**Mission 3: Be a Express Mongoose Master**

**Module 12: Explore the Fundamentals of node.js**

**Lecture 12-1: How the Web Works**

When we open a website in the browser, a full process begins behind the scenes to connect our device (the client) with another computer (the server) to fetch data. This process involves several key steps: the browser sends an HTTP request to a server using the TCP/IP protocol over the internet. The request includes method type, headers, and sometimes a body. The server, which communicates using an IP address (not a domain name), processes the request and responds with an HTTP response that contains a status code, headers, and the main response body—the content we finally see on our screen. This entire interaction is possible through the client-server architecture and follows a structured request-response model.

**1. Client-Server Architecture**

The foundation of how the web works lies in the **client-server model**. A **client** is typically a web browser or application that makes a request for data. The **server** is a computer that listens for these requests and sends back responses. This structure allows centralized handling of data and logic, enabling users around the world to interact with websites and services.

**2. Request-Response Model**

The **request-response model** is the cycle through which clients and servers communicate. The client initiates a **request** to the server—this could be to fetch a web page, submit form data, etc. The server then processes that request and sends back a **response**. This loop is fundamental to every interaction on the web.

**3. Protocols**

A **protocol** is a set of rules that define how data is transmitted over the internet. One of the most important protocols in web communication is **HTTP (Hypertext Transfer Protocol)**. It governs how clients and servers format and transmit messages.

* **HTTP**: Defines how messages are formatted and transmitted between clients and servers.
* **HTTPS**: The secure version of HTTP. The “S” stands for **Secure**, and it uses **SSL/TLS encryption** to protect data from being intercepted during transfer.

**4. Domain Name, IP Address, and URL Structure**

When a user types a URL in the browser, it usually follows this format:  
protocol://domain-name/path — e.g., https://example.com/about

* **Domain Name**: A human-friendly address (like google.com) that maps to the server's actual location.
* **IP Address**: A numerical label (e.g., 172.217.160.78) that identifies a device on the internet. **Servers understand IP addresses**, not domain names.
* **DNS (Domain Name System)**: Translates domain names into IP addresses.
* **Port Number**: Specifies a particular process or service on a server. Common ones include 80 for HTTP and 443 for HTTPS.
* **Real Address**: The complete address used for communication often looks like: protocol://IP\_address:port\_number.

**5. TCP/IP and Socket Connection**

**TCP/IP** is the core communication protocol for the internet:

* **TCP (Transmission Control Protocol)**: Ensures reliable transmission of data packets by establishing a connection between client and server. It checks for errors and guarantees data arrives in the correct order.
* **IP (Internet Protocol)**: Handles the addressing and routing of data packets so they reach the correct destination.
* **Socket Connection**: A **socket** is one endpoint in a two-way communication link between two programs. TCP/IP uses sockets to establish and maintain the connection needed for web requests and responses.

**6. HTTP Request Structure**

An **HTTP request** is what the client sends to the server. It contains:

* **Request Method**: Defines the type of action. Common methods include:
  + GET: Retrieve data
  + POST: Send data (e.g., form submission)
  + PUT: Update existing data
  + DELETE: Remove data
* **Request Headers**: Key-value pairs that carry metadata, such as content type, authorization, and more.
* **Request Body**: Optional. Contains data the client wants to send to the server (typically used in POST or PUT requests).

**7. HTTP Response Structure**

Once the server processes the request, it sends back an **HTTP response**, which contains:

* **Status Code and Message**: Indicates the result of the request. Examples:
  + 200 OK: Successful
  + 404 Not Found: Resource not found
  + 500 Internal Server Error: Server failed to process request
* **Response Headers**: Provide metadata about the response, such as content type and caching information.
* **Response Body**: The main content returned by the server, such as an HTML page, JSON data, or images. This is what the user typically sees in the browser.

**Lecture 12-2: Frontend vs Backend Development**

When building a web application, two key sides work together: the **frontend** and the **backend**. The frontend is what users interact with—it runs in the browser (client-side) and is responsible for structure, style, and behavior. The backend runs on the server and handles data storage, logic, and interaction with databases. While frontend code runs in the browser after being converted to JavaScript, backend code runs on the server and can be written in multiple languages like JavaScript (via Node.js), Python, or PHP. In this model, the backend acts as a middleman between the client and the database. Websites can be either static (same content every time) or dynamic (content changes based on logic or data). Dynamic sites can be built using **Server-Side Rendering (SSR)** or **Client-Side Rendering (CSR)**, often powered by APIs that let the frontend fetch live data from the backend.

**1. Frontend and Backend Roles**

The frontend is the client-facing part of a web application. It runs in the browser and is responsible for how a website looks and responds to user actions. Frontend code (like HTML, CSS, and JavaScript) must be interpreted by the browser, so all code is ultimately converted to JavaScript before execution.

The backend, on the other hand, is the server-side logic of an application. It handles requests, processes data, interacts with databases, and sends responses. Backend code runs directly on the server and can be written in various languages such as Node.js (JavaScript runtime), Python, or PHP. Unlike frontend code, backend code is not visible or accessible to the user.

**2. Backend as the Middleman**

In a full-stack system, the backend plays the role of a middleman between the frontend and the database. When a user sends a request (like submitting a form), the frontend sends it to the backend server. The backend processes the request, interacts with the database if needed, and returns a response to the frontend.

Example:  
A file might be stored in the backend (e.g., user data), and a request is made from the frontend to access or modify it. The backend processes this request and updates or sends the data as needed.

**3. Static vs Dynamic Websites (In-Depth)**

A **static website** is made up of fixed content. Each page is pre-built using HTML and looks the same for every user. When someone visits the website, the server simply sends the existing HTML file to the browser without any processing or customization. Static websites are typically faster to load, easier to host, and secure since there's no backend logic or database connection involved. However, they cannot display user-specific data or respond to changes in real-time.

In contrast, a **dynamic website** generates content based on logic or data at the time of the request. These websites are built using both frontend and backend technologies and often connect to a database. Dynamic websites are essential when personalized content, user authentication, or interactive features are required.

There are two main ways to build dynamic websites:

**a) Server-Side Rendering (SSR)**

In **Server-Side Rendering**, the backend generates the complete HTML content based on data and logic and sends it to the browser. For example, when a user visits a news site, the server fetches the latest articles from the database, renders them into HTML using a template engine (like EJS, Handlebars, etc.), and sends that HTML to the browser. This approach is great for SEO (since search engines can read the fully rendered content) and provides a faster initial page load.

**How SSR works:**

1. Client makes a request (e.g., visiting a URL).
2. Server processes the request and fetches data if needed.
3. Server uses a **template string** to generate HTML dynamically.
4. Server sends the complete HTML response to the browser.

**b) Client-Side Rendering (CSR)**

In **Client-Side Rendering**, the server usually sends a minimal HTML file with a JavaScript bundle. The browser then fetches data from the backend using **API calls** (typically via fetch or axios), and the frontend JavaScript takes care of rendering the content. Frameworks like React, Vue, or Angular are commonly used in CSR.

**How CSR works:**

1. Client loads the initial HTML + JS from the server.
2. JS runs in the browser and makes an API request.
3. Server sends back data in JSON format.
4. JS dynamically updates the page with new content.

CSR allows rich interactivity and faster navigation after the first load, but it can affect SEO and the initial load time if not optimized properly.

**Key Differences:**

|  |  |  |
| --- | --- | --- |
| Aspect | Static Website | Dynamic Website (SSR/CSR) |
| Content | Predefined and fixed | Generated per user or logic |
| Server interaction | No backend needed | Requires backend/server |
| Performance | Very fast | Slightly slower (depends) |
| Personalization | Not possible | Easily achievable |
| Example use cases | Portfolio, Blog, Landing page | E-commerce, Dashboards, Social Media |

In modern web development, many applications use a hybrid approach—where SSR is used for initial page load and CSR is used for interactive parts of the app. This balances performance, SEO, and user experience.

**4. API and Its Benefits**

An **API (Application Programming Interface)** is a set of rules that allows the frontend to communicate with the backend. It defines how the frontend can send requests and get responses from the server or database.

**Benefits of Using APIs:**

* **Separation of concerns**: Frontend and backend can be developed independently.
* **Reusability**: APIs can be used across multiple platforms (web, mobile).
* **Scalability**: API-based systems can handle more users efficiently.
* **Flexibility**: Developers can update frontend or backend without breaking the entire system.

**5. Keyword Definitions**

* **Frontend**: The client-side of a web app that users see and interact with (HTML, CSS, JS).
* **Backend**: The server-side logic that handles data and communication with the database.
* **Client**: The browser or device that requests data.
* **Server**: The machine or system that processes client requests.
* **Node.js**: A JavaScript runtime that allows using JS on the backend.
* **Static Website**: A site with fixed content that doesn’t change based on user input.
* **Dynamic Website**: A site that updates content dynamically based on logic or data.
* **SSR (Server-Side Rendering)**: Webpage content is generated on the server and sent to the client.
* **CSR (Client-Side Rendering)**: Webpage content is generated in the browser using data from APIs.
* **API**: A bridge that allows communication between client and server.

**Lecture 12-3: Why Node js was invented**

Web development has evolved from simple, text-based pages to rich, interactive applications requiring powerful backend logic. Traditionally, full-stack developers needed to learn two different languages — one for the browser (like JavaScript) and one for the server (like PHP, Python, or Java). Node.js changed this by allowing JavaScript to run outside the browser, specifically on the server. Built on Chrome's V8 engine and written in C and C++, Node.js gave developers the ability to use a single language across both client and server. Its architecture, which includes event loops, a call stack, web APIs, and asynchronous handling via callback queues, makes it well-suited for building scalable, real-time applications. However, it's not perfect, especially for CPU-heavy tasks. Node.js remains popular due to its simplicity, performance, and large ecosystem of packages — made possible through key dependencies like V8 and libuv.

**1. Evolution of Web Development & The Birth of Full-Stack Roles**

In the early days of the internet, websites were simple documents that displayed plain **text**. Eventually, the demand for better design led to the introduction of **CSS**, which made it possible to style web pages. As user expectations grew, so did the need for **interactivity**, which gave rise to **JavaScript** — a scripting language designed to run in the browser and manipulate the **DOM (Document Object Model)**.

However, developers who wanted to build both the frontend and backend of an application had to learn two different programming languages. For instance, they used JavaScript for frontend behavior and PHP, Python, or Ruby for backend logic. This split increased the learning curve and development complexity for full-stack developers.

**2. Why Node.js Was Invented**

Node.js was created to solve this problem. It allowed **JavaScript to run on the server**, enabling developers to write both frontend and backend logic in the same language. This eliminated the need for switching between different languages and brought consistency to the development workflow. The invention of Node.js empowered JavaScript to leave the browser environment and perform tasks like reading files, handling databases, and managing servers — all of which were previously outside its reach.

**3. JavaScript Engine and Code Execution Process**

JavaScript runs inside the browser using a **JavaScript engine** — for example, Chrome uses the **V8 engine**. When JS code is executed, it goes through the following process:

**JS Code → Parser → Abstract Syntax Tree (AST) → Interpreter → Compiler → Output**

First, the parser reads the JavaScript code and converts it into an **Abstract Syntax Tree (AST)** — a tree-like representation of the code structure. The **interpreter** starts executing the code line-by-line for quick feedback, while the **compiler** (often a Just-In-Time compiler) optimizes the code for better performance during execution. The output is what the user sees or what the program returns.

**4. What Is Node.js? A JavaScript Runtime Outside the Browser**

**Node.js** is not a programming language or framework — it’s a **JavaScript runtime environment** built using **C, C++**, and the **V8 engine**. It allows JavaScript to be executed **outside the browser**, especially on the server-side. This makes it possible to use JavaScript to handle files, databases, APIs, network requests, and more — capabilities that traditional JavaScript running in the browser doesn't have.

**5. Why JavaScript Could Not Access the Server Before Node.js**

In a browser, JavaScript is sandboxed for security reasons. It only has access to the **DOM**, which allows it to manipulate HTML, CSS, and handle browser-based events. It **cannot directly access the file system, server, or databases** — features that backend languages like PHP or Python can handle. This limitation is what Node.js overcame by creating a bridge between JS and the server environment.

**6. How Node.js Executes Code: Key Components**

Node.js handles code execution using several internal components:

* **Call Stack**: This keeps track of function calls and their order.
* **Heap**: An area in memory used to store objects and variables.
* **Web APIs**: When asynchronous tasks (like timers or network requests) are initiated, they are handed over to these APIs provided by Node (not the browser).
* **Callback Queue**: When async tasks are complete, their callback functions are queued here.
* **Event Loop**: Continuously checks if the call stack is empty and if there are callbacks in the queue. If so, it moves them to the call stack to be executed.

This system allows Node.js to handle thousands of concurrent connections **without blocking**, making it perfect for real-time applications.

When Node.js runs a JavaScript program, the process starts with the **Call Stack**, where all function calls are tracked. Whenever a function is invoked, it is pushed onto the stack. If a function involves a long-running task, such as reading a file or making a network request, it doesn’t wait there. Instead, Node.js offloads this task to the **Web APIs**, which are provided by the environment (not part of JavaScript itself). These APIs handle operations like timers, HTTP requests, or file system access independently. Once the asynchronous task is completed, a **callback function** associated with that task is sent to the **Callback Queue**. Meanwhile, the **Event Loop** is constantly checking whether the call stack is empty. If it is, the event loop pushes the next function from the callback queue onto the call stack for execution. While this happens, Node.js also uses a **Heap** — a memory space — to store variables and objects. This architecture allows Node.js to handle multiple requests concurrently and efficiently without blocking the main thread, making it ideal for real-time and high-performance applications.

**7. Node.js Architecture and Dependencies: V8 and libuv**

Node.js relies on two major components:

* **V8 Engine**: Developed by Google, this is the same engine used in Chrome to execute JavaScript. It converts JS into machine code quickly and efficiently.
* **libuv**: A C library that provides **event-driven architecture** and handles **asynchronous I/O operations**. It manages the **event loop** and **thread pool**, enabling non-blocking operations such as file reads and network requests.

These components work together to give Node.js its speed and efficiency.

**8. Advantages and Popularity of Node.js**

Node.js is extremely popular because it allows **JavaScript everywhere** — on both client and server. It supports **non-blocking I/O**, has a massive package ecosystem via **npm**, and is easy to learn for developers already familiar with JS. It’s widely used in startups, real-time applications (like chat apps), REST APIs, and microservices.

**9. Limitations of Node.js**

Despite its advantages, Node.js has some limitations. It is **not suitable for CPU-intensive tasks** like image processing or complex mathematical computations. Since Node.js uses a single-threaded event loop, heavy CPU tasks can **block** the loop, degrading performance for all users. For such cases, languages like Python, C++, or Go may be more suitable.

**Lecture 12-4: High level overview of Node.js architecture**

**📌 Understanding Node.js Event-Driven Architecture**

We often hear that **Node.js is event-driven**, but what does that actually mean?

Let’s take a simple example from everyday life.

Suppose your **cousin says they’ll bring you a packet of chips**. They go to the store, buy it, and later **knock on your door**. You take the chips from them at that time.

Here, your cousin doesn’t tell you **exactly when** they'll return. Instead, **you wait for a signal (the knock)** that tells you they’ve come back. You don’t stop your life in the meantime—you go on doing other tasks.

This is exactly how **Node.js works**. It delegates a task (like reading a file or fetching data), and then **moves on to the next task** without waiting. Once the previous task is completed, **an event is triggered**, and **a callback function runs** to handle the result.

This entire flow is controlled by the **event loop**, which is often called **the heart of Node.js** because it handles almost everything internally.

**🧠 Before You Understand the Event Loop: Understand Process and Thread**

**What is a Process?**

Think of a **process** as a program that’s loaded into memory to run. For example, when you write a program, it’s just a set of instructions. It lives on your hard drive as a file, but it’s not "alive" yet.

When you run that file, your computer loads it into RAM, creates a specific environment for it to run, and this running instance is called a **process**. It includes resources like memory, registers, the program counter, and the stack.

Every process is isolated and runs independently. You can have multiple processes running at the same time, each with its own memory and context.

Now, when you run it with the command:

node server.js

Your operating system:

1. Loads the file into RAM (memory).
2. Creates a **new environment to run this program**.
3. Allocates memory, registers, and other necessary resources.

This running environment is called a **process**.

So, a **process** is:

* An independent unit of execution.
* Has its own memory, call stack, and other runtime components.
* Isolated from other processes.

🧠 You can think of a process like a hotel room that has its own setup—bed, AC, bathroom—and doesn’t share it with any other room (process).

**What is a Thread?**

A **thread** is the smallest unit of execution inside a process. A process can have one or more threads. Each thread has its own call stack, registers, and program counter.

There are two main types:

* **Single-threaded**: Only one thread runs tasks one by one.
* **Multi-threaded**: Multiple threads can run tasks in parallel.

Node.js is **single-threaded**, meaning it uses one main thread to run code. But it can still handle many tasks efficiently—thanks to its **asynchronous and non-blocking** model.

**⚙️ Node.js Runtime = Single Thread + Event Loop + Thread Pool**

When you run a JavaScript program with Node.js, you're actually running it in a special environment. This environment (Node.js runtime) is itself a **process**.

When you run a JavaScript file in Node.js:

1. A **process** is created.
2. A **single thread** is started to execute your JavaScript code.
3. Behind the scenes, **Node.js sets up an event loop** and a **thread pool (from libuv)** to handle asynchronous tasks.

Node.js runs on a **single thread**, which executes all your top-level code (outside any callback or event handler). It:

1. Loads and initializes modules.
2. Registers event listeners and callback functions.
3. Starts the **event loop**.

**🔁 Event Loop and Thread Pool**

Once everything is set up, the **event loop** starts running. It continuously checks for tasks like incoming data, timer completions, or file reads. When it finds a task ready to be executed, it picks the associated callback and runs it.

But what about heavy tasks like reading a big file or performing complex calculations?

Here’s where **the thread pool** comes in.

Node.js uses a **libuv-based thread pool** (default size: 4 threads) to offload heavy or blocking operations like file I/O. For example:

* When your code requests to read a file, the task is sent to the thread pool.
* A thread from the pool handles it without blocking the main thread.
* Once it’s done, it sends the result back to the event loop, which then executes the callback.

This way, **other users or tasks are not blocked**, and everything runs smoothly.

Let’s explain this important concept with a **real example** and **step-by-step flow**.

**🧪 Example Code:**

console.log('1');

setTimeout(() => {

console.log('2');

}, 2000);

console.log('3');

**✅ What happens when we run this?**

1. **Step 1: JavaScript engine starts execution**
   * It runs line by line.
   * Outputs 1.
2. **Step 2: setTimeout() is registered**
   * You tell Node.js: “Run this callback **after 2 seconds**.”
   * Node.js hands this off to **libuv** (a C++ library that manages the thread pool, timers, etc.).
   * The callback is registered and left alone for now.
   * Execution moves on without waiting.
3. **Step 3: Outputs 3**
   * This line is executed right after setTimeout.
4. **Step 4: Event Loop Starts Checking**
   * The main script is now done.
   * Node.js now enters the **event loop**.
   * It waits for events to happen (like timers finishing, I/O completing).
5. **Step 5: Timer expires after 2 seconds**
   * After 2 seconds, the setTimeout task is marked as **ready**.
   * Event loop picks up the callback (console.log('2')) and moves it to the **call stack**.
6. **Step 6: Callback executes**
   * 2 is printed.

**⏱ Final Output:**

1

3

2

**💡 So, What Is the Event Loop Doing?**

Think of the event loop as a **security guard** at a club:

* You (the code) tell the guard (event loop) that some VIPs (callbacks) will arrive later.
* The guard waits at the door.
* When a VIP shows up (like the result of a timer or file read), the guard lets them in one by one.
* No VIP can enter unless the guard is free to let them in (call stack is empty).

**🔄 Thread Pool – What If a Task Is Blocking?**

Suppose you have a heavy task, like reading a large file from disk.

If JavaScript tries to do it directly on the main thread, it will **block** other tasks. So instead:

* Node.js passes that task to **libuv’s thread pool** (default: 4 threads).
* One of the threads works on that task.
* When done, it **notifies the event loop**.
* The event loop picks up the callback and executes it.

**✅ This is how Node.js stays non-blocking and fast, even with just one main thread.**

**Summary**

Even though Node.js runs on a **single thread**, it:

* Uses the **event loop** to manage tasks efficiently.
* Offloads blocking operations to a **thread pool**.
* Supports **asynchronous execution**, allowing multiple tasks to progress at the same time.

This is the power of Node.js’s **event-driven architecture**—it helps you build fast, scalable applications, even with a single thread.

**Lecture 12-5: Single threaded node.js**

**Client-Server Architecture: Then and Now**

In the past, web applications often had the server handle everything. This meant the **server** contained all the **HTML, CSS, and JavaScript** needed to display the user interface. When you visited a website, the server would send you a complete, ready-to-display page. This approach worked well for browsers, but it limited flexibility. If you wanted to build a mobile app, you'd effectively need a separate server setup for it, or you'd be unable to reuse your server-side code.

Modern applications separate the **server (backend)** from the **client (frontend)**.

* The **client** can be a web browser, a mobile app (Android or iOS), or a desktop application. Its job is to handle the **user interface (UI)** and user interactions using technologies like HTML, CSS, and JavaScript.
* The **server** is purely for backend tasks. It manages **databases**, performs **heavy computations**, and handles core business logic.

When a client needs data, it sends a **request** to the server, and the server responds by sending back **JSON (JavaScript Object Notation) data**. The client then takes this JSON data and processes it to display it in its own unique UI.

The big advantage of this separation is **cross-device compatibility**. The same backend server can provide data to a browser, a mobile app, or a desktop app, as they all receive the same JSON. This makes development more efficient and allows for broader platform reach.

**Types of Server Tasks**

A server generally deals with two main types of tasks:

1. **I/O Intensive Tasks (Input/Output Intensive):** These tasks involve waiting for data to be read from or written to external sources. Examples include:
   * Fetching data from a **database**.
   * Reading or writing **files** from disk.
   * Making requests to **external APIs** (other servers).
   * Sending large amounts of data (like images) to the client. During these tasks, the server often spends more time waiting for the external operation to complete than actively computing.
2. **CPU Intensive Tasks (Central Processing Unit Intensive):** These tasks require significant processing power from the server's CPU to perform calculations. Examples include:
   * **Complex data transformations**.
   * **Image or video processing**.
   * **Encryption or decryption**.
   * Running sophisticated **algorithms**. These tasks keep the CPU busy with active computation.

**Multi-Threaded Servers: How They Work**

Traditionally, many server-side languages and frameworks operate as **multi-threaded servers**. Think of a multi-threaded server as having multiple "workers" (threads) ready to handle requests simultaneously.

When a client sends a request, a **dedicated thread** on the server picks up that request and handles its entire process. If another client sends a request at the same time, a **different thread** can handle it independently.

The main benefit here is that **threads don't block each other**. If one request is waiting for a database to respond (an I/O operation), another request, handled by a separate thread, can proceed without waiting. This allows for excellent **concurrency**.

However, multi-threaded servers usually have a **fixed number of threads**. If all threads are busy, any new incoming requests will have to **wait in a queue** until a thread becomes free. For example, if a server has 10 threads, it can handle 10 requests concurrently. An 11th request would wait. This waiting can lead to delays.

To manage this limitation, multi-threaded systems often employ **scaling strategies**:

* **Horizontal Scaling:** Adding more servers. If one server has 10 threads, adding another server doubles the capacity to 20 threads. This means more machines, more setup, and higher costs.
* **Vertical Scaling:** Upgrading a single server's resources, like adding more CPU cores or RAM. For instance, upgrading an 8-core server to a 32-core server. This increases the power of a single machine, but higher-end hardware is very expensive.

Both scaling methods lead to significantly increased costs and resource consumption.

**Node.js: Single-Threaded with Non-Blocking I/O**

Node.js is unique because it's fundamentally a **single-threaded runtime**. This means your main JavaScript code runs on just one thread. At first, this seems problematic: how can one thread handle many requests concurrently without blocking?

Node.js solves this with a brilliant design: **non-blocking I/O**, powered by an **Event Loop** and an underlying **Thread Pool**.

1. **I/O Intensive Tasks:** When Node.js encounters an I/O operation (like fetching data from a database or reading a file), it doesn't execute that operation on its single main thread. Instead, it **offloads** the task to an internal **Thread Pool** (managed by libuv under the hood). The main Node.js thread immediately becomes **free** to process the next incoming request. It doesn't wait for the I/O to complete.
2. **Asynchronous Processing:** Once the task in the Thread Pool finishes (e.g., the database returns data), it notifies the **Event Loop**. The Event Loop then places a "callback" for that completed task into a queue. When the main Node.js thread finishes its current execution, the Event Loop picks up the next callback from the queue and executes it. This is **asynchronous** execution.

This mechanism is called **Non-Blocking I/O** because even though there's only one main thread, I/O operations don't block subsequent requests. Many I/O requests can be initiated and handled concurrently by the Thread Pool, while the main thread remains responsive.

However, there's a "catch" with Node.js and **CPU Intensive Tasks**: Historically, CPU-intensive tasks **run directly on the main Node.js single thread**. If a complex calculation takes a long time (e.g., 10 seconds), the **entire Node.js application will be blocked** during that period. No other requests (even I/O ones) can be processed until that heavy computation finishes. This is why Node.js was traditionally not recommended for applications that are primarily CPU-bound.

**Modern Solution: worker\_threads** Fortunately, recent Node.js versions introduced the **worker\_threads module**. This allows developers to explicitly create and manage additional threads within a Node.js application. Now, you can offload those CPU-intensive tasks to these dedicated worker threads, ensuring the main Node.js thread remains free and non-blocked.

This means Node.js can now effectively handle both I/O intensive tasks (via the Event Loop and Thread Pool) and CPU intensive tasks (via worker\_threads), making it a highly versatile and powerful runtime. The **Event Loop** continues to be the core orchestrator, ensuring smooth, non-blocking operations.

**Overall Summary:** Traditional servers often bundle client and server logic, typically using a multi-threaded approach to handle concurrent requests. While multi-threading prevents blocking between requests, it faces limitations in scalability without significant cost increases. Node.js, a single-threaded runtime, overcomes this by using non-blocking I/O: it offloads I/O tasks to a separate thread pool, keeping its main thread free for new requests, orchestrated by an Event Loop. For CPU-intensive tasks, which previously blocked the single thread, Node.js now offers worker\_threads to enable true multi-threading, expanding its capabilities for a wider range of applications.

**Lecture 12-6: How Event Loop Works**

**The Event Loop: Orchestrating Node.js's Concurrency**

As we know, Node.js is a single-threaded runtime. This means your main JavaScript code executes on a single thread. However, Node.js can still handle many operations concurrently, especially I/O intensive tasks. This is primarily managed by the **Event Loop** and an underlying **Thread Pool**.

When an I/O intensive task (like a database query or file read) is encountered by the single thread, it's offloaded to the **Thread Pool** for execution. Once the task in the Thread Pool completes, the result is sent back to the single thread, which then prepares the response for the user. The entire process of offloading tasks to the Thread Pool, completing them, and sending back responses is orchestrated by the **Event Loop**.

The Event Loop operates on an **event-driven architecture**. This means it constantly "listens" for events (like a new request coming in or an I/O operation completing). When an event is "triggered," the Event Loop takes action:

1. It sends the task to the Thread Pool if it's an I/O operation.
2. Once the Thread Pool finishes the task, it signals back to the Event Loop.
3. The Event Loop then pushes the result (via a callback function) to be processed by the single thread.
4. Finally, the single thread sends the response back to the user.

The Event Loop is a continuous process that runs as long as the Node.js application is active. It acts like a "watchman," always observing for triggered events and ensuring they are handled efficiently without blocking the main single thread.

**How the Event Loop Works: Phases and Queues**

The Event Loop executes in distinct "phases," constantly looping through them. When a Node.js process starts, the Event Loop activates and begins this continuous cycle. It also manages several "queues" where operations wait to be processed. The most important one is the **Callback Queue**.

The Event Loop's operational flow involves several phases, executed in a specific order within each cycle:

1. **Timers Phase (setTimer callbacks):**
   * The Event Loop first checks for any **setTimeout()** or **setInterval()** callbacks that are due to execute. These are functions scheduled to run after a certain delay.
   * These timers have the highest priority in this specific cycle of the event loop.
2. **I/O Callbacks Phase (I/O polling and callbacks):**
   * After processing timers, the Event Loop moves to this phase.
   * It checks for and executes callbacks related to **I/O operations** that have completed (e.g., database query results, file read completions, network requests). These are the tasks that were initially offloaded to the Thread Pool.
3. **setImmediate() Callbacks Phase:**
   * This phase handles callbacks scheduled by **setImmediate()**. These are functions that are executed immediately after the current phase of the Event Loop completes.
4. **Close Callbacks Phase (close events):**
   * Finally, this phase handles any close event callbacks, such as those triggered when a socket or handle is unexpectedly closed.

**Between these main phases**, the Event Loop also processes special queues:

* **process.nextTick() Queue:** Callbacks in this queue have the **highest priority** and are executed immediately after the current operation on the call stack completes, *before* the Event Loop moves to the next phase. If you have a process.nextTick() call, it will run even before setImmediate() or setTimeout().
* **Microtask Queue (Promises, queueMicrotask):** This queue holds callbacks for resolved Promises and tasks scheduled with queueMicrotask(). These microtasks are also executed right after the current operation on the call stack finishes, and before the Event Loop proceeds to the next main phase. They generally run *after* process.nextTick() callbacks.

Understanding these phases and queues is crucial for comprehending how Node.js manages concurrency and the order in which different types of operations are processed. While you might not always need to manipulate these directly in daily coding, knowing this architecture is vital for advanced Node.js development, debugging performance issues, and customizing its behavior.

**Overall Summary:** The Node.js Event Loop orchestrates its single-threaded, non-blocking I/O model. It continuously cycles through distinct phases (Timers, I/O Callbacks, setImmediate, Close Callbacks) to process events. I/O tasks are offloaded to an internal Thread Pool, and their results return to the Event Loop, which then queues their callbacks for the single thread. High-priority process.nextTick() and Microtask (Promises) queues are processed between main Event Loop phases, ensuring efficient and non-blocking execution flow. Understanding these phases and queues is key for advanced Node.js development.

**Lecture 12-7: Install Node js using fnm**

Let's break down the process of installing Node.js using FNM (Fast Node Manager) and understand Node.js versioning.

**Understanding Software Versioning**

In the digital world, we constantly work with various software and packages, from mobile apps to developer tools. You'll notice that every piece of software you use has a **version number**.

Think about your mobile phone: your Android operating system frequently gets new updates, right? Or if you're a Windows user, you get Windows updates. When you install a Facebook update from the Play Store, it often comes with security fixes or new features. Each of these updates signifies a change, and these changes are tracked by a **version number**. This numbering helps us identify different iterations of a software.

**Node.js Versioning Explained**

Node.js, being a piece of software, also follows a versioning scheme. It's common to work with different Node.js versions, so understanding its versioning is crucial. A typical Node.js version, for example, 20.11.1, is divided into three parts separated by dots:

1. **Major Version (e.g., 20):**
   * This number indicates a **major change** in the software.
   * Major changes often introduce **breaking changes**, meaning features that worked in previous major versions might not work the same way (or at all) in the new major version.
   * For example, when a significant new system or paradigm was introduced into Node.js, it might trigger a major version increment.
   * Node.js version 20 is a Long Term Support (LTS) version, meaning it receives extended maintenance. Node.js version 24 is a newer major version.
2. **Minor Version (e.g., 11):**
   * This number signifies **minor changes** or **improvements** to existing features.
   * Minor versions typically add new functionalities in a backward-compatible way, meaning they shouldn't break existing code.
   * For instance, an optimization or enhancement to an existing feature within the Node.js 20 series would increment the minor version (e.g., from 20.10.x to 20.11.x).
3. **Patch Version (e.g., 1):**
   * This number represents **small updates**, primarily for **bug fixes** or **security patches**.
   * Patch versions are meant to be fully backward-compatible and address critical issues without introducing new features or breaking existing ones.
   * For example, a quick security update to Node.js 20.11.0 would result in version 20.11.1.

These three numbers combined give a complete picture of a software's version, indicating the scope of changes it contains.

**Installing Node.js Using FNM on Windows**

The lecture focuses on installing Node.js using **FNM (Fast Node Manager)**, a tool that makes managing multiple Node.js versions easy. The example given is for Windows.

Here's a breakdown of the installation steps and common issues:

1. **Install FNM via PowerShell:**
   * The first step is to open PowerShell and run the command: wget install-fnm.now.sh -OutFile install-fnm.ps1; & install-fnm.ps1 (Note: The lecture used wget install.fnm.now.sh -OutFile install-fnm.ps1; & install-fnm.ps1 but the official FNM script is https://fnm.vercel.app/install).
   * This command downloads the FNM installation script and then executes it, installing FNM on your system.
2. **Verify FNM Installation:**
   * After installation, you might try to check the FNM version by typing fnm --version in PowerShell.
   * **Common Issue:** You might receive an error stating that fnm is not recognized.
   * **Solution:** The installer often suggests closing and reopening your PowerShell terminal. This is because environment variables (which tell your system where to find fnm) need to be reloaded. After restarting PowerShell, fnm --version should display the version.
3. **Locating FNM Installation Path (for manual environment variable setup):**
   * FNM typically automatically adds its path to your system's environment variables. However, if it doesn't, you might need to add it manually.
   * To find the path, navigate to: C:\Users\<YourUsername>\AppData\Local\fnm. (Note: AppData is usually a hidden folder, so you might need to enable "Show hidden items" in File Explorer's View tab.)
   * Inside the fnm folder, you'll likely find the fnm.exe executable. The path to this folder (e.g., C:\Users\<YourUsername>\AppData\Local\fnm) should be added to your system's Path environment variable. This ensures your command line can find the fnm command.
4. **Installing a Node.js Version with FNM:**
   * Once FNM is installed and accessible, you can install a specific Node.js version. For example, to install Node.js version 20, you would use: fnm install 20.
   * FNM will download and install the specified Node.js version.
5. **Setting a Default Node.js Version:**
   * After installing a Node.js version, you can set it as the default for your system: fnm default 20.
   * Now, when you type node --version in your terminal, it should show the default version you set (e.g., v20.x.x).
6. **Managing Multiple Node.js Versions:**
   * FNM's real power comes from easily switching between different Node.js versions.
   * To see all installed Node.js versions, use: fnm list.
   * To switch to a different version, use: fnm use <version\_number> (e.g., fnm use 24). This temporarily changes the Node.js version for your current terminal session.
   * To set a new default version, use fnm default <version\_number>.

Using FNM simplifies managing multiple Node.js versions on your machine, which is incredibly useful for developers working on different projects that might require specific Node.js environments.

**Overall Summary:** Software versioning uses major, minor, and patch numbers to indicate the scope of changes (breaking, new features, bug fixes, respectively). Node.js follows this. Installing Node.js with FNM (Fast Node Manager) on Windows streamlines version management. After installing FNM via PowerShell, you can use commands like fnm install <version>, fnm default <version>, and fnm use <version> to easily install, set default, and switch between different Node.js versions, which is essential for developers working with varied project requirements.

**Lecture 12-8: Modular System in node js**

**The Evolution of JavaScript Scope and Organization**

In the early days of web development, we would create a website's structure with HTML, beautify it with CSS, and add interactivity using JavaScript. Back then, when declaring variables in JavaScript, we commonly used the var keyword.

**The Problem with var and Global Scope**

The main issue with var was that variables declared with it were often **globally accessible**. Global scope refers to a top-level object in JavaScript (like the window object in browsers) where many built-in functions (like setTimeout, setInterval) and globally declared variables reside.

For instance, if you declared var myVariable = 10; or a function var myFunction = function() { ... };, both myVariable and myFunction would be accessible directly through window.myVariable and window.myFunction (in a browser environment). This means any script, anywhere on the page, could potentially access or modify these variables and functions.

This global accessibility led to significant problems:

* **Naming Conflicts:** If multiple JavaScript files were included in an HTML page, and each file declared a variable or function with the same name using var, they would **overwrite** each other, leading to unexpected behavior and bugs.
* **Lack of Encapsulation:** It was difficult to create self-contained pieces of code, as everything could potentially be accessed or modified by other parts of the application.

**Introducing let and const for Block Scope**

To solve these problems, ES6 (ECMAScript 2015) introduced let and const. Variables declared with let or const are **block-scoped**, meaning they are only accessible within the block of code (e.g., inside curly braces {}) where they are defined, not globally.

For example, if you declare let myVariable = 10;, myVariable will *not* be accessible via window.myVariable in the global scope; attempting to do so would result in undefined. This fundamental change helped prevent naming conflicts and provided better encapsulation for variables.

**Immediate Invoked Function Expressions (IIFEs)**

Even before let and const became widely adopted, developers used a pattern called **Immediately Invoked Function Expressions (IIFEs)** to create isolated scopes. An IIFE is a function that is defined and executed immediately.

**Example of an IIFE:**

(function() {

let myLocalVariable = 10; // This variable is only accessible inside this IIFE

function add(a, b) {

return a + b;

}

console.log(add(myLocalVariable, 5));

})();

If you had two separate JavaScript files, each with an IIFE, and both IIFEs declared a variable named myLocalVariable or a function named add, they would not conflict because each exists within its own isolated function scope. This was a good way to prevent global namespace pollution.

While IIFEs were effective for preventing conflicts, they become challenging to manage and organize as an application grows very large. It's not practical to wrap every single piece of code in an IIFE. This led to the development of **modular systems**.

**Modular Systems in Node.js**

Modular systems allow you to break down your code into small, independent, and reusable units called **modules**. Each module is a self-contained "chunk of code" that encapsulates its own variables and functions, preventing global conflicts and promoting better organization.

Node.js primarily supports two main modular system concepts:

1. **CommonJS (CJS):** This is the original and default module system in Node.js.
   * **Exporting:** To make code available from one file to another, you use the module.exports object. You assign what you want to export (variables, functions, objects) to module.exports or exports.

// myModule.js

const PI = 3.14;

function add(a, b) {

return a + b;

}

module.exports = { PI, add }; // Exporting multiple items

* + **Importing (Requiring):** To use code from another module, you use the require() function.

// main.js

const { PI, add } = require('./myModule.js'); // Importing from myModule.js

console.log(add(PI, 5));

* + **File Naming:** CommonJS modules typically use the .js file extension.
  + **Analogy:** Think of CommonJS like a system where one country (your module file) explicitly **exports** a product (your code) to another country (another module file) that then **requires** or imports that product to use it.

1. **ECMAScript Modules (ESM or ES Modules):** This is the standardized module system for JavaScript, now also fully supported in Node.js.
   * **Exporting:** You use the export keyword.

// myModule.mjs (or .js if configured)

export const PI = 3.14;

export function add(a, b) {

return a + b;

}

// export default someDefaultValue; // For default exports

* + **Importing:** You use the import keyword.

// main.mjs (or .js if configured)

import { PI, add } from './myModule.mjs'; // Importing specific items

// import myDefaultValue from './myModule.mjs'; // For default imports

console.log(add(PI, 5));

* + **File Naming:** ES Modules typically use the .mjs file extension, or you can configure package.json to treat .js files as ESM.

Both CommonJS and ES Modules serve the same purpose: to make code in one file accessible and reusable in another file, while maintaining isolation and preventing global scope conflicts.

**Types of Modules in Node.js**

Node.js applications commonly use three types of modules:

1. **Local Modules:**
   * These are modules you **create yourself** within your project.
   * You write your own JavaScript files, define functions or variables, and then export them (using module.exports for CommonJS or export for ESM).
   * Then, in other files within your project, you require() or import these exported items to use them.
   * **Example:** If you have math.js with an add function, you'd export add from math.js and then require or import it into your app.js file.
2. **Built-in Modules:**
   * These are modules that come **pre-installed with Node.js** itself. They provide core functionalities like file system operations (fs), network communication (http), path manipulation (path), etc.
   * You don't need to install them; you just require() or import them directly by their name.
   * **Example:** const fs = require('fs'); or import http from 'http';
3. **Third-party Modules:**
   * These are modules created by **other developers** and are typically published to a package registry like **npm (Node Package Manager)**.
   * You install them into your project using npm install <package-name>.
   * Once installed, you can require() or import them into your project just like built-in modules.
   * **Example:** const express = require('express'); (after running npm install express)
   * These third-party packages themselves are often collections of modules, and the developers of these packages have already handled exporting their functionalities for you to use. You simply install and import.

Modular systems are fundamental to building scalable, maintainable, and organized Node.js applications. They allow developers to create clean, reusable code, avoiding the "spaghetti code" that can result from global scope pollution.

**Q57) What is the sessionStorage API in JavaScript?**

**Answer:** sessionStorage is similar to localStorage, but with one key difference: it only persists data for the duration of the page session. A session ends when the browser or tab is closed. It is typically used for storing temporary data that only needs to be available during a single session.**Example:**

sessionStorage.setItem('theme', 'dark');

let theme = sessionStorage.getItem('theme');

console.log(theme); // Outputs "dark"

In this example, the setItem() method stores a value in the session storage, and the getItem() method retrieves it. The data will be cleared when the session ends (i.e., when the tab is closed).

**Q58) What is the Geolocation API in JavaScript?**

**Answer:** The Geolocation API allows websites to access the geographical location of a user's device. It is commonly used for applications like maps or location-based services. The API provides methods to get the user's current position or watch for changes in their position..**Example:**

navigator.geolocation.getCurrentPosition(function(position) {

console.log('Latitude: ' + position.coords.latitude);

console.log('Longitude: ' + position.coords.longitude);

});

In this example, getCurrentPosition() is used to retrieve the user's current geographical coordinates. The position object contains the coords property with latitude and longitude.

**Q59) How does the Web Storage API differ from cookies in JavaScript?**

Answer: The Web Storage API (which includes localStorage and sessionStorage) differs from cookies in several ways:

* Storage Size: Web Storage can store larger amounts of data (up to 5-10MB per domain) compared to cookies, which are limited to around 4KB.
* Lifetime: localStorage persists data across sessions, while cookies can have expiration dates set by the server.
* Data Handling: Cookies are sent with every HTTP request, while data in Web Storage is stored on the client side and not transmitted with requests, improving performance.
* Simplicity: Web Storage is easier to use and more efficient for client-side storage compared to cookies.

**Q60) What is the Notification API in JavaScript?**

**Answer:** The Notification API allows web pages to display notifications to the user, even if the page is not in the foreground. This API is often used in conjunction with service workers to send push notifications for real-time updates, such as messages or alerts...**Example:**

if (Notification.permission === 'granted') {

new Notification('Hello, you have a new message!');

} else {

Notification.requestPermission().then(permission => {

if (permission === 'granted') {

new Notification('Hello, you have a new message!');

}

});

}

In this example, the Notification object is used to display a notification. Before sending a notification, the browser must request permission to show notifications.

📝 Common Interview Follow-Ups(will be added later):

* How would you handle errors in the Fetch API?
* What are some common use cases for the localStorage and sessionStorage APIs?
* How do you ensure compatibility for the Geolocation API across different browsers?
* How do you handle JSON responses from APIs using the Fetch API?
* What are some security concerns when using localStorage and sessionStorage?
* How can you set expiration for localStorage data?
* How would you handle sending data through the Fetch API using POST requests?
* How can you use the Notification API to send push notifications with service workers?