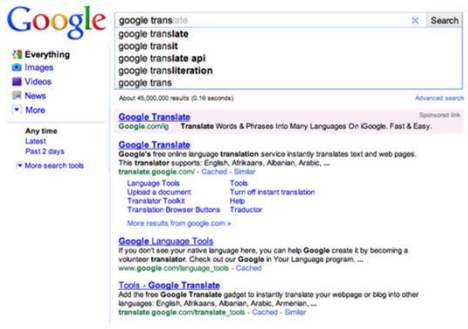
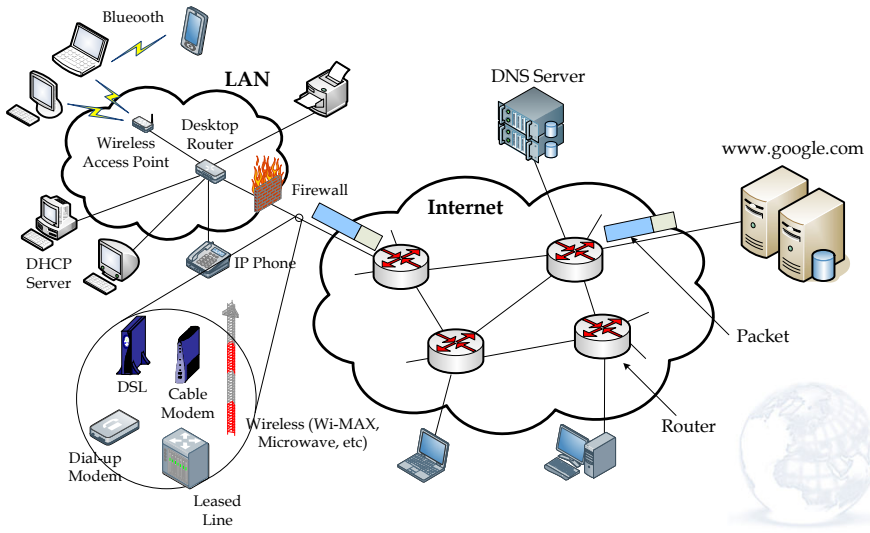
Lecture 1: Introduction to Communication Networks

Prof. Mohammed Hawa
Electrical Engineering Department
University of Jordan

What is the Internet?



Behind the Scenes



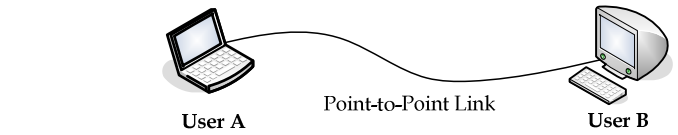
Extreme Number of Protocols!

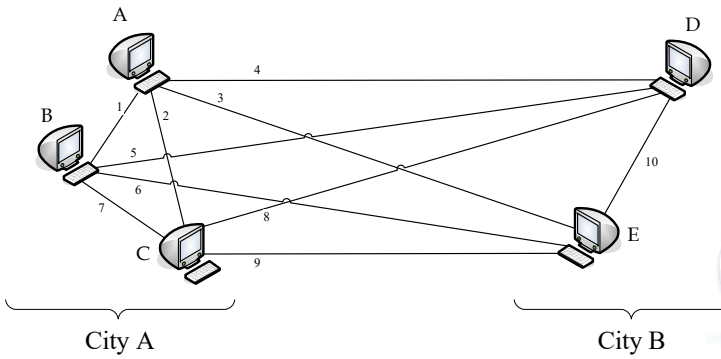
Layer	TCP/IP model (RFC 1122)	Other	SS7	SNA	AppleTalk suite	OSI suite
7. Application	SDP, SOAP, GTP, STUN, IMAP, IRC, POP, POP3, SSH, Telnet, rlogin, Gopher, Whois, BitTorrent, ECHO, RTP, RTSP, ENRP, NFS, RTCP, XMPP, NNTP, SSI, DNS, FTP, TFTP, HTTP, NFS, NTP, NNTP, DHCP, SMPP, SMTP, SNMP, RIP, BGP (both run over UDP or TCP), OSPF (runs over IP)	HL7, Modbus	INAP, MAP, TCAP, ISUP, TUP	APPC	AFP, ZIP, RTMP, NBP	FTAM, X.400, X.500, DAP, ROSE, RTSE, ACSE
6. Presentation	ASN.1, MIME, XDR, SSL, TLS	TDI, ASCII, EBCDIC, MIDI, MPEG, NCP			AFP	ISO/IEC 8823, X.226, ISO/IEC 9576-1, X.236
5. Session	Sockets: Session establishment in TCP, SIP, RPC.	Named Pipes, NetBIOS, SAP, ASAP, SDP		DLC	ASP, ADSP, PAP	ISO/IEC 8327, X.225, ISO/IEC 9548-1, X.235
4. Transport	DCCP, RSVP, ECN, TCP, UDP,PPTP, L2TP, SCTP	NBF, nanoTCP, nanoUDP			DDP	ISO/IEC 8073, TP0, TP1, TP2, TP3, TP4 (X.224), ISO/IEC 8602, X.234
3. Network	IP (IPv4 · IPv6), IPsec, ARP, ICMP, ICMPv6, IGMP, IS-IS, IGRP, EIGRP, ARP, RARP	NBF, Q.931	SCCP, MTP		ATP (TokenTalk or EtherTalk)	ISO/IEC 8208, X.25 (PLP), ISO/IEC 8878, X.223, ISO/IEC 8473-1, CLNP X.233.
2. Data Link (LLC/MAC)	NDP, Tunnels, PPTP, PPP, PPPoE, PPPoA, SLIP	802.3 (Ethernet), 802.11a/b/g/n (Wi-Fi), 802.16 (Wi-MAX), 802.15 (Bluetooth), 802.1Q (VLAN), ISDN, ATM, HDP, FDDI, Fibre Channel, Frame Relay, HDLC, ISL, Q.921, Token Ring, CDP	MTP, Q.710	SDLC	LocalTalk,AppleTalk Remote Access, PPP	ISO/IEC 7666, X.25 (LAPB), Token Bus, X.222, ISO/IEC 8802-2 LLC Type 1 and 2
1. Physical		RS-232, V.35, V.34, I.430, I.431, T1, E1, 10BASE-T, 100BASE-TX, POTS, SONET, SDH, DSL, 802.11a/b/g/n PHY, etc	MTP, Q.710	Twinax	RS-232, RS-422, STP, PhoneNet	X.25 (X.21bis, EIA/TIA-232, EIA/TIA-449, EIA-530, G.703)

Communication Network

- A communication network is an arrangement of **hardware** and **software** that allows users to exchange **information**.
- Another definition of a communication network is a set of nodes that are **interconnected** to permit the exchange of **information**.
- Examples of Communication Networks:
  - Telephone/Cellular Telephone Network (for voice communications).
  - Computer Network (for sharing programs, data, accessing printers and servers).
  - These networks are merging nowadays (e.g., VoIP systems, 4G and 5G systems).

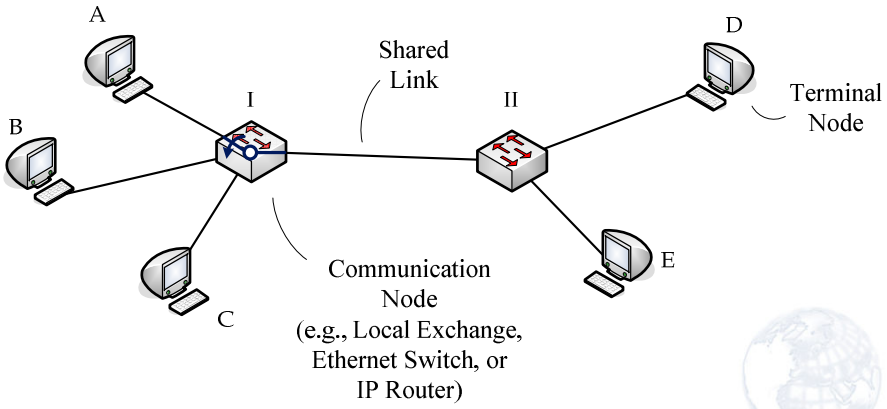
Point-to-Point Networks





N nodes require $N(N-1)/2$ links

Shared Links: *Higher Utilization*

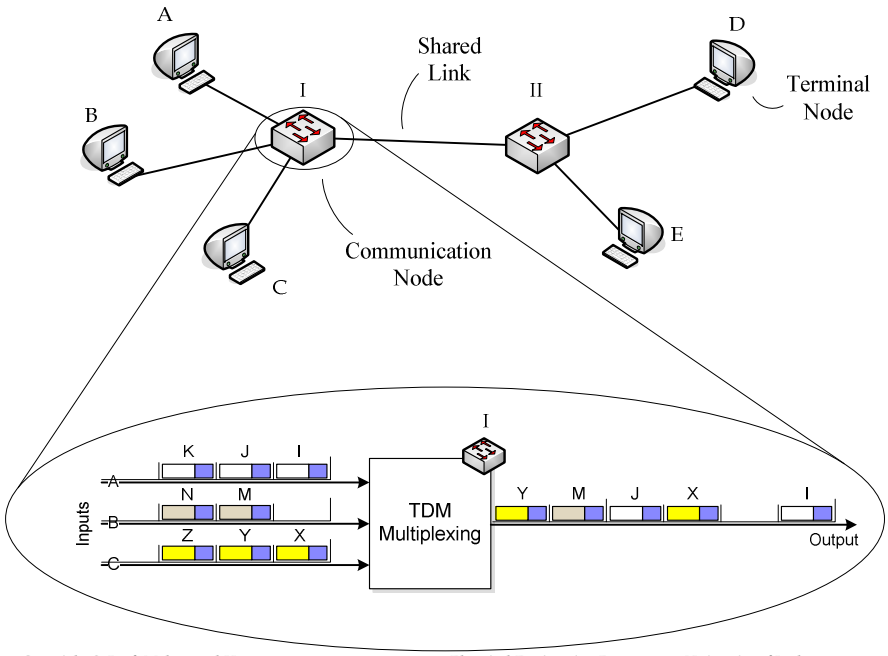


Methods of Sharing Resources (*Switching at Comm. Nodes*)

- **Circuit Switching:**
  - Used in PSTN (POTS) (Telephony Networks).
- **Message Switching:**
  - Used in a very small number of data networks, and in Email gateways.
- **Packet Switching:**
  - Used in most data networks (and the Internet).
  - *Connection-Oriented* vs. *Connectionless*
- **Virtual Circuit Switching:**
  - Typically built on top of Packet Switching
  - E.g., Asynchronous Transfer Mode (ATM) network.
  - E.g., Multiprotocol Label Switching (MPLS).

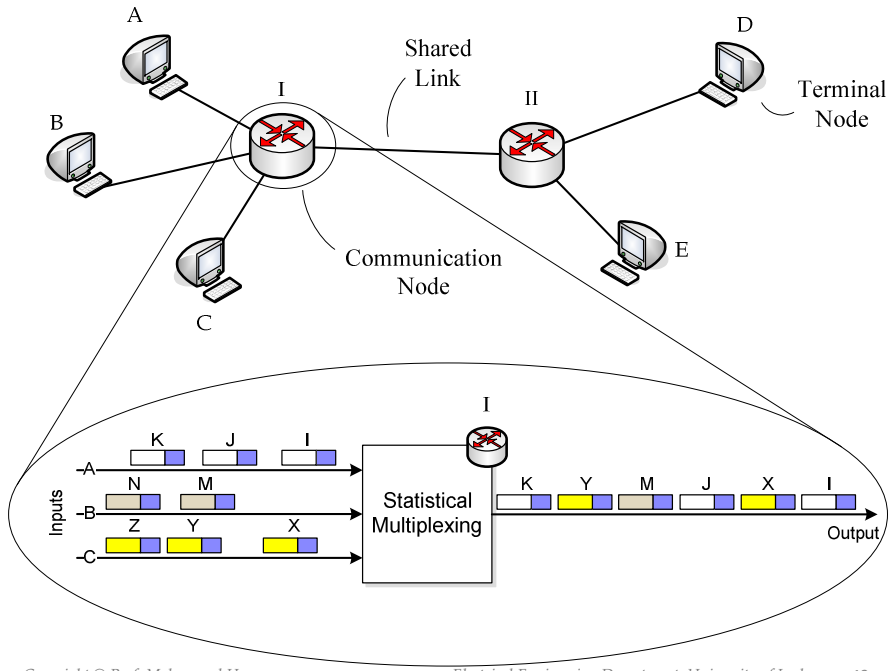
Circuit Switching

- Suitable for time-sensitive (delay-intolerant) traffic, such as voice (voice is interactive by nature).
- Used in PSTN (POTS) (Telephony Networks).
- A ***single channel*** is reserved between the source and destination ***before starting*** to send traffic (done by dialing).
- This channel ***cannot be used*** by any other users ***during*** the conversation (phone call).
- All traffic of the call must go through the same channel.
- One channel can be one *FDM band* or one *TDM slot*, and *not necessarily* one full physical medium.
- The channel can be used for other users only *after* the call has finished.

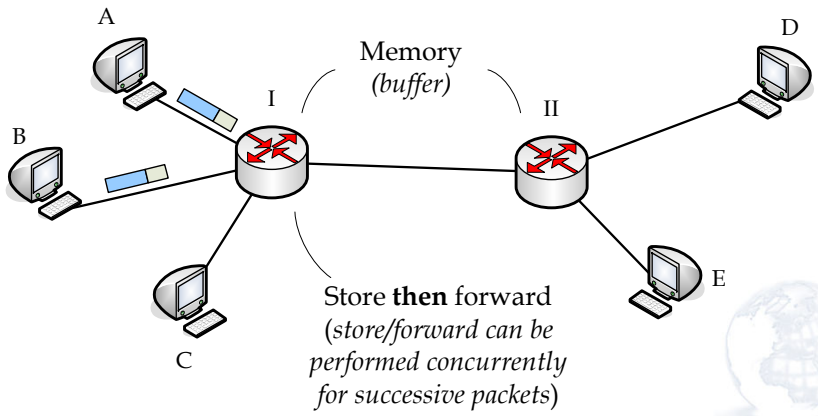


Message and Packet Switching

- A **Message** is typically a sizable chunk of information (e.g., one file, one email, etc).
- A message can be divide into *K* smaller chunks, called **Packets**, before being transmitted.
  - Segmentation/Reassembly (Advantages?)
- Both Message switching and Packet switching use the concept of **Statistical Multiplexing**.
- Statistical Multiplexing is different than Channel multiplexing, FDM multiplexing, or TDM multiplexing (*circuit switching*).
- Both Message switching and Packet switching use the concept of **Store and Forward**.



Both Message switching and Packet switching use the concept of **Store and Forward**



Packet Switching

- Suitable for delay-tolerant traffic (e.g. Web browsing, ftp, etc).
- Used in data networks.
- The ***path*** taken by packets belonging to one flow ***can be used*** by other information flows (i.e., the path is ***shared***).
- This path can change dynamically during the conversation:
  - Thus, two packets of the same message (or flow of messages) can follow two totally different paths through the network.
- Paths are not reserved (no dialing before sending traffic):
  - However, the existence of a session-establishment (connection-setup) phase before starting communications decides whether we have connection-oriented (e.g. TCP) or connectionless (e.g. UDP) packet switching.
  - The session-establishment is used for initializing the source and destination, not for reserving the path.
- Message switching is similar to packet switching but uses larger chunks (messages) not smaller ones (packets).

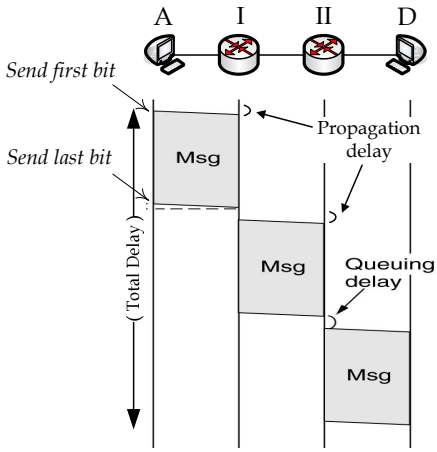
Advantages of packet switching

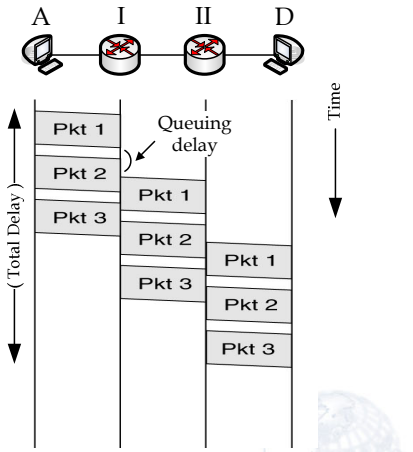
- Statistical multiplexing is more efficient in **utilizing** the channel compared to TDM (vs. circuit switching).
- There is no need for **dialing** stage before sending traffic (vs. circuit switching).
- No **blocking** of incoming traffic (vs. circuit switching busy tone after dialing).
- No need to store **network-wide states** (difficult and expensive) since actual paths are not reserved (vs. circuit switching).
- Hence, routers are much **cheaper** and consume less power compared to local exchanges and main exchanges.
- Multiple users sharing a link can interleave their packets and thus maintain continuous communications **concurrently** (vs. message switching).

Advantages of packet switching

- Packet switching is more **efficient** than message switching because intermediate nodes do not waste time storing-and-forwarding whole messages in sequence, which reduces total time delay of sending data, especially as the number of intermediate nodes increases (vs. message switching).
- A bit error during transmission of one packet or a packet drop at an intermediate node means a single packet needs to be retransmitted, not the whole message (vs. message switching).
- Probability of a single bit error in a large message is higher than the probability of a single bit error in a small packet.
- If there are multiple paths between two nodes, some packets of a message can be sent through one path while other packets can be sent through another path, reducing congestion and providing redundancy and survivability (vs. message and circuit switching).

Advantages of packet-switching



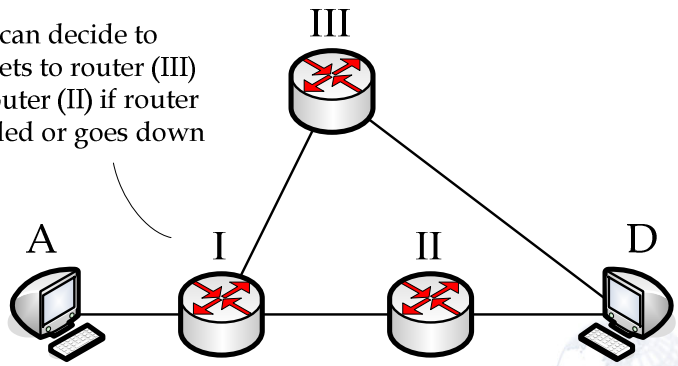


Total Delay = *TRANS* + *PROP* + *QUEUE* + *PROC*
TRANS = $(N+1)\times T = 3T$

TRANS = $T + N\times T/K = T + 2\times T/3$ ($< 3T$)
N: Number of intermediate nodes
K: Number of packets in message

Advantages of packet-switching

Router (I) can decide to forward packets to router (III) rather than router (II) if router (II) is overloaded or goes down



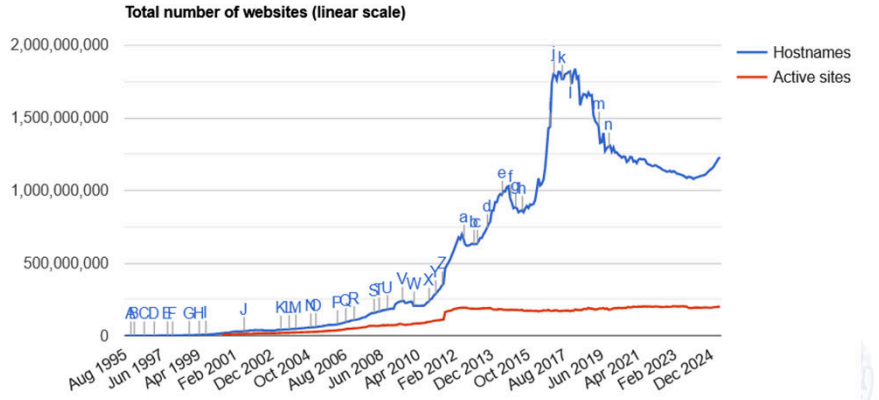
Advantages of circuit switching

- These are also disadvantages of packet switching and message switching.
- Circuit switching provides the minimum time delay for sending data after the initial dialing phase, as it does not utilize store-and-forward (no queueing delay), plus there is no need for processing delay (no packet header). Useful for delay-intolerant traffic.
- No overhead added to each packet (header). Unlike packet and message switching where intermediate nodes need to know how to route each packet or message individually without having a specific path reserved.
- No possibility of congestion since extra traffic is blocked before it enters the network.

Virtual Circuit Switching

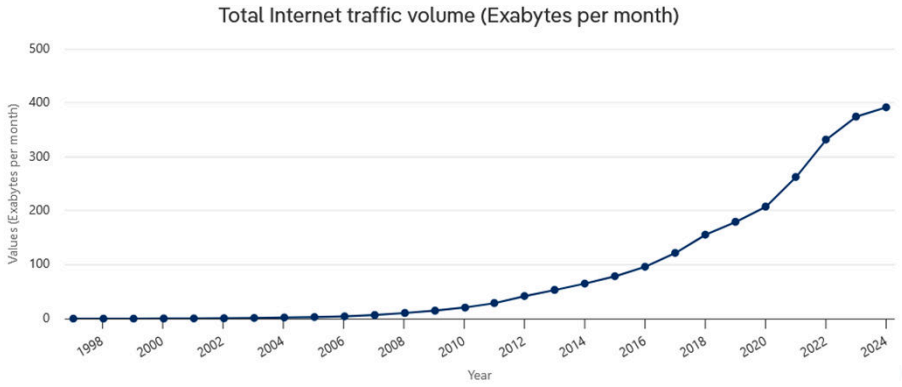
- A hybrid between circuit switching and packet switching.
- Typically resource reservation (*not* path reservation) is done at intermediate nodes before sending traffic on top of packet switching.
  - Like reserving a seat when you go to the movies.
- *Disadvantage*: Requires storing state information all across the network (similar to circuit switching)
- *Advantage*: Easier to provide Quality-of-Service per flow, and reduces congestion.
- Defines flows that typically follow a predetermined path (through resource reservations).
- ATM network uses virtual circuit switching on top of cell (packet) switching, with a well-define dial-up.

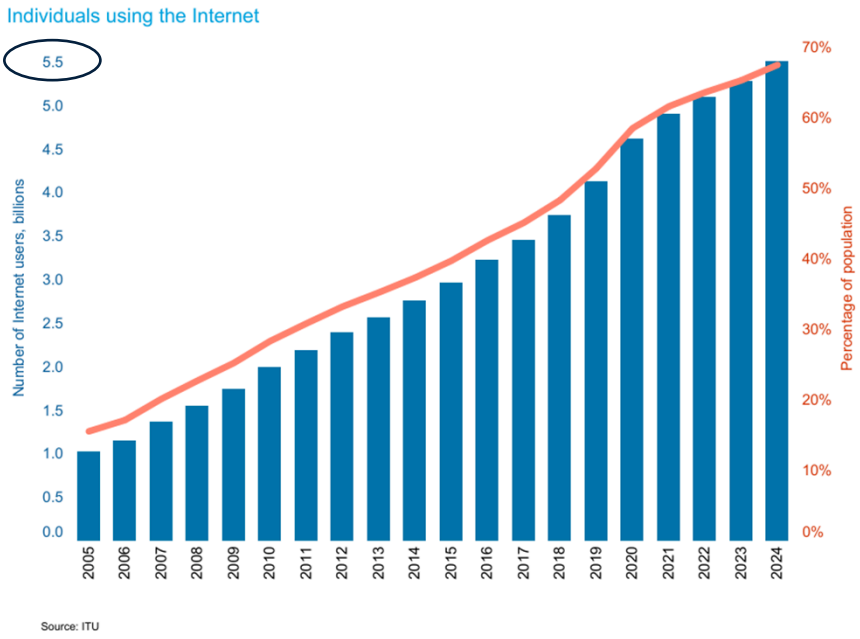
The Internet has *matured*

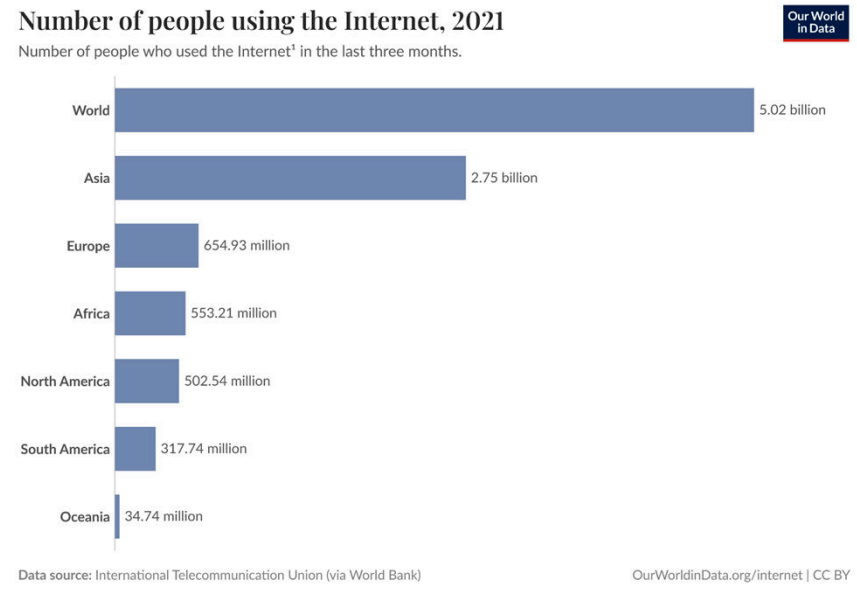


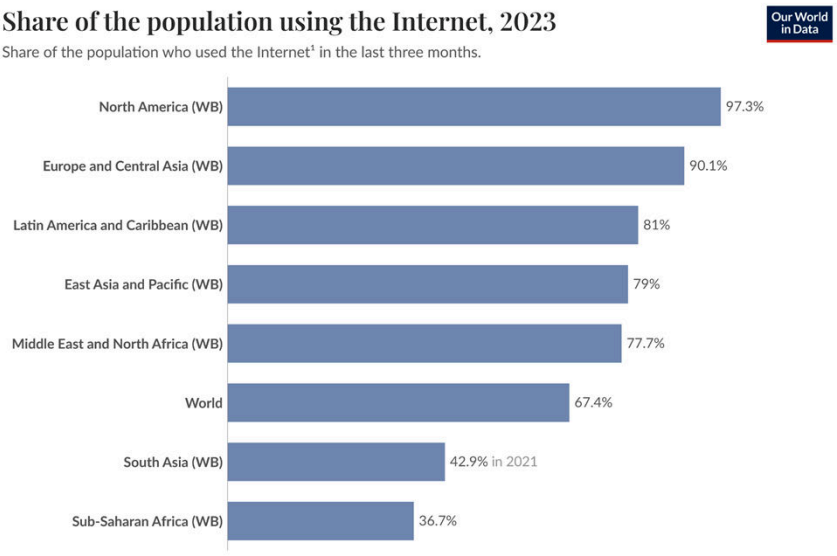
But still *increasing* traffic

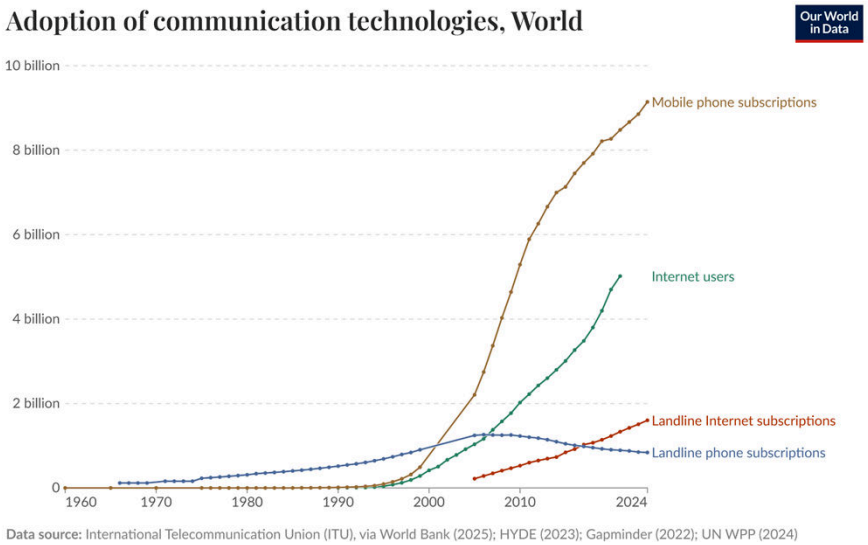
- YouTube, TikTok, Facebook, WhatsApp, etc
- Exabyte (EB) is 10^{18} bytes: million trillion bytes








Share of the population using the Internet, 2023
Share of the population who used the Internet[1] in the last three months.
Our World in Data
North America (WB)
97.3%
Europe and Central Asia (WB)
90.1%
Latin America and Caribbean (WB)
81%
East Asia and Pacific (WB)
79%
Middle East and North Africa (WB)
77.7%
World
67.4%
South Asia (WB)
42.9% in 2021
Sub-Saharan Africa (WB)
36.7%
Data source: International Telecommunication Union (ITU), via World Bank (2025)
OurWorldinData.org/internet | CC BY


Adoption of communication technologies, World
Our World in Data
10 billion
8 billion
6 billion
4 billion
2 billion
0
1960
1970
1980
1990
2000
2010
2024
Mobile phone subscriptions
Internet users
Landline Internet subscriptions
Landline phone subscriptions
Data source: International Telecommunication Union (ITU), via World Bank (2025); HYDE (2023); Gapminder (2022); UN WPP (2024)