Domain Name System (DNS)

Motivation

- IP addresses hard to remember
- Meaningful names easier to use
  - Assign names to IP addresses
- Name resolution – map names to IP addresses when needed
- Namespace – set of all names
  - Flat
  - Hierarchical

Flat Namespace

- Each host given a name
- Special file to keep name-address mapping (ex. /etc/hosts file in Linux)
- All hosts must know the current mapping for all other hosts with which they want to communicate
- Central authority to maintain authoritative host file with which all other hosts sync (ex. HOSTS.TXT at NIC in the old days)
- Makes the hostname file too large and the entire scheme unmanageable and impractical in any large network (ex., Internet)

Hierarchical Namespace

- Break complete namespace into *domains*
- Domains broken up recursively into *subdomains* to create any level of hierarchy
- Delegate task of name allocation / resolution
  - Name allocation for any subdomain left to subdomain authority
  - Name resolution done by name server for subdomain

DNS

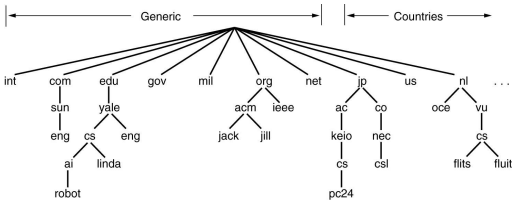
- Naming system for the internet
- Specifies
  - A hierarchical naming scheme
  - Name resolution mechanism
- Can handle multiple object types within one system
  - “Type” associated with each name to distinguish different types of entities
  - Ex. the name “cse.iitkgp.ernet.in” can be a domain name, a simple host name, an email server name etc.

- RFC 1034/1035, many other related ones (See *http://www.dns.net/dnsrd/rfc/* for a list of DNS related RFCs (incl. ones that updates 1034/1035)
- DNS-relevant important websites
  - www.iana.org
  - www.icann.org
  - www.internic.net

DNS Namespace

- Complete namespace is a tree of domains
- Root is a special domain (no name)
- Top level domains – domains at second level of tree
  - *com, edu, gov, net, mil, int, org, arpa, in*, country specific domains (*us, in, kr* etc.)
  - Managed by delegated authorities
    - Ex. for .in domain, NCST/National Internet Exchange of India
- Domains from third level
  - Managed by local authorities

DNS Namespace (contd)



DNS Names

- Every node in the tree has a label (max 63 bytes, case insensitive)
- Sibling nodes must have different labels
- DNS name of a node = sequence of labels from that node to root, separated by '.'
- Absolute names – names that end with '.'
- Relative names – names that does not end with '.', meaning they will be completed by appending something
- Nodes can be domains or hosts
- Arbitrary hierarchy allowed (but implementations usually limit name length to 255 bytes)

- Domain : subtree of the DNS namespace tree
- Zone : part of the tree for which the naming authority has been delegated to some name server
- Domain *x.y* and Zone *x.y* may not be same, as part of *x.y* domain may have its own naming authority and is not part of *x.y* zone

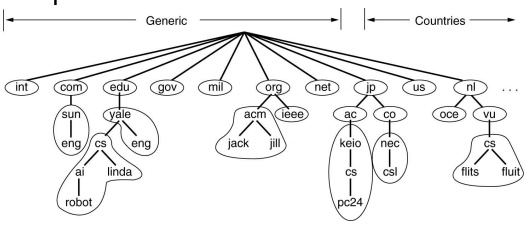
Name Servers

- Contains mapping information for one or more zones (*zone files* - text files in standard format)
- Maps names to IPs (forward lookup, mandatory) or IPs to names (reverse lookup, optional)
- Primary/Master name server : gets mapping data for zone from zone file on the host it runs on
- Secondary name server: pulls zone file data from primary name server (*zone transfer*)
- Authoritative server for a zone: either a primary or secondary server for that zone
- A host can be primary for some zones and secondary for others at the same time

Root Servers

- Name servers for root zone
- Contains name server for all top level domains
- Currently 13 root servers spread all over the world (all are secondaries of a hidden primary, *a.root-servers.net* through *m.root-servers.net*)
- All DNS name servers knows at least one root server

Name Servers



Domain Name Resolution: Overall Steps

- User program issues the request
- Query to name server is formulated
- The name server checks if name in database.
- If not, ask the higher level name server
- Finally the user program gets IP Address or error

Name Resolution

- Resolver
  - Accesses name server for name resolution
  - Knows the address of at least one name server
  - Sends a DNS request to the name server
  - Standard access routine: gethostbyname()
- Name server
  - Gets request from resolver
  - Looks up the name and sends back response

Name Resolution Basics

- Contact root server for name server of top level domain
- Name server for top level domain gives name server for next level domain
- Process continues until mapping is found or error

Example

- To resolve www.yahoo.com, first contact root server to get name server for *com*
- Querying name server for *com* gives name server for *yahoo.com*
- Querying name server for *yahoo.com* gives IP address of *www.yahoo.com*
- Three queries needed to resolve the name in the worst case

Recursive/Iterative Query

- Recursive Query
  - DNS server either gives the mapping, or forwards the request to the name server that may have it
  - Original requestor finally gets either the mapping or an error
  - May be ok for lower level domains with less request volumes
  - Not suitable for higher level domains with high request volumes

- Iterative
  - If DNS server does not have mapping, it gives the address of the name server that may have it (*referral*)
  - Original requestor contacts the new name server
  - Repeated until mapping is found or no referral is obtained (error)
- Servers must implement iterative query, may implement recursive query

Caching

- Caching employed at both client and server for efficiency
  - Lookup results in cache (both final IP address, or name server addresses for intermediate domains)
  - Refreshed at regular intervals
- Caching Name Servers: not authoritative for any zone, only caches entries for other zones

Resource Records (RR)

- Each zone file contains a set of resource records for that zone
- Each RR has: name, type, TTL, Rdata, plus some other fields
- RR Types (16 bit value):
  - SOA : Start of authority
  - NS : authoritative name server for the domain
  - A : hostname
  - MX : mail server
  - CNAME : alias name
  - HINFO : CPU and OS Info
  - PTR : pointer to another part of namespace
  - SRV : Service name (RFC 2782)
  - Others….

- TTL : indicates how long the RR can be cached (32 bit integer in seconds)
- RDATA : a type specific value (for ex., an IP address for A type etc.)
- Some other fields in RR not of interest to us

```
$TTL 3D
@      IN     SOA     mc1.land-5.com. root.land-5.com. (
                      199609206      ; serial, todays date + todays serial #
                      8H   ; zone file refresh period for secondaries
                      2H   ; retry period for secondaries if primary is unreachable
                      4W   ; expiry time if zone file cannot be refreshed
                      1D )  ; minimum TTL of any RR
              NS      mc1.land-5.com.
              NS      ns2.psi.net.
              MX      10  mailsrv.land-5.com.  ; Primary Mail Exchanger
              MX      20  backupmail.land5.com.
              TXT     "LAND-5 Corporation"
router          A          206.6.177.1
mc1.land-5.com.    A          206.6.177.2
mc2.land-5.com.    A          206.6.177.3
mailsrv            A          206.6.177.4
ftp          CNAME     mc1.land-5.com.
news         CNAME     mc1.land-5.com.
funn            A        206.6.177.2
```

```
www    CNAME  mc1.land-5.com.
       CNAME  mc2.land-5.com.

telnet.tcp      SRV  10  1  23 mc2.land-5.com.
                SRV   10  3 23  mc1.land-5.com.

subdomain1.land-5.com.  NS   ns1.subdomain1.land-5.com.
subdomain2.land-5.com.  NS   ns2.subdomain2.land-5.com.

ns1.subdomain1     A     202.122.132.7
ns2.subdomain2     A     202.122.136.9
```

Forwarders

- A DNS server X to which DNS queries can be sent by another DNS server Y if it cannot resolve it
- X resolves it and sends back the result to Y. X also caches.
- Motivation:
  - No internet connection for Y
  - Forwarder cache builds up over time
  - Forwarder may be able to resolve most queries
- X may or may not be authoritative for any zone
- Y does not need to know root servers

Protocol Details

- Usually runs on UDP port 53
- Uses TCP for zone transfers (and some large responses)
- TCP can also be used for normal operation, though not used normally
- Same message format for query and response

DNS Message Format

HEADER (12 bytes)
QUESTIONS
ANSWERS **(Resource Records)**
AUTHORITY **(Resource Records)**
ADDITIONAL **(Resource Records)**

Header Format

Identification	**Flags**
# of questions	**# of answer RRs**
# of authority recs.	**# of additional RRs**

DNS Header FLAGS field

1	4	1	1	1	1	3	4
QR	OPCODE	AA	TC	RD	RA	000	RCODE

QR: 0 means message is query, 1 means response.
OPCODE: 0 is *standard query* (use 0).
AA: 1 means authoritative answer (set by server).
TC: 1 means response was truncated (set by server).
RD: 1 means recursion desired (set by client).
RA: 1 means recursion available (set by server).
000: must be three zero bits.
RCODE: return code. 0 is no error, 3 is name error, etc.

Question Format

- Each *question* includes a variable length *query name* that specifies a hostname
- Each question also includes
  - *query type* (what type of RRs are asked for, ex., A, SRV etc.)
  - *query class* is 1 for Internet Addresses

Question Format

? bytes	2 bytes	2 bytes
query name	query type	query class

Query Name is a sequence of one or more *labels*.

Each *label* is a single byte count, followed by that many characters.

The last label must have a count of 0.

Query Name Example

The name www.iitkgp.edu would be sent like this:

3	w	w	w	6	i	i	t	k	g	p	3	e	d	u	0

1 byte count

last count must be 0!

Each count byte is a binary value in the range 0-63
count bytes are not ASCII !

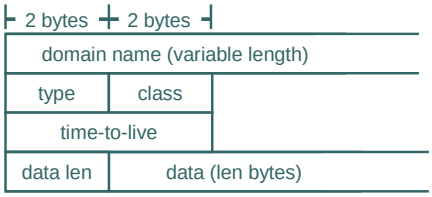
Some Query Type Field Values

A	1	IP Address
NS	2	Name Server
CNAME	5	Canonical Name
PTR	12	Pointer
HINFO	13	Host Info
MX	15	Mail Exchanger
ANY	255	*everything*

Answer Format

- The *answers, authority* and *additional information* parts of a response are all provided via the same format –a Resource Record (RR).
- Each Resource Record specifies the value of a single resource along with information about the resource (what kind it is, how long the information is valid, etc.)

Resource Record Format



Reverse Lookup

- IP to name mapping
- Not mandatory to implement, but most DNS servers support
- All IP addresses are part of the special zone in-addr.arpa
  - Ex. 10.5.17.2 will map to the name 2.17.5.10.in-addr.arpa
  - PTR type RR kept to map this to a name
  - Lookup similar otherwise

Dynamic Update

- Simple DNS requires the primary name server to be updated manually when a mapping changes – not good for working with protocols like DHCP
- Dynamic DNS updates allow dynamic updates to zone files by messages
- For more details, see RFC 2136