HTTP/HTTPS

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3 min read

Every time you interact with the internet, you're using **HTTP** (HyperText Transfer Protocol) or its secure counterpart, **HTTPS**.

These protocols are the fundamental language spoken between clients and servers, defining how information is requested and delivered.

In this chapter, we'll delve into their core principles, key differences, and crucial evolution from HTTP/1.1 to HTTP/3.

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1. What is HTTP?

HTTP (HyperText Transfer Protocol) is a stateless, text-based application-layer protocol used for communication between web clients and servers. It's the standard for

- TCP vs UDP
- Load Balancers
- Load Balancing Algorithms
- Checksums

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between web clients and servers. It's the standard for

transmitting web pages and data over the internet.

Key Characteristics:

- **Application Layer Protocol**: HTTP operates at Layer 7 of the OSI model.
- **Client-Server Model**: Communication is always initiated by a client (e.g., your browser, a mobile app, a microservice) sending a request to a server. The server then processes the request and sends a response back to the client.
- **Built on TCP**: HTTP traditionally sits on top of TCP (Transmission Control Protocol) at the Transport Layer, leveraging TCP's reliable, ordered, and connection-oriented delivery. By default, HTTP uses **port 80**.

Example HTTP Request and Response

Request:

```
GET /index.html HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64
Accept: text/html,application/xhtml+xml,application/
Accept-Language: en-US,en;q=0.5
Connection: keep-alive
```

Response:

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=UTF-8
Content-Length: 1024
Date: Mon, 11 Apr 2023 10:00:00 GMT

<!DOCTYPE html>
<html>
<head><title>Example Domain</title></head>
<body><h1>Hello World!</h1></body>
</html>
```

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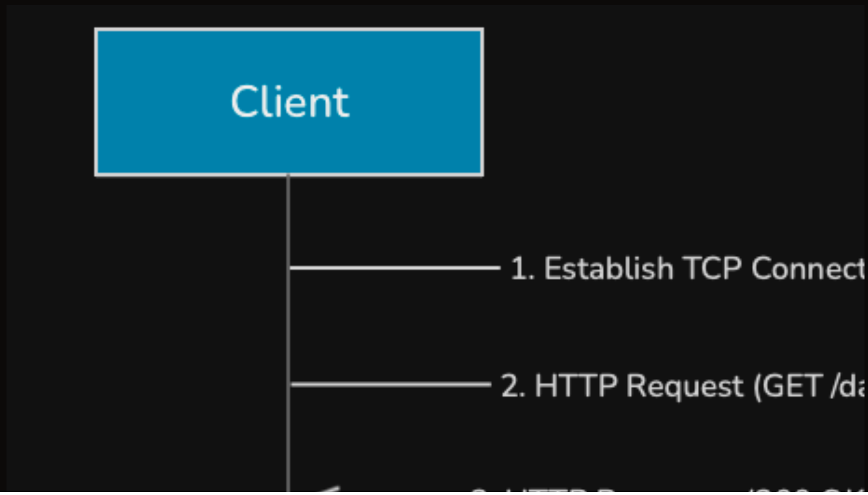
2. How HTTP Works

At its core, HTTP operates on a simple request/response model:



```
<----- 3. HTTP Response (200 OK
```

1. **TCP Connection**: The client first establishes a TCP connection with the server (or reuses an existing one).
2. **HTTP Request**: The client sends an HTTP request message. This message includes:
    - An **HTTP Method** (e.g., `GET`, `POST`).
    - The **URL** of the resource.
    - **HTTP Headers** (key-value pairs providing additional context, e.g., `Host`, `User-Agent`).
    - Optionally, a **message body** (e.g., for `POST` requests).

3. **Server Processing**: The server receives the request, processes it (e.g., fetches data from a database, runs business logic).
4. **HTTP Response**: The server sends an HTTP response message back to the client. This includes:
    - An **HTTP Status Code** (e.g., `200 OK`, `404 Not Found`).
    - **Response Headers** (e.g., `Content-Type`, `Content-Length`).
    - The **message body** (e.g., the requested HTML content, JSON data).

5. **Connection Closure/Reuse**: The TCP connection is ei-

ther closed after the response (HTTP/1.0, though uncommon now) or kept open for subsequent requests (**HTTP Keep-Alive** in HTTP/1.1+).

Statelessness:

HTTP is inherently **stateless**. This means each request from a client to a server is treated as an independent transaction; the server doesn't "remember" any previous requests from that client.

In system design, this is both a blessing and a curse:

- **Pros**: Easier to scale, as any server can handle any request without needing prior context.
- **Cons**: Requires mechanisms like **cookies**, **session IDs**, or **JWTs (JSON Web Tokens)** to maintain user state at the application level.

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3. HTTP Methods and Status Codes

HTTP methods (or verbs) indicate the desired action to be performed on a resource. HTTP status codes indicate the outcome of an HTTP request.

Common HTTP Methods:

Common HTTP Methods:

Method	Use Case	Idem-potent?
`GET`	Retrieve data	Yes
`POST`	Submit new data, create resources	No
`PUT`	Update/replace an existing resource	Yes
`DELETE`	Remove a resource	Yes
`PATCH`	Apply partial modifications to a resource	No
`HEAD`	Get headers only (no body)	Yes

Idempotency is crucial in system design. An idempotent operation can be performed multiple times without changing the result beyond the initial application. This is vital for retries in distributed systems where network failures are common. `GET`, `PUT`, and `DELETE` are idempotent, while `POST` and `PATCH` generally are not.

Common HTTP Status Codes:

- **1xx (Informational)**: Request received, continuing process.

- **2xx (Success)**:
  - `200 OK`: Request succeeded.
  - `201 Created`: Resource successfully created.
- **3xx (Redirection)**: Further action needed to complete the request.
  - `301 Moved Permanently`: Resource moved.
  - `302 Found`: Temporary redirect.
- **4xx (Client Error)**:
  - `400 Bad Request`: Invalid syntax.
  - `401 Unauthorized`: Authentication required.
  - `403 Forbidden`: Server understood, but refuses to authorize.
  - `404 Not Found`: Resource not found.
- **5xx (Server Error)**:
  - `500 Internal Server Error`: Generic server error.
  - `502 Bad Gateway`: Server acting as gateway received invalid response.
  - `503 Service Unavailable`: Server temporarily unable to handle request.

4. Limitations of HTTP

While revolutionary, HTTP had significant limitations that became critical as the internet evolved into a platform for sensitive transactions and personal data:

1. **No Encryption**: All data (requests, responses, headers, body) is sent in **plain text**. This means anyone with access to the network path (e.g., your ISP, a public Wi-Fi operator, or a malicious actor) can easily read your information.
2. **No Authentication**: There's no inherent way to verify the identity of the server you're communicating with. You could be talking to an imposter without knowing.
3. **No Integrity**: Data transmitted over HTTP can be modified in transit without detection. A malicious actor could change the contents of a webpage or an API response.

These vulnerabilities exposed users to serious security risks:

- **Eavesdropping**: Confidential information (passwords, credit card numbers) could be stolen.
- **Man-in-the-Middle (MITM) Attacks**: An attacker could intercept communication, impersonate both parties, and read or alter data.

- **Injection Attacks**: Malicious code could be injected into unencrypted web traffic.

As web applications scaled and began handling more sensitive data, the need for robust security and privacy became paramount, leading to the development and widespread adoption of HTTPS.

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5. What is HTTPS?

HTTPS (HTTP Secure) is not a separate protocol but rather HTTP layered on top of **SSL/TLS (Secure Sockets Layer / Transport Layer Security)**. This cryptographic protocol provides secure communication over a computer network. By default, HTTPS uses **port 443**.

HTTPS provides three core guarantees:

1. **Encryption (Confidentiality)**: All data exchanged between the client and server is encrypted, making it unreadable to third parties who might intercept the traffic. It's like sealing your message in an unbreakable digital envelope.
2. **Integrity**: It ensures that the data has not been tampered with or corrupted during transit. If any changes occur,

both the client and server will detect them.

3. **Authentication**: It verifies the identity of the server (and optionally the client) using digital certificates. This assures the client that they are talking to the legitimate server and not an imposter.

The foundation of HTTPS is **Public Key Infrastructure (PKI)**, which uses a combination of public and private keys, along with digital certificates issued by trusted **Certificate Authorities (CAs)**, to establish secure connections.

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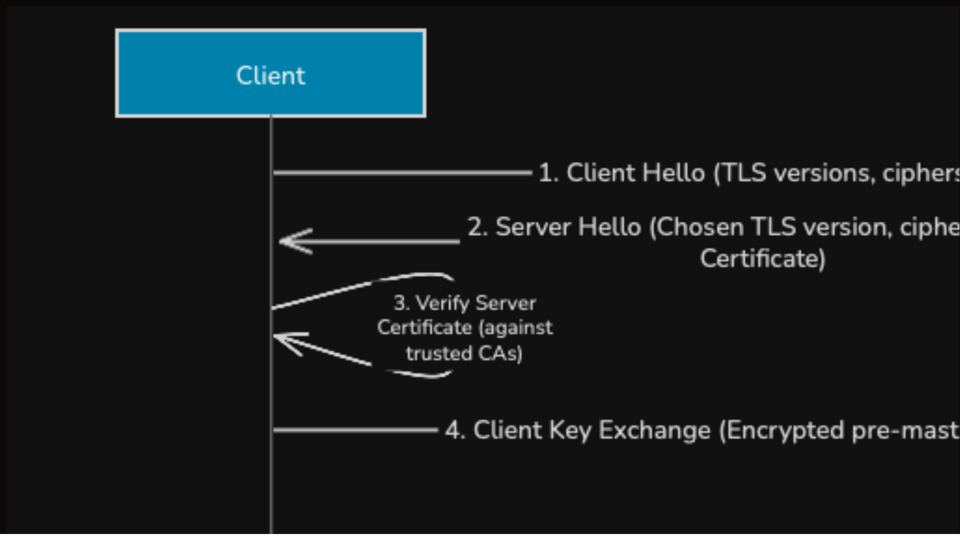
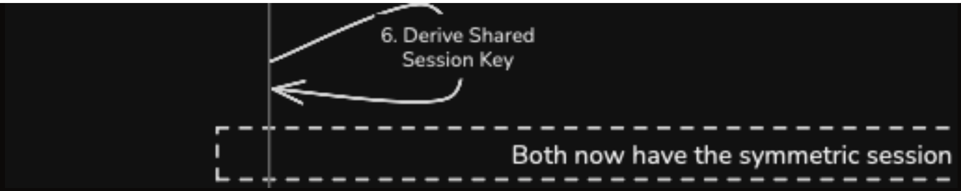
6. How HTTPS Works

The secure connection in HTTPS is established through a process called the **TLS Handshake**.





1. **Client Hello**: The client initiates the connection, sending a "Client Hello" message that includes its supported TLS versions, cipher suites, and a random number.
2. **Server Hello**: The server responds with a "Server Hello," selecting the best TLS version and cipher suite, along with its own random number and its **SSL/TLS certificate**.
3. **Certificate Verification**: The client verifies the server's certificate by checking its validity, expiry date, and whether it's issued by a trusted **Certificate Authority (CA)**. This step ensures the client is talking to the legitimate server.
4. **Key Exchange**: The client and server then use public-key cryptography (from the server's certificate) to securely exchange a **pre-master secret**. Both parties then independently derive a **shared symmetric session key** using this secret and the random numbers.
5. **Encrypted Communication**: Once the session key is established, all subsequent application data (HTTP requests and responses) is encrypted and decrypted using this much faster **symmetric encryption** key.

Modern TLS versions (especially TLS 1.3) have significantly optimized this handshake process, often allowing **0-RTT (Zero Round Trip Time)** connections for clients that have previously connected to a server, reducing latency.

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7. HTTP vs. HTTPS: Key Differences

Feature	HTTP	HTTPS
Security	Unencrypted, data in plain text	Encrypted via SSL/TLS
Port	80	443
Performance	Slightly faster due to less overhead	Slightly higher latency (improving with TLS 1.3)
Authentication	None	Server authentication via digital certificates
Data Integrity	No guarantee, susceptible to tampering	Guaranteed against tampering
SEO & Trust	Lower ranking, browser warnings, "Not Secure"	Preferred by search engines, padlock icon, user trust
Use Case	Local development, internal, non-sensitive apps	All production web traffic, APIs, sensitive data

In modern applications, HTTPS is the undisputed default for all communication, especially in distributed systems handling any form of sensitive data.

8. Evolution of HTTP Protocols

HTTP has undergone significant evolution to meet the growing demands of the web.

HTTP/1.1 (1997)

- Introduced **persistent connections** (keep-alive), allowing multiple requests over a single TCP connection, reducing overhead.
- Enabled **caching mechanisms** and **virtual hosting**.
- **Limitation**: Still suffered from **head-of-line blocking**. Even with persistent connections, requests were processed sequentially. If one request was slow, it blocked all subsequent requests on that connection.

HTTP/2 (2015)

- Addressed HTTP/1.1's limitations by introducing **binary framing**, **multiplexing**, and **header compression**.
- **Binary Framing**: Data is no longer sent as plain text but in a binary format, making it more efficient to parse.
- **Multiplexing**: Allows multiple concurrent requests and responses over a *single TCP connection*, eliminating head-of-line blocking.
- **Header Compression (HPACK)**: Reduces redundant

header data, saving bandwidth.

- **Server Push**: Servers can proactively send resources to the client that it anticipates the client will need (e.g., CSS before it's requested in the HTML).
- **System Design Impact**: Significantly improved latency and efficiency for loading complex web pages with many assets. This is the foundation for many modern APIs and microservices.

HTTP/3 (2018, RFC 9114)

- The most radical change: it runs over **UDP (User Datagram Protocol)** instead of TCP, utilizing the **QUIC (Quick UDP Internet Connections) protocol**.
- **Why UDP?**: To overcome TCP's own head-of-line blocking (where a single lost packet on a TCP connection can stall all streams on that connection) and reduce handshake latency.
- **0-RTT Connection Establishment**: For repeat connections, HTTP/3 can often send data in the very first packet, dramatically reducing setup latency.
- **Connection Migration**: A client can seamlessly switch networks (e.g., from Wi-Fi to cellular) without dropping the connection, as QUIC connections are identified by a unique ID, not IP/port.

- **System Design Impact**: Ideal for real-time applications, faster connection establishment, and improved performance on unreliable networks. Google, YouTube, and Cloudflare are major adopters.