Domain Name System (DNS)

- Internet communication requires IP addresses
- Humans prefer to use computer names
- Automated system available to translate names to addresses
- Known as *Domain Name System (DNS)*
- November 1987

- RFC 1034: Informational
- RFC 1035: Implementation details

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DNS Functionality

- Given
  - Name of a computer
- Return
  - Computer's internet (IP) address
- Method
  - Distributed lookup
  - Client contact server(s) as necessary

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Domain Name Syntax

- Alphanumeric segments separated by dots
- Examples:
  - www.tcd.ie
  - ntrg.cs.tcd.ie
  - www.research.att.com
- Most significant part on the right

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Domain Name Acquisition

- Organization
  - Chooses a desired name
  - Must be unique
  - Registers with central authority
  - Placed under one *top-level domain*
- Names subject to international law
  - Trademarks
  - Copyright

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Top-Level Domains (TLDs)

- .com commercial organization
- .edu U.S. educational institution
- .gov U.S. government organization
- .mil U.S. military group
- .net major network provider or other
- .org organization other than above
- .arpa temporary ARPA domain (still used)
- .int international organization
- country code A country (e.g. ie or gr (grrr))

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Within Top-Level Domains

- Subdivision possible
- Arbitrary levels possible
- Not standardized
- Controlled locally by organization

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Example Name Structure

- First level: `com`
- Second level is company name: `cisco`
- Third level is division within company: `security`
- Fourth level either
  - Company subdivision: `crypto`
  - Individual computer: `smtp`

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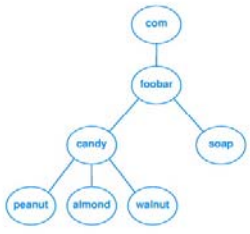
DNS Illustrated



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DNS Key Concepts

- The number of segments in a domain name corresponds to the naming hierarchy
- There is no universal standard for this hierarchy; each organization can choose its own naming convention
- Furthermore, names within an organization do not need to follow a uniform pattern; individual groups within the organization can choose a hierarchical structure that is appropriate for that group

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DNS Client/Server Interaction

- Client known as *resolver*
  - Actually a library that applications link against
- Multiple DNS servers used
- Arranged in a hierarchy
- Each server corresponds to an adjacent part of the global naming hierarchy

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Inter-Server Links

- All domain name servers are linked together to form a unified system
- Each server knows how to reach a root server, and
- How to reach servers that are authorities for names further down the hierarchy

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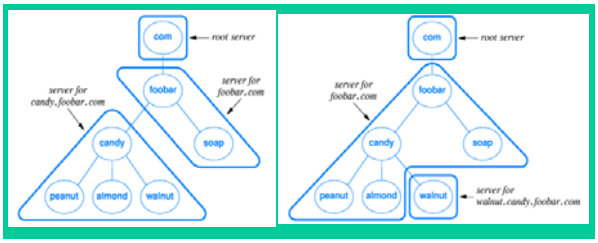
DNS Hierarchy



- Choice made by organization `foobar`

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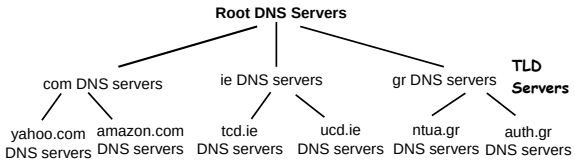
Distributed Hierarchical Database



- Root servers and TLD servers typically do not contain hostname to IP mappings
- They contain mappings for locating authoritative servers

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DNS Root Name Servers

- Contacted by local name server that can not resolve name
- Root name server:
  - Contacts authoritative name server if name mapping not known
  - Gets mapping
  - Returns mapping to local name server

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TLD and Authoritative Servers

- Top-level domain (TLD) servers: Responsible for com, org, net, edu, etc., and all top-level country domains ie, gr, …
- Authoritative DNS servers: Organization's DNS servers, providing authoritative hostname to IP mappings for organization's servers (e.g., web and mail)
  - Can be maintained by organization or service provider

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Local Name Server

- Each ISP (residential ISP, company, university) has one
  - Also called ``default name server''
- When a host makes a DNS query, query is sent to its local DNS server
  - Acts as a proxy, forwards query into hierarchy
  - Reduces lookup latency for commonly searched hostnames

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Caching and Updating Records

- Once (any) name server learns mapping, it *caches* mapping
  - Cache entries timeout (disappear) after some time
  - TLD servers typically cached in local name servers
    - * Thus root name servers not often visited
- Update/notify mechanisms under design by IETF
  - RFC 2136
  - http://www.ietf.org/html.charters/dnsind-charter.html

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DNS Records

DNS: Distributed DB storing resource records (RR)

RR format: `(name, value, type, ttl)`

- Type=A
  - **`name`** is hostname
  - **`value`** is IP address
- Type=NS
  - **`name`** is domain (e.g. foo.com)
  - **`value`** is IP address of authoritative name server for this domain
- Type=CNAME
  - **`name`** is alias name for some ``canonical'' (the real) name `www.ibm.com` is really `servereast.backup2.ibm.com`
  - **`value`** is canonical name
- Type=MX
  - **`value`** is name of mail server associated with **`name`**

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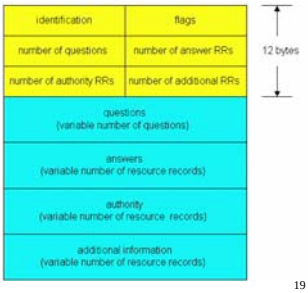
DNS Protocol and Messages (1/2)

DNS protocol: *Query* and *reply* messages, both with same *message format*

Message header:

- Identification: 16 bit # for query, reply to query uses same #
- Flags:
  - Query or reply
  - Reply is authoritative



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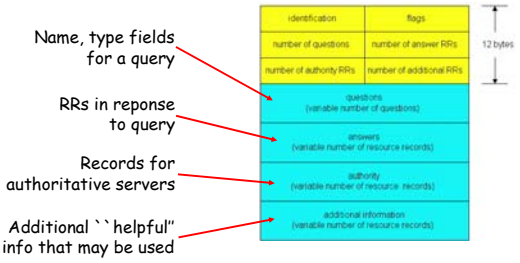
DNS Protocol and Messages (2/2)



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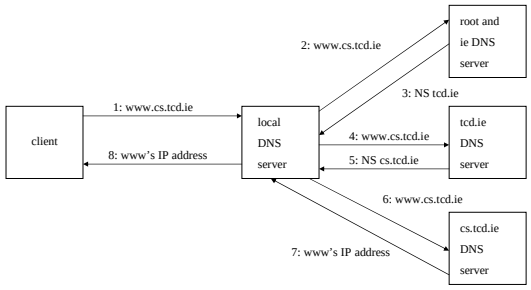
Inserting Records Into DNS

- Example: Just created startup ``Network Fun''
- Register name networkfun.com at a registrar (e.g., Network Solutions, Inc.)
  - Need to provide registrar with names and IP addresses of your authoritative name server (primary and secondary)
  - Registrar inserts two RRs into the com TLD server:
  * (networkfun.com, dns1.networkfun.com, NS)
  * (dns1.networkfun.com, 212.212.212.1, A)
- Put in authoritative server (dns1.networkfun.com) Type A record for www.networkfun.com and Type MX record for networkfun.com
- How do people get the IP address of your web site?

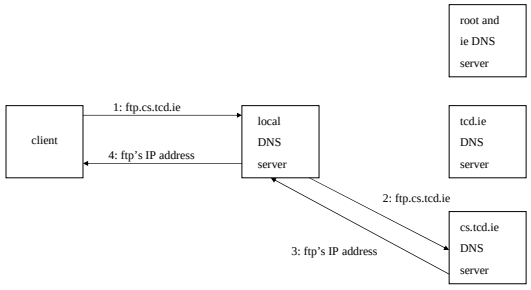
DNS Lookup Example



DNS Caching

- DNS responses are cached:
- Quick response for repeated translations
- Other queries may reuse some parts of lookup
  * NS records for domains
- DNS negative queries are cached
- Don't have to repeat past mistakes
- E.g. misspellings
- Cached data periodically times out
- Lifetime (TTL) of data controlled by owner of data
- TTL passed along with every record

Subsequent Lookup Example



Reverse DNS

- Given numeric IP address, find DNS name
- To find 150.10.20.1:
  - Query 1.20.10.150.in-addr.arpa
  - Get back server.acme.com

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DNS Attacks

- Cache poisoning
- Reverse DNS attack
  - Known as the Bellovin/Mockapetris attack

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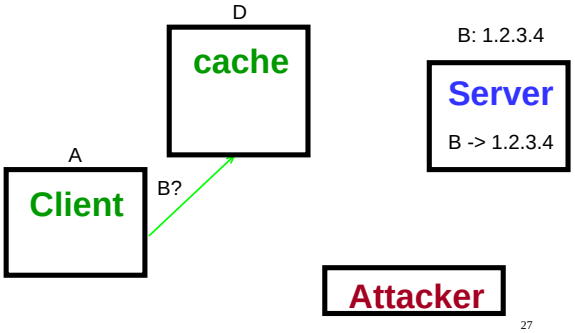
DNS Lookup: A asks D for B's IP address



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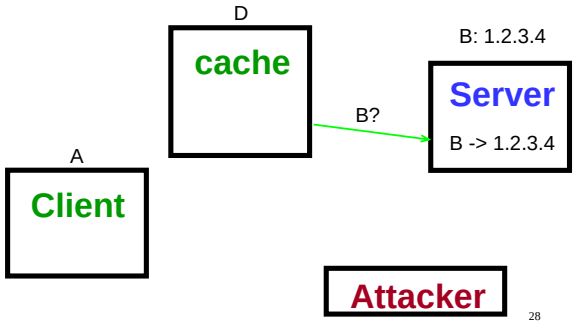
DNS Lookup: D asks B (or someone who knows about B)



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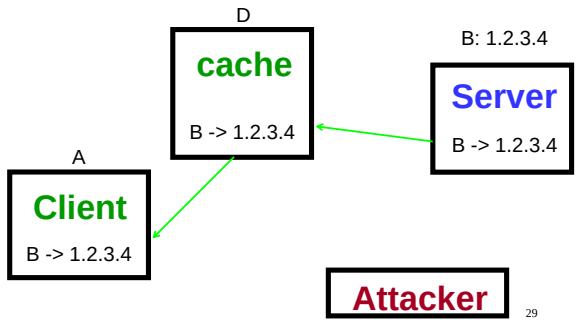
DNS Lookup: B answers, D caches the answer, and tells A



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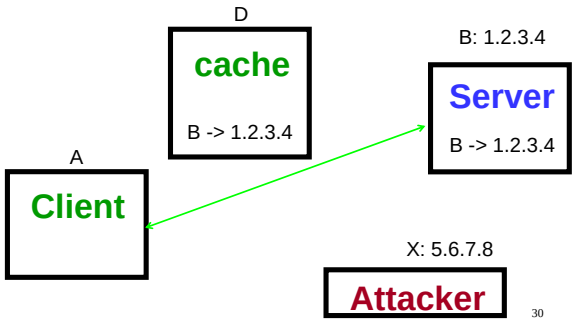
DNS Lookup: A uses the answer



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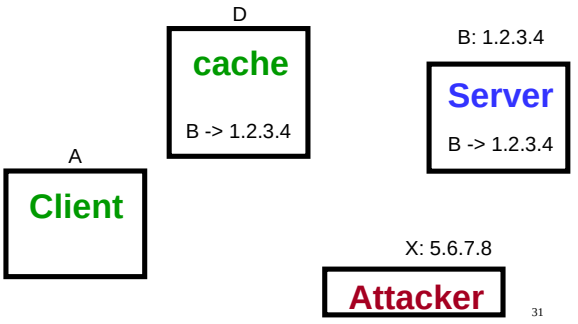
DNS Lookup: D remembers the answer for a given period



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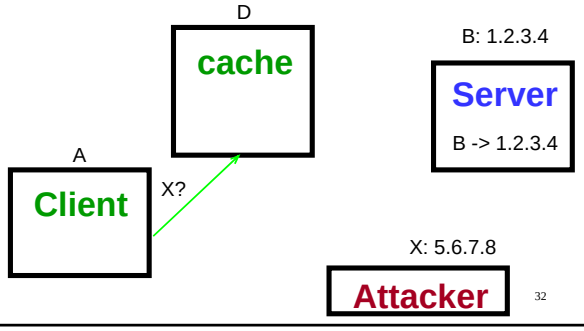
DNS Cache Poisoning Attack: Attacker C arranges for D to ask him a question



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DNS Cache Poisoning Attack:
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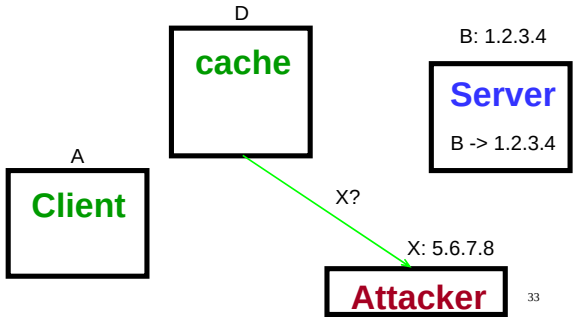

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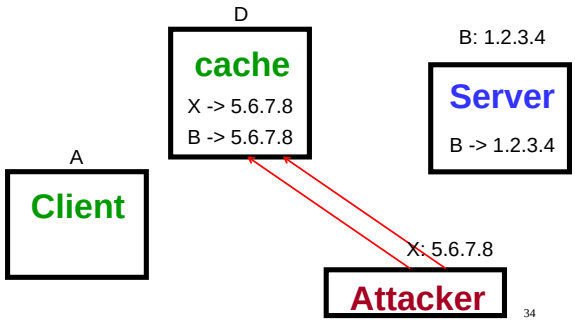
DNS Cache Poisoning Attack: The attacker gives an answer, plus…



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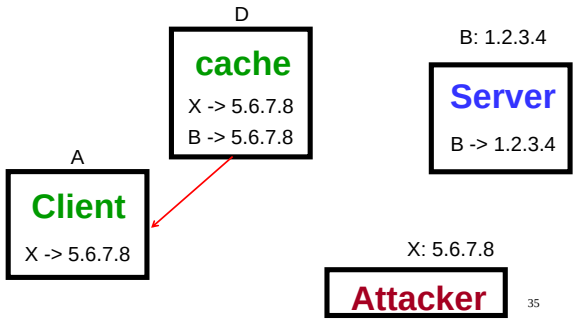
DNS Cache Poisoning Attack:
A gets his answer, and uses it



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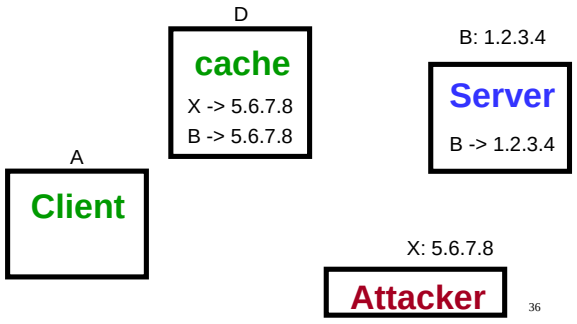
DNS Cache Poisoning Attack:
The cache has an extra answer



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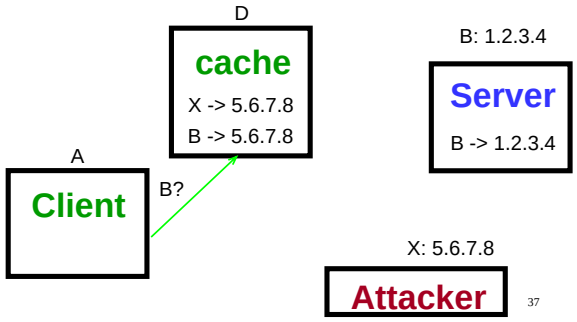
DNS Cache Poisoning Attack: Now A asks for B's address



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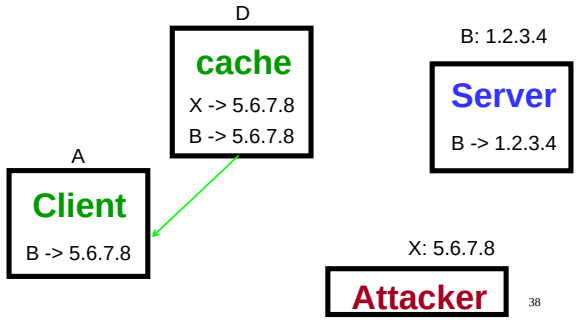
DNS Cache Poisoning Attack: D ``knows'' the answer already, and returns it



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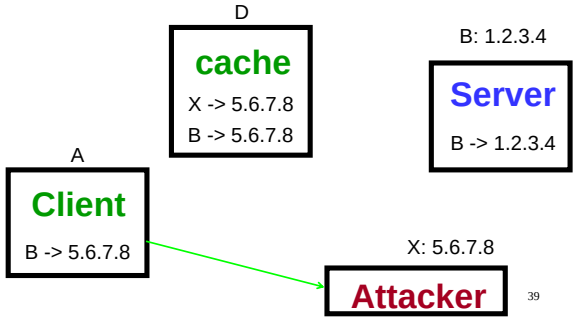
DNS Cache Poisoning Attack: A uses the answer



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DNS Cache Poisoning

- Older versions of bind fall for this
- You can even send an answer without a query, to some implementations!
- DNS responses can be spoofed to
  - What if the query gets two answers: Use the first?!
- DNSsec fixes this

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Bellovin/Mockapetris Attack

- Trust relationships use DNS names
  - /etc/hosts.equiv contains ntrg.cs.tcd.ie
- Requests come with numeric IP source address
  - Use reverse DNS to find DNS name
  - Decide access based on /etc/hosts.equiv

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Attack

- Gain control of DNS service for domain
- Select target machine in domain
- Find trust relationships
  - SNMP, finger can help find active sessions, etc.
  - Example: Target trusts host1
- Connect:
  - Attempt rlogin from compromised machine
  - Target contacts reverse DNS server with IP addr1
  - Use modified reverse DNS to say addr1 is host1
  - Target allows rlogin

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Defense Against This Attack

- Double-check reverse DNS:
  - Modify rlogind, rshd to query DNS server
  - See if DNS name maps to numeric IP address
- Authenticate entries in DNS tables:
  - DNSsec
  - Requires some form of PKI…

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