The internet: IP addressing and routers

4.1.3 · Networks · revision notes

How the internet is made of many connected networks, how IP addresses identify devices, and how routers pass packets across the internet from one network to the next. Expect definitions, questions on IPv4 and IPv6 addresses (sometimes with binary or hexadecimal), and 'Describe how…' questions about routing.

Key facts

- Internet: a worldwide network of interconnected networks
- IPv4: 32 bits, four denary numbers from 0 to 255 separated by dots (about 4.3 billion addresses)
- $2^8 = 256$, so each part of an IPv4 address is from 0 to 255
- Packet = header (source and destination IP addresses, sequence number) + payload (the data)
- IP address: identifies a device so that data can be delivered to it
- Grade 6+ only IPv6: 128 bits, eight groups of four hexadecimal digits separated by colons
- Router: forwards packets between networks using the destination IP address
- The web is a service (web pages) that runs on the internet; they are not the same thing

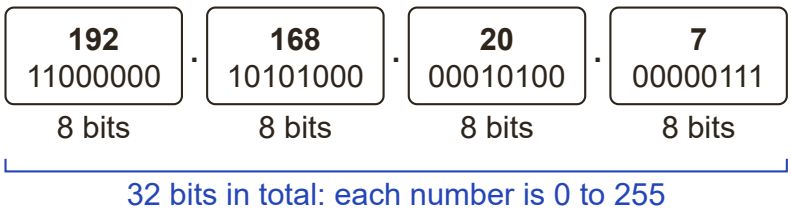
Notes

A network of networks

- The **internet** is a worldwide network of interconnected networks: home, school and business LANs are connected to the networks of internet service providers (ISPs), which are connected to each other.
- The networks are joined by **routers**. At home, one router joins your LAN to your ISP's network. No single central computer controls the internet.
- The **World Wide Web** is not the same thing: it is the collection of web pages that you reach *using* the internet.

IP addresses

- Every device that communicates across the internet needs an **IP address**. It identifies the device so that data can be sent to the right place, like the address on a letter.
- An **IPv4** address is 32 bits long. It is written as four denary numbers separated by dots, e.g. 192.168.20.7.
- Each of the four numbers is stored in 8 bits, so it must be from 0 to 255. For example, 192.168.1.300 is not a valid address.

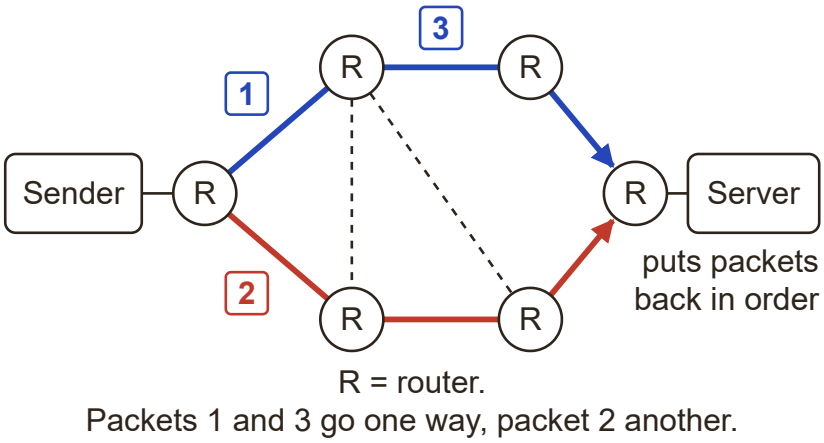


The IPv4 address 192.168.20.7: four denary numbers, each stored in 8 bits.

- 32 bits give 2^{32} (about 4.3 billion) different addresses. So many devices are now online that IPv4 addresses have run out.
- An **IPv6** address is 128 bits long, written as eight groups of four hexadecimal digits separated by colons, e.g. 2a02:0c7f:5d10:0000:0000:0a4b:91e2:0006. It gives 2^{128} addresses, vastly more than IPv4. Grade 6+ only

Packets and routers

- Data is split into **packets**. Each packet has a header containing information such as the source and destination IP addresses and a sequence number, followed by the data itself (the payload).
- A **router** forwards packets between networks. It reads each packet's destination IP address, looks it up in its routing table and sends the packet on to the next router on a suitable route.
- Packets pass from router to router (hop by hop) until they reach the destination network.
- Packets from the same file are routed separately, so they can take different routes and arrive out of order. The receiving computer puts them back in order using their sequence numbers.



Each router reads the destination IP address and forwards the packet. Packets can take different routes and arrive out of order.

- Because there are many routes and no central point, the internet keeps working when a link or router fails: routers simply send packets another way. Grade 8+ only

How to answer each type of question

State a definition or identify a valid IP address

1 mark each | Grade 4

1. Learn short, precise definitions of the internet, an IP address and a router.
2. For 'Identify the valid IPv4 address', check that there are exactly four numbers and that each is from 0 to 255.

Example. (a) State the purpose of an IP address. (1)
(b) Identify the valid IPv4 address. (1)
A 10.256.4.1
B 172.16.9
C 88.201.0.45
D 64.12.8.3.9

Model answer.

(a) To identify a device on a network so that data can be sent to it (1)

(b) C (1)

Describe how routers send data across the internet

3 to 4 marks | Grade 6

1. Start with packets: the data is split into packets, each with the destination IP address in its header.
2. Say what each router does: it reads the destination address and uses its routing table to decide where to send the packet next.
3. Say that packets go from router to router until they reach the destination network, possibly by different routes.

Example. A student in Leeds requests a video from a server in Canada.
Describe how routers are used to deliver the video data to the student's computer. (4)

Model answer. The video data is split into packets, and each packet's header contains the IP address of the student's computer as the destination (1). Each router reads the destination IP address (1) and uses its routing table to forward the packet to the next router on a suitable route (1). The packets pass from router to router across many networks until they reach the student's network, and different packets may take different routes (1).

Convert an IPv4 address to binary

1 to 2 marks | **Grade 6**

1. Treat each of the four numbers separately.
2. Convert each one to an 8-bit binary number using the place values 128, 64, 32, 16, 8, 4, 2, 1.
3. Keep leading zeros so that every group has exactly 8 bits.

Example. Convert the IPv4 address 200.10.64.129 into 32-bit binary. Write each group of 8 bits separately. (2)

Model answer.

11001000 00001010 (first two groups correct) (1)
01000000 10000001 (last two groups correct) (1)

Compare IPv4 and IPv6, or explain why IPv6 was introduced

2 to 4 marks | **Grade 7**

1. Give the size of each: IPv4 is 32 bits and IPv6 is 128 bits.
2. Give how each is written: denary numbers with dots, or hexadecimal digits with colons.
3. For 'why', link the number of bits to the number of possible addresses and to the growth in the number of devices online.

Example. (a) Give **two** differences between IPv4 addresses and IPv6 addresses. (2)
(b) Explain why IPv6 was introduced. (2)

Model answer.

(a) An IPv4 address is 32 bits long, whereas an IPv6 address is 128 bits long (1). IPv4 addresses are written as four denary numbers separated by dots, whereas IPv6 addresses are written as groups of hexadecimal digits separated by colons (1).

(b) 32 bits allow only about 4.3 billion (2^{32}) different addresses (1). So many devices, such as phones and smart devices, now connect to the internet that there are not enough IPv4 addresses, and 128 bits give vastly more (1).

Don’t lose marks

- Saying the internet and the World Wide Web are the same thing.
- Saying each part of an IPv4 address can go up to 256. The largest 8-bit number is 255.
- Saying IPv6 addresses are 64 bits or are written in denary. They are 128 bits, written in hexadecimal.
- Writing that a router 'sends data to the right computer'. Say that it reads the destination IP address and forwards the packet between networks towards the destination.
- Saying that all the packets of a file take the same route. Each packet is routed separately.

More tips

Memory tricks

- IPv4: 4 numbers × 8 bits = 32 bits. IPv6 is 128 bits, four times as long.
- Valid IPv4 check: exactly 3 dots, and no number above 255.
- v4 uses dots and denary; v6 uses colons and hex.
- A router is like a postal sorting office: it looks only at the address on each packet and passes it on towards its destination.

Exam technique

- Definitions are quick marks: learn precise one-line definitions for the internet, an IP address and a router.
- When comparing IPv4 and IPv6, write both sides in each point: 'IPv4 is…, whereas IPv6 is…'.
- In routing answers use the key words: packet, destination IP address, router, routing table, route.
- For binary conversions, write each 8-bit group separately so that the examiner can mark each part.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Define the internet**
The internet is a worldwide network of interconnected networks.

Grade 4 — **State the purpose of an IP address**
An IP address identifies a device on a network so that data can be delivered to it.

Grade 5 — **Recognise a valid IPv4 address**
It has exactly four denary numbers, each from 0 to 255, separated by dots, e.g. 81.24.160.3.

Grade 6 — **Describe how routers forward packets**
Each router reads a packet's destination IP address and sends the packet on towards the destination network.

Grade 6 — **Convert an IPv4 address to binary**
Convert each of the four numbers to an 8-bit binary number, keeping any leading zeros.

Grade 6 — **Compare IPv4 and IPv6 addresses**
IPv4 uses 32 bits written as four denary numbers; IPv6 uses 128 bits written as groups of hexadecimal digits.

Grade 7 — **Explain why IPv6 was introduced**
32-bit IPv4 allows only about 4.3 billion addresses, which is not enough for all the devices now online.

Grade 8 — **Explain why the internet survives link failures**
There are many routes and no central point, so routers send packets around a failed link or router.

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