DNS

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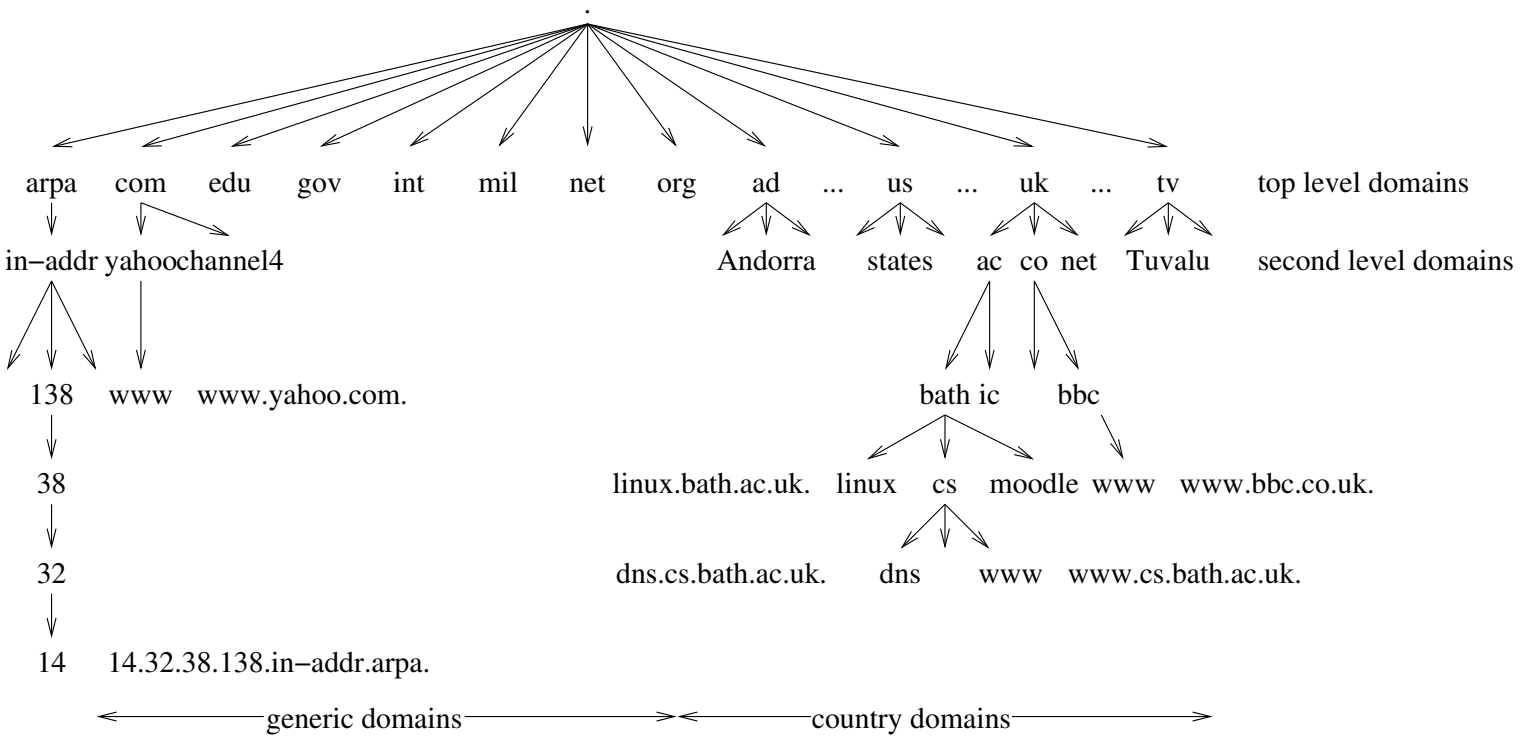
There is a part of the tree dedicated to this with TLD `arpa`

DNS



The DNS hierarchy

DNS

If we have the IP address `138.38.32.14` we can do a request for `14.32.38.138.in-addr.arpa`

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We get `clan.bath.ac.uk`

DNS

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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`

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

DNS

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DNS is actually a many-many relationship of names and addresses

- 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`

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newswww.bbc.net.uk.      77      IN  A       212.58.226.33
```

`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
```

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www.microsoft.com.       68      IN  CNAME   toggle.www.ms.akadns.net.
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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

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toggle.www.ms.akadns.net. 285    IN  CNAME   g.www.ms.akadns.net.
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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

```
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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
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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.
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lb1.www.ms.akadns.net.    285     IN  A       207.46.19.190
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lb1.www.ms.akadns.net.    285     IN  A       207.46.193.254
```

And that refers to four different addresses

DNS

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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

This allows for load sharing; and also can be used for *geofencing*: giving different services to clients in different places (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

In programs, if we need to look up an address, we can use a simple function call to `getaddrinfo()` (previously `gethostbyname()`) that hides all this complexity from us

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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.

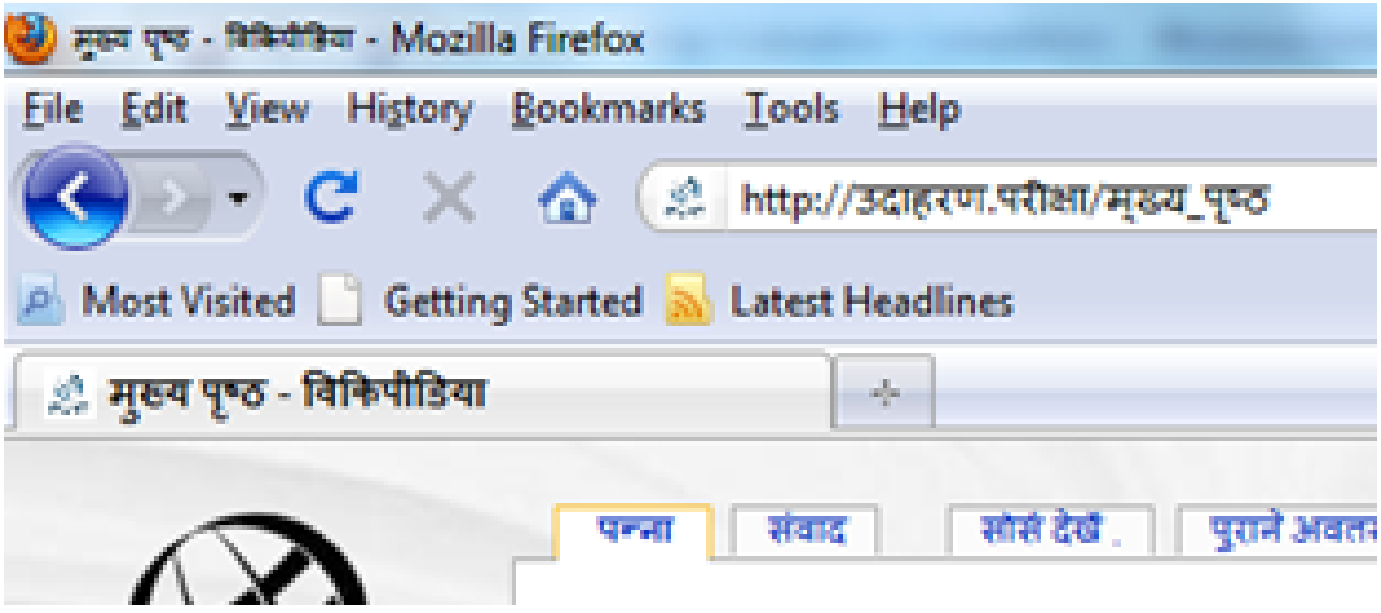
;; ADDITIONAL SECTION:
ns1.bbc.co.uk.          311     IN      A       132.185.132.21
ns1.thny.bbc.co.uk.     32106   IN      A       212.58.227.48
ns1.thdo.bbc.co.uk.     33051   IN      A       212.58.224.21
```

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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DNS names are a big source of money, so often a source of contention over who should be in control of what

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

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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 (see later)

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

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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

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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

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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*

Transport Layer

We now move up a layer: the Transport Layer

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Other data protocols exist in this layer, but TCP and UDP are currently the important ones

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This is done by ports

A port is just a 16 bit integer: 1-65535

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E.g., an email server may indicate it wants packets addressed to TCP port 25; a browser would listen on port 80 (and 443)

Transport Layer

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So when a TCP packet with destination port 25 arrives its data will be given to the email program

An analogy: a host as a block of flats. To address a letter to a specific person you need both a building address (IP address) and a flat number (port)

Transport Layer

TCP and UDP ports are entirely separate: one service can be listening for for a TCP connection on a port and another service for UDP on the same port number

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TCP and UDP are completely separate and do not interact at all (at the transport level)

Transport Layer

Certain *well-known* ports are reserved for certain services

- web server on port 80
- email server on port 25
- FTP on port 21
- hundreds of others. See `/etc/services` and RFC6335

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- hundreds of others. See `/etc/services` and RFC6335

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Typically, port numbers under 1024 are reserved for privileged programs

Transport Layer

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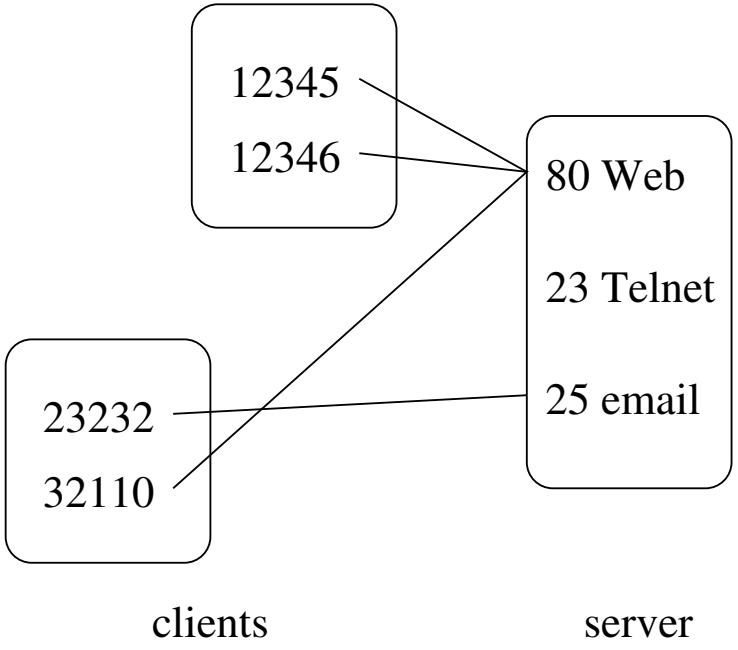
You can run a web server on port 25 if you wish: you will just confuse anyone who tries to send you email

Transport Layer



Transport layer ports

Ports also enable multiple simultaneous connections between two machines, e.g., fetching several web pages

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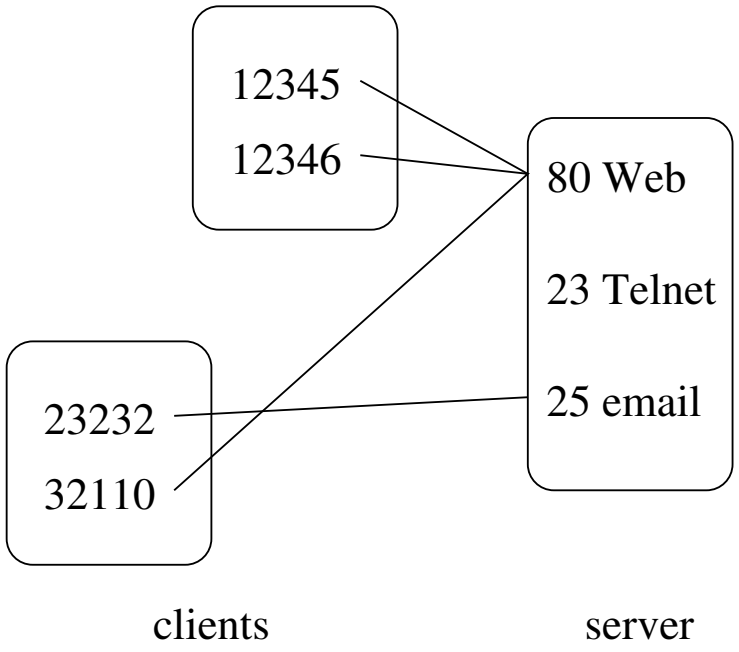

Transport layer ports

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The source port (destination port on the returning packet) allows the client OS to identify which packet belongs to which client program

Transport Layer

Source ports are usually chosen afresh “at random” (usually: just increment by 1 for each time) for each new connection and are called *ephemeral* ports as they only live for the duration of the connection

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The quad

source address
source port
destination address
destination port

specifies a connection uniquely: the hosts involved and the processes on those hosts

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Thus the OS can identify which process an ICMP belongs to

And a non-initial IP fragment won’t have such identifying information, so this is why ICMPs are not generated for errors involving such fragments

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NAT, again

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Exercise Read about *port address translation*

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Exercise Read about *port address translation*

Exercise Sometime we wish to allow an external host to initiate a connection with a private host. Read about *port forwarding*