Exercise walk-through

2.1.3

Finding a server: URLs, the Domain Name Service and IP addressing

A-Level Computer Science

You must be able to

- explain how a **Uniform Resource Locator** (**URL**) is used to locate a resource on the
- explain the use of **IP addresses** in the transmission of data over the internet, including

1 The method

Method — A URL has three parts, and DNS only cares about the middle one

A **Uniform Resource Locator** is the full address of one resource on the **World Wide Web**:

part	example	what it does
protocol	`https://`	which set of rules to talk to the server with
domain name	`www.exercises.lol`	which **server** – the only part DNS resolves
path	`/library/physics.pdf`	which **resource on** that server, handled by the server itself

Method — A URL has three parts, and DNS only cares about the middle one

△ Two careless answers to avoid. The URL does **not** contain the IP address – that is exactly what has to be looked up. And the **path is not sent to DNS**: DNS returns one address for the whole domain, and the server works out which file is wanted afterwards.

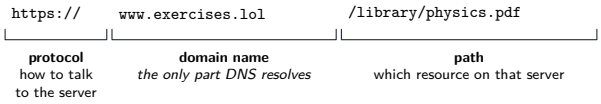
The role of the Domain Name Service. DNS is a distributed system of name servers that holds the mapping from **domain name to IP address**. The browser asks a name server for the domain; if that server does not hold the record it passes the query up the hierarchy – root, then the top-level domain, then the **authoritative** server for that domain – until the address is found and returned. Results are **cached** on the way back, in the name servers, the operating system and the browser, so the same name is not looked up again for every page.

Method — A URL has three parts, and DNS only cares about the middle one

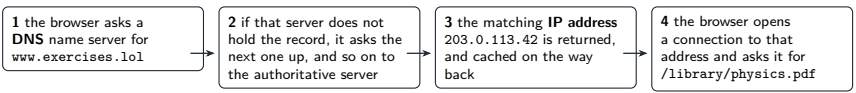
Two reasons DNS exists, both worth marks: people can use names that are easy to remember instead of numbers; and a site can be **moved to a different server** by changing one DNS record, with no visitor having to learn a new address.

Method — A URL has three parts, and DNS only cares about the middle one

A Uniform Resource Locator is the full address of one resource on the World Wide Web : center △ Two careless...



A domain name is for people. A router needs an address, so the name must be looked up:



Without **DNS** every site would have to be reached by its number, and a site could never change servers without every visitor learning a new address. Caching is what keeps the system usable: the same lookup is not repeated for every page, so the root servers are not asked billions of times a second.

Method — IP addresses: two formats, and two independent pairs of adjectives

- **IPv4 – 32 bits**, written as four denary numbers 0-255 separated by dots (`192.168.1.20`). That is about 4.3 billion addresses, and the internet has run out of them.
- **IPv6 – 128 bits**, written as eight groups of four **hexadecimal** digits separated by colons. It was introduced *because* IPv4 ran out; the vastly larger address space is the reason, not extra speed.
- **How an address is associated with a device**: a device's network interface has a permanent **MAC address** burned in, and an IP address is **assigned** to it on the network – by hand for a static address, or by a **DHCP** server when it connects for a dynamic one. So the IP address belongs to the device's *position in a network*, not to the device.

Method — IP addresses: two formats, and two independent pairs of adjectives

Public or private. A **public** address is unique across the whole internet and can be reached from it. A **private** address is unique only within one network; a router translates between the private addresses inside and the single public address outside.
Security implication: a device on a private address cannot be contacted directly from the internet, so it is far less exposed – and, for the same reason, a machine that must accept connections (a web or mail server) needs a public one.
Static or dynamic. A **static** address is fixed. A **dynamic** address is issued when the device connects and may be different next time. A server needs a static address or DNS would point at the wrong machine; an ordinary client is given a dynamic one, so an address is only in use while it is actually needed.
Subnetting divides one network into smaller **subnets** by using some of the host part of the address as a subnet number. It reduces the traffic each part has to carry,

Method — IP addresses: two formats, and two independent pairs of adjectives

because a message for a device in the same subnet need not be passed to the others, and it lets each subnet be managed and secured separately.

△ The two pairs are **independent**. Every address is public *or* private **and** static *or* dynamic – “private” does not mean “dynamic”.

Method — IP addresses: two formats, and two independent pairs of adjectives

Public or private.

	IPv4	**IPv6**
	`192.168.1.20`	`2001:0db8:85a3::8a2e:0370:7334`
	four groups of 8 bits, written in decimal, so each group is 0 to 255	eight groups of 4 hexadecimal digits, separated by colons
	32 bits in all: about 4.3 billion addresses, which the internet has run out of	**128 bits** in all: enough that running out is not a practical concern
public or private?	a **public** address is unique across the whole internet and reachable from it; a **private** address is unique only inside one network, and a router translates between the two	so a device on a private address cannot be contacted directly from outside – which is a real security gain, and also why a server needs a public one
static or dynamic?	a **static** address is fixed and does not change; a **dynamic** address is handed out on connection and may differ next time	a web or mail server needs a **static** one, or DNS would point at the wrong machine; an ordinary client is given a **dynamic** one, so an address is only used while it is needed

The two pairs are **independent**: every address is public *or* private *and* static *or* dynamic. **Subnetting** splits one network into smaller ones by using part of the host portion of the address as a subnet number – which cuts the traffic each part has to carry and lets each be managed and secured separately.

IPv4 against IPv6, and what public/private and static/dynamic each mean

2 Practice

Practice 2.1 ▪ 3 marks

A user enters the URL `https://www.exercises.lol/library/physics.pdf`. State the three parts of this URL and what each one identifies.

Solution 2.1

Method: A URL has three parts, and DNS only cares about the middle one — p.4

Worked steps

- `https://` is the **protocol**, which identifies the rules used to communicate with the server B1
- `www.exercises.lol` is the **domain name**, which identifies the **server** holding the resource B1
- `/library/physics.pdf` is the **path**, which identifies **which resource** on that server B1

Practice 2.2 ▪ 2 marks

Explain the role of the **Domain Name Service**.

Solution 2.2

Method: A URL has three parts, and DNS only cares about the middle one — p.4

Worked steps

- DNS holds the mapping from **domain name to IP address**, distributed across many name servers B1
- so that a browser given a name can obtain the address the data must actually be sent to B1

Practice 2.3 ▪ 2 marks

State the format of an **IPv4** address and the format of an **IPv6** address.

Solution 2.3

Worked steps

- **IPv4**: **32 bits**, written as four denary numbers in the range 0-255, separated by dots B1
- **IPv6**: **128 bits**, written as eight groups of four hexadecimal digits, separated by colons B1

Practice 2.4 ▪ 2 marks

Explain why **IPv6** was introduced.

Solution 2.4

Worked steps

- IPv4 has only about 4.3 billion addresses (2^{32}), and the number of devices connected to the internet has exhausted them B1
- IPv6's 128-bit addresses give an address space large enough that running out is not a practical concern B1

Practice 2.5 ▪ 2 marks

State **one** security implication of a device having a **private** rather than a public IP address.

Solution 2.5

Method: IP addresses: two formats, and two independent pairs of adjectives — p.8

Worked steps

- a private address is not reachable directly from the internet, because it is unique only inside its own network B1
- so the device cannot be contacted – or attacked – directly from outside; an attacker must get past the router first B1

Practice 2.6 ▪ 1 mark

State what is meant by a **dynamic** IP address.

Solution 2.6

Method: IP addresses: two formats, and two independent pairs of adjectives — p.8

Worked steps

- an address that is issued to the device when it connects to the network, and which may be a different address the next time it connects B1

3 Exam-style

Exam-style 3.1 ▪ 1 mark

Which of these is a valid **IPv4** address?

A `192.168.1.300`

B `2001:0db8:85a3::8a2e:0370:7334`

C `192.168.1.20`

D `www.example.com`

Solution 3.1

A `192.168.1.300`

B `2001:0db8:85a3::8a2e:0370:7334`

C `192.168.1.20` ✓

D `www.example.com`

Worked steps

C

- each part of an IPv4 address must be in the range 0-255, so **A** is invalid B1

Exam-style 3.2 ▪ 7 marks

A user types a URL into a web browser and presses enter.

Exam-style 3.2 (a) ▪ 3 marks

Describe the role of the **Domain Name Service** in what happens next.

Solution 3.2 (a)

Method: A URL has three parts, and DNS only cares about the middle one — p.4

Worked steps

- the browser takes the **domain name** out of the URL and sends it to a **DNS name server** B1
- the name server looks up the domain name and finds the **IP address** it maps to, asking other name servers if it does not hold the record itself B1
- the address is returned to the browser, which then sends its request for the resource to that address B1

Exam-style 3.2 (b) ▪ 2 marks

Explain why name servers, the operating system and the browser each keep a **cache** of recent DNS results.

Solution 3.2 (b)

Worked steps

- a cached result answers the next request for the same name immediately, so the page loads faster and no query has to leave the machine B1
- and it removes an enormous amount of repeated traffic from the name servers, which could not otherwise handle every lookup for every page B1

Exam-style 3.2 (c) ▪ 2 marks

State what happens when the name server that is contacted does **not** hold a record for that domain.

Solution 3.2 (c)

Worked steps

- it passes the query on to another name server, working up the hierarchy – root, then top-level domain, then the **authoritative** server for that domain B1
- the address found there is returned back down the chain to the browser, and cached along the way B1

Exam-style 3.3 ▪ 10 marks

A small company has 40 devices on one network. They reach the internet through a single router.

Exam-style 3.3 (a) ▪ 3 marks

Explain the difference between a **public** and a **private** IP address, and state which of the two the 40 devices will have.

Solution 3.3 (a)

Method: IP addresses: two formats, and two independent pairs of adjectives — p.8

Worked steps

- a **public** IP address is unique across the whole internet and can be reached from it B1
- a **private** IP address is unique only within one network, and a router translates between the private addresses inside and the public address outside B1
- the 40 devices have **private** addresses; the router holds the single public one B1

Exam-style 3.3 (b) ▪ 2 marks

State **one** security benefit of that arrangement.

Solution 3.3 (b)

Worked steps

- none of the 40 devices can be contacted directly from the internet, since their addresses have no meaning outside the company's own network **B1**
- so an attacker on the internet cannot reach a device without first getting through the router, which greatly reduces the exposed surface **B1**

Exam-style 3.3 (c) ▪ 3 marks

Explain the difference between a **static** and a **dynamic** IP address, and give **one** situation in which a static address is necessary.

Solution 3.3 (c)

Worked steps

- a **static** address is fixed and does not change B1
- a **dynamic** address is assigned when the device connects, typically by a DHCP server, and may differ next time B1
- a static address is necessary for anything that must be found at a known address – a web, mail or file **server**, because DNS records point at a fixed address B1

Exam-style 3.3 (d) ▪ 2 marks

State what is meant by **subnetting**, and give **one** reason the company might use it.

Solution 3.3 (d)

Worked steps

- subnetting divides one network into smaller **subnets**, using part of the host portion of the address as a subnet number B1
- one reason: traffic meant for a device in the same subnet need not be carried by the others, so congestion falls; or each subnet (for example the office and the guest wi-fi) can be secured and managed separately B1