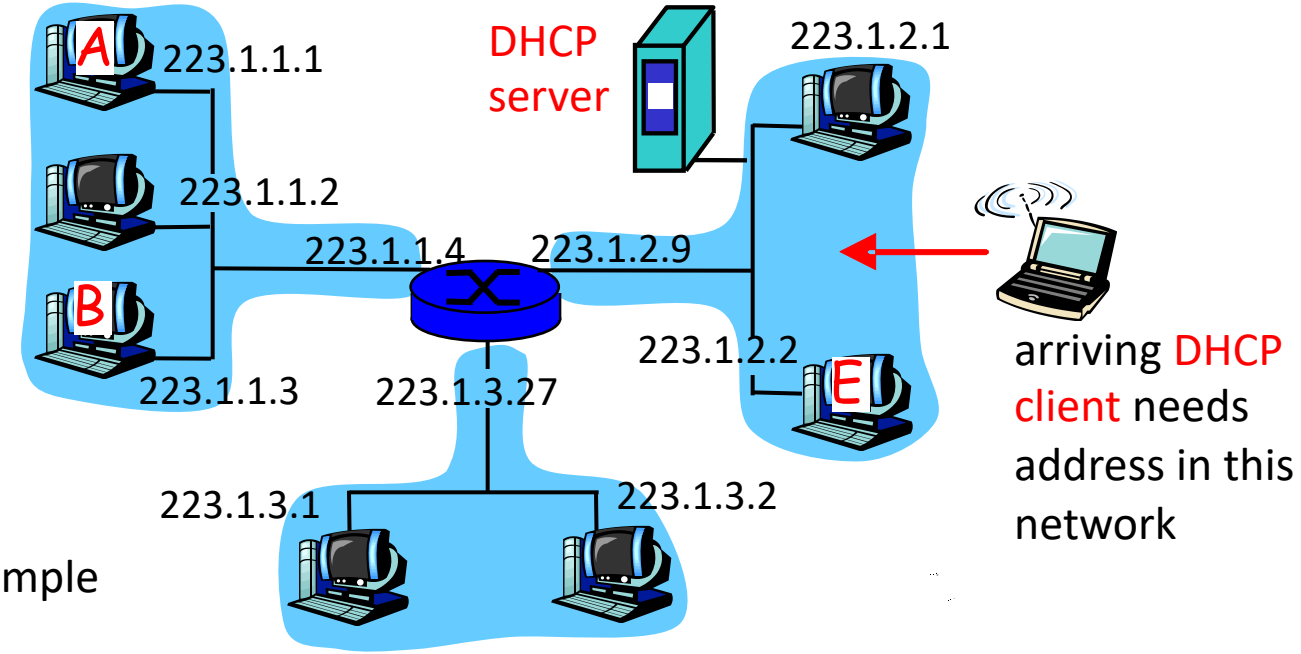
DHCP: Dynamic Host Configuration Protocol

- How does a device get an IP address when it joins a network?
  - Can be configured **manually**, however more often this task is **done automatically using DHCP**.
  - DHCP: Defined in RFC 2131 (March 1997)



DHCP

- DHCP is a **client-server** protocol
- DHCP server manages the pool of available IP addresses in a network
  - There is typically one DHCP server in each subnet
  - At home, the router acts as DHCP server

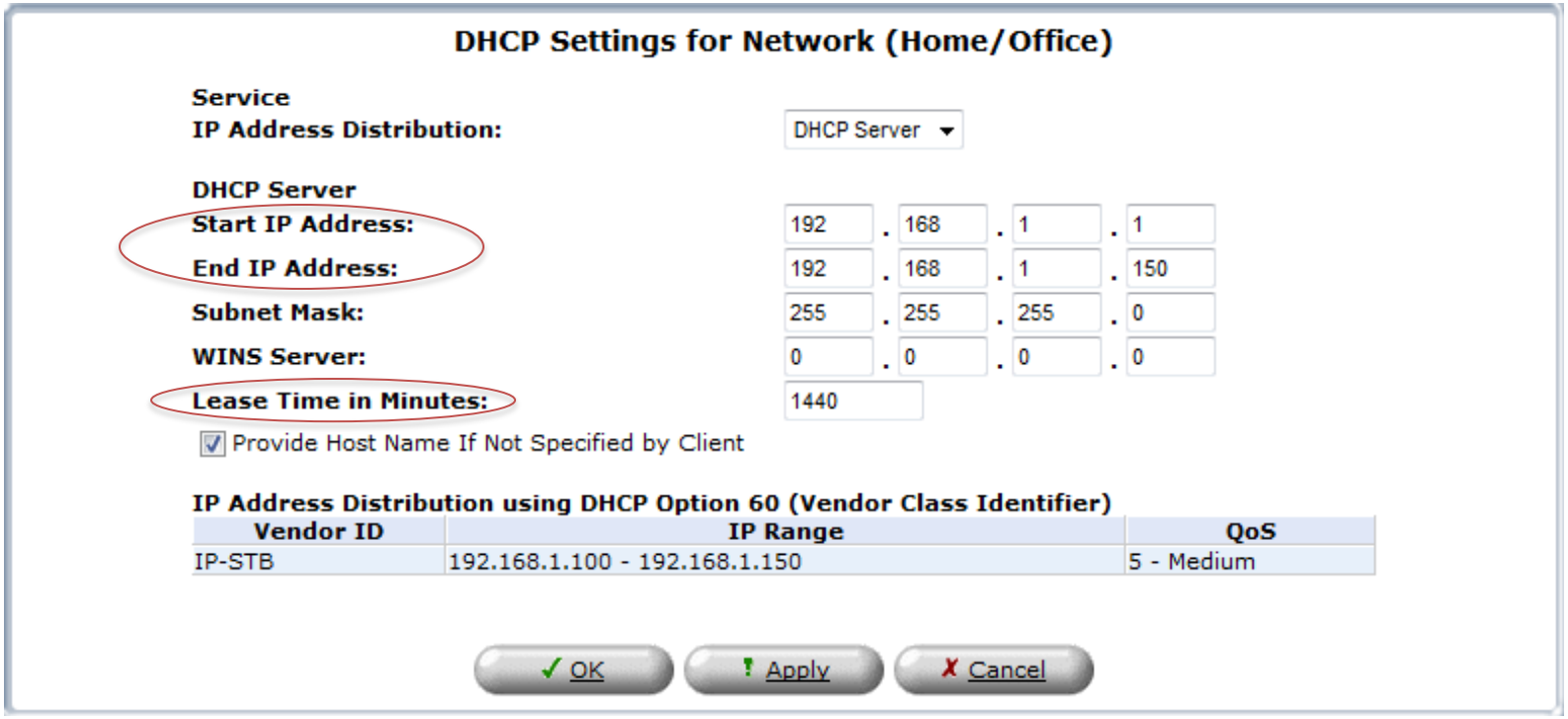


DHCP example

DHCP

- DHCP server can allocate addresses in 3 ways:
  - **Manual**: **permanent** assignment
    - The IP address assigned is not necessary the first available IP address (could be an easy to remember address)
    - Assigned by network administrator
    - Popular for **support devices** such as **printers**
  - **Automatic**: **Permanent** assignment
    - Addresses allocated by DHCP server on a **first-come first served basis.**
    - Once **allocated** it will be **always assigned**
    - Popular for servers, wireless APs, etc.
  - **Dynamic**: **Leased for short time** from address pool
    - Assign any address in the pool
    - Allows address reuse
    - Popular in LANs and ISP

Server Setting Example

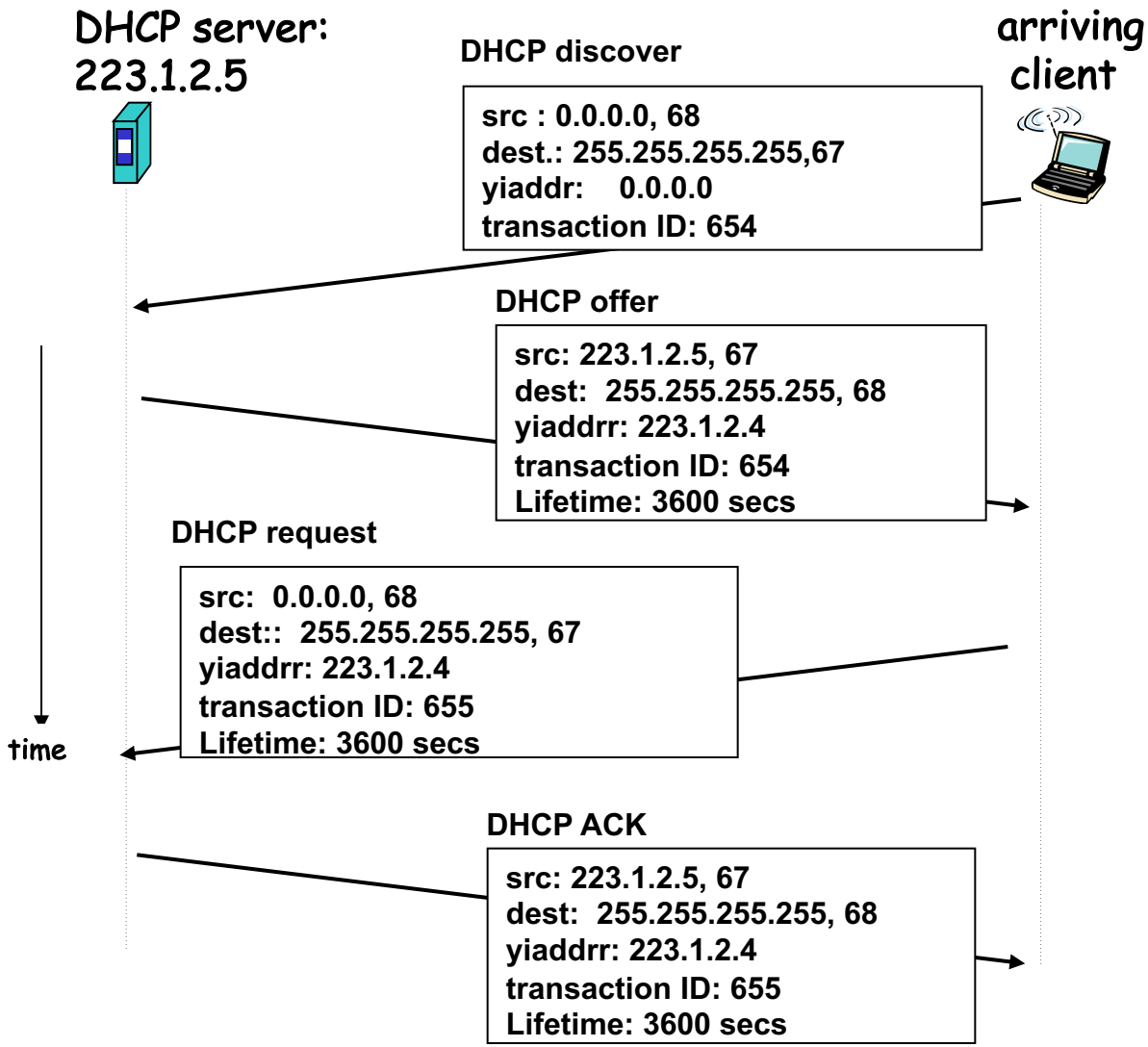


Setting of a server. Start IP address and End IP address specify range of available addresses

DHCP Dynamic Assignment

- IP address is leased for a certain time, called **lease time**
- When a host leaves the network, its address is **returned to the pool** of addresses
  - Useful when **computers will only be connected intermittently** to the network (not servers)
  - Considered as a solution to IP address shortage

1. DHCP server discovery: client **broadcast** message to find a DHCP server (DHCP server is at UDP port 67)
2. DHCP server offer: **broadcast** message, that client receives with suggested IP address and lease duration
   - Multiple servers may respond
3. DHCP request: client choose server and respond to offer
   - **Broadcast** so other servers know
4. DHCP ACK: server confirms



"yiaddr" your Internet address = address allocated to newly arriving client

DHCP: Network Information

- The DHCP server provides an **IP address for a fixed duration** (lease time) in response to a client's DHCP request

- The client can request the DHCP server for an **extension** of the lease before the lease expires
  - Attempts to provide same address as before if possible

- The DHCP server also provides to the client**:**
  - **Subnet mask**
  - **Default gateway (router):**
    - that is how we know the IP address of the router
    - Then we use ARP to get its MAC address
  - **Address of local DNS server**
    - DNS - next

Support Services

- How does a device get an IP address when it joins a network?
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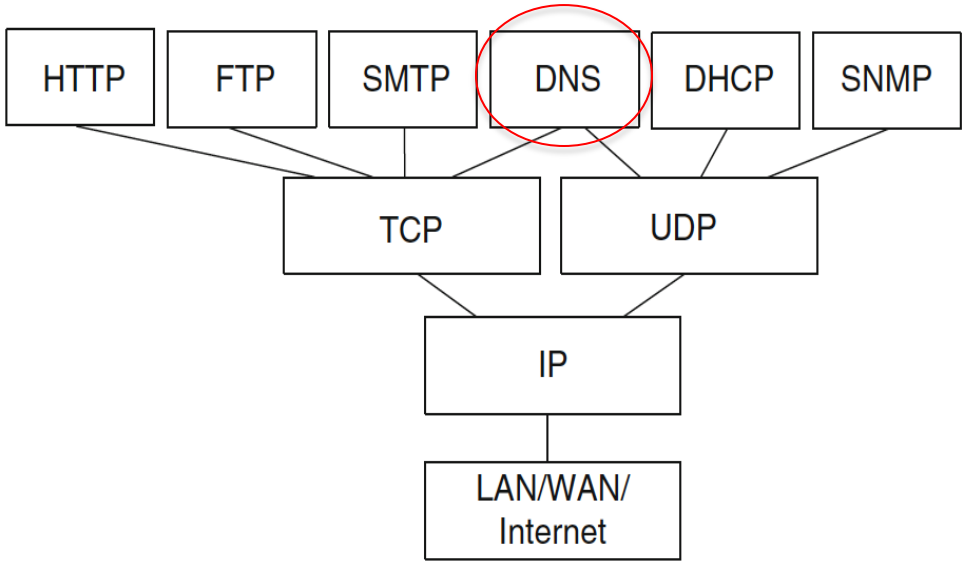


The need for a Name Service

- **How to get the IP address of server (destination)?**
- Initially, the Internet was small, and all users maintained a *hosts* file to translate **names to IP addresses**
  - Entries appeared as follows:

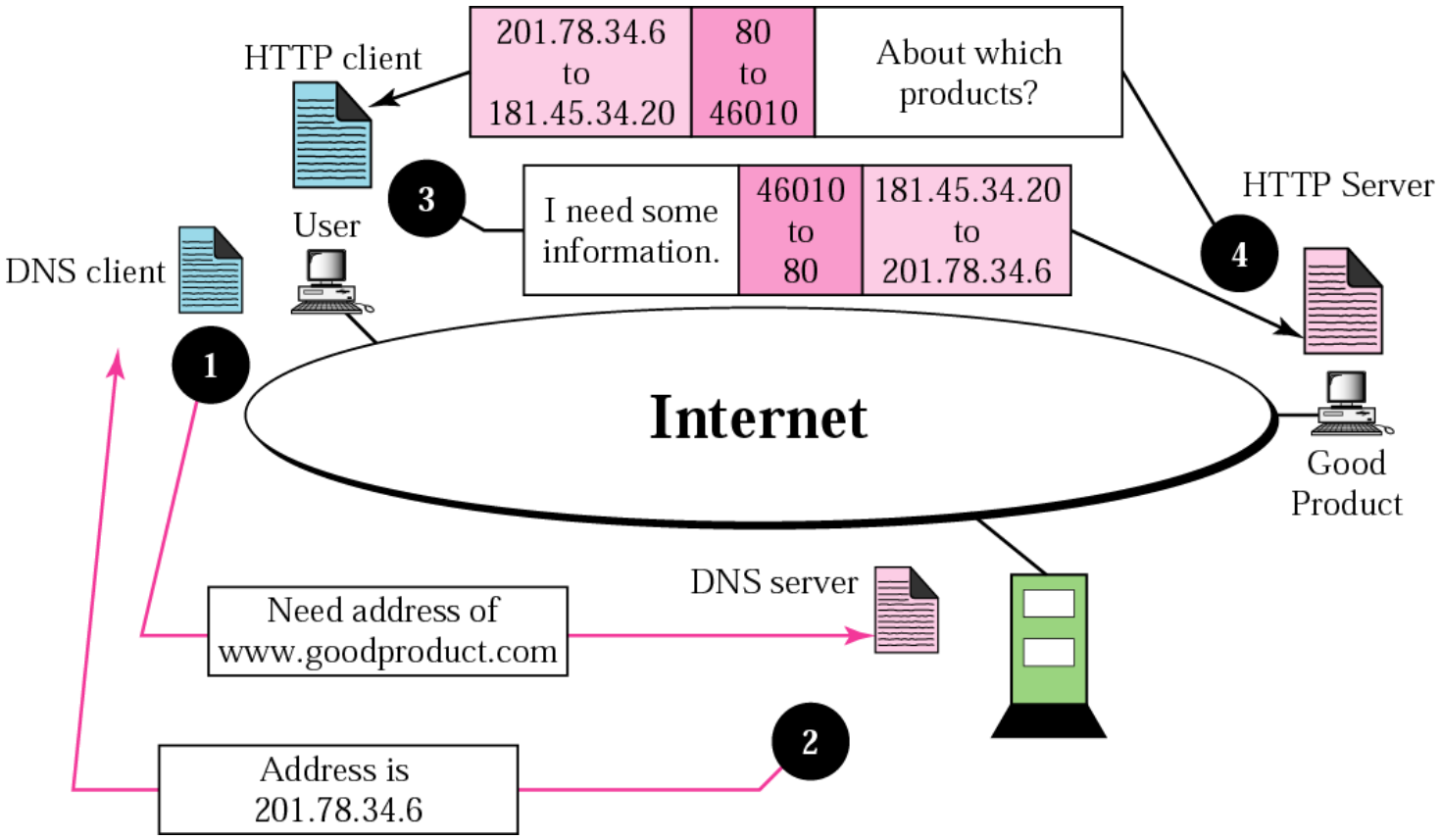
    `131.247.222.249 www.usf.edu`

  - But, as more users came online, it became difficult for end-users to maintain hosts file
- The need was recognized for a **system**
  - that **maintains accurate name-IP address mappings**
  - easy to maintain
  - easy to use

Domain Name System (DNS)

- The domain name system is the set of **databases** that performs the **correspondence between domain names and IP addresses**
  - Domains: part of a naming system that is administered by an entity
  - DNS: RFC 1034, RFC 1035

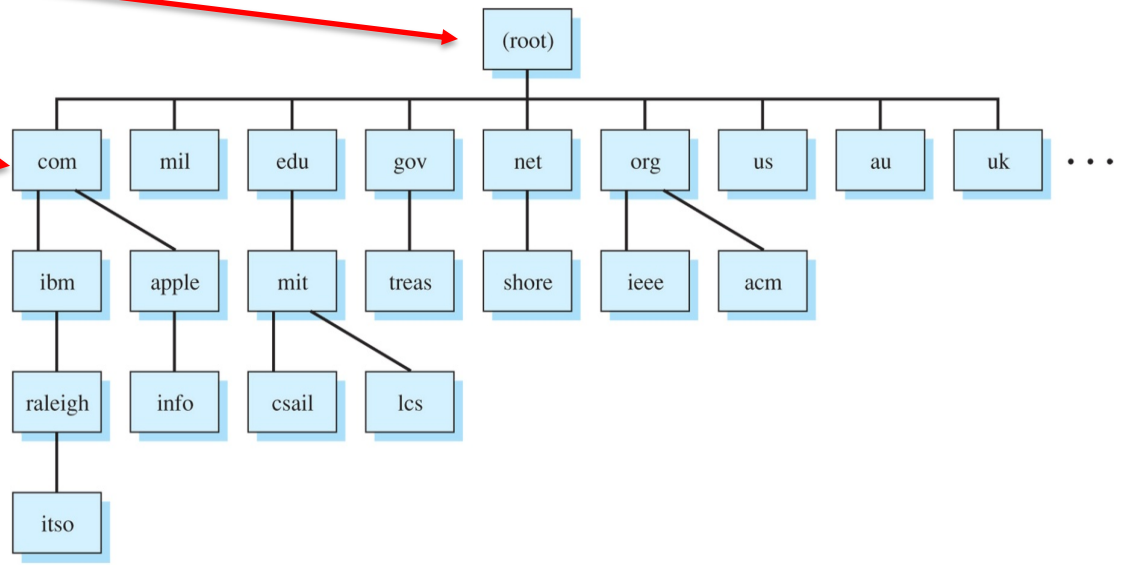
Simplified Example: IP Addresses and Domain Names



DNS

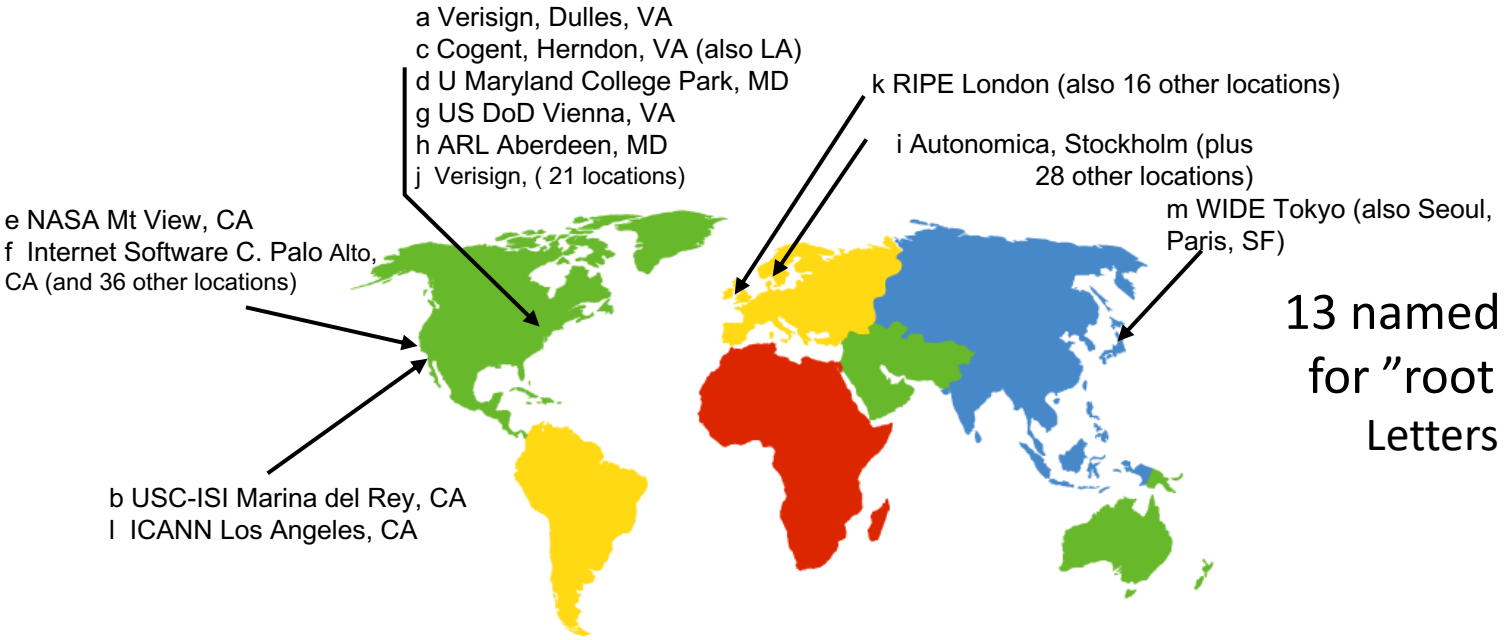
- Why not a centralize DNS?
  - Single point of failure, Traffic volume, Maintenance

- Domain names are arranged **hierarchically**:
  - **Root name server**: DNS originate from a common **root**
  - **Top level domains**
  - **Sub-domains**



DNS: Root Name Servers

- https://www.iana.org/domains/root/servers
- Root name servers: have addresses of TLD
  - 13 named authorities for ”root server”
    - Redundant servers for each for reliability under failure
- Contacts authoritative name server if name mapping (IP address from URL) is not known



13 named authorities for ”root servers” Letters a – m

Top level domains

- A number of top-level domains (TLD) have been created
  - Maintained by Internet Assigned Number Authority (IANA) in ICANN (Internet Corporation for Assigned Names and Numbers)

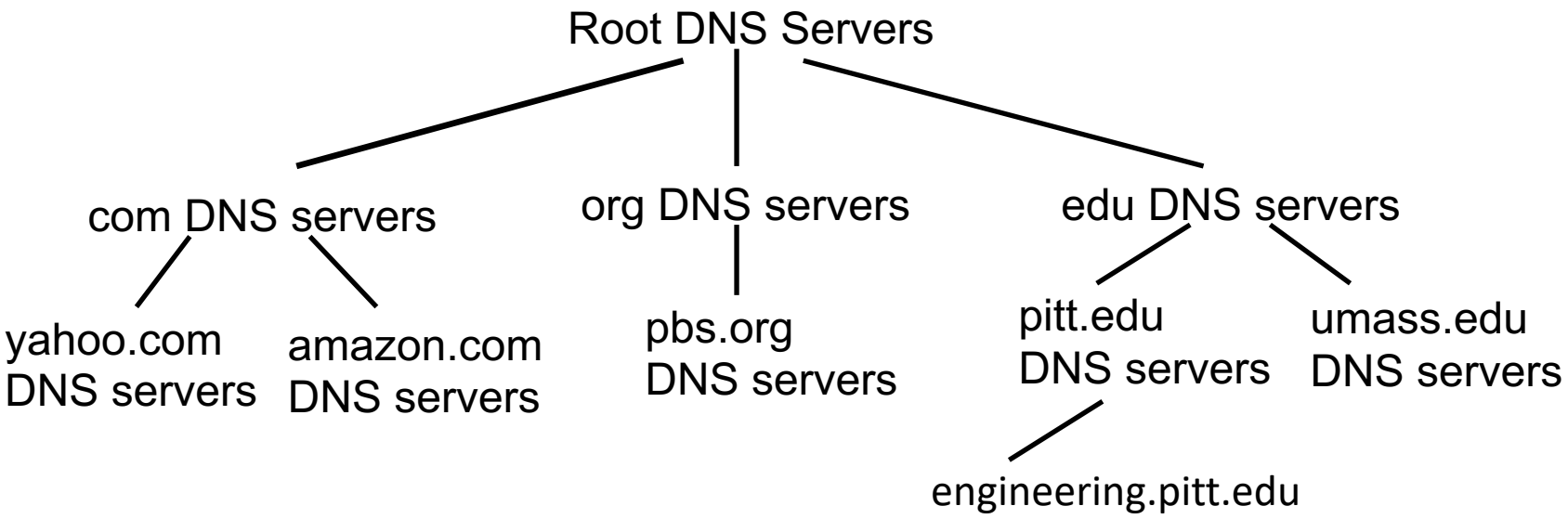
- Open domains:
  - Anybody can register: **.com, .org, .net,**

- Limited domains
  - Conditions must be satisfied for membership
  - **.edu (education), .gov (government), .mil (military)**

Domain Hierarchy

- Each **domain** is responsible to translating its **immediate sub-domain names** **to IP addresses**
    - Domain "**edu**" has IP addresses of:
        - **Pitt.edu, cmu.edu, usf.edu,..**
        - Each of these is also a domain and include IP addresses of their subdomains
            - **Pitt.edu** include IP addresses of:
                - **library.pitt.edu, engineering.pitt.edu,…**

Distributed, Hierarchical Database



Distributed, Hierarchical Database

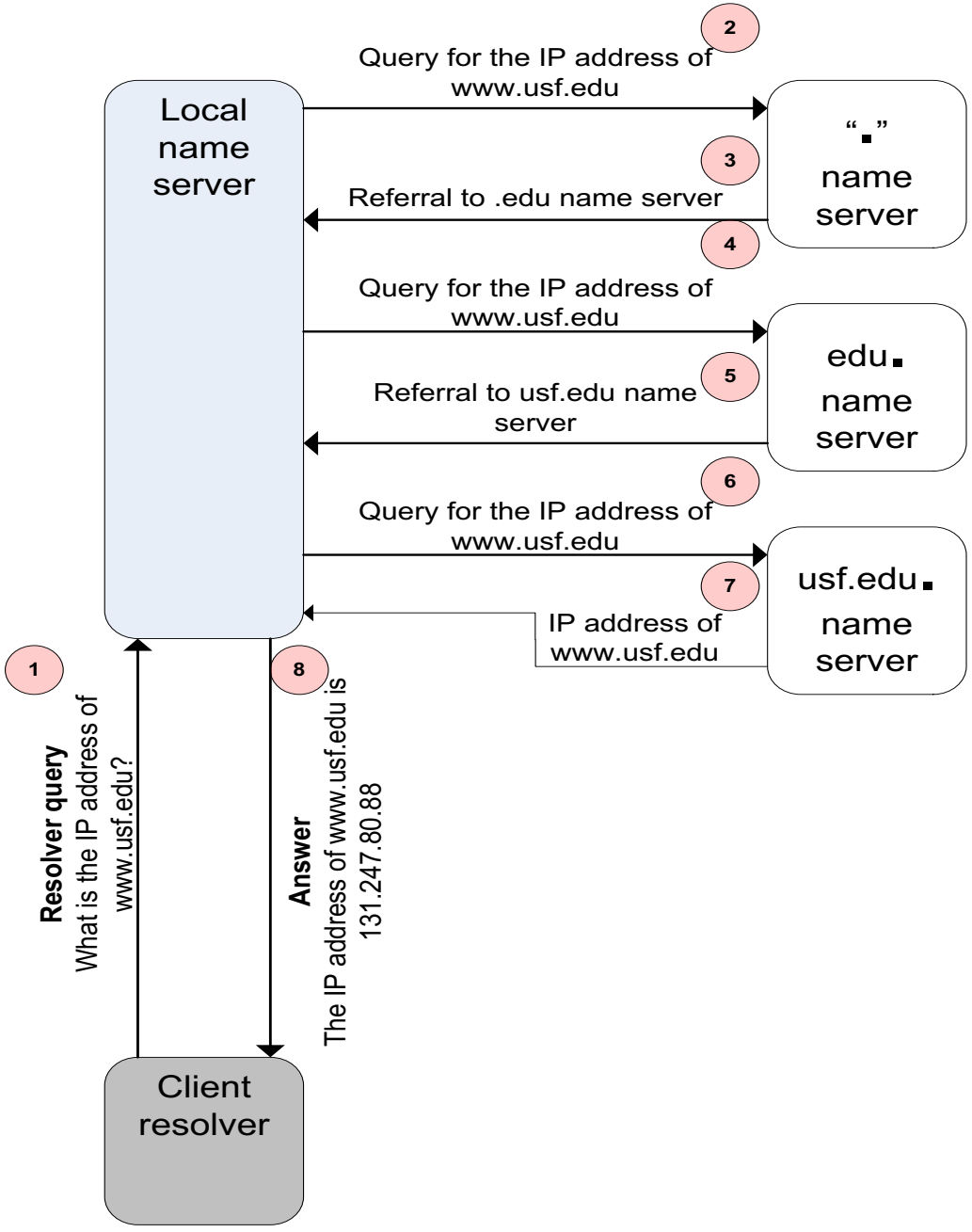
Client wants IP for **www.amazon.com**

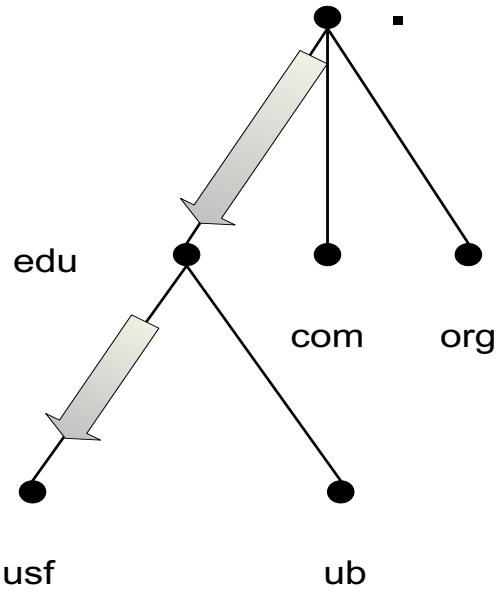
1. Client queries a "**root**" server to find "**com**" DNS server
2. Client queries **com** DNS server to get **amazon.com** DNS server
3. Client queries **amazon.com** DNS server to get IP address for server www.amazon.com
   - Note that the first part of url address is the machine name, the rest is the domain name

Local Name Server is Contacted First

- Each ISP, company, university has **one local DNS**.
  - also called “default name server”
- When host makes DNS query, query is sent to its local DNS server
  - Local DNS server then forwards query into hierarchy
  - **DNS queries and responses are on port 53 using UDP**
- Home networking, router acts as local DNS server

Recursive DNS Query Resolution



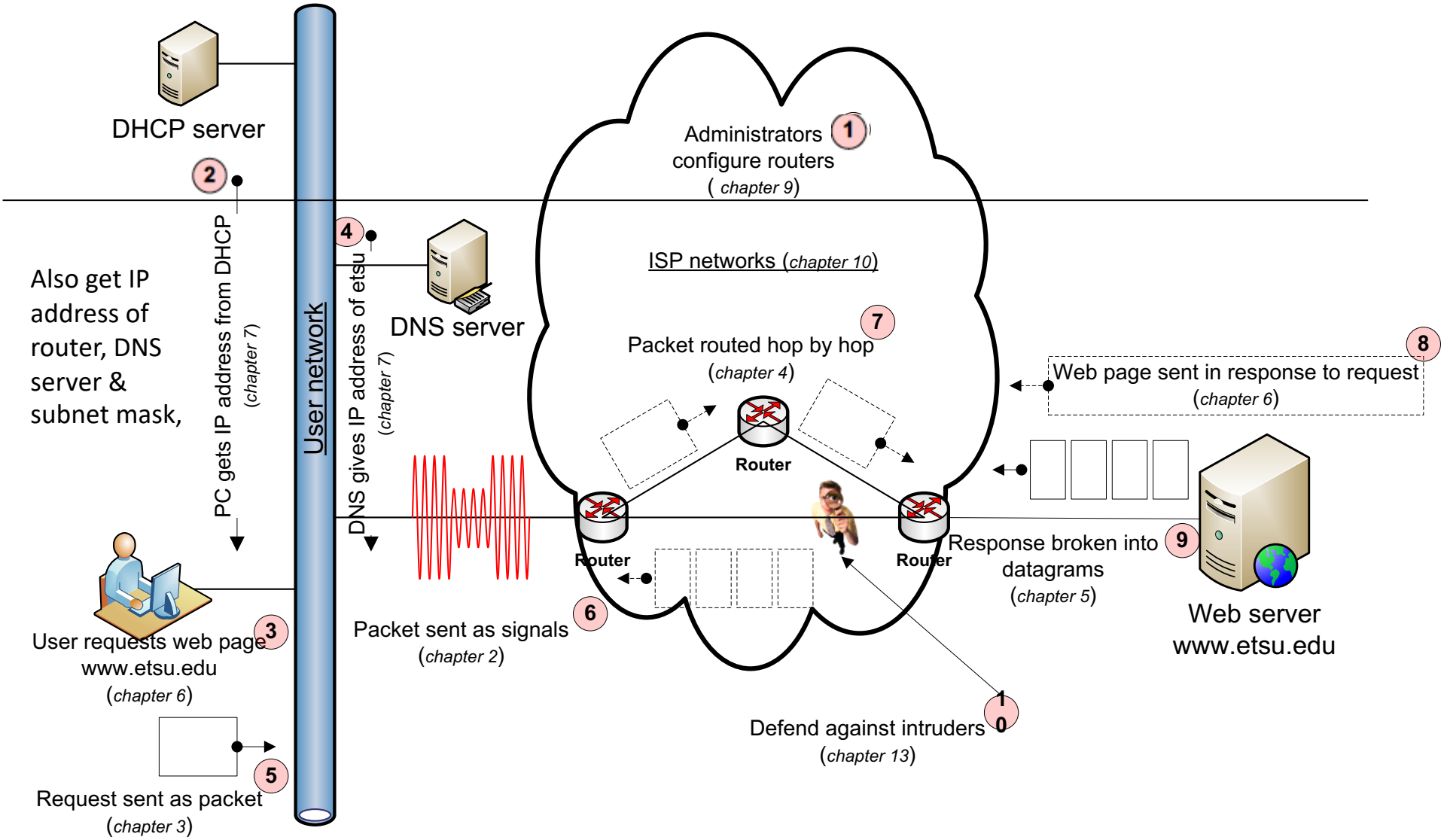


DNS: Caching and Updating Records

- Once a name server learns mapping (name to IP address), it caches it
  - Cache entries timeout (disappear) after some time
  - **TLD servers typically cached in local name servers**
    - Thus, root name servers not often visited
- Update mechanisms design by IETF
  - RFC 2136

Slide modified from Agrawal

Anatomy of a web request



Key takeaways

- Application layer protocols specify format and sequence of messages exchanged
  - HTTP is used for web requests
  - Support services
    - DHCP
    - DNS