



Collegedunia NCERT Notes

The Ultimate NCERT Revision Guide for Class 12 Computer Science

Chapter 11: Data Communication

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Also see for this chapter: [NCERT Solutions](#) | [Formula Sheet](#) | [Exemplar Solutions](#)

1 Data Communication and Its Components

The term **data communication** is made of two words: *data* and *communication*. Data can be any text, image, audio, video or multimedia file. Communication is the act of sending or receiving data. Put them together and data communication means the exchange of data between two or more connected devices over a shared path. The devices that take part must be able to both send and receive data, for example computers, mobile phones and laptops. This first section sets up the vocabulary you will use for the whole chapter: what the components are, what each one does, and how they fit together.

1.1 What Data Communication Means

When two computing devices talk to each other over a network, data leaves one device, travels along a path, and arrives at the other. The two end devices are called **nodes**. A small office network, for instance, may join a computer, a printer, a server and a switch so they can share files and a single printer. The path between them is the heart of the whole idea, because without a reliable path the data never arrives.

Definition to memorise

Data communication is the exchange of data between two or more networked or connected devices. The devices must be capable of sending and receiving data over a communication medium. In computer communication, the sender and the receiver are both called **nodes**.

1.2 The Five Components

Every act of data communication needs five things to be present. Miss any one and the exchange fails. These five are the standard answer to the very common exam question, so learn them as a set.

- **Sender:** a device that can send data, such as a computer, mobile phone, smart-watch or video recorder.
- **Receiver:** a device that can receive data, such as a computer, printer, laptop, mobile phone or television.
- **Message:** the actual data being exchanged, in the form of text, number, image, audio, video or multimedia.
- **Communication media:** the path the message travels along, also called the medium, link or transmission media. It may be wired or wireless.
- **Protocol:** the set of rules both parties follow so that the exchange is successful and reliable. Ethernet and HTTP are two examples you already know.



both ends obey the same **protocol**

Five components in one phrase

"Some **R**eaders **M**iss **C**lever **P**oints" recalls **S**ender, **R**eceiver, **M**essage, **C**ommunication media, **P**rotocol. Drop any letter and your answer loses a mark.

1.3 Why a Protocol Is Needed

A sender and a receiver may sit on different networks, in different places, running at different speeds. Left to themselves they would never agree on how data should look or how fast to send it. A protocol settles all of that in advance. It is simply a set of standard rules the sender, the receiver and every device in between must follow.

Talking on the phone

A phone call is a tiny protocol in action. You say “hello”, wait for a reply, take turns speaking, and say “bye” to end. Both people follow the same unwritten rules, so the conversation works. Computers need the same kind of agreed rules, written down as a protocol.

1.4 How the Components Work Together

It helps to see the five components in one continuous story rather than as a list. Suppose a laptop sends a photo to a printer over Wi-Fi. The laptop is the **sender**; the photo file is the **message**; the air carrying the Wi-Fi signal is the **communication media**; the printer is the **receiver**; and the rules that decide how the photo is split, addressed and acknowledged form the **protocol**. If the printer is busy, the protocol decides how the laptop waits and retries. Every real exchange you use daily, from a text message to a video call, plugs into this same five-part frame.

- The **message** can be any data type: text, number, image, audio, video or multimedia. The components do not change with the data type.
- The same physical device can be a sender at one moment and a receiver the next, which is exactly what full-duplex communication needs.
- The **media** may be wired (a cable) or wireless (air); we study the full list later in this chapter.

2 Measuring the Capacity of a Channel

In data communication the transmission medium is also called a **channel**. The capacity of a channel is the maximum amount of signal or traffic it can carry. Two measures describe this capacity: **bandwidth** and **data transfer rate**. They sound similar but mean different things, and exams often test whether you can tell them apart, so this section keeps them clearly separate and shows the unit ladder for each.

2.1 Bandwidth

Bandwidth is the range of frequencies a channel makes available for sending data. The wider this range, the more data the channel can carry, so a higher bandwidth gives a higher data transfer rate. Normally bandwidth is the difference between the highest and lowest frequency present in the composite signal. It is measured in **Hertz (Hz)**.

Bandwidth

$$\text{Bandwidth} = f_{\max} - f_{\min}$$

where $f_{\max}$ is the highest frequency and $f_{\min}$ is the lowest frequency in the composite signal. The unit is Hertz (Hz).

Unit	Value
1 KHz	1000 Hz
1 MHz	1000 KHz = 1 000 000 Hz
1 GHz	1000 MHz

Bandwidth is a width, not a speed

Bandwidth is measured in Hertz because it is a *width of frequencies*. Data transfer rate is measured in bits per second because it counts *bits per unit time*. If the unit is Hz, the question is about bandwidth; if the unit ends in bps, it is about data transfer rate.

2.2 Data Transfer Rate

Data travels as signals over a channel, and each signal carries one or more bits. The **data transfer rate** is the number of bits sent from source to destination in one second. It is also called the **bit rate** and is measured in **bits per second (bps)**. Note that the higher units here climb in powers of two, not powers of ten.

Unit	Value
1 Kbps	2^{10} bps = 1024 bps
1 Mbps	2^{20} bps = 1024 Kbps
1 Gbps	2^{30} bps = 1024 Mbps
1 Tbps	2^{40} bps = 1024 Gbps

MBps is not Mbps

MBps means Megabyte per second, while **Mbps** means Megabit per second. One byte is 8 bits, so 1 MBps equals 8 Mbps. Mixing up the capital B and small b changes the answer by a factor of eight, which is a classic numerical trap.

2.3 A Worked Capacity Problem

The NCERT chapter gives a sample problem (Example 11.1). A user uploads a text document at 10 pages every 20 seconds. Each page has 1600 characters and each character is 8 bits. Find the required data rate of the channel. Always show the formula, then the substitution, then the arithmetic.

Data rate steps

$$\text{Total characters} = 10 \times 1600 = 16000$$

$$\text{Total bits} = 16000 \times 8 = 128000 \text{ bits}$$

$$\text{Data rate} = \frac{\text{Total bits}}{\text{Time}} = \frac{128000}{20} = 6400 \text{ bps}$$

So the channel must support at least **6400 bps** (6.4 Kbps using the plain 1000 scale) to upload at that speed. The method is general: convert everything to bits, then divide by the time in seconds.

Why your video buffers

A video stream needs a steady data rate. If your channel's rate drops below what the video needs per second, the player runs out of data and pauses to buffer. This is the same bits-per-second idea, just felt as a spinning wheel.

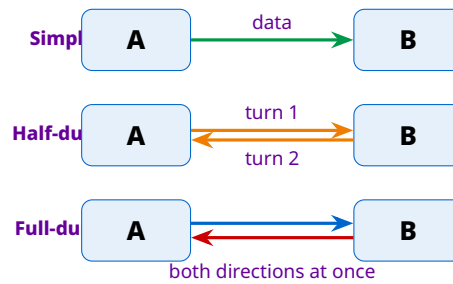
3 Modes and Switching Techniques

Once a path exists, two further questions arise. First, in which directions can data flow along it? That is decided by the **mode** of communication. Second, when a network has many devices, how is a temporary path chosen between a particular sender and receiver? That is decided by the **switching technique**. This section covers both, because together they describe how data actually moves across a busy network.

3.1 Simplex, Half-duplex and Full-duplex

Data communication happens over a point-to-point or multipoint channel, and it falls into three modes by direction. Picture each as a kind of road.

- **Simplex:** one-way only. One device always sends, the other always receives, like a one-way street. A keyboard sending keystrokes to a computer, or audio sent to a speaker, is simplex.
- **Half-duplex:** two-way, but only one direction at a time, like a narrow one-lane bridge. A walkie-talkie is half-duplex: press to talk, release to listen.
- **Full-duplex:** two-way at the same time, like a two-way road with traffic flowing both ways at once. A mobile phone call is full-duplex; both people can speak and hear together.



Mode	Direction	Example
Simplex	one way only	keyboard, speaker
Half-duplex	both ways, not together	walkie-talkie
Full-duplex	both ways, together	mobile phone, landline

Tell the duplexes apart

Half the time = **half**-duplex (take turns). **Full** time in both directions = **full**-duplex (talk together). Simplex has the word “simple” in it: one direction, the simplest case.

3.2 Why Switching Is Needed

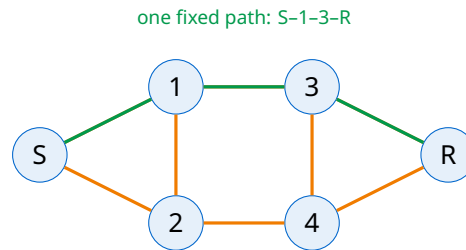
In a network with many devices, you could give every pair its own dedicated link (a mesh) or wire every device to one central device (a star). Both work, but for large networks they grow far too costly. **Switching** solves this by routing data through intermediate nodes, forming a temporary route only when needed. Two switching techniques are standard: circuit switching and packet switching.

The core idea of switching

Instead of permanent links between every pair of devices, switching builds a **temporary route** through the network for each exchange of data. This shares the same links among many users and keeps large networks affordable.

3.3 Circuit Switching

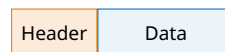
In **circuit switching**, a single dedicated path is fixed between sender and receiver *before* any data is sent. This path is a connected sequence of links, and every packet of the message follows that same path. The classic example is the old telephone system: when you placed a call, the switching equipment found one physical channel from your phone all the way to the receiver’s phone, and the whole call used that channel.



3.4 Packet Switching

In **packet switching**, the message is first broken into small pieces called **packets**. Each packet travels independently, and different packets of the same message may take different routes depending on which links are free. Every packet carries a **header** with the destination address plus other information, and a **data** part with the message piece. At the destination all packets are reassembled into the complete message. A channel is busy only while a packet is passing; once done, it is free for other users.

One packet



address, information message piece

Feature	Circuit switching	Packet switching
Path	one fixed path for all	each packet routed separately
Set up	dedicated path made first	no path made in advance
Channel use	held for the whole call	busy only per packet
Example	old telephone call	the Internet

The Internet uses packet switching

Every web page you open arrives as packets that may travel by different routes and arrive out of order, then get reassembled by your device. This is why the Internet keeps working even when one link is congested: packets simply take another route.

Packets are not always in order on the way

Students often assume packets stay in sequence during the journey. They do not. Different packets can take different routes and arrive out of order; the receiver puts them back in the right sequence at the end.

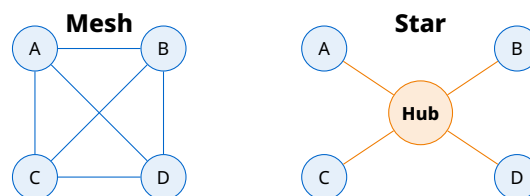
3.5 Point-to-Point versus Multipoint

Switching answers how a route is built, but there is a related idea: how many devices share one link. A channel can be **point-to-point** or **multipoint**, and the

two switching techniques operate over these.

- **Point-to-point:** the link joins exactly two devices, and the whole capacity of the link is reserved for that pair. A direct cable between two routers is point-to-point.
- **Multipoint:** more than two devices share the same link, so the capacity is divided among them and access has to be managed so two devices do not transmit at once.

A dedicated connection for every pair of devices is called a **mesh** arrangement, and a central device wired to every other device is a **star** arrangement. Both give clean point-to-point links but become costly as the network grows, which is the very reason switching exists.



Spot the switching answer fast

If the question says “a dedicated path is set up before sending”, the answer is **circuit switching**. If it says “the message is broken into pieces that travel independently”, the answer is **packet switching**. The keyword in the question gives it away.

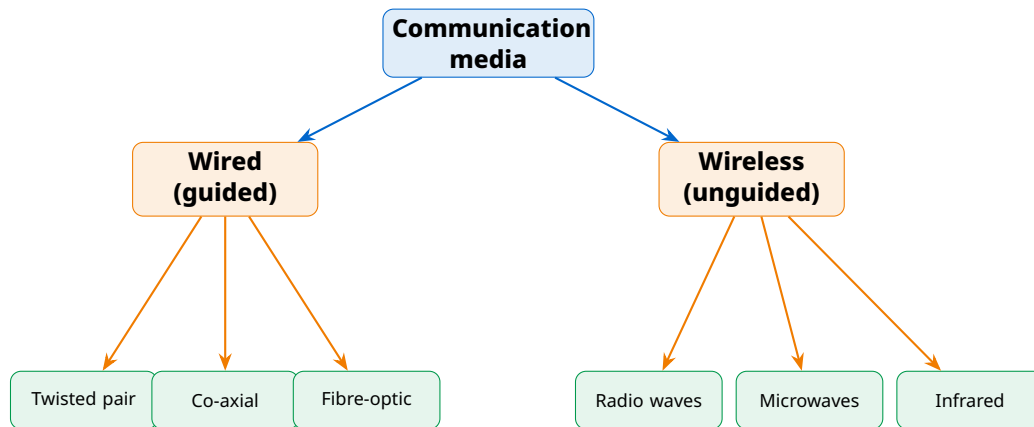
4 Transmission Media

A **transmission medium** is anything that can carry signals between a source and a destination. The electric wire to a ceiling fan and the air between two people talking are both media. In data communication, transmission media are classified into two big families: **guided** (wired) and **unguided** (wireless). This section walks through both families and the specific cables and waves inside each, because comparing them is a guaranteed exam topic.

4.1 Guided versus Unguided

The first split is whether there is a physical wire or not.

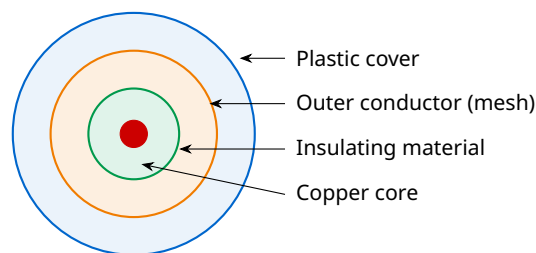
- **Guided (wired) media:** a physical link of wire or cable carries the signals between nodes, for example metallic cable or fibre-optic cable.
- **Unguided (wireless) media:** data travels through air as electromagnetic waves using an antenna, with no physical wire.



4.2 Wired Media: Twisted Pair, Coaxial, Fibre

Three guided media are in common use. Twisted pair and coaxial cable carry electric signals; optical fibre carries light.

- **Twisted-pair cable:** two insulated copper wires twisted together like a helix. The twisting cuts down electrical interference from nearby pairs. It is cheap and common in telephone lines and LANs. It comes as **UTP** (unshielded) and **STP** (shielded, with an extra metal shield).
- **Coaxial cable:** a central copper core, an insulating layer, an outer copper-mesh conductor, and a plastic cover. Its shielding gives more bandwidth than twisted pair and carries higher-frequency signals over longer distances.
- **Optical fibre:** a thin glass strand carries data as light. The core is wrapped in lower-density glass called **cladding**, then an outer jacket of PVC or Teflon. It uses refraction to keep the light inside. It has very high bandwidth, is light in weight, sends signals over long distances and is immune to electromagnetic noise. But it is expensive and unidirectional, so two cables are needed for full-duplex.



Coaxial cable cross-section

Medium	Carries	Note
Twisted pair	electric signals	cheap, used in LAN and phone lines
Coaxial	electric signals	more bandwidth, longer distance
Optical fibre	light signals	highest bandwidth, noise-immune, costly

Optical fibre advantages and limits in one line

Plus points: very high bandwidth, long distance, light weight, no electromagnetic interference. Minus points: expensive and unidirectional, so two fibres are needed for two-way communication. State both sides for full marks.

UTP and STP in detail. Twisted-pair cable comes in two forms. In **UTP (unshielded twisted-pair)** the pairs have only their plastic insulation, so it is cheap and flexible and is the cable most home and office LANs use. In **STP (shielded twisted-pair)** an extra metal shield wraps the pairs, cutting interference further at a higher cost. Each twisted pair acts as a single communication link, and the twisting itself is what reduces crosstalk from neighbouring pairs.

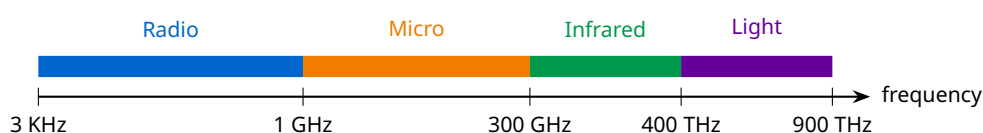
Backbone networks and repeaters. Optical fibre is the usual choice for **backbone networks**, the high-capacity links that interconnect different segments of a network and let different LANs or subnetworks exchange information. Over long distances any signal weakens, so **repeaters** are installed along the path to regenerate the signal back to its original strength. Dish-shaped antennas, mounted high on buildings to stay in line-of-sight, play a similar long-distance role for wireless links.

Undersea fibre cables

The data that crosses oceans between continents travels mostly through optical fibre cables laid on the sea bed. Their huge bandwidth and immunity to electrical noise are exactly why fibre, not copper, carries the world's backbone traffic.

4.3 Wireless Media and the Wave Spectrum

In wireless communication, information travels as electromagnetic signals through air. The usable spectrum runs from **3 KHz to 900 THz**, and it is divided by frequency into four bands: **radio waves**, **microwaves**, **infrared waves** and **visible (light) waves**. Of these, radio, micro and infrared are the three useful for wireless data communication.



Wave	Key properties
Radio waves	Range 3 KHz to 1 GHz. Omni-directional (travel in all directions). 300 KHz to 30 MHz can travel long distances. Susceptible to interference. 3 to 300 KHz can penetrate walls. Used in AM/FM radio, TV, cordless phones.
Microwaves	Range 1 GHz to 300 GHz. Unidirectional. Cannot penetrate solid objects like walls or hills. Need line-of-sight (both antennas facing each other). Used in point-to-point links such as radar and satellite. Very large carrying capacity.
Infrared waves	Range 300 GHz to 400 THz. Very high frequency. Cannot penetrate solid objects. Used for short-distance point-to-point links such as mobile-to-mobile, remote-control-to-TV and Bluetooth-type devices.

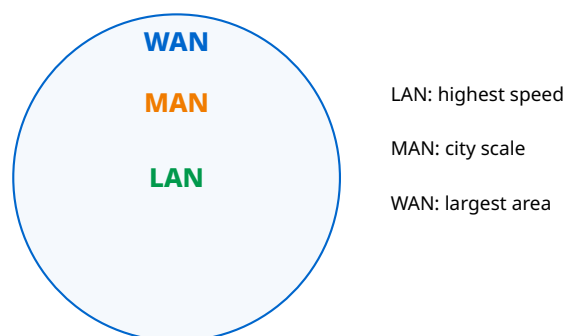
Radio is omni-directional, microwave is not

A common slip is to call microwaves omni-directional. They are **unidirectional** and need line-of-sight, which is why dish antennas are mounted on tall buildings facing each other. Radio waves are the omni-directional ones.

4.4 Network Reach: LAN, MAN and WAN

Wireless technologies connect devices, but networks themselves are also classified by the area they cover. This is the basis of exercise Q3, so keep the three sizes clear.

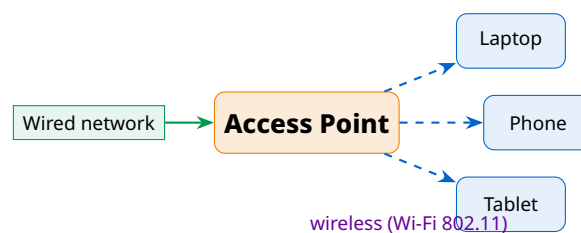
- **LAN (Local Area Network):** covers a small area such as a room, building or campus. Because the distances are short, it has the **highest speed** of the three.
- **MAN (Metropolitan Area Network):** spans a city or large town, sitting between LAN and WAN in both size and speed.
- **WAN (Wide Area Network):** spans a country or even the globe, so it **covers the largest area**. The Internet is the biggest WAN.



4.5 Wireless Technologies: Bluetooth and Wi-Fi

On top of these waves sit named wireless technologies. Two are in the syllabus.

- **Bluetooth:** a short-range technology for connecting phones, mice, headphones and keyboards. Each device has a low-cost transceiver chip using the unlicensed **2.4 GHz** band. Range is about **10 metres** at **1 to 2 Mbps**. Devices within range form a personal area network called a **piconet**, in a master-slave setup where one master serves up to **7 active slaves**.
- **Wireless LAN (Wi-Fi):** a wireless local area network, a popular way to reach the Internet. The IEEE standard for it is **802.11**, popularly called Wi-Fi. Devices connect through an **access point (AP)** that links to a wired router, switch or hub. Wi-Fi lets users move freely within the network area while staying connected.



Bluetooth numbers

“**10-7-2.4**” captures the Bluetooth facts: **10** metres range, **7** active slaves per master, **2.4** GHz band. Three numbers, three marks.

5 Mobile Generations and Protocols

The last big theme of the chapter has two parts. First, how mobile networks have grown from 1G to 5G, since the mobile network is now the world’s most used. Second, the named **protocols** that make the Internet work, from HTTP for web pages to TCP/IP for moving data. Both parts are heavy on definitions and abbreviations, so this section lays them out as clear, exam-ready points.

5.1 From 1G to 5G

Mobile technology is grouped into generations by landmark achievements. Learn what each generation added.

Gen	Around	What it added
1G	1982	Voice calls only, using analog signals.
2G	1991	Digital voice (better quality), more capacity, encryption for security, plus SMS and MMS.
3G	2001	Digital voice and data together, Internet access on the same towers, faster data, more simultaneous calls.
4G	later	Much faster than 3G; supports interactive multimedia, video, wireless Internet and broadband services.
5G	developing	Aimed at IoT and machine-to-machine (M2M); data transfer in Gbps, far faster than 4G.

Why 5G matters for IoT

5G is built for the Internet of Things, where billions of small devices such as sensors, smart meters and connected cars talk to each other. Its high speed and ability to handle many devices at once make machine-to-machine communication practical at scale.

Remember each generation by its headline feature

Tie one word to each generation: 1G = analog voice, 2G = digital voice plus SMS, 3G = data and Internet, 4G = fast multimedia and video, 5G = Gbps for IoT. A one-word tag per generation is enough to answer the order-and-feature question.

5.2 What a Protocol Defines

A **protocol** is a set of standard rules the sender, receiver and all in-between devices follow. We need protocols for jobs such as **flow control**, **access control** and **addressing**.

- **Flow control** matches speeds. If computer A sends at 1024 Mbps but computer B receives at 512 Mbps, B must tell A to slow down, or data is lost.
- **Access control** decides which node may use a shared link at a given moment, so packets from two senders do not collide.



A protocol also defines how computers identify one another, the form data takes in transit, how a node decides whether a packet is for it or to be forwarded, how to confirm all data arrived without loss, and how packets are reordered at the destination.

5.3 Web and File Protocols: HTTP, FTP, PPP, SMTP

Several named protocols handle specific jobs. These short notes are exactly the kind asked in “write a short note” questions.

- **HTTP (HyperText Transfer Protocol):** the primary protocol for accessing the World Wide Web. It is a request-response (client-server) protocol that runs over TCP. Developed by Tim Berners-Lee at CERN in 1989. When you type a URL, the browser sends an HTTP request and the server returns the web page.
- **FTP (File Transfer Protocol):** used to transfer files between machines, also on a client-server model. It sets up a connection, optionally authenticates with a user ID and password, then transfers the file. It handles differences in file naming, data format and directory structure.
- **PPP (Point-to-Point Protocol):** establishes a dedicated direct link between two devices, defining how they authenticate each other. Used between two directly connected routers, or by a home computer dialling an ISP through a modem. It keeps packets in order and asks for re-send of damaged or lost packets.
- **SMTP (Simple Mail Transfer Protocol):** used for email. It reads the message header (the addresses) like an envelope, without caring about the content. Mail is queued, the sender program delivers it to each destination, and the receiver program places it in the right mailbox.

Expand the abbreviations

HTTP = HyperText Transfer Protocol. **FTP** = File Transfer Protocol. **PPP** = Point-to-Point Protocol. **SMTP** = Simple Mail Transfer Protocol. **DNS** = Domain Name System (maps a name like ncert.nic.in to its IP address). Examiners love the full forms.

The HTTP request-response cycle. HTTP is the most-tested protocol, so trace its flow. A web page is written in a markup language such as HTML and stored on a web server, reachable by its **URL**. When you type a URL in a browser, a logical link is set up between your machine (the **client**) and the web server using HTTP. The browser sends an HTTP **request**; the server fetches the page and sends back an HTTP **response**; the browser displays it. The same idea, request then response, repeats for every page you open.



DNS in a line. You remember names like ncert.nic.in, but the network needs numeric IP addresses. The **Domain Name System (DNS)** is the service that translates a human-friendly domain name into the IP address of the server, so your browser can reach it. Think of DNS as the phone book of the Internet.

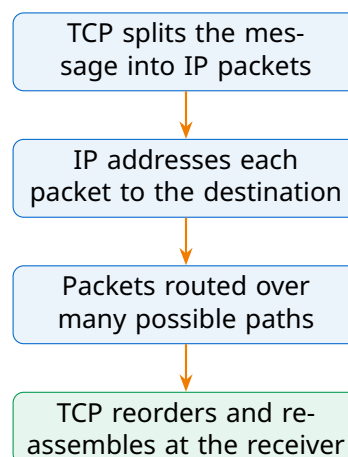
Match protocol to job

“**H**ome **F**or **P**retty **S**weets” lines up **H**TT**P** (web pages), **F**TP (files), **P**PP (direct link), **S**MTP (email). One job per protocol keeps them from blurring together.

5.4 TCP/IP: How the Internet Moves Data

TCP/IP stands for Transmission Control Protocol / Internet Protocol. It is a set of standard rules built on a client-server model, where a client requests a service from a server. The two halves do different jobs.

- **IP** gives every node on the Internet an **IP address** so each can be identified. It is the glue that holds the whole Internet together.
- **TCP** breaks the message into small **IP packets**, makes sure they are delivered to the right IP address, and reorders them so the message arrives in sequence. Because the Internet has many redundant paths, two packets of one message can take different routes; TCP reassembles them at the destination.

**Split the TCP/IP roles cleanly**

Remember it as a division of labour: **IP** handles *addressing* (who and where), **TCP** handles *reliable delivery and ordering* (breaking up, guaranteeing arrival, putting back in order). Naming the two jobs separately wins the mark.

[Download the Full NCERT Solutions PDF](#)

6 Exam Practice and Quick Revision

This final section turns the chapter into points you can revise the night before a test. It works through the NCERT exercise questions, lists the traps examiners set,

and ends with a one-glance summary strip. Read it after the main sections, not instead of them.

6.1 Solved Exercise Questions

The questions below follow the NCERT exercise. Try each before reading the answer.

Q1. What is data communication, and what are its main components?

Data communication is the exchange of data between two or more networked or connected devices. Its five components are the **sender**, the **receiver**, the **message**, the **communication media** and the **protocol**.

Q2. Which communication mode allows communication in both directions simultaneously?

Full-duplex communication. Both devices send and receive at the same time, as in a mobile phone call.

Q3. Among LAN, MAN and WAN, which has the highest speed and which covers the largest area?

LAN has the highest speed (it is small and local), while **WAN** covers the largest area (it can span countries). MAN sits in between.

Q4. What are the three categories of wired media? Explain them.

Twisted-pair cable (two twisted copper wires, cheap, used in LANs and phone lines), **coaxial cable** (copper core with shielding, more bandwidth and longer reach), and **optical fibre** (glass strand carrying light, very high bandwidth, noise-immune but costly).

Q6. Which transmission media carries signals in the form of light?

Optical fibre cable. The data travels as light inside a thin glass strand, kept inside by refraction off the cladding.

Q8. What is the frequency range for radio waves?

Radio waves cover roughly **3 KHz to 1 GHz**.

Q9. 18 Gbps is equal to how many bits per second?

Using $1 \text{ Gbps} = 2^{30} \text{ bps} = 1\,073\,741\,824 \text{ bps}$:

$$18 \text{ Gbps} = 18 \times 2^{30} = 19\,327\,352\,832 \text{ bps.}$$

(On the plain 10^9 scale it is $1.8 \times 10^{10} \text{ bps}$.)

Q10. HTTP stands for?

HyperText Transfer Protocol.

Q13. A composite signal has frequencies between 500 MHz and 1 GHz. What is its bandwidth?

Bandwidth is the difference between the highest and lowest frequency:

$$\text{Bandwidth} = 1 \text{ GHz} - 500 \text{ MHz} = 1000 \text{ MHz} - 500 \text{ MHz} = 500 \text{ MHz.}$$

6.2 Compare Wired and Wireless Media

NCERT Q5 asks you to compare the two media families. Keep the table ready.

Point	Wired (guided)	Wireless (unguided)
Path	physical wire or cable	air, no physical wire
Carrier	electric signal or light	electromagnetic waves
Mobility	device is tied to the cable	device can move freely
Interference	lower, especially fibre	higher, weather and obstacles
Examples	twisted pair, coaxial, fibre	radio, microwave, infrared

6.3 Common Exam Traps

These small mistakes cost easy marks. Check yourself against each.

- Measuring bandwidth in bits per second. Bandwidth is in Hertz; the data rate is in bps.
- Confusing MBps (megabyte) with Mbps (megabit); they differ by 8.
- Saying microwaves are omni-directional. They are unidirectional and need line-of-sight.
- Forgetting that optical fibre is unidirectional, so full-duplex needs two fibres.
- Mixing up circuit and packet switching: circuit fixes one path first; packet routes each packet on its own.

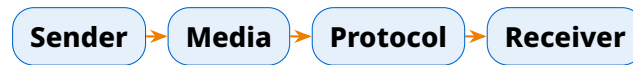
6.4 One-Glance Revision Strip

Skim this to refresh the whole chapter in two minutes.

Chapter in a nutshell

- Five components: sender, receiver, message, communication media, protocol.
- Capacity is measured by **bandwidth** (in Hz) and **data transfer rate** (in bps).
- Three modes: simplex, half-duplex, full-duplex.
- Two switching techniques: circuit (one fixed path) and packet (each packet routed alone).
- Wired media: twisted pair, coaxial, optical fibre. Wireless waves: radio, microwave, infrared.
- Wireless tech: Bluetooth (10 m, 2.4 GHz, piconet) and Wi-Fi (802.11, access point).
- Mobile generations: 1G to 5G, from analog voice to Gbps data for IoT.

- Protocols: HTTP, FTP, PPP, SMTP, DNS, and TCP/IP for moving Internet data.



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