ECE 435 – Network Engineering
Lecture 11

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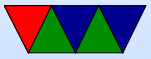
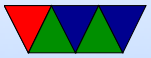
Announcements

- Reminder, no class Monday the 17th (Presidents' Day)
- HW#3 due
- HW#4 will be Posted
  Using tools to access DNS info, let me know if you have trouble.
- Working on getting HW#2 graded



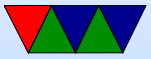
Domain Name System (DNS)

- Hierarchical distributed database
- Maps hostnames to IP addresses
- Why do we need it?
  - Can you remember numbers? Send e-mails to vince@192.168.8.1?
  - What if server moves?
- RFC 1034/1035 (1987), supersedes RFC 882/883 (1983)
- If there's a network problem, it's "always DNS" (or maybe BGP)



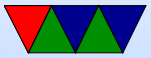
Ancient History

- In early days NIC.arpa had a "HOSTS.TXT" file you downloaded occasionally with all known machines. Didn't really scale.
- Trivia, called SRI (stanford research) on phone to get Elizabeth "Jake" Feinler during business hours and she'd manually add you to list.
- /etc/hosts is a relic of this, usually checked first
- On Linux this is configured via `/etc/nsswitch.conf`



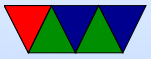
Domain Names

- Which ones can you name? .com/.org/.gov/.edu/.net/.mil
- Country codes (.us/.uk/.ie etc) (.io drama)
- Huge expansion in the last few years (.horse)
- Owner of a domain can subdivide, i.e. eece.maine.edu
- How do you buy them? Used to be fairly expensive and only for two years at a time from a single registrar. Not so much anymore.
- whois will show you info on who owns (less details than old days)



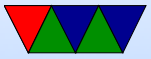
Name Rules

- Can have 127 levels, each 1-63 chars.
- Usually total name cannot exceed 253 chars.
- LDH (letters,digits,hyphens, cannot start with hyphen, not all numbers)
- Case-insensitive
- International names: "punycode". Trouble, why? Foreign letters that look like ASCII ones.
- punycode – snowman example `http://xn--n3h.net/`
- First commercial name 15 March 1985 symbolics.com



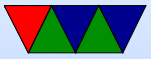
example.com set aside (why be careful with your example names?)

- Shortest? g.cn. Various one-letter domains (like x.org) but they were later reserved.
- Typosquatting, domain squatting, copyrighted names, etc.



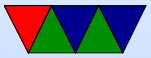
DNS Server

- Listens on port 53, usually UDP
  (Special case if $>$ 512 bytes: use TCP)
- A simple request might look something like:
  a bunch of flags specifying options
  `google.com type: A class: IN`
- A simpler response will restate the question then have the response: `google.com type: A class: IN: addr 1.2.3.4`
- Note it's a binary protocol, not chatty ascii text

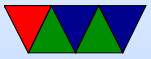


Zone Records

- 5-tuple, NAME TTL CLASS TYPE VALUE
  - TTL (how long to cache)
  - Class (usually IN for internet)
    Mostly reserved, with two obsolete networks chaos, hesiod
  - Type and RDATA (resource data)
  - Common types
    - SOA – start of authority (parameters) primary source, e-mail of admin, etc

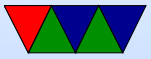


- A – IPv4 address of host (32bit int) `linux.deater.net 86400 IN A 1.2.3.4` can have multiple and be cycled through round-robin
- AAAA – IPv6
- MX – Mail exchange (can have multiple, can specify priority)
- NS – name sever (name server for this domain)
- CNAME – Canonical name, allows aliases (can have www.example.com point to example.com, then not have to update entry if example.com moves)
- PTR – alias for IP, for reverse lookup



`4.3.2.1.in-addr.arpa`

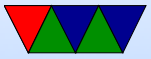
- HINFO – cpu and OS type (text) (uncommon)
- TXT – raw ASCII text
- SRV – new – sort of generic version of MX
- SPF – which machines can send e-mails (avoid spam)
- DKIM – keys for e-mail verification



DNS Hacks

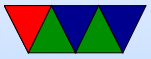
- Can you store other things in records? Text adventure? File transfer? Tunneling (iodine?)

- DNS filesystem, storing text files in other people's DNS `https://blog.benjojo.co.uk/post/dns-filesystem-true-cloud-storage-dnsfs`



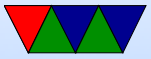
DNS Lookup – Client

- Basically: application calls a library (resolver) with the hostname.
  `gethostbyname()` HW#2
- Operating system / C library starts request (This example is how it goes on Linux)
  - First check `/etc/nsswitch.conf` to see what protocols to use. Might say to check local files (`/etc/hosts`) or local directory (NIS/LDAP) first
  - If DNS specified, looks up nameserver info



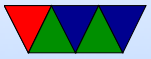
(`/etc/resolv.conf`)

- Sends DNS request via UDP to local nameserver



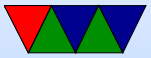
DNS Lookup – Nameserver

- Listens for request on UDP
- If happens to be official nameserver for this machine, get *authoritative response* (from responsible zone)
  the alternative is a cached response
- If local DNS server doesn't know about it, it has to ask up the chain.
- If totally not known, query "root" server. So if looking up weaver-lab.eece.maine.edu will ask root, which will direct to .edu DNS server



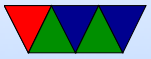
Root DNS Servers

- Traditionally was 13 root servers mostly in US
- Single-letter server names, limitation of number that can fit in single 512B UDP packet
- a.root-servers.net through m.root-servers.net
- These days clusters of machines around world mirrored using anycast, see `https://root-servers.org/`
- There was one (D) at University of Maryland when I was there



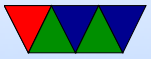
Recursive Query

- The recursive lookup might have to start with the root server if it doesn't know the domain (but not if it's cached)
- It will then ask the .edu server for .maine.edu
- Then if it doesn't know .eece.maine.edu it might have to ask another
- Ideally things are cached all along the way



DNS Lookup – Caching

- Results are cached
- Length of time in (TTL) filed
  caching up to 68 years (or none at all). Why low values? Why can that be bad?
- Caching also means usually the root server does not have to respond to each request
- Applications can cache lookups
  Things like browsers don't want to keep re-looking up
- The Operating System can cache lookups (stub resolver)

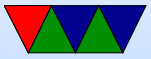


Three types of requests

1. Recursive, ask recursive resolver, want the address or an error

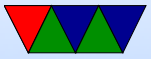
2. Iterative, if server doesn't have the info, will return a referral to server one further down domain space

3. Non-recursive. Respond from server directly either because it's authoritative, or else cached



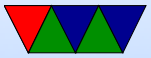
How do you know what DNS server to use?

- Usually your ISP would tell you
- These days set up so DHCP will set it up for you
- Companies offer “easy to remember” ones you can use, google 8.8.8.8 and cloudflare 1.1.1.1



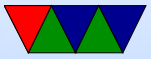
DNS Query with dig – dnsutils

```
dig weaver-lab.eece.maine.edu

; <<>> DiG 9.11.3-2-Debian <<>> weaver-lab.eece.maine.edu
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 1268
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 512
;; QUESTION SECTION:
;weaver-lab.eece.maine.edu. IN A

;; ANSWER SECTION:
weaver-lab.eece.maine.edu. 3599 IN A 130.111.218.24

;; Query time: 79 msec
;; SERVER: 8.8.8.8#53(8.8.8.8)
;; WHEN: Tue Sep 25 14:12:42 EDT 2018
;; MSG SIZE  rcvd: 70
```



Reverse DNS request

- Given IP address, how can you find the name?
- Linux can use the "host" command.
- For IPv4, there is special in-addr.arpa domain
- To look up 1.2.3.4, lookup 4.3.2.1.in-addr.arpa
- It will iterate down. This gets trickier now with non-contiguous IP allocations.
- Similar thing for IPv6 using ip6.arpa

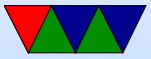


DNS Packet format

- Packet format

16-bits	16-bits
ID	Control Flags
Query Count	Answer Count
Authority Count	Additional Count
. . .	
. . .	

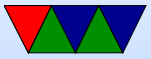
- Flags
  - QR – request (0) or response (1)
  - OpCode – QUERY, IQUERY, STATUS, NOTIFY,



UPDATE

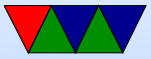
- AA – Authoritative Answer (1) or cache (0)
- Truncated – (1) means too big for UDP
- RD – Recursion Desired
- RA – Recursion Available
- Z – zeros (reserved)
- AD – Authenticated Data (DNSSEC)
- CD – Checking Disabled (DNSSEC)
- RCODE – Error Code

- Counts say how many of each included
- Then the actual requests



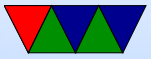
Decoding DNS packet

- Would be nice to decode a DNS packet from a network dump
- Turns out decoding a DNS packet is *really* tricky
- Original protocol was relatively straightforward but modern real-life there's a lot going on



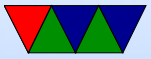
Zone Transfers

- Zone transfers – copying zone list between machines



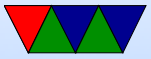
Name Server Software

- Can you set up your own?
- BIND/named
- dig / nslookup tools



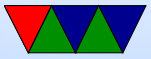
DNS Security – DNSSEC

- RFC 3833
- Digitally sign response
- Can provide things like public keys
- Backwards compatible
- Slow uptake
- Article on DNSSEC `https://www.potaroo.net/ispcol/2024-05/dnssec-fin.html`



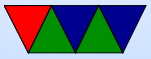
DNS Security – Cache Poisoning Attack

- Make request that causes a recursive lookup
- Immediately flood server with spoofed response packets with inaccurate info
- This is easier as only 16-bit IDs in protocol so easy to try all of them
- Can get inaccurate info into cache and will hand out bad info



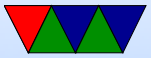
DNS Security – 0x20 Encoding

- Used to avoid cache poisoning attack
- DNS lookups case independent
- So server can toggle case in random way, eXaMPlE.cOm
- (Toggling case is equivalent to flipping bit 0x20)
- Poison attacks would have to not only guess 16-bit value but also the pattern of flipped bits which is much harder



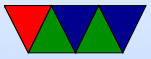
DNS Security – Amplification Attack

- Send requests to DNS server with spoofed return address
- UDP makes this easy
- Do this with enough servers, can be DDoS



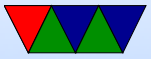
DNSSEC Security – Crashing Attack

- https://www.theregister.com/2024/02/13/dnssec_vulnerability_internet/
- 1/3 of DNS servers handle DNSSEC?
- Sending specially crafted encrypted data can take hours to decode, essentially DOSing the DNS server



DNS Privacy

- Can people spy on your web-browsing through DNS?
- 1.1.1.1 and 8.8.8.8 name servers?
- Can a web-browser tunnel DNS over https?



https DNS Tunneling

- Some browsers want to tunnel DNS over https
- Bypass your ISP's DNS servers and use ones from your browser
- Is this more or less secure?
- Are there privacy implications?
- Why might your ISP/company not like this?