DNS - Domain Name System

TCP/IP class

Jim Binkley

outline

- introduction
- naming scheme
- protocol
  - format
  - record types
  - how it works
- reverse lookup
- implementation - named config files
- summary - futures

bibliography

- RFCs
  - 1034 - Internet Domain Naming Philosophy (87)
  - 1035 - Protocol standard (87)
  - updated in 1101/1183 in 1990
- Evi Nemeth's Unix Sys. Admin Handbook
- Sun Network Documentation
- BSD Bind docs
- Steven's TCP/Proto book gives good protocol explanation

Some DNS urls of interest

- ICANN - Inet Corporation for Assigned Names and Numbers - www.icann.org
  - DNS administration
  - see the FAQ for recent info
- http://www.internic/net/regist.html
  - accredited list of registrars for .com/.net/.org
- http://www.isc.org/products/BIND
  - where to get DNS BSD Bind software

intro

- DNS - Domain Name System
- distributed database: (key, value) pairs include:
  - 1. map DNS names to ip number (ADDRESS)
    - sirius.cs.pdx.edu to 131.1.2.3
    - connect(2) wants an ip number, so does sendto(2)
  - 2. map ip number to DNS name (PTR)
  - 3. mail routing, (MX)
    - mail cat@cs.pdx.edu -> sirius.cs.pdx.edu
  - 4. aliases (CNAME)
    - www.cs.pdx.edu is actually sirius.cs.pdx.edu

intro

- done with distributed client/server implementation
- system is hierarchical and very scalable
- Internet-wide service, possibly the largest nameserver paradigm on the block
- DNS is of course both a protocol specification and an implementation
- BSD BIND/named implementation (4.9?)

intro - why?

- computers use ip numbers, people want names, 1.2.3.4 not as good as foo.com
- all computers can’t be named “fluffy” so we need a hierarchical naming system to avoid host name conflicts
- origin rooted in /etc/hosts file which has ip address to name mapping, but obviousally doesn’t scale to Internet-wide

3 schemes for name lookup

- 1. put it in /etc/hosts and distribute that periodically (rdist/cron/rcp, whatever)
- 2. Sun’s NIS (Network Info. System)
  - 1. not supported on all hosts
  - 2. can’t go outside your admin. domain
    - (Tek could do it, but can’t manage it with Intel)
  - 3. can do more than DNS, passwd, groups too
- 3. DNS

Berkeley Internet Name Domain

- parts include:
  - **named** - a name server, takes files as database including a list of names/ip pairs, DNS roots, master configuration file
  - **resolver** - client side library code for making DNS lookup, linked to apps like telnet, etc., inside **gethostbyname**(3), **gethostbyaddr**(3) calls
- debug tools: **nslookup**, **dig** (elsewhere)

intro - protocol

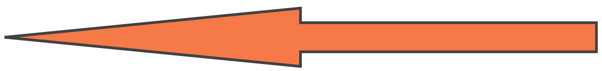
- DNS basically send/recv style message protocol. Here's the question, what's the answer?
- uses UDP for query/response
- may switch to TCP if response too big
- uses TCP to xfer database between primary and secondary domain servers (zone transfer)

DNS naming scheme

- problems to overcome...
  - arpanet /etc/hosts file grew too big
  - 30000+ hosts named venus
  - UUCP gave us human-names mixed with route, we don’t want the route in the name a!b!c!d from a to d ...
- **we need hierarchical names with distributed control of naming authority**

sample name

- sirius.cs.pdx.edu.



  from right to left (top to bottom), right is general, left is specific
- root is on right (1st dot)
- namespace is a tree of domains, root domain, edu, pdx, cs, etc

names

- DNS **labels** acc. to RFC 1032 should be short (12 chars max), but 64 is actually allowed
- names are case-insensitive
- can be relative; e.g., sirius, but smart resolver code has to append local domainname correctly
- edu is TOP level domain
- pdx is 2nd-level. Apply to NIC registration service (http://rs.internic.net) for 2nd-level
- they must guarantee uniqueness

names

- internic manages root and 2nd-level
- local admins manage 3rd-level (or more) and can distribute that management locally if size warrants
- the rest of the world is **NOT** involved in how we manage our DNS names internally

names

- **domain name** - tree is made up of hierarchy of domains, each node is a domain and we go from right to left

  edu, pdx.edu, cs.pdx.edu,
- labels are unique only within a domain
- **absolute domain name** has root dot and is called **FQDN - Fully Qualified Domain Name**
- if relative, name must be completed somehow

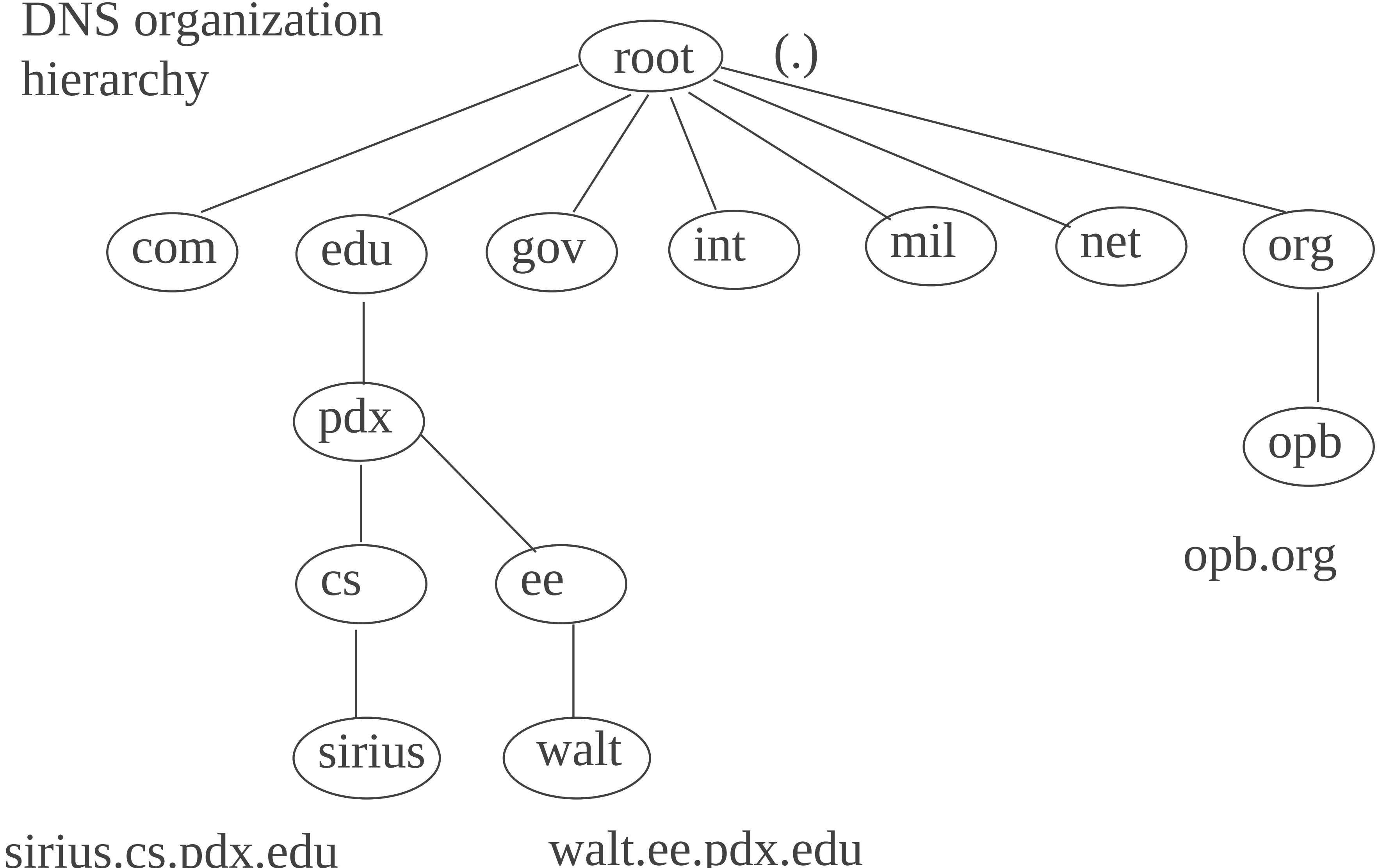
names

- **zone**: namespace is partitioned into zones, zones are a set of names managed by 1 server, server will have > 1 zone to manage
- typically DNS server must have partner server elsewhere for redundancy, manages its zone and somebody else's too

DNS supports > 1 name hierarchy

- organizational
- reverse lookup
- country
- Liberian freighter registry? (not yet...)

DNS organization
hierarchy



organizational domains

- mostly but not all U.S.

  com - commercial

  edu - educational

  gov - U.S. goverment

  int - international organizations

  mil - U.S. military

  net - networks

  org - other organizations

recent proposal - new domains

- .arts - entertainment/cultural
- .firm - firms or businesses
- .info - information providers
- .nom - personal names
- .rec - entertainment/recreation entities
- .store - bus offering goods for purchase
- .web - WWW related entities

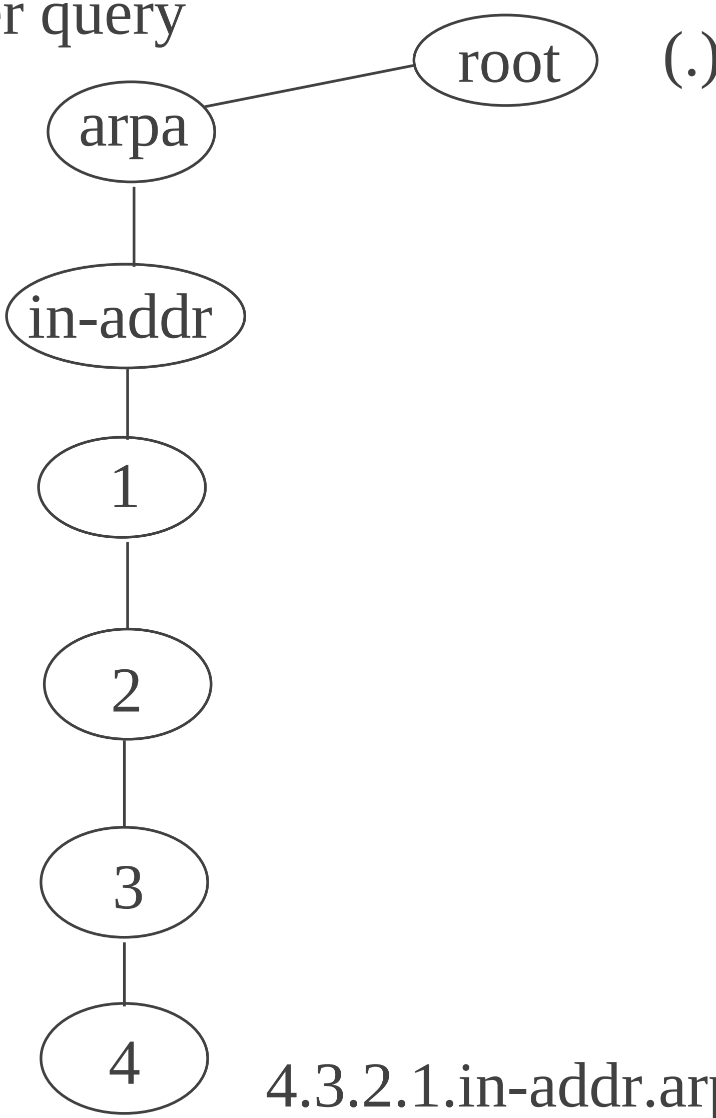
or alternative registries even

- name.space
- AlterNIC
  - .exp, .ltd, .lnx, .med, .nic, and .xxx

Acc. To ICANN, recent new TLDs (wotsa TLD?)

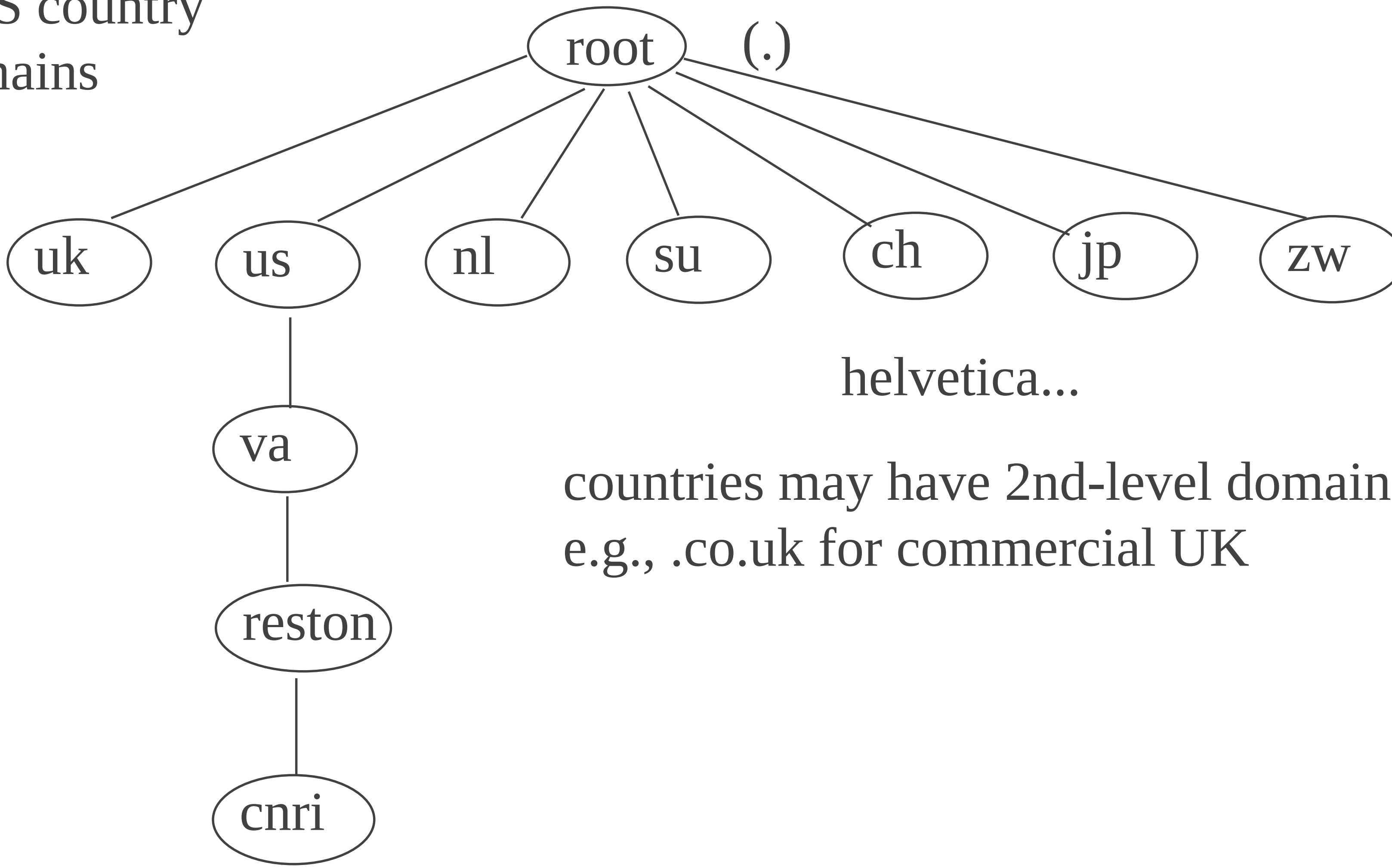
- .aero, air transport industry
- .biz
- .coop, cooperatives
- .info
- .museum
- .name, individual humans
- .pro - lawyers, Drs, accountants

DNS pointer query hierarchy



4.3.2.1.in-addr.arpa, note for ip = 1.2.3.4

DNS country domains



helvetica...

countries may have 2nd-level domains; e.g., .co.uk for commercial UK

cnri.reston.va.us

DNS record types

- adding a record types isn’t easy
- name has type, client must ask for it by type
- Basic = ADDRESS, PTR, MX
- Zone=SOA (start of authority), NS (name server, server for a zone)
- optional = CNAME (alias), HINFO (host info), RP (responsible person), WKS (deprecated, but well known services), TXT (text)

record types

- you can start to see that a query = (name, type); (sirius.cs.pdx.edu.,A)
- a name may map to more than one item, e.g., sirius.cs.pdx.edu, type A, might have 1-n ip addresses associated with it

protocol header

- typically UDP request, reply
- request/reply format
- request = fixed header + question section
- reply = fixed header + query + answer sections
- question = (name, type, class = IP) with name in compressed format
- reply = set of **Resource Records** (RR)

DNS query/response format

fixed header

6 2-byte fields = 12 in all

identification	flags
# questions	# answers
# authorities	# extra A RRs
1 or more questions	
1 or more answers (RRs)	
authorities (NS RRs)	
A records for NS records	

+ query

+ reply

...

...

variable length

node: id field used by client to match responses

header - flags field

QR	opcode	AA	TC	RD	RA	(zero)	return code	
1	4	1	1	1	1	3	4	= 16 bits

QR - 0 if query, 1 if response

opcode - 0, standard query; 1, inverse; 2, server status request

AA - authoritative answer. Answer is from NS that maintains zone

TC - truncated. Using UDP, and answer was > 512 bytes

RD - recursion desired. If not set then iterative, NS may return list of other NS servers to try.

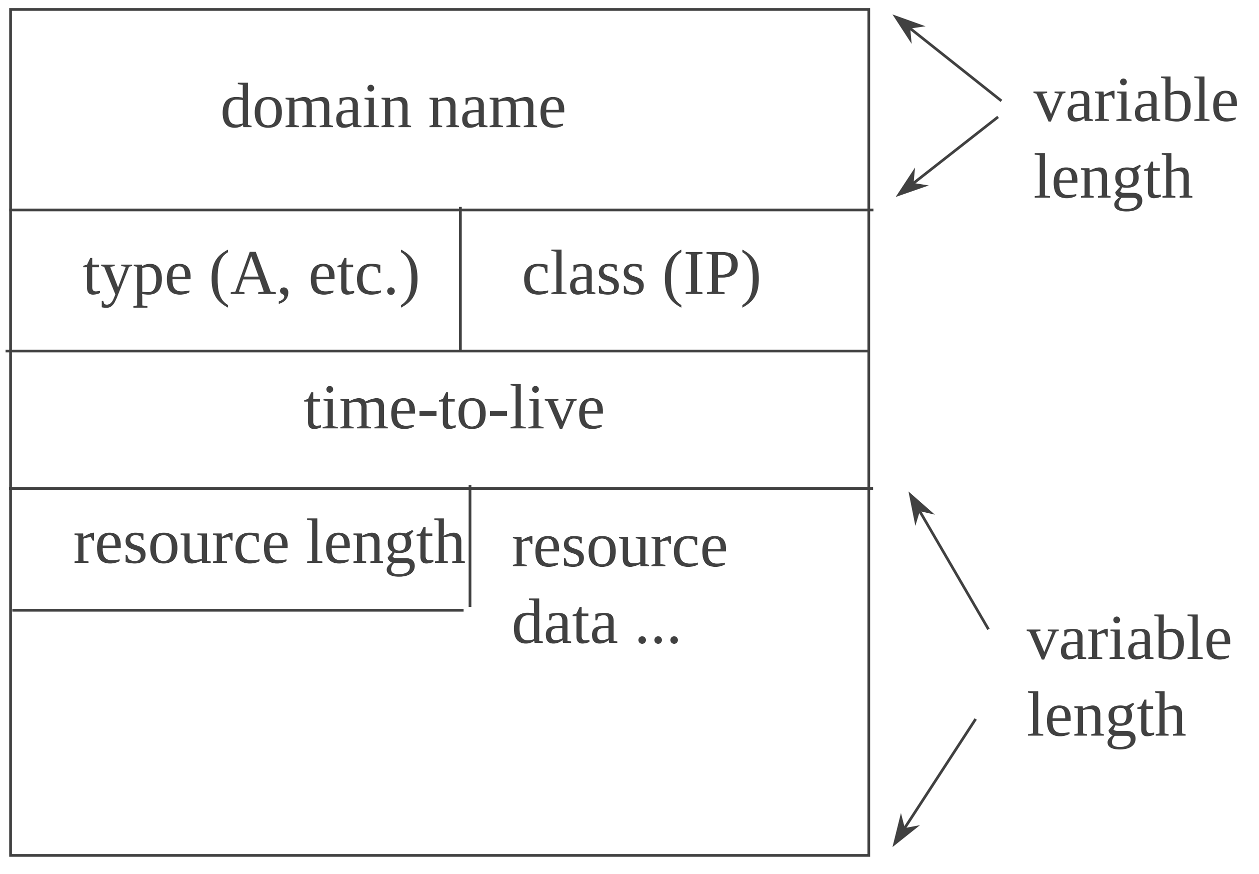
RA - recursion available. Set if server supports recursion

rcode - error codes, 0 means no error. Only set if name invalid.

question portion

- query part logically (name, type, class)
- class is IP
- type is A, NS, PTR, CNAME, MX, etc.
- name is encoded and variable length with a count (size) for each label in the name
- typically 1 question (and no answers yet...)

Resource Record format



RR format

- domain name - same format as in query
- TTL - in seconds, value often 86400, 1 day
- resource data, the answer, for example if the query was **foo.com**, the answer might be **192.12.1.2**

theory of operation/server-side

- person responsible for zone supplies 1 or more name servers
- primary name server and 1 or more secondary servers elsewhere necessary
- hope is to avoid single point of failure
- admin must change zone file and notify name server to reload (signal to named on UNIX)
- currently sans security, can’t change zone info dynamically, must be manual

operation - root servers

- name server must contact other name servers for non-local info
- need IP address to contact... hmm....
- each name server has list of root servers, need IP addresses for them
- root servers know 2nd-level servers, refer name servers to them
- see how to get list of root names later

operation

- port 53 used for queries/answers
- may use UDP/TCP if answer too big
- TCP used for zone transfer between primary and secondary servers

how it works

- % telnet local.machine.com
- DNS is invoked to do name mapping to get IP address. (arp before udp before tcp...)
- client “resolver” code must have addresses for local name servers to prime the pump
- on UNIX, */etc/resolv.conf*
- *gethostbyname(3)* calls resolver code which uses info in *resolv.conf* file

/etc/resolv.conf

```
#
domain cs.pdx.edu
# search cs.pdx.edu. ee.pdx.edu.
#
nameserver 131.252.20.183
nameserver 131.252.20.2
nameserver 128.95.120.1
```

operation - types of name resolution

- 2 ways to resolve a name used in DNS
- **iterative -** contact name servers one at a time. You ask a root server and it gives you a list of contacts (NS + A records)
- **recursive -** ask a name server to do the whole job
- resolvers are assumed to be simple and do things recursively
- root servers are busy and are iterative

when server gets query

checks to see if name lies in its zones

if so

  translates name to A and returns RRs

if not, acc. to “howto” code

  if recursive

    contacts other servers (root/2ndary)

      until it gets A, and returns it

  else iterative (e.g., root server)

    returns NS with A records

1 query - how many answers?

- if you ask for sirius.cs.pdx.edu, you get two A records (last time I checked)
- multi-homed host > 1 address record by definition

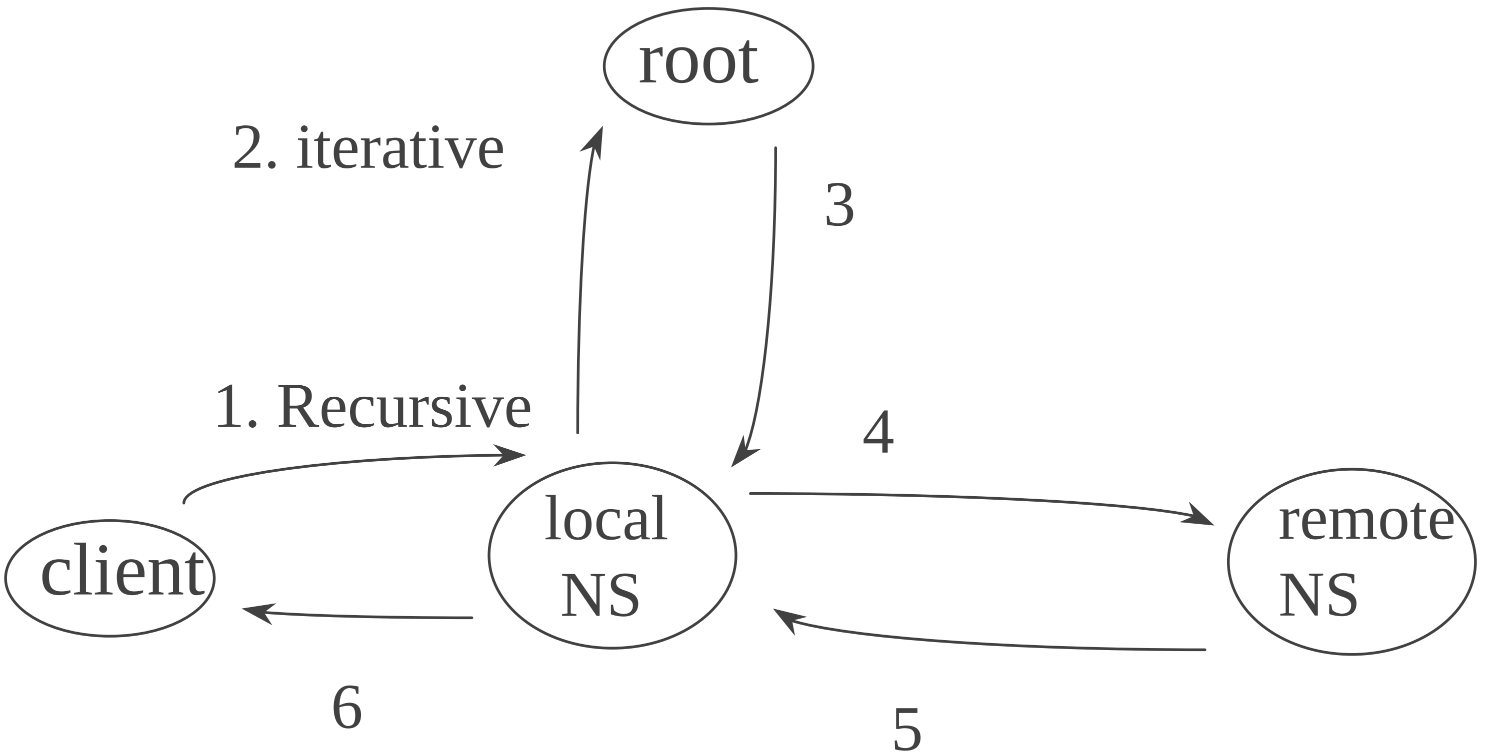
local lookup:

- send request to local server
- server returns **authoritative** response

remote lookup

- ask local NS (recursive)
- local NS may return **cached** hit. This is called a **non-authoritative** answer
- may ask root server in iterative fashion, get list of secondary servers
- ask secondary server, cache result
- return result to client

remote lookup picture



caching

- we don’t want to work down the tree every time as root servers have a heavy load
- server data from remote systems thus kept locally with timeout (1 day typical)
- without timeout we would have remote systems with DNS, ip mapping where ip address might change
- cached data is non-authoritative

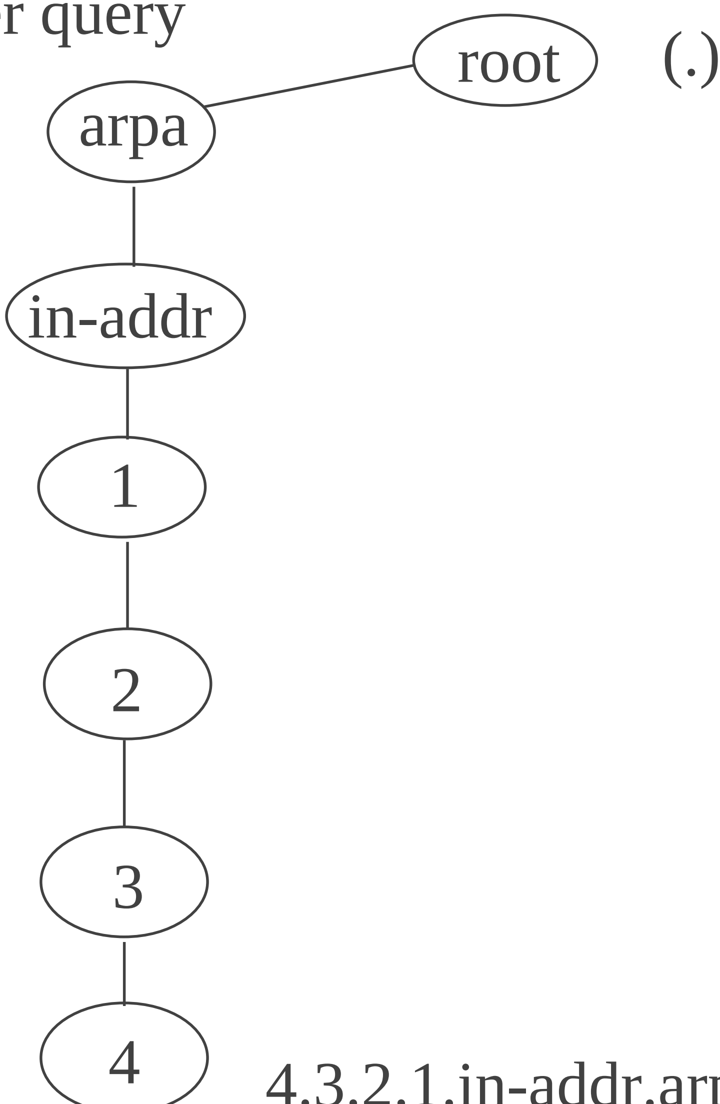
reverse address lookup

- is Alex Trebec involved with the DNS?
- pose an answer (IP address), get a question (DNS name)...
- gethostbyaddr(3), ip in, DNS out
- make a pointer query (PTR)
- special tree using in-addr.arpa domain
- class A, B, C net part at top, host at bottom

reverse address lookup

- if we didn’t have tree organized by address, how would we do it?
- search through from domain roots? (take a lifetime...)
- gethostbyaddr(3) often used as weak security check, get DNS domain part and make sure it is in xyzzy domain (foo.com)
- gethostbyaddr(3) may automatically check that returned ip matches name by internal gethostbyname(3) call

DNS pointer query hierarchy



4.3.2.1.in-addr.arpa, note for ip = 1.2.3.4

nslookup - debug utility

- it’s a shell, **help** and **exit** are commands
- from the command-line

  % *nslookup foo.com*

  1.2.3.4 <----- you (may) get an answer
- basically a resolver (client-side) for testing
- to do reverse-pointer lookup

  -> *set type=PTR*

  -> *1.254.138.128.in-addr.arpa*.
- yes, you have to reverse the address to put it in normal form, above is for 128.138.254.1

named - config

- /usr/somewhere/in.named - BSD named DNS server, started as server at boot
- /etc/named.boot - named configuration file
- not inetd based, start after syslog
- roughly:

  /usr/etc/in.named -r /etc/named.boot
- named.boot tells named where to find database files

named files

- besides *named.boot*
- /somewhere/named/*named.ca* (name may be different) - cache of root servers as RR records
- *hosts* - primary RR (A records, MX, CNAME, etc), one or more
- *reverse pointer* - PTR query records, one or more

named.boot - sample

```
; named.boot
; pdx-domain
; directory means where the db files hang out
directory        /usr/local/lib/named
; root cache
cache  named.ca
; what kind of server/domain name/filename
primary   0.0.127.in-addr.arpa  localhost
primary   cs.pdx.edu  zone.pdx.cs
primary   20.252.131.in-addr.arpa  revp.131.252.20
primary   21.252.131.in-addr.arpa  revp.131.252.21
```

more details on boot file

- **primary** keyword indicates this named is primary server for zone info in that file
- **secondary** keyword says that host is secondary nameserver, need ip address + cache file name
- single name server can support more than one zone
- may have caching only server, no data files
- **forwarders**, can point interior NS at one NS that will cache all external queries
- **xfrnets** - can restrict who can do zone tranfer

root cache

- get one from ftp://rs.internic.net/domain/named.cache
- need to “prime the pump”, 9 currently
- “dot” in NS record is for domain field and means “root domain”
- can use nslookup to check given 1 root server
  -> server = a.root-servers.net.
  -> set type=ns
  -> .

root cache example (don’t use)

```
; /domain/named.root
;
.                        3600000 IN NS  a.root-servers.net.
a.root-servers.net.      3600000      A   198.41.0.4
;
.                        3600000 IN NS  b.root-servers.net.
b.root-servers.net.      3600000      A   128.9.0.107
;
etc... through
i.root-servers.net.
```

RR - SOA

SOA - source of authority and start of zone db

```
; start of authority
; @ - current zone symbol
@  IN SOA foo.com.  joebob@foo.com. (
        1001;   serial #, increment when change zone
            ;   used to make zone xfer happen
       21600;   6 hours, time to zone xfer
        1800;   30 minutes, 2nd retry if primary missing
     1209600;   expire, 2 weeks for 2nd if no 1st
     432000 ); minimum, 5 days, ttl on RRs
```

RR - NS

NS - name server record.   Assume foo.com

; ns, name servers for this domain, all primarys and

;   secondaries

foo.com.   IN   NS   a.foo.com.

foo.com.   IN   NS z.somethingelse.com.

; ns records for the current domain are not necessary

; needed however in parent for subdomains

; don’t forget the A records for the NS records

admin   IN   NS   a.admin.foo.com.

marketing IN NS z.mrkt.foo.com.

RR - A and other records

Address records are heart of DNS

```
; the data part
localhost     IN    A    127.0.0.1
foobar        IN    A    192.0.0.1
snarp         IN    A    192.0.0.2
flozzle       IN    A    192.0.0.3
www           IN    CNAME  foobar.foo.com.
foo.com       IN    MX  foobar.foo.com.
multi         IN    A    192.0.0.4
              IN    A    192.0.0.5
```

update of zone files

- change the serial # in the SOA record
- add the A records or whatever
- kill -HUP signal to named
- secondary won't change until refresh time passed, will check serial # first, cache current data in "data file"
- zone xfer done with TCP, port 53

DNS futures

- types are attribute OF the name, not in the name
- not easy to change types since you must change code everywhere, but it happens
- e.g., there are ISDN/X.25 record types
- would like DNS to be dynamic but 1st
- DNS needs a secure protocol

DNSSEC

- IETF working group
- add security to DNS
- dynamic DNS updates
- KEY/SIG records using RSA public keys
- zone authority may sign all DNS records
- new USER record as well
- hence can authenticate user@dns