

03 - Application Layer (Electronic Mail, DNS)

The application layer is where user-facing applications like web browsers, email, and file transfer protocols operate.

▼ Electronic Mail System (Email)

Email is a system that allows users to send and receive messages over a network.

▼ Three Main Components

1. User Agent (UA):

- Software used to **compose, send, and read emails**.
- Example: Outlook, iPhone Mail, Gmail.

2. Mail Server:

- Has:
 - **Mailbox**: stores incoming emails.
 - **Message queue**: stores emails waiting to be sent.
- Example: Gmail's backend server storing your emails.

3. SMTP (Simple Mail Transfer Protocol):

- Used for sending emails between mail servers.
- Uses TCP port 25 to transfer messages reliably.

▼ How Email is Sent

Example: Alice sends email to Bob

1. Alice writes an email to bob@some school.edu using her User Agent (UA).
2. Her UA sends it to her mail server using SMTP.
3. The mail server opens a TCP connection to Bob's mail server.

4. SMTP sends the message to Bob's mail server.
5. Bob's mail server places the message in his mailbox.
6. Bob reads it using his User Agent with POP3 or IMAP.

Retry mechanism: If delivery fails, the system retries for a few days.

▼ SMTP Protocol (RFC 2821)

SMTP (Simple Mail Transfer Protocol) is used to send emails from a client to a server or between servers. Typically, an email, including its body and attachments (objects), is sent as a single message in SMTP. While attachments are encoded (e.g., using MIME), they are part of one email message, not sent as separate messages unless the email is split due to size limitations (rare in modern systems).

▼ Client-server model

- Sender's mail server acts like a client.
- Receiver's mail server acts like a server.

▼ Three phases

1. Handshake (greeting)
2. Message Transfer
3. Closure

▼ SMTP Commands:

- MAIL FROM: sender address
- RCPT TO: recipient address
- DATA: message body
- QUIT: end session

▼ Example: SMTP Conversation

```
S: 220 hamburger.edu      // Server greeting
C: HELO crepes.fr          // Client introduction
S: 250 Hello crepes.fr
```

```
C: MAIL FROM: <alice@crepes.fr>
S: 250 Sender ok
C: RCPT TO: <bob@hamburger.edu>
S: 250 Recipient ok
C: DATA
S: 354 Enter mail, end with "."
C: Do you like ketchup?
C: How about pickles?
C: .
S: 250 Message accepted
C: QUIT
S: 221 Connection closing
```

▼ SMTP vs HTTP

Feature	SMTP	HTTP
Type	Push	Pull
Communication	Server to server	Client to server
Message format	7-bit ASCII	Binary allowed
Multiple files	Sent together	Sent separately

▼ Mail Message Format

- RFC 822 defines the structure.
- Components:
 - Header: TO, FROM, SUBJECT, etc. (Different from SMTP commands!)
 - Body: Actual message content.
- Example:

```
TO: bob@school.edu
FROM: alice@work.com
SUBJECT: Meeting Reminder
```

Hi Bob, don't forget the meeting at 3PM!

▼ Mail Access Protocols

SMTP is only used to send emails.

To retrieve emails from a mail server, we use:

▼ POP3 (Post Office Protocol v3)

- **Download and keep:** Email is downloaded to the device and keep a copy in the server
- **Download and delete:** Email is deleted from the server.
- Example: Outlook downloads mail, then it disappears from Gmail inbox.

▼ IMAP (Internet Mail Access Protocol)

IMAP (Internet Message Access Protocol) is designed to manage emails on a server, allowing users to access and organize their emails from multiple devices. Unlike POP3, which typically downloads emails to a client and may remove them from the server, IMAP keeps emails stored on the server by default. This enables synchronization across devices, and emails remain on the server unless explicitly deleted.

- Allows syncing and managing emails on the server.
- Example: Gmail syncs emails across your phone, tablet, and laptop.

▼ HTTPs

- Web-based email like Gmail, Yahoo! Mail.

▼ Domain Name System (DNS)

▼ What is DNS?

- It's like the phonebook of the internet.
- Translates domain names (like `www.cisco.com`) into IP addresses (like `198.133.219.25`).

▼ DNS in Action

1. You type `www.cisco.com` into your browser.
2. Your computer asks the **DNS Resolver** (part of the OS) to find its IP.

3. The resolver asks the **local DNS server**.

4. If needed, it queries:

- **Root DNS servers**
- **TLD (Top Level Domain) servers** (.com, .org, etc.)
- **Authoritative DNS servers** (responsible for specific websites)

5. Finally, the IP address is returned, and your browser loads the page.

▼ DNS Structure

1. Root Servers

- 13 main logical servers (like A to M) located globally (e.g., Verisign, NASA, ICANN).

2. TLD Servers

- Handle domains like .com, .edu, .org, .uk, .bd, etc.
- Example: Network Solutions manages .com domains.

3. Authoritative Servers

- Owned by individual organizations.
- Store the actual IP mappings (e.g., google.com → 142.250.72.206).

▼ DNS Queries

Iterative Query

- Each server replies with "I don't know, but ask this next one."

Recursive Query

- Server takes full responsibility and does all the work until it finds the answer.
- More load on DNS servers.

▼ DNS Caching

- Caching saves previously looked-up IPs to save time.
- Each entry has a TTL (Time to Live).

- After TTL expires, a fresh lookup is done.
- Problem: Outdated cache can lead to errors if IP has changed.

▼ DNS Record Types

Record Type	Description
A	Maps hostname to IP address. Example: (google.com, 142.250.72.206, A)
NS	Points to authoritative name server.
CNAME	Alias of another name. Example: (www.google.com → google.com)
MX	Mail server for domain. Example: (google.com → mail.google.com)

▼ Adding Records to DNS

(Example: networkuptopia.com)

1. Register the domain name.
2. Create:
 - A record for main site.
 - CNAME for alias like www.networkuptopia.com.
 - NS record for its DNS server.
 - MX record for email server.

▼ Summary

- Email uses **SMTP to send** messages, and **POP3/IMAP to retrieve** them.
- DNS maps **domain names** to **IP addresses** using a **hierarchical** and **distributed** system.
- DNS improves speed via caching but requires updating with TTL.
- Both email and DNS are crucial for how the internet works today.