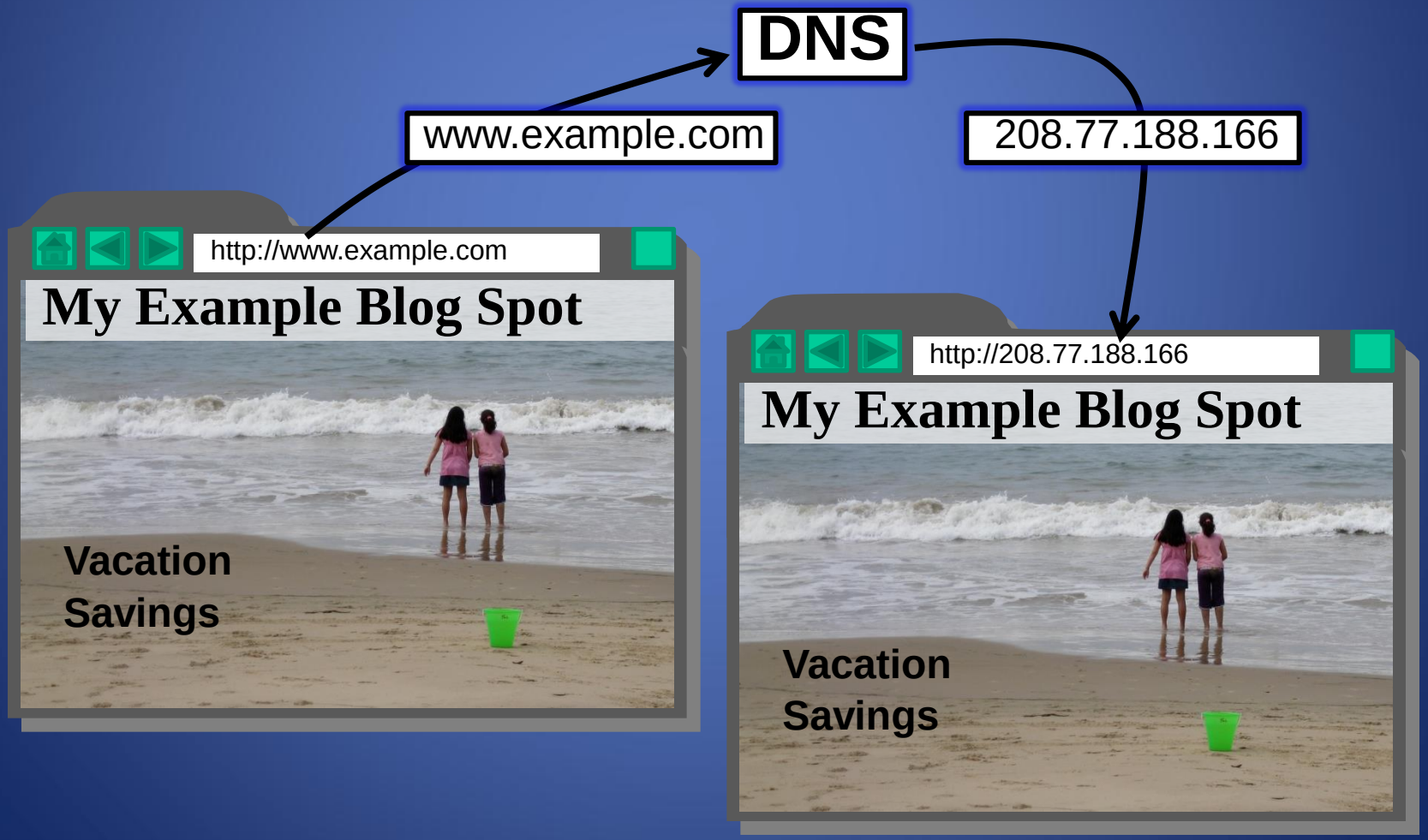
Computer Networks: Domain Name System

Domain Name System

- The domain name system (DNS) is an application-layer protocol for mapping domain names to IP addresses



Domain Name System

- DNS provides a distributed database over the internet that stores various resource records, including:
  - Address (A) record: IP address associated with a host name
  - Mail exchange(MX) record: mail server of a domain
  - Name server (NS) record: authoritative server for a domain

For example, if example.com wishes to sub-delegate "john.example.com." to John who works at Example, inc., lines like this can be added to the example.com zone file:

```
john.example.com. NS ns1.john.example.com.
john.example.com. NS ns2.john.example.com.
# It's important to provide "glue"; in other words, let the world know
# the IPs for these name servers.
ns1.john.example.com. 10.9.8.7
ns2.john.example.com. 10.5.77.65
```

John, who is running is own nameservers with the IPs 10.9.8.7 and 10.5.77.65 then has a zone file for john.example.com. that looks something like this:

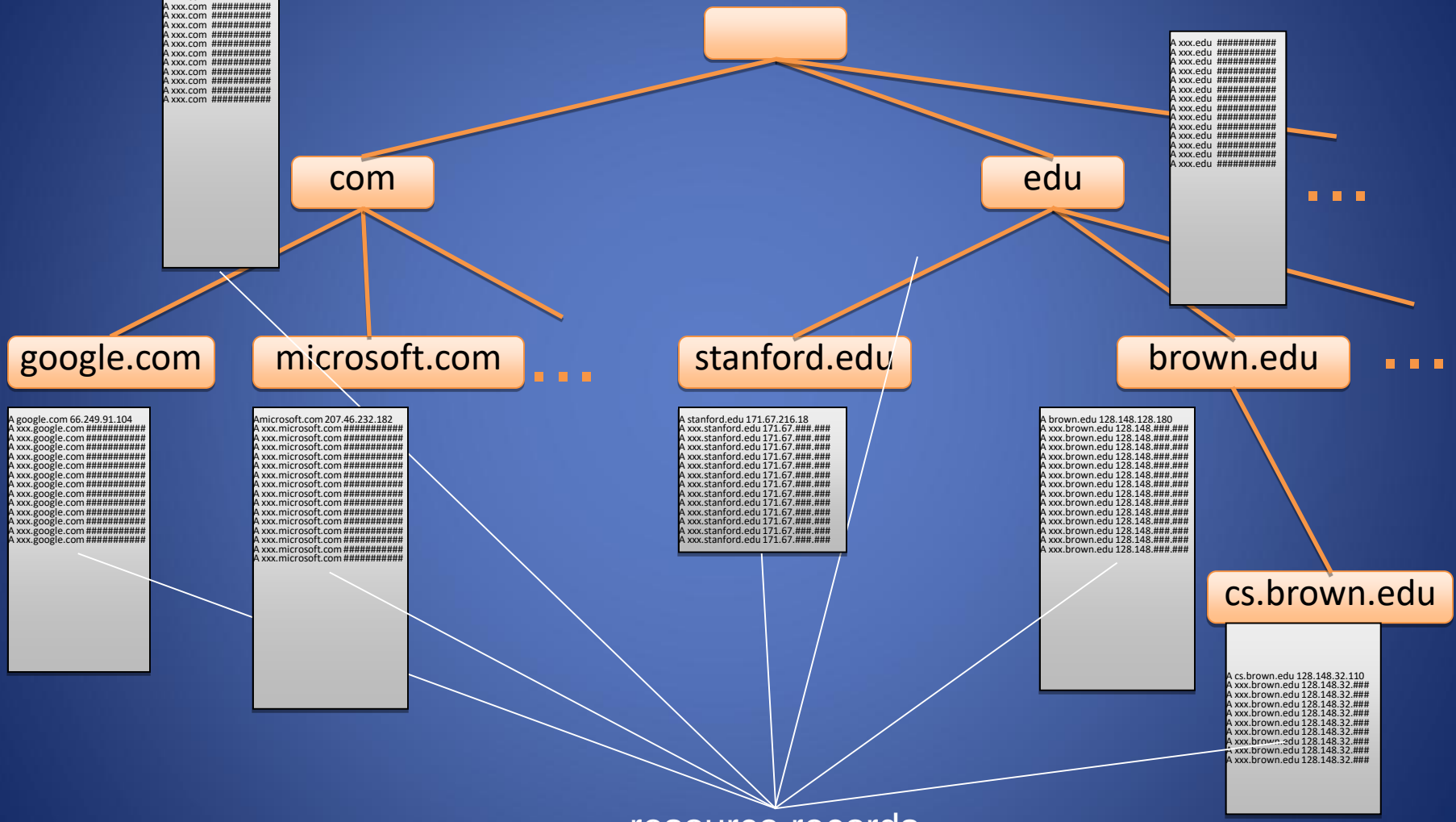
```
# It is best if the NS records for a subzone agree with the delegation
# records above
john.example.com. NS ns1.john.example.com.
john.example.com. NS ns2.john.example.com.

ns1.john.example.com. 10.9.8.7
ns2.john.example.com. 10.5.77.65

# Now that that is out of the way, here is the rest of the zone
john.example.com. 10.9.8.7
www.john.example.com. 10.5.77.65
john.example.com. MX 10 mail.john.example.com.
mail.john.example.com. 10.9.8.7
```

Example DNS entries from http://www.maradns.org/tutorial/recordtypes.html

Name Servers

- Domain names:
  - Two or more labels, separated by dots (e.g., cs166.net)
  - Rightmost label is the top-level domain (TLD)
- Hierarchy of authoritative name servers
  - Information about root domain
  - Information about its subdomains (A records) or references to other name servers (NS records)
- The authoritative name server hierarchy matches the domain hierarchy: root servers point to DNS servers for TLDs, etc.
- Root servers, and servers for TLDs change infrequently
- DNS servers refer to other DNS servers by name, not by IP: sometimes must bootstrap by providing an IP along with a name, called a glue record

DNS Tree


com
edu
google.com
microsoft.com
stanford.edu
brown.edu
cs.brown.edu
resource records

Namespace Management

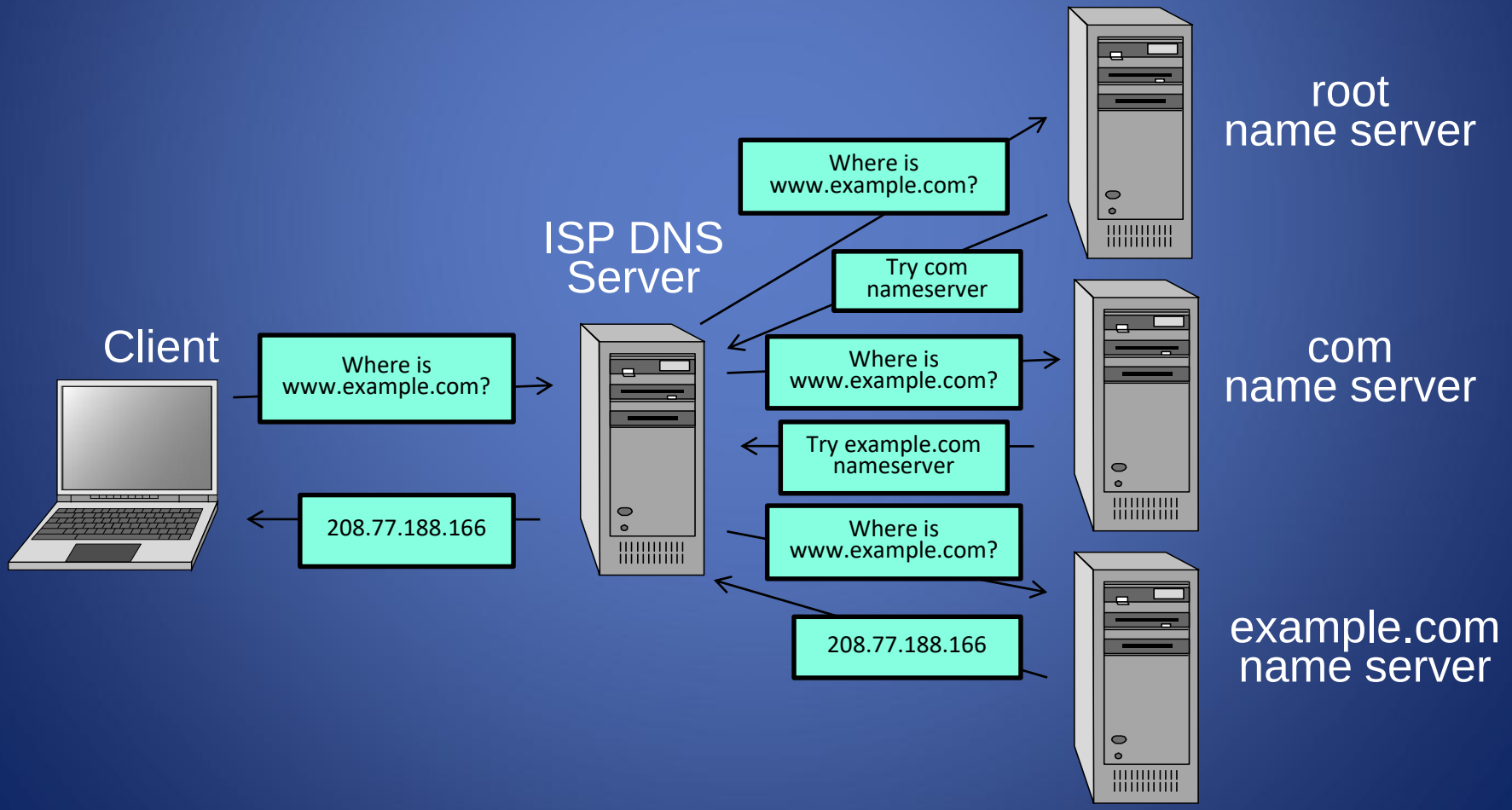
- ICANN: Internet Corporation for Assigned Names and Numbers
- ICANN has the overall responsibility for managing DNS. It controls the root domain, delegating control over each top-level domain to a domain name registry
- Along with a small set of general TLDs, every country has its own TLD -- (cTLDS) – controlled by the government.
- ICANN is the governing body for all general TLDs
- Until 1999 all .com, .net and .org registries were handled by Network Solutions Incorporated.
- After November, 1999, ICANN and NSI had to allow for a shared registration system and there are currently over 500 registrars in the market
- Also since 1999, ICANN has created additional gTLDs including some which are sponsored by consortiums or groups of companies.

Top Level Domains

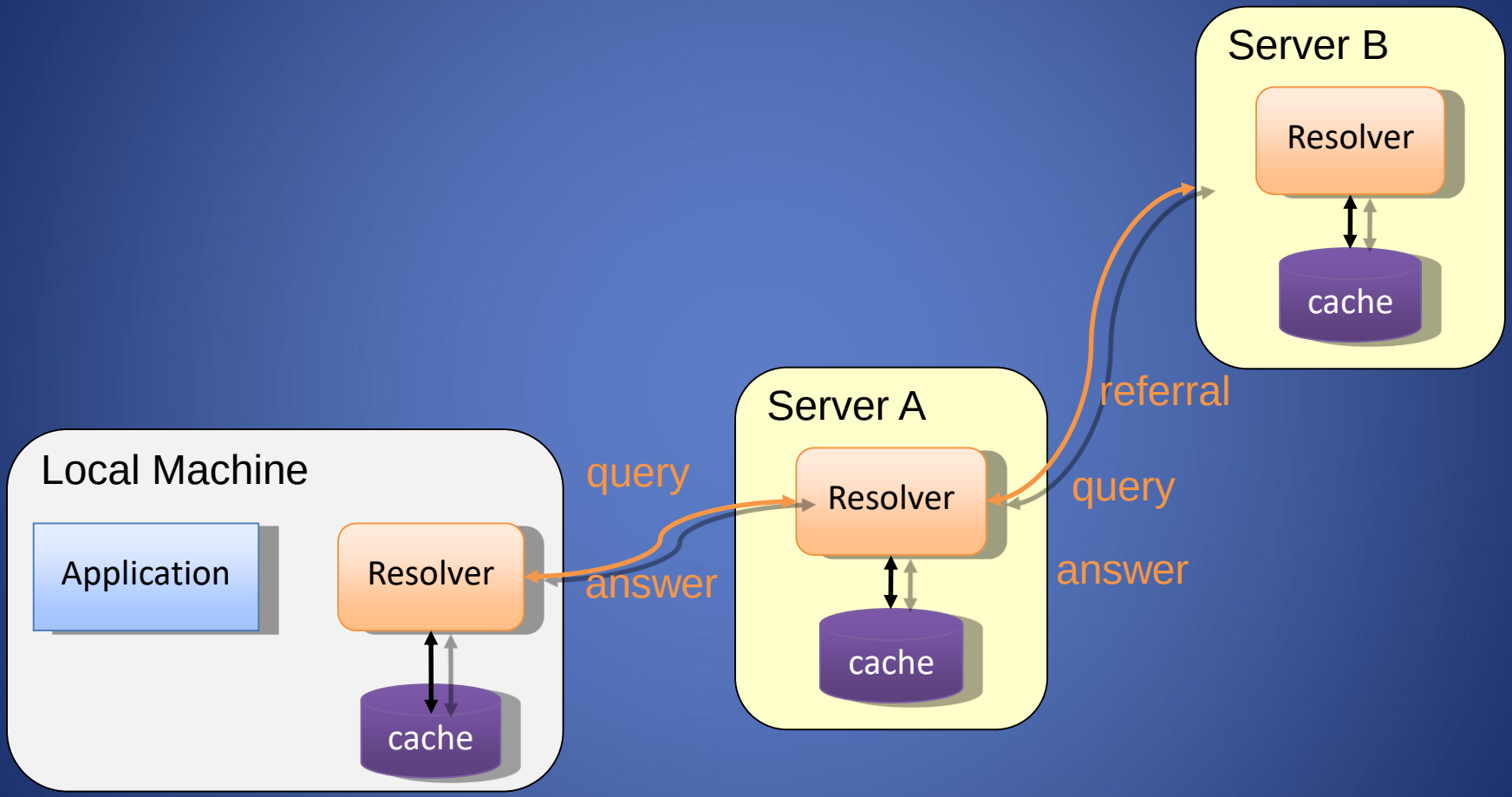
- Started in 1984
- Originally supposed to be named by function
  - .com for commercial websites, .mil for military
- Eventually agreed upon unrestricted TLDs for .com, .net, .org, .info
- In 1994 started allowing country TLDs such as .it, .us
- Tried to move back to hierarchy of purpose in 2000 with creation of .aero, .museum, etc.

Name Resolution

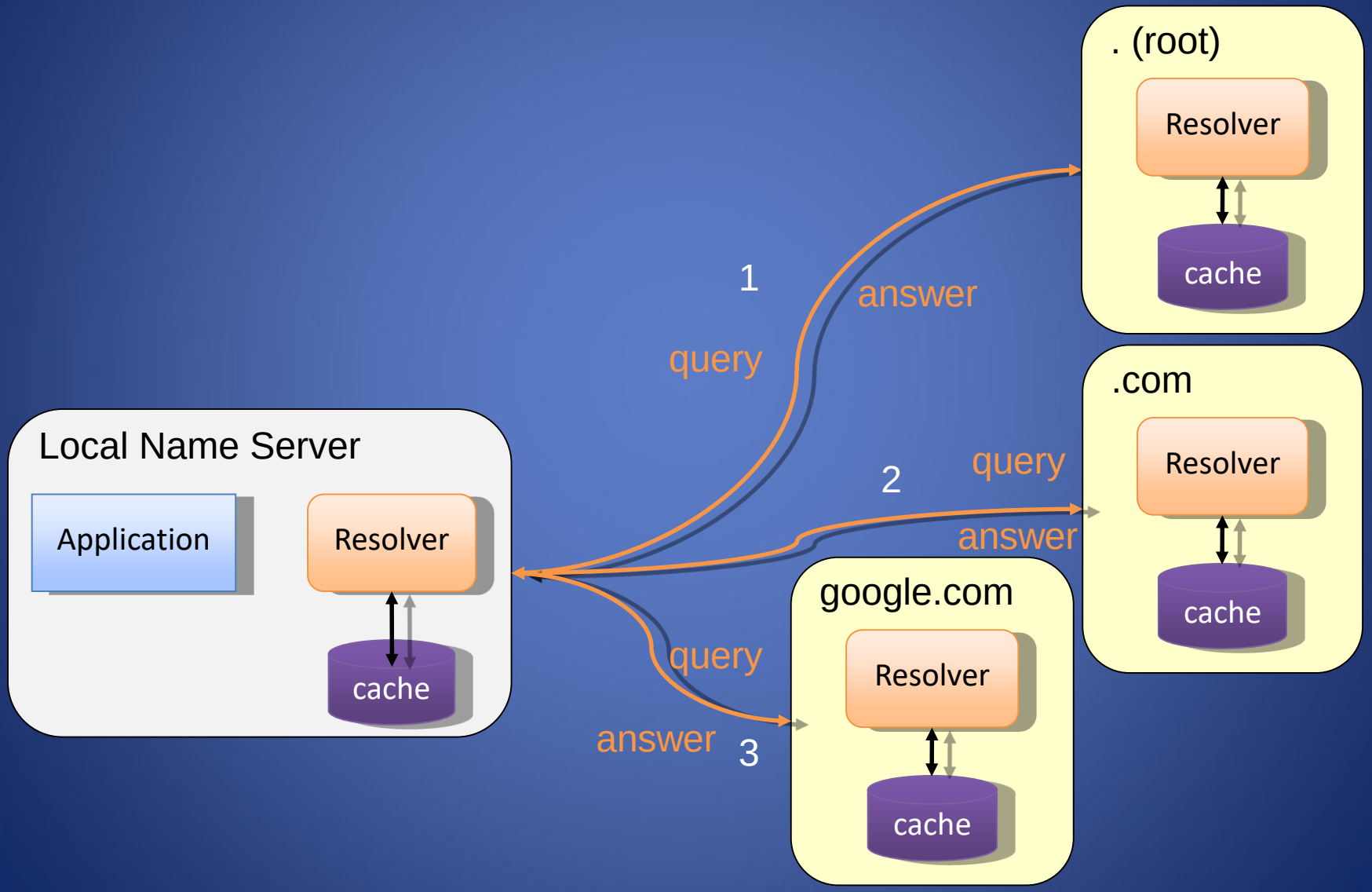
- Zone: collection of connected nodes with the same authoritative DNS server
- Resolution method when answer not in cache:



Recursive Name Resolution



Iterative Name Resolution



Authoritative Name Servers

- Control distributed among authoritative name servers (ANSs)
  - Responsible for specific domains
  - Can designate other ANS for subdomains
- ANS can be master or slave
  - Master contains original zone table
  - Slaves are replicas, automatically updating
- Makes DNS fault tolerant, automatically distributes load
- ANS must be installed as a NS in parents' zone

Dynamic Resolution

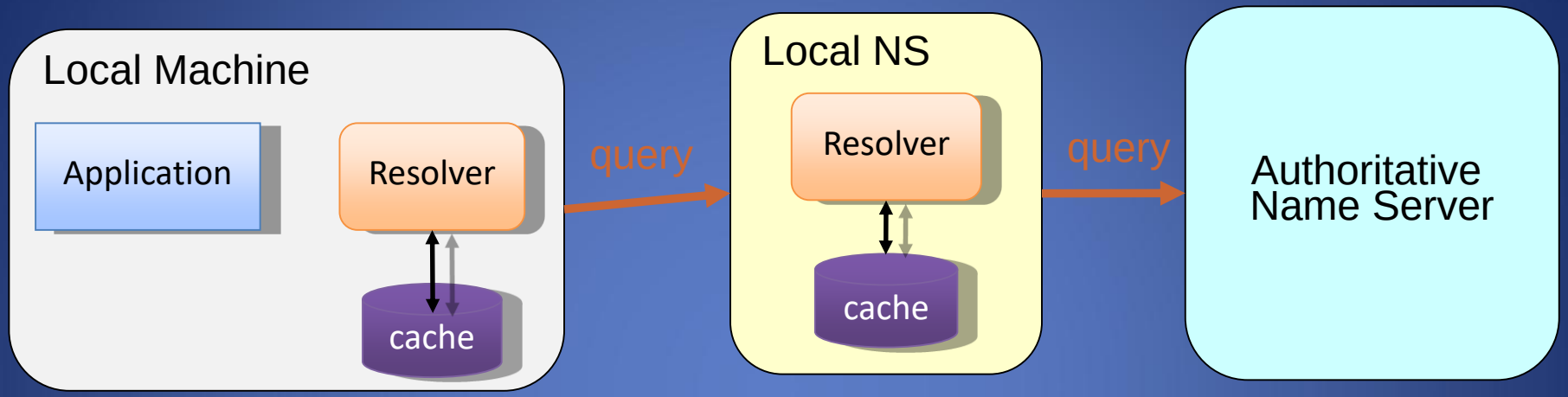
- Many large providers have more than one authoritative name server for a domain
- Problem: need to locate the instance of domain geographically closest to user
- Proposed solution: include first 3 octets of requester's IP in recursive requests to allow better service
- Content distribution networks already do adaptive DNS routing

DNS Caching

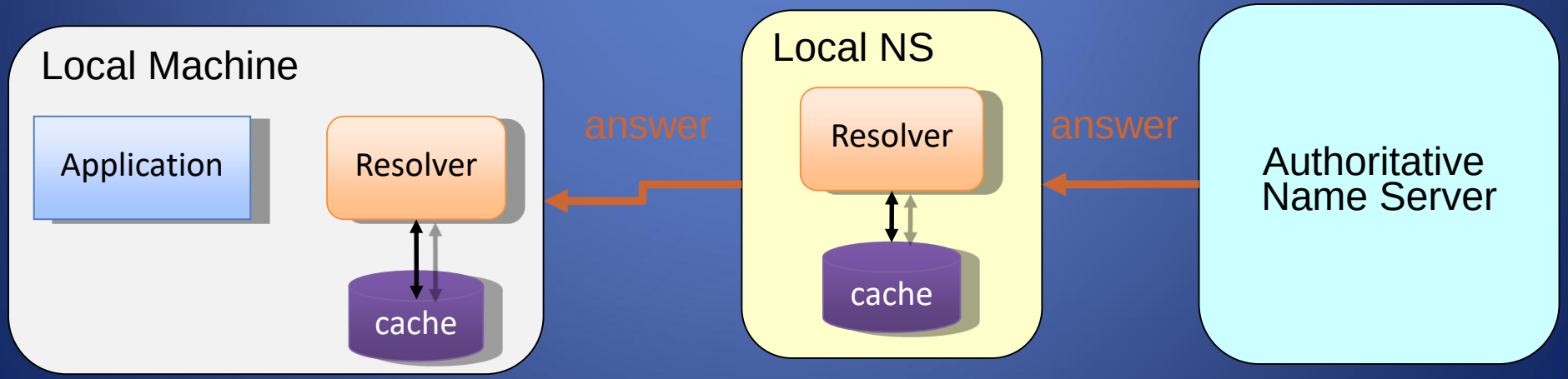
- There would be too much network traffic if a path in the DNS tree would be traversed for each query
  - Root zone would be rapidly overloaded
- DNS servers cache results for a specified amount of time
  - Specified by ANS reply's time-to-live field
- Operating systems and browsers also maintain resolvers and DNS caches
  - View in Windows with command ipconfig /displaydns
  - Associated privacy issues
- DNS queries are typically issued over UDP on port 53
  - 16-bit request identifier in payload

DNS Caching

Step 1: query yourdomain.org

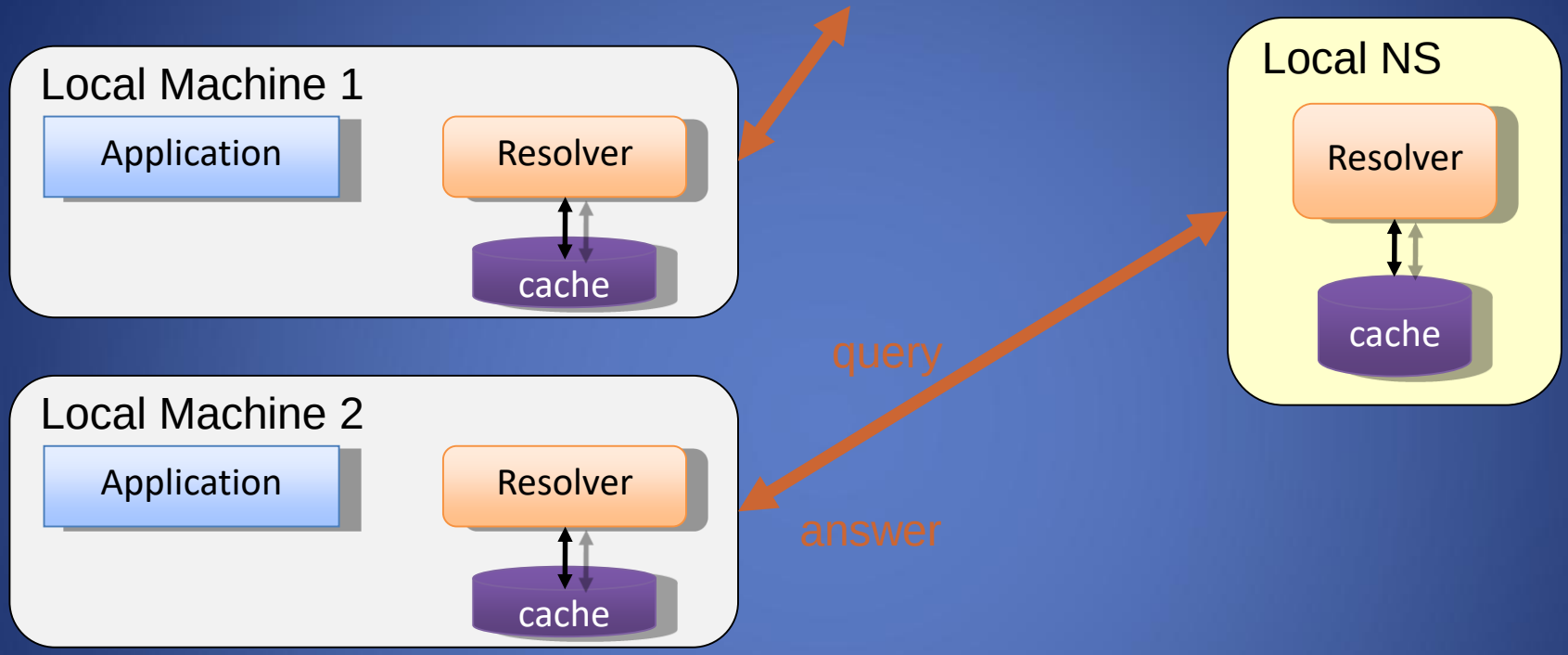


Step 2: receive reply and cache at local NS and host



DNS Caching (con'd)

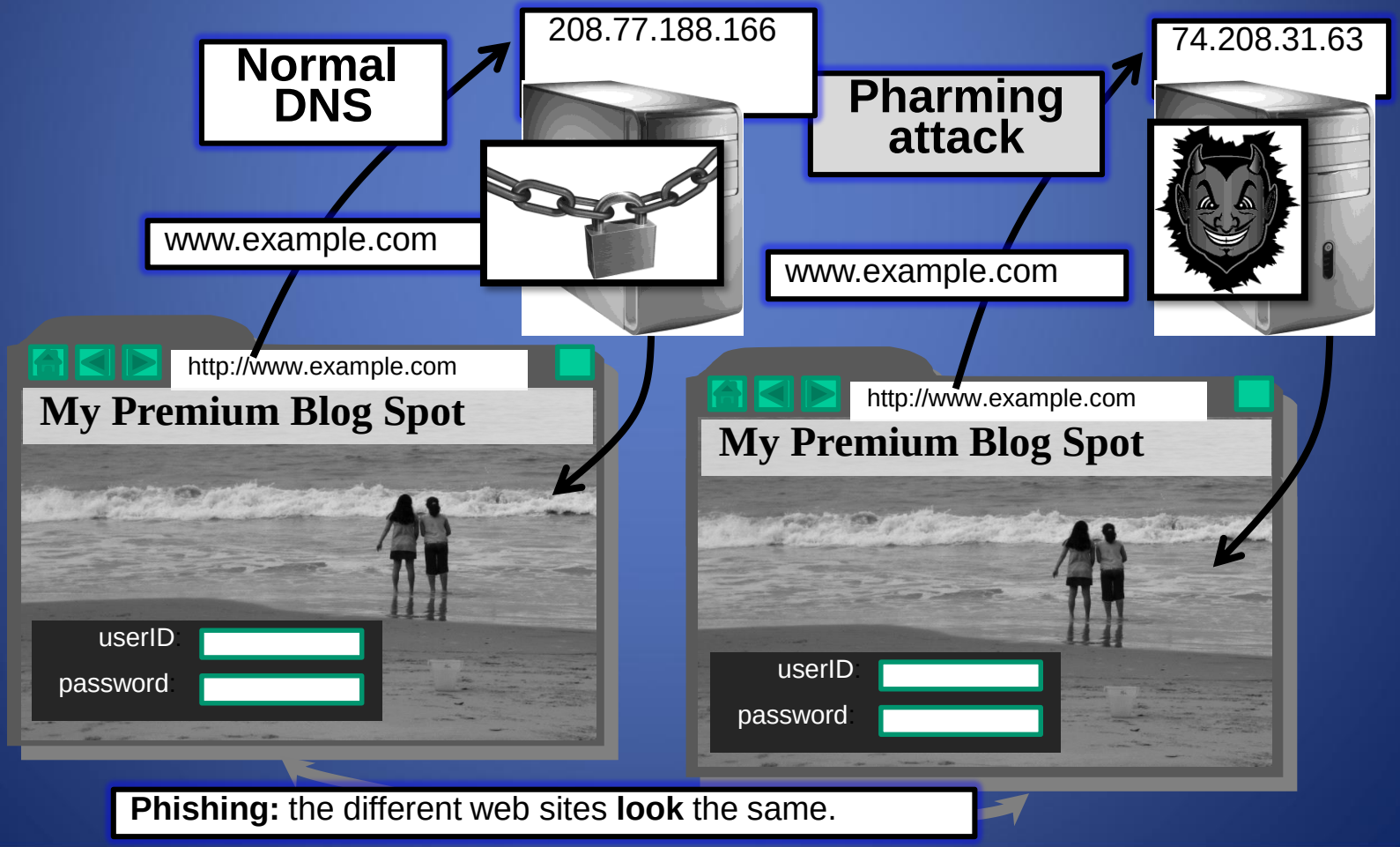
Step 3: use cached results rather than querying the ANS



Step 4: Evict cache entries upon ttl expiration

Pharming: DNS Hijacking

- Changing IP associated with a server maliciously:



DNS Cache Poisoning

- Basic idea: give DNS servers false records and get it cached
- DNS uses a 16-bit request identifier to pair queries with answers
- Cache may be poisoned when a name server:
  - Disregards identifiers
  - Has predictable ids
  - Accepts unsolicited DNS records

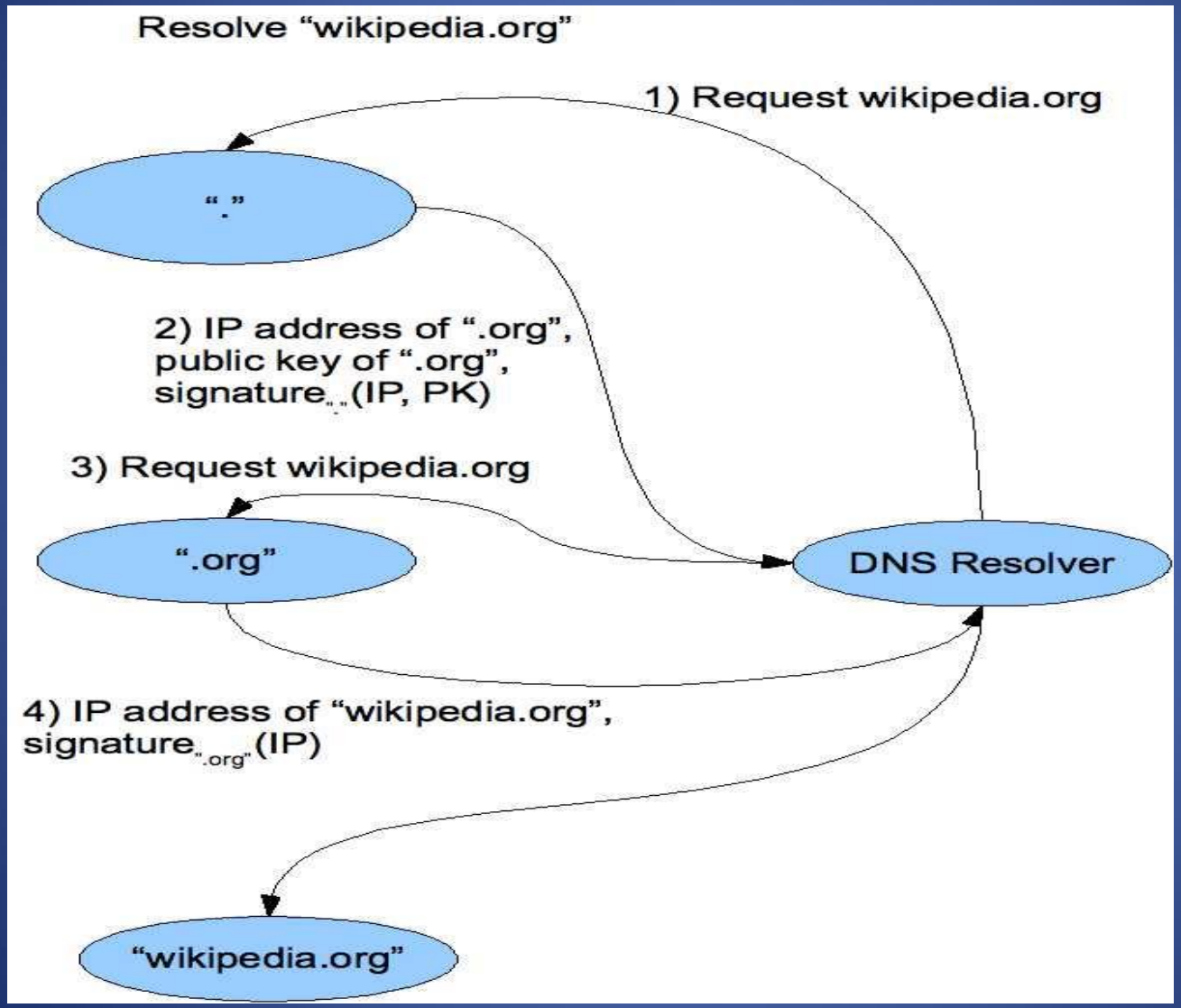
DNS Cache Poisoning Prevention

- Use random identifiers for queries
- Always check identifiers
- Port randomization for DNS requests
- Deploy DNSSEC
  - Challenging because it is still being deployed and requires reciprocity

DNSSEC

- Guarantees:
  - Authenticity of DNS answer origin
  - Integrity of reply
  - Authenticity of denial of existence
- Accomplishes this by signing DNS replies at each step of the way
- Uses public-key cryptography to sign responses
- Typically use trust anchors, entries in the OS to bootstrap the process

DNS Signing


Resolve “wikipedia.org”
1) Request wikipedia.org
“.”
2) IP address of “.org”,
public key of “.org”,
signature“.”(IP, PK)
3) Request wikipedia.org
“.org”
DNS Resolver
4) IP address of “wikipedia.org”,
signature“.org”(IP)
“wikipedia.org”

DNSSEC Deployment

- As the internet becomes regarded as critical infrastructure there is a push to secure DNS
- NIST is in the process of deploying it on root servers now
- May add considerable load to dns servers with packet sizes considerably larger than 512 byte size of UDP packets
- There are political concerns with the US controlling the root level of DNS