The Domain Name System (DNS)

- Each Internet host is assigned a **host name** and an **IP address**
  - Host names are structured character strings, e.g., www.cs.iastate.edu
  - IP addresses are 32-bit integers, e.g., 129.186.3.6
- DNS is the naming service of the Internet that resolve host names to IP addresses
- DNS allows users of Internet applications to refer to remote hosts by name rather than by address

Host name translated into IP address. The numbers 1–5 show the sequence of steps in the process.
DNS Name Space

- Names in the DNS name space are called **domain names**
  - A **domain name** identifies a realm of administrative authority within the Internet
  - Domain names are structured names, i.e., they consist of multiple components
  - Example domain names: cs.iastate.edu, ieee.org, ox.ac.uk
- The DNS name space is represented by a tree with two types of nodes
  - **Leaf** nodes represent hosts
  - **Non-leaf** nodes represent domains
- Two types of top-level domains
  - Generic top-level domains: com, edu, gov, etc.
  - Country-code top-level domains: us, uk, fr, etc.

There are two types of top-level domains
- Generic top-level domains: com, edu, gov, etc.
- Country-code top-level domains: us, uk, cn, etc.
Zones

- The DNS name space is partitioned into zones
  - Each zone corresponds to some administrative authority responsible for that portion of the name space
- Administrative responsibility over any zone may be divided by creating additional zones
  - E.g., Princeton University zone is responsible for all subdomains except for EE and CS; EE and CS are separate zones
- Each zone is implemented by two or more name servers
  - There is one primary name server that stores data for the zone
  - There is one or more secondary name servers that download zone data from the primary server

DNS is implemented by a hierarchy of name servers. The root zone is implemented by 13 root server clusters which are authoritative for queries to the top-level domains of the Internet.
Resource Records

- Zone data are stored in resource records. Each resource record is a 5-tuple (Name, Value, Type, Class, TTL)
  - The Name field specifies a domain or a host
  - The Type field specifies how the Value field should be interpreted
  - The Class field is set to IN for Internet
  - The TTL field indicates how long the resource record may be cached

<table>
<thead>
<tr>
<th>Type of Record</th>
<th>Associated Entity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Host</td>
<td>IP address of the host</td>
</tr>
<tr>
<td>NS</td>
<td>Domain</td>
<td>Name of a name server for the domain</td>
</tr>
<tr>
<td>CNAME</td>
<td>Host</td>
<td>Canonical name of the host; used to define an alias</td>
</tr>
<tr>
<td>MX</td>
<td>Domain</td>
<td>Name of a mail server for the domain</td>
</tr>
</tbody>
</table>

Resource Records in Root Name Server

(edu, a3.nstld.com, NS)
(a3.nstld.com, 192.5.6.32, A)
(com, a.gtld-servers.net, NS)
(a.gtld-servers.net, 192.5.6.30, A)
... (type NS and type A records for other top-level domains)

- A root name server maintains an NS record and an A record for each top-level domain (e.g., edu, com, us, uk).
- There are 13 root name servers, with names in the form letter.root-servers.net, where letter ranges from A to M.
Resource Records in edu Name Server

<princeton.edu, dns.princeton.edu, NS>
< dns.princeton.edu, 128.112.129.15, A>
<purdue.edu, ns.purdue.edu, NS>
<ns.purdue.edu, 128.210.7.163, A>
... (type NS and type A records for other domains under the edu domain)

• The edu name server maintains an NS record and an A record for each domain under the edu domain

Resource Records in Princeton Name Server

(cs.princeton.edu, dns1.cs.princeton.edu, NS)
(dns1.cs.princeton.edu, 128.112.136.10, A)
(ee.princeton.edu, helios.ee.princeton.edu, NS)
(helios.ee.princeton.edu, 128.196.28.166, A)
(jupiter.physics.princeton.edu, 128.196.4.1, A)
(saturn.physics.princeton.edu, 128.196.4.2, A)
... (type A records for other hosts in Princeton University)

• EE and CS do not belong to the Princeton zone, so Princeton name server does not contain resource records for EE and CS
Resource Records in CS Name Server

(www.cs.princeton.edu, coreweb.cs.princeton.edu, CNAME)
(coreweb.cs.princeton.edu, 128.112.136.35, A)
(cs.princeton.edu, mail.cs.princeton.edu, MX)
(mail.cs.princeton.edu, 128.112.136.72, A)
(penguins.cs.princeton.edu, 128.112.155.166, A)
... (type A records for other hosts in CS)

Name Resolution

• The client program running on each Internet host is initialized with the address of a local name server
  – The local name server knows the address of one or more root name servers
• To resolve a name, a client sends a query to the local name server
  – The local name server queries other name servers on the client’s behalf if it cannot resolve the name
Iterative vs. Recursive Name Resolution

- In **iterative name resolution**, if the queried name server does not have a match for the queried name, it returns the IP address of a lower level name server
  - The local name server then queries the lower level name server; it continues this process until it locates a name server that can resolve the queried name
- In **recursive name resolution**, if the queried name server does not have a match for the queried name, it requests a lower level name server to resolve the queried name
  - The queried name server does not refer the local name server to a different name server as in iterative name resolution
Recursive name resolution: the numbers 1–10 show the sequence of steps in the process.

Comparison between Recursive and Iterative Name Resolutions

- Recursive name resolution puts higher demand on each name server
- Recursive name resolution often has lower communication cost than iterative name resolution
Caching (1)

- Caching is used in DNS name servers
- A name server can store DNS query results for a period of time determined in the TTL field of the resource record
- Benefits of caching
  - Reduces the burden on the root servers
  - Reduces DNS traffic across the Internet
  - Increases performance in Internet applications

Caching (2)

- With iterative name resolution, only local name servers perform caching
- With recursive name resolution, all name servers can perform caching

<table>
<thead>
<tr>
<th>Server for node</th>
<th>Should resolve</th>
<th>Receives and caches</th>
</tr>
</thead>
<tbody>
<tr>
<td>cs</td>
<td>penguins</td>
<td>--</td>
</tr>
<tr>
<td>princeton</td>
<td>cs</td>
<td>address of penguins.cs.princeton.edu</td>
</tr>
<tr>
<td>edu</td>
<td>princeton</td>
<td>address of penguins.cs.princeton.edu #&lt;cs.princeton.edu&gt;</td>
</tr>
<tr>
<td>root</td>
<td>edu</td>
<td>address of penguins.cs.princeton.edu #&lt;cs.princeton.edu&gt; #&lt;princeton.edu&gt;</td>
</tr>
</tbody>
</table>

Recursive name resolution of penguins.cs.princeton.edu. Name servers cache intermediate results. The notation #<name> represents the address of the name server responsible for name.