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Note we now have *three* kinds of addresses: physical, network and human

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Exercise The file lives on as `/etc/hosts` under Unix. Look at this file

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That is, machines running a DNS server program

Aside

In the usual way, when talking about these things, we blur the distinction between the service and the host it lives on. The host might well be running other services, such as DCHP, as well

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Exercise Find out the services your home Access Point runs

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`uk` is in the domain `.` (*dot* or *root*)

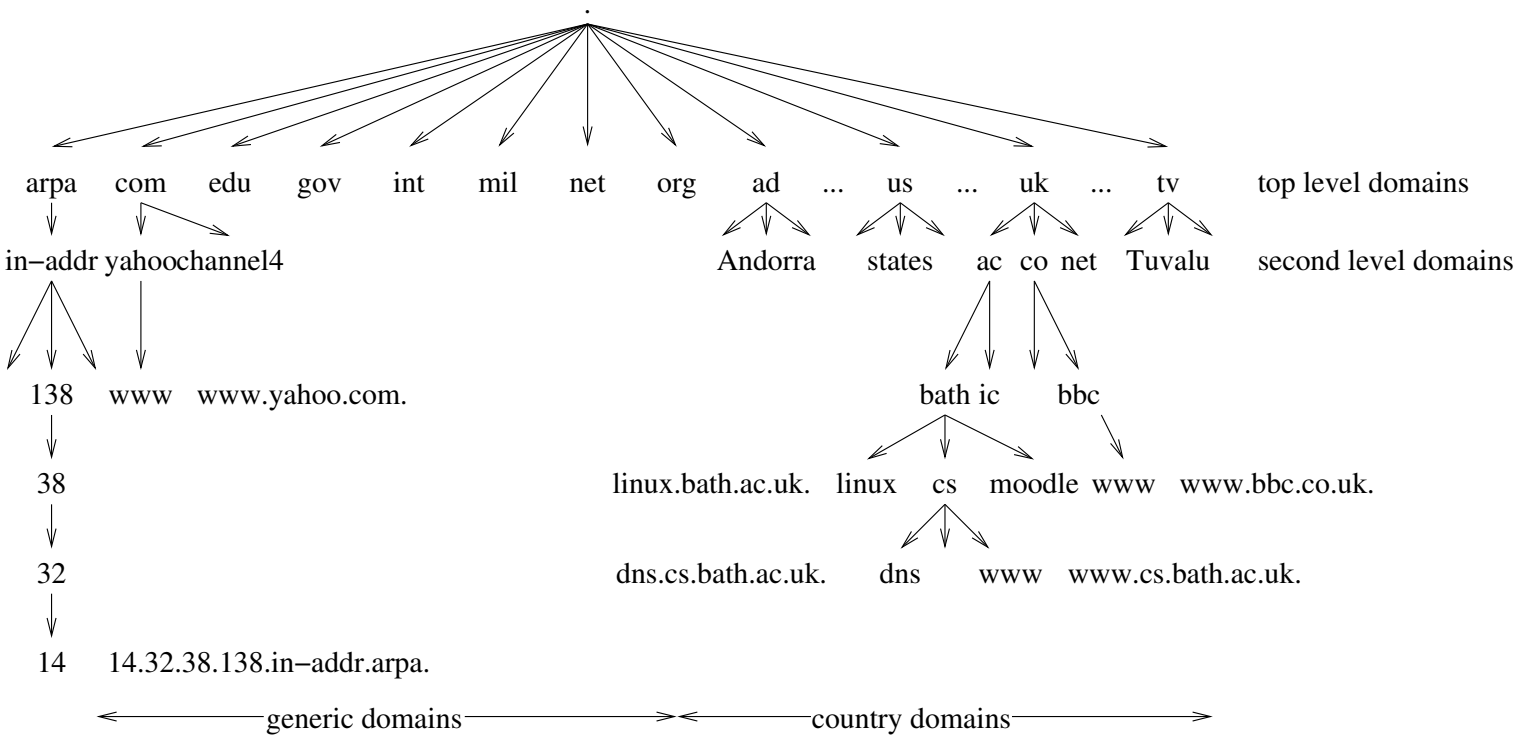
Each node in this tree is called a *label*

DNS

`www.llanfairpwllgwyngyllgogerychwyrndrobwllllantysiliogogogoch.com`
is a valid name

Labels may be up to 63 bytes long

DNS



The DNS hierarchy

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They get to charge money for labels in the next level

But the important bit is that they *delegate* management of lower labels to other organisations

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So, starting a dot, we can work our way down the tree to find the machine we want

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A few years ago, there was a convention of having an off-site replica, too, e.g., Bath used `ns2.ja.net`

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If a host on the Bath network needs to look up a local name, `linux.bath.ac.uk`, say, it sends a request to one of the local servers, e.g., `ns2.bath.ac.uk`

And the local server will look it up and return the answer

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So it can send the DNS request to one of these servers

DNS

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If a host in the University requires a name lookup of a non-local name, say `news.bbc.co.uk`, it sends a DNS request to the **local** DNS server, `ns1.bath.ac.uk`, say

DNS

In this example, the Bath server does not have responsibility for the name `news.bbc.co.uk`, but it will helpfully do a lookup for us. It will run down the DNS tree in a *recursive lookup*

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The Bath server `ns1` sends a *start of authority* (SOA) request to a random *top level* server to find who is responsible for the `uk` label

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This a machine that is responsible for `uk` labels

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It gets the IP address `194.130.56.40`

DNS

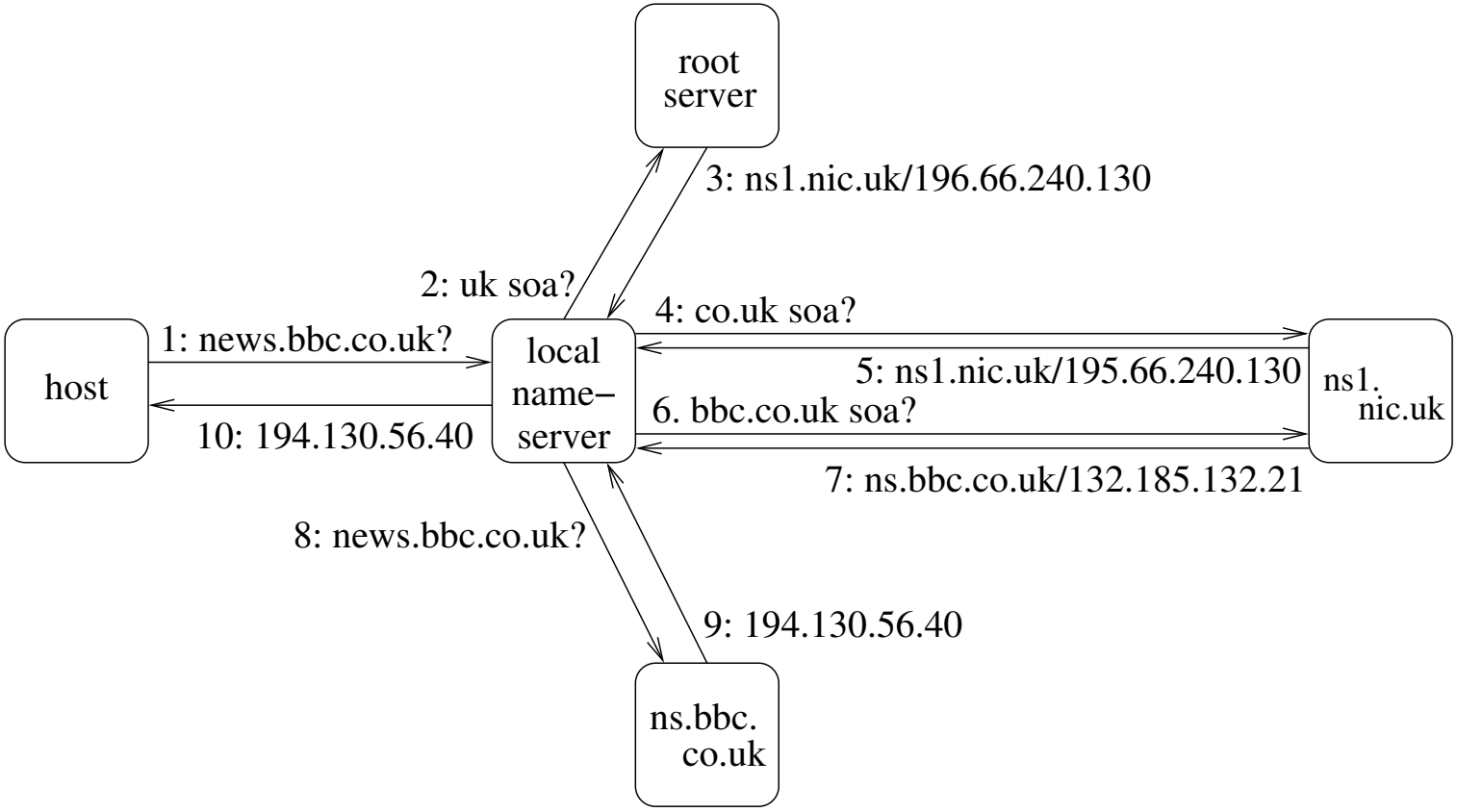
It now knows the server reponsible for the address we want

The server sends an *address* (A) request for `news.bbc.co.uk` to `ns.bbc.co.uk`

It gets the IP address `194.130.56.40`

Finally, the Bath server can relay this back to the original requesting host

DNS



DNS lookup

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Similarly, given a request for `www.bbc.co.uk`, it can go directly to `ns.bbc.co.uk`

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Stable, long lived associations will have a long TTL

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This means a faster response and a decrease in network traffic

And less work for the host

DNS

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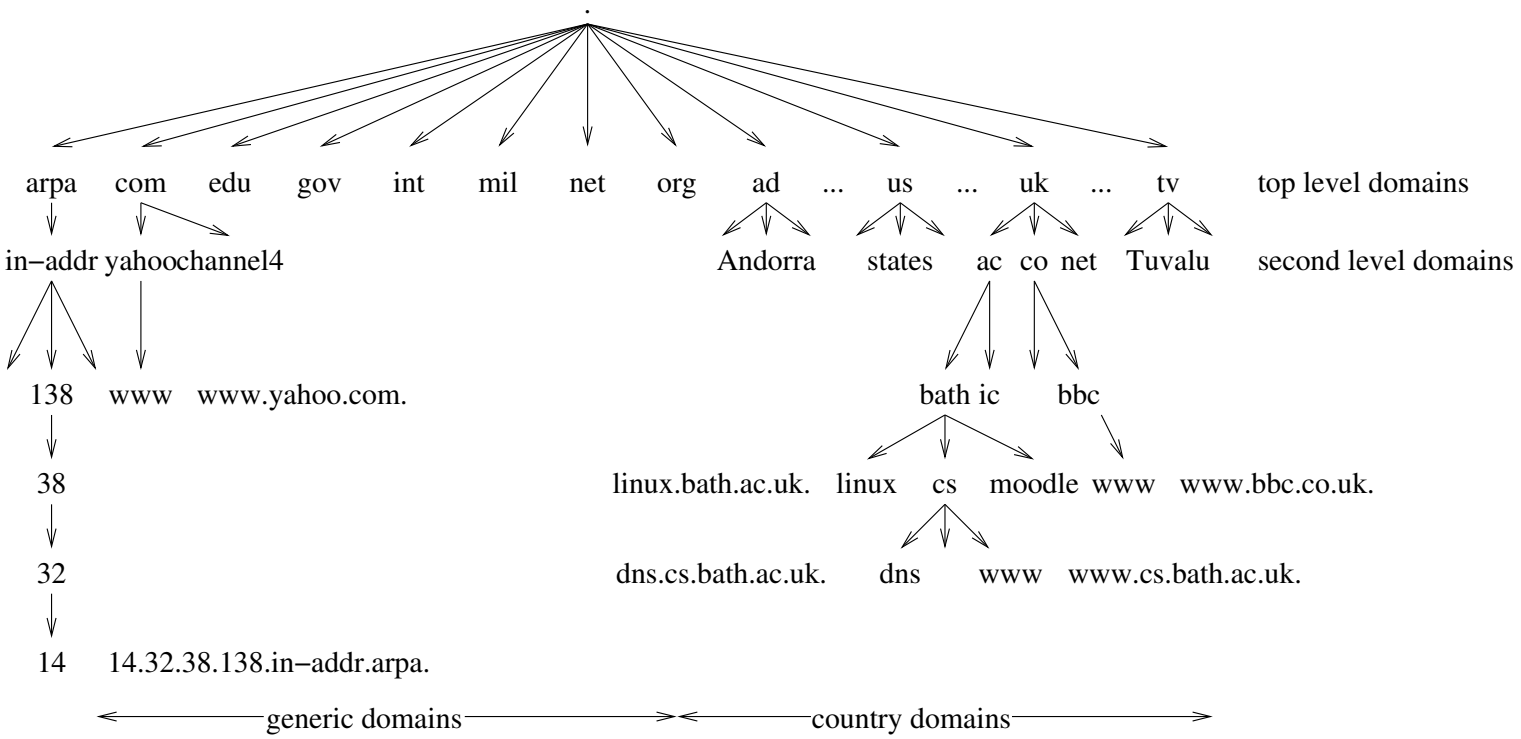
There is a part of the tree dedicated to this with TLD `arpa`

DNS



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We get `clan.bath.ac.uk`

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- AAAA address: name to IPv6 address
- SOA start of authority: name to responsible name server
- MX mail server: name to a mail server for that domain. E.g., `bath.ac.uk` used to have mail server `138.38.32.14`

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- AAAA address: name to IPv6 address
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- MX mail server: name to a mail server for that domain. E.g., `bath.ac.uk` used to have mail server `138.38.32.14`

And many more: about 50 in total, though few are used frequently

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- One address can have several names

DNS

Both `news.bbc.co.uk` and `newswww.bbc.net.uk` resolve to `212.58.226.33`

```
news.bbc.co.uk.          1619    IN  CNAME   newswww.bbc.net.uk.
newswww.bbc.net.uk.      77      IN  A       212.58.226.33
```

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`news.bbc.co.uk` is an *alias* for the real *canonical name* `newswww.bbc.net.uk`

This allows us tricks, like moving the Web server to different hosts, even different ISPs or different countries, but keeping its public name the same

DNS

- One name can have several IP addresses associated. This allows *load sharing*, e.g., a Web server can actually be several machines spread about anywhere in the world

DNS

```
www.microsoft.com.        68      IN  CNAME   toggle.www.ms.akadns.net.
toggle.www.ms.akadns.net. 285     IN  CNAME   g.www.ms.akadns.net.
g.www.ms.akadns.net.      285     IN  CNAME   lb1.www.ms.akadns.net.
lb1.www.ms.akadns.net.    285     IN  A       207.46.19.190
lb1.www.ms.akadns.net.    285     IN  A       207.46.19.254
lb1.www.ms.akadns.net.    285     IN  A       207.46.192.254
lb1.www.ms.akadns.net.    285     IN  A       207.46.193.254
```

DNS

```
www.microsoft.com.       68      IN  CNAME   toggle.www.ms.akadns.net.
toggle.www.ms.akadns.net. 285    IN  CNAME   g.www.ms.akadns.net.
g.www.ms.akadns.net.     285     IN  CNAME   lb1.www.ms.akadns.net.
lb1.www.ms.akadns.net.   285     IN  A       207.46.19.190
lb1.www.ms.akadns.net.   285     IN  A       207.46.19.254
lb1.www.ms.akadns.net.   285     IN  A       207.46.192.254
lb1.www.ms.akadns.net.   285     IN  A       207.46.193.254
```

`www.microsoft.com` is an alias: its canonical name is `toggle.www.ms.akadns.net`;

DNS

```
www.microsoft.com.       68      IN  CNAME   toggle.www.ms.akadns.net.
toggle.www.ms.akadns.net. 285    IN  CNAME   g.www.ms.akadns.net.
g.www.ms.akadns.net.     285     IN  CNAME   lb1.www.ms.akadns.net.
lb1.www.ms.akadns.net.   285     IN  A       207.46.19.190
lb1.www.ms.akadns.net.   285     IN  A       207.46.19.254
lb1.www.ms.akadns.net.   285     IN  A       207.46.192.254
lb1.www.ms.akadns.net.   285     IN  A       207.46.193.254
```

But that is an alias for `g.www.ms.akadns.net`;

DNS

```
www.microsoft.com.        68      IN  CNAME   toggle.www.ms.akadns.net.
toggle.www.ms.akadns.net. 285     IN  CNAME   g.www.ms.akadns.net.
g.www.ms.akadns.net.      285     IN  CNAME   lb1.www.ms.akadns.net.
lb1.www.ms.akadns.net.    285     IN  A       207.46.19.190
lb1.www.ms.akadns.net.    285     IN  A       207.46.19.254
lb1.www.ms.akadns.net.    285     IN  A       207.46.192.254
lb1.www.ms.akadns.net.    285     IN  A       207.46.193.254
```

And that is an alias for `lb1.www.ms.akadns.net`;

DNS

```
www.microsoft.com.        68      IN  CNAME   toggle.www.ms.akadns.net.
toggle.www.ms.akadns.net. 285     IN  CNAME   g.www.ms.akadns.net.
g.www.ms.akadns.net.      285     IN  CNAME   lb1.www.ms.akadns.net.
lb1.www.ms.akadns.net.    285     IN  A       207.46.19.190
lb1.www.ms.akadns.net.    285     IN  A       207.46.19.254
lb1.www.ms.akadns.net.    285     IN  A       207.46.192.254
lb1.www.ms.akadns.net.    285     IN  A       207.46.193.254
```

And that refers to four different addresses

DNS

And a DNS server can give out different lookups dependent on who is asking

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A recent lookup for `www.microsoft.com` returned `104.78.177.250` from one location, and `2.18.85.172` from another

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This allows for load sharing; and also can be used for *geofencing*: giving different services to clients in different place, e.g., videos that are licensed only for certain regions

DNS

Exercise Redo these lookups to see how they currently turn out

Exercise Compare having DNS give out multiple IP addresses for a given name against giving out different addresses for different clients against using anycast addresses

DNS

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Under Linux the `dig` tool can be used to do direct lookups

DNS

```
% dig news.bbc.co.uk
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 15281
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 2, ADDITIONAL: 2

;; QUESTION SECTION:
;news.bbc.co.uk.                        IN      A

;; ANSWER SECTION:
news.bbc.co.uk.         193     IN      CNAME   newswww.bbc.net.uk.
newswww.bbc.net.uk.     76      IN      A       212.58.226.73

;; AUTHORITY SECTION:
bbc.net.uk.             85129   IN      NS      ns0.thdo.bbc.co.uk.
bbc.net.uk.             85129   IN      NS      ns0.rbsov.bbc.co.uk.

;; ADDITIONAL SECTION:
ns0.thdo.bbc.co.uk.     9490    IN      A       212.58.224.20
ns0.rbsov.bbc.co.uk.    9490    IN      A       212.58.227.47
```

DNS

Quite often a DNS server will reply with more information than we requested, e.g., the lookup of the CNAME `newswww.bbc.net.uk` in the above

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This means we don't have to do an additional query to get the actual IP address we were looking for

DNS

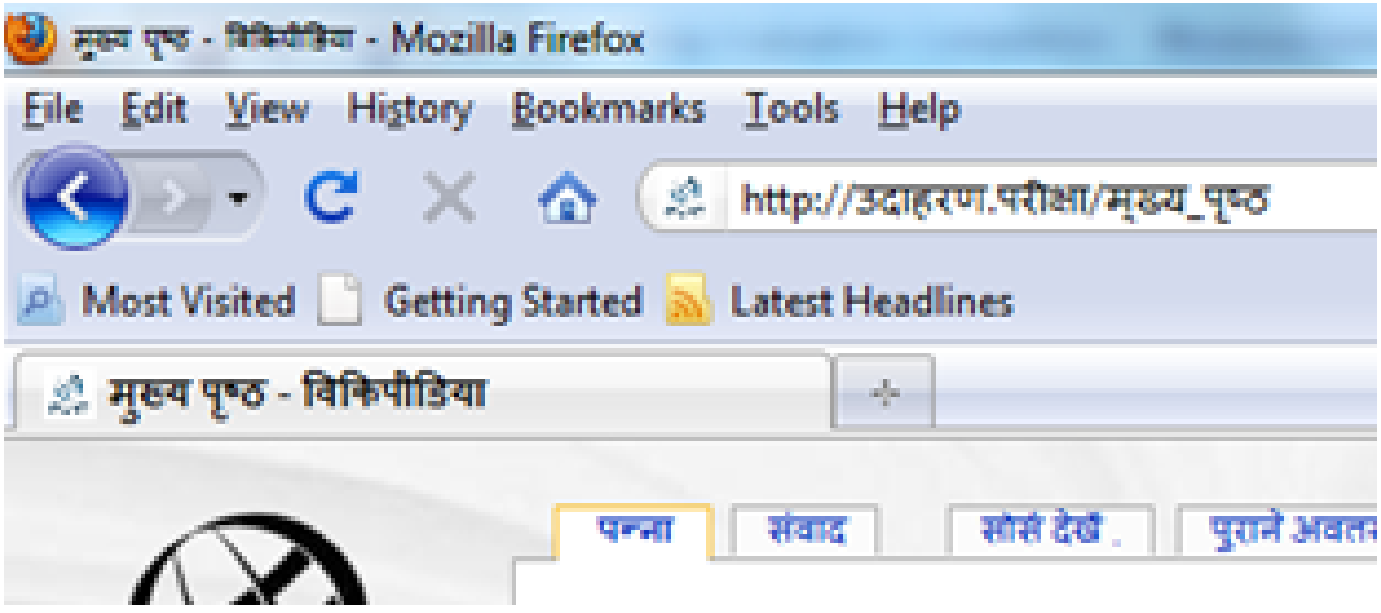
```
% dig -x 212.58.226.73
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 32413
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 4, ADDITIONAL: 3

;; QUESTION SECTION:
;73.226.58.212.in-addr.arpa.    IN      PTR

;; ANSWER SECTION:
73.226.58.212.in-addr.arpa. 50081 IN    PTR     newslb305.telhc.bbc.co.uk.

;; AUTHORITY SECTION:
226.58.212.in-addr.arpa. 50081  IN      NS      ns1.thdo.bbc.co.uk.
226.58.212.in-addr.arpa. 50081  IN      NS      ns1.thny.bbc.co.uk.
226.58.212.in-addr.arpa. 50081  IN      NS      ns1.bbc.co.uk.
226.58.212.in-addr.arpa. 50081  IN      NS      ns.bbc.co.uk.

;; ADDITIONAL SECTION:
ns1.bbc.co.uk.          311     IN      A       132.185.132.21
ns1.thny.bbc.co.uk.     32106   IN      A       212.58.227.48
ns1.thdo.bbc.co.uk.     33051   IN      A       212.58.224.21
```

DNS

```
% dig +trace www.google.com
.                       180695  IN      NS      E.ROOT-SERVERS.NET.
.                       180695  IN      NS      J.ROOT-SERVERS.NET.
.                       180695  IN      NS      I.ROOT-SERVERS.NET.
...
com.                    172800  IN      NS      A.GTLD-SERVERS.NET.
com.                    172800  IN      NS      B.GTLD-SERVERS.NET.
com.                    172800  IN      NS      C.GTLD-SERVERS.NET.
...
google.com.             172800  IN      NS      ns1.google.com.
google.com.             172800  IN      NS      ns2.google.com.
google.com.             172800  IN      NS      ns3.google.com.
...
www.google.com.         604800  IN      CNAME   www.l.google.com.
l.google.com.           86400   IN      NS      b.l.google.com.
l.google.com.           86400   IN      NS      d.l.google.com.
...
```

DNS

DNS labels can be in arbitrary character sets, not just Latin



A non-Latin DNS name

From `blog.icann.org`

DNS

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Exercise Read about the controversies behind the introduction of new top-level DNS labels like `me` and `search`

DNS

Exercise Try looking up

- AAAA for `bath.ac.uk`
- AAAA for `facebook.com`
- SOA for `bath.ac.uk`
- A for `moodle.bath.ac.uk`
- And so on

DNS

Exercise And

- MX for `bath.ac.uk`

What is the Uni's mail server physical location?

What are the privacy/security/legal aspects?

Then try MX for `bath.edu`, an address the University uses for alumni (graduates and past staff)

DNS

Exercise Read about the public DNS servers like `1.1.1.1`, `8.8.8.8` and others; why would you want to use them over your local DNS server?

Exercise What are the privacy/security/legal aspects of using public servers?

Exercise Find out how to buy a DNS name

DNS

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When the reply fits within 512 bytes, UDP is used for the reply by the server

To keep datagrams small, if the reply is more than 512 bytes, the server sends a reply with a “truncated” flag set, and the client resends the request but using TCP

Now, UDP is fast but unreliable, and 512 byte datagrams won’t be fragmented (recall: must be able to send 576 bytes IP), so there is little complication if a DNS datagram is lost: the source will just send a new request

DNS

UDP is preferred as it is fast with little overhead; while a TCP connection has a considerable setup cost

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So small and fast wherever possible; but slower and reliable if needed

DNS

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- Then I could receive a spoof IP address leading to someone else's web page: a problem if, say, I was looking for the page of a bank or shop
- The spoof page could be made to look identical to the real bank web page, inviting me to enter my id and password

DNS

Exercise The security company RSA was attacked by DNS spoofing. Read about this

Exercise April 2018: routes to Amazon DNS servers were faked so that DNS requests were sent to fake servers. Read about this

Exercise Your home connection probably uses your ISP as a DNS server. ISPs have been known to rewrite DNS replies. They also might block access to other public DNS servers. Read about this

DNS

A partial solution exists in *Secure DNS* (DNSSec), which uses cryptography to authenticate DNS lookups

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Not much in use as it was introduced when people still thought that cryptography was too expensive to use

DNS

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So there has been a move by some people to use DNS over TLS (see TLS later and RFC7858) that encrypts DNS requests and replies

This has a fair overhead over plain DNS, but provides both authentication and privacy

DNS

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- The overhead can be managed fairly well (see HTTP *Keep-Alive* and TLS reconnections)

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But:

- The overhead can be managed fairly well (see HTTP *Keep-Alive* and TLS reconnections)
- While an uncooperative ISP could block the DNS over TLS assigned port (853) the HTTPS port (443) cannot be blocked without a lot of collateral damage to normal browsing

DNS

Exercise CIDR makes PTR lookups harder as netmasks, and therefore the delegations, are no longer on a byte boundary. Read RFC2317 on how CNAMES are used to solve this problem

Exercise Read about how (or if) DoH is supported in your browser

Exercise Read about *DNS over Twitter* and *DNS over SMS*