



Modern Web Applications with **Next.JS**

Learn Advanced Techniques to
Build and Deploy Modern, Scalable
and Production Ready React
Applications with Next.JS



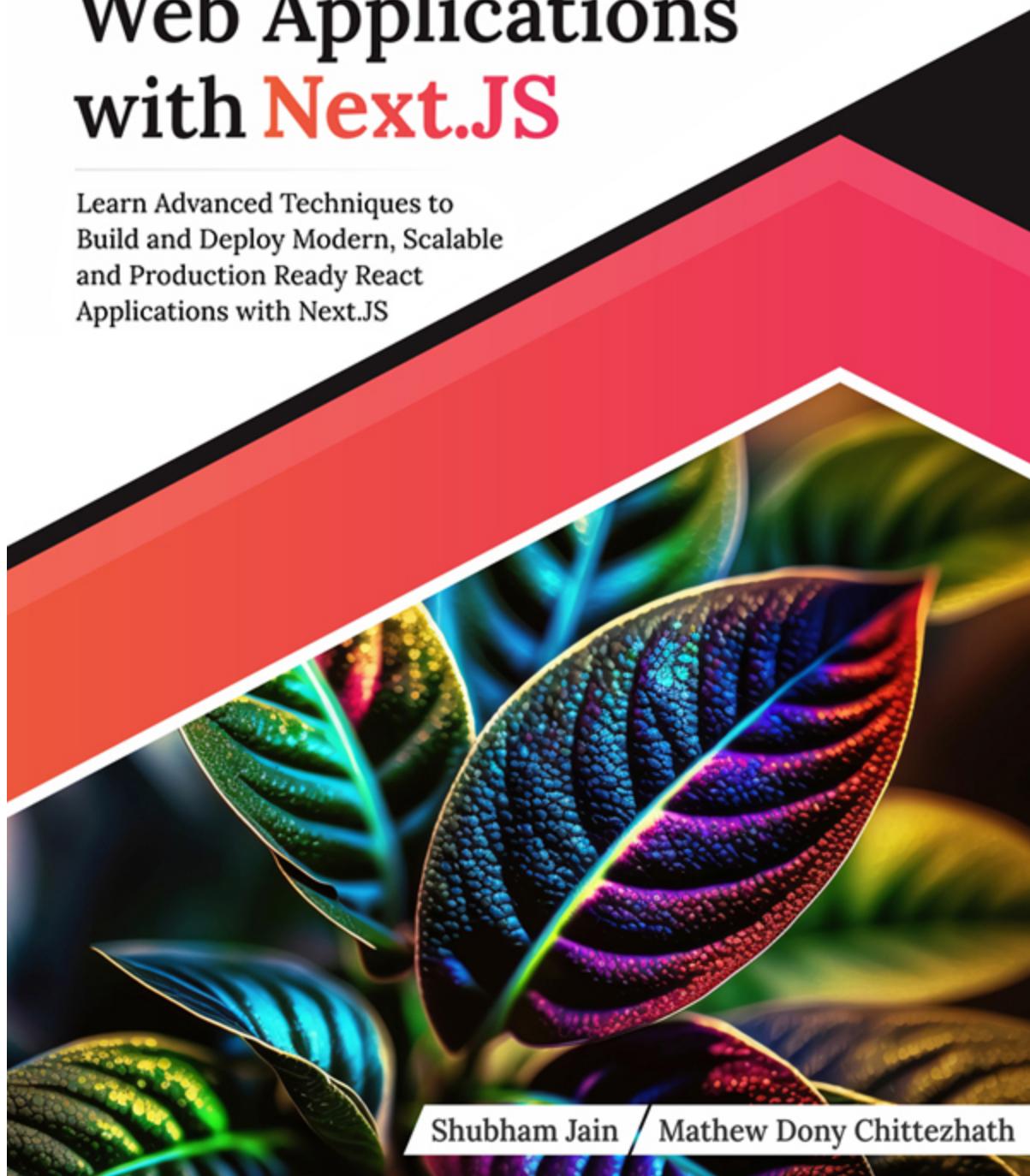
Shubham Jain

Mathew Dony Chittezhath



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Dedicated To

those who have shaped my journey: my family, for their nurturing love; my friends, for their unwavering support; my mentors, for their guiding wisdom; and to the software engineering community.

Mathew Dony Chittezhath

To the dreamers and builders, the ones who breathe life into lines of code and turn ideas into digital reality. This book is dedicated to the passionate minds and relentless spirits that drive innovation in the world of web development. To those who embrace challenges as opportunities, and who find joy in the elegant dance of technology and creativity.

In particular, I dedicate this book to you, dear reader. Your curiosity and commitment to mastery inspire the very essence of these pages. May the knowledge within empower you to push the boundaries of what's possible with Next.js. Here's to the endless possibilities that unfold when we code with purpose, learn with enthusiasm, and create with heart.

My beloved Parents:

Shri Pushpendra Jain

Anjana Jain

and

My wife Riddhi Vanawat

Shubham Jain

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Shubham Jain: Shubham Jain, an experienced full-stack software engineer, specializes in end-to-end web development and deployment. He holds a Master's degree in Information Technology, demonstrating his dedication to learning and expertise. With a profound passion for technology and a dedication to creating user-centric software, he remains at the forefront of the ever-evolving tech landscape, consistently delivering delightful experiences for users.

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Extensively used JavaScript framework JQuery to build Ajax-driven web applications.

Good communication and quick learning skills are his strengths.

Specialties: Javascript, Angular JS/2/4/5/6, React JS, Redux, MySQL, Apache, Jquery, Web Services, HTML5, CSS3, Node JS, Express JS, Java Core, Docker, Kubernetes, GitLab, Spring Boot, Java, .NET, SQL, Database, Design, Agile, API, Testing, AWS, CI/CD, NoSQL, Python.

Supreet Sethi is a seasoned professional with over 10 years of experience in JavaScript and React. As a dedicated tech lead, Supreet brings a sharp focus to web development, creating advanced SaaS applications using Agile Scrum methodology. His technical skills encompass React.js, React Native, Redux, and Next.js, showcasing not only his execution abilities but also a seasoned perspective in the field. Beyond tech, Supreet's leadership stands out in successfully guiding teams and projects. His excellent people skills, critical thinking, and goal-oriented approach create an environment where innovation thrives. Additionally, Supreet excels as a JavaScript teacher, simplifying complex concepts and providing practical insights from real-world scenarios. Whether leading a team, designing complex structures, or teaching the next generation of developers, Supreet Sethi embodies a well-rounded approach to excellence in technical skills, leadership, and education.

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Shubham Jain: I am deeply grateful to several individuals and organizations who have played pivotal roles in the creation of this book. Their unwavering support and encouragement have been instrumental in bringing this project to fruition.

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I would also like to acknowledge the incredible team that stood by me during this endeavor. Your unwavering support, patience, and understanding, especially in granting me the time to complete the first part of the book and allowing its publication in multiple segments, were essential. Given the vast and dynamic nature of image processing as a field of research, it was essential to explore various problem areas comprehensively without overwhelming the reader with an overly voluminous work.

Once again, thank you to everyone who has contributed to this book in various ways. Your support has been invaluable, and I am deeply appreciative of the trust and encouragement you have shown me throughout this journey.

Mathew Dony Chittezhath: First and foremost, I'd like to express my deepest gratitude to the innovative minds behind React – the team at

Facebook – who not only transformed the landscape of front-end development but also fostered a dynamic and supportive community around it. Your vision and relentless commitment have empowered countless developers, including myself, to craft intuitive and scalable applications.

Special thanks go to the vast React community: the developers, mentors, educators, and enthusiasts. Your open-source contributions, insightful tutorials, and invaluable feedback have been the backbone of this book. It's the collective wisdom and experience of this community that has made understanding and mastering React achievable and enjoyable.

To my friends and family, thank you for your unyielding support and patience during this journey. Writing a book is no small feat, and your understanding, encouragement, and occasional cups of coffee were the fuel I needed to see this project through.

Lastly, to the readers: thank you for entrusting me with your time and effort in learning React. I hope this book provides you with the knowledge and skills needed to harness the full potential of React in your projects. Always remember that continuous learning and collaboration are the keys to growth in this ever-evolving field.

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Preface

Welcome to "Mastering Web Applications with Next.js and JavaScript." In the ever-evolving world of web development, staying at the forefront of technology is essential. Next.js, a powerful framework built on top of React, has gained immense popularity for building robust and efficient web applications.

This book is designed to take you on a comprehensive journey through Next.js and JavaScript, providing you with the knowledge and skills needed to develop modern, performant web applications. Whether you are a seasoned developer looking to expand your skill set or a newcomer to the world of web development, this book will equip you with the tools to excel in your web application projects.

[Chapter 1: Introduction to Web Applications with Next.js and JavaScript](#)

What You'll Learn: An overview of web applications, Next.js, and JavaScript in the context of web development.

[Chapter 2: Recall React](#)

What You'll Learn: A review of key React concepts and principles to prepare for Next.js development.

[Chapter 3: Next.js Fundamentals](#)

What You'll Learn: Core principles and fundamentals of Next.js, including routing and server-side rendering.

[Chapter 4: Next.js new version - Core Concepts](#)

What You'll Learn: Exploring the latest version of Next.js and its core concepts for building modern web applications.

[Chapter 5: Optimizing Next.js Applications](#)

What You'll Learn: Techniques and strategies to optimize Next.js applications for performance and efficiency.

[Chapter 6: Understanding Routing in Next.js](#)

What You'll Learn: In-depth understanding of routing in Next.js and how to navigate between pages.

[Chapter 7: State Management in Next.js](#)

What You'll Learn: Implementing state management solutions in Next.js applications for data handling.

[Chapter 8: Restful and GraphQL API Implementation](#)

What You'll Learn: Implementing RESTful and GraphQL APIs in Next.js applications for data retrieval and manipulation.

[Chapter 9: Using Different Types of Databases](#)

What You'll Learn: Working with various types of databases and integrating them into Next.js applications.

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[Chapter 11: Securing App with Next Auth](#)

What You'll Learn: Implementing authentication and authorization mechanisms in Next.js applications using Next Auth.

[Chapter 12: Developing a CRUD Application with Next.js](#)

What You'll Learn: Building a CRUD (Create, Read, Update, Delete) application from scratch using Next.js.

[Chapter 13: Deployment Architecture](#)

What You'll Learn: Exploring deployment architectures and strategies for deploying Next.js applications to production environments.

We are excited to embark on this learning journey with you. Each chapter is carefully crafted to provide you with a deep understanding of Next.js and its practical applications. By the end of this book, you will have the knowledge and confidence to build modern web applications that meet the demands of today's digital landscape. Let's get started!

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Downloading the code bundles and colored images

Please follow the link to download the **Code Bundles** of the book:

<https://github.com/OrangeAVA/Modern-Web-Applications-with-Next.JS>

The code bundles and images of the book are also hosted on
<https://rebrand.ly/546338>

In case there's an update to the code, it will be updated on the existing GitHub repository.

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CHAPTER 1

Introduction to Web Applications with Next.js and JavaScript

Introduction

Welcome to the world of web applications! In this chapter, we'll explore how to build robust, high-performance web applications using Next.js and React. Whether you're a seasoned web developer or just starting out, this book will provide you with a comprehensive introduction to the exciting world of web development. Next.js is a powerful framework for building server-side rendered React applications. By combining the power of React with the simplicity and ease-of-use of Next.js, we can create web applications that are both fast and scalable. So, let's get started and build some amazing web applications together!

Structure

In this chapter, the following topics will be covered:

- What are web applications?
- What is Next.js and why it's gaining popularity?
- Features and benefits of using Next.js for building dynamic web applications
- A review of JavaScript fundamentals, including data types, control structures, functions, and objects
- Advanced JavaScript concepts, such as asynchronous programming, promises, and ES6 features
- How to use Next.js to build server-side and client-side rendered React applications
- How to create a simple Next.js application on your computer

Web applications and its building blocks

Web development is the process of building websites and web applications. A web application is a software program that runs on a web server and is accessed through a web browser. The three fundamental building blocks of web development are HTML, CSS, and JavaScript.

Difference between Websites and web applications

The terms **website** and **web application** are often used interchangeably, but they have some distinct differences. A website is a collection of static web pages that provide information or content to visitors. Websites are usually designed to be navigated by visitors, who are passive consumers of the content. Examples of websites include blogs, news sites, and company homepages. A web application, on the other hand, is a software program accessed through a web browser and provides interactive functionality to users. Web applications are more complex than websites and require user input and interaction to function. Examples of web applications include social media platforms, online marketplaces, and productivity tools. The main difference between websites and web applications is the level of interactivity and functionality they provide. While websites are primarily focused on providing information, web applications allow users to perform complex tasks and interact with other users. Another difference is the level of customization and personalization available in web applications. Websites generally provide a standardized experience for all visitors, while web applications can tailor their functionality and content to individual users based on their preferences and behavior. Concisely, while both websites and web applications are accessed through web browsers and are hosted on the internet, web applications provide a more interactive and customizable experience than websites.

HTML (Hypertext Markup Language)

HTML is the standard markup language used for creating web pages and applications. It provides the structure and content of web pages and applications by defining elements such as headings, paragraphs, images, and hyperlinks. HTML uses a tag-based language, where each tag represents a specific element on the page.

Here is an example of how an HTML element is defined:

```
<!DOCTYPE html>
<html>
<head>
  <title>My Web App</title>
</head>
<body>
  <h1>Welcome to my web app!</h1>
  <p>My name is Mathew and we're going to learn Next.js!</p>
</body>
</html>
```

The preceding code gives the following output when viewed in a web browser:

Welcome to my web app!

My name is Mathew and we're going to learn Next.js!

Figure 1.1: Website output

In this example, we have defined a basic HTML page that includes a title, a header, and a paragraph. The `<!DOCTYPE html>` tag specifies the document type and the `<html>` tag is the root element of the HTML page. The `<head>` tag contains information about the page, such as the `<title>`, and the `<body>` tag contains the content of the page.

HTML provides a wide range of elements that can be used to create web pages and applications. These elements include headings (`<h1>` to `<h6>`), paragraphs (`<p>`), lists (`` and ``), links (`<a>`), images (``), tables (`<table>`, `<tr>`, `<td>`), forms (`<form>`, `<input>`, `<textarea>`, `<button>`), and many more.

Cascading Style Sheets (CSS)

CSS is used for describing the presentation of web pages, including colors, fonts, and layout. It is used to style the HTML elements defined on the page. CSS can be used to apply styles to specific elements, or it can be used to apply styles globally to the entire web page.

Here is an example of how a CSS rule is defined:

```
h1 {  
    font-size: 24px;  
    color: red;  
}
```

In the preceding example, we have defined a CSS rule that applies styles to all h1 elements on the page. We have set the font size to 24 pixels and the color to red.

If we link the preceding CSS code to our HTML page, we get the following output:

Welcome to my web app!

My name is Mathew and we're going to learn Next.js!

Figure 1.2: Updated HTML page

CSS provides a wide range of properties that can be used to style HTML elements. These properties include font properties (**font-size**, **font-family**, **font-weight**, **font-style**), color properties (**color**, **background-color**), layout properties (**margin**, **padding**, **border**, **width**, **height**), and many more.

CSS also provides a wide range of selectors that can be used to apply styles to specific elements on the page. These selectors include tag selectors (**h1**, **p**, **ul**, **li**), class selectors (**.my-class**), ID selectors (**#my-id**), attribute selectors (**[attribute=value]**), and many more.

JavaScript

JavaScript is a high-level programming language that is used for creating interactive and dynamic web pages. It is used for adding functionality to web pages, such as event handling, form validation, and API requests and responses. JavaScript is executed by the web browser and is used to interact with the HTML and CSS on the page. JavaScript code can be added to HTML files using the **script** element, which can be placed in the head or body section of the HTML file. Alternatively, JavaScript code can be

included in a separate file and linked to the HTML file using the `src` attribute.

We are now going to extend our original example and add some JavaScript magic to make our web application interactive:

```
<!DOCTYPE html>
<html>
<head>
  <title>My Web App</title>
</head>
<body>
  <h1 style="color:red;">Welcome to my web app!</h1>
  <p>My name is Mathew and we're going to learn Next.js!</p>
  <button id="myButton">Click me!</button>
  <script>
    var button = document.getElementById("myButton");
    button.addEventListener("click", function() {
      alert("Wooho! You have clicked this button!");
    });
  </script>
</body>
</html>
```

In the preceding example, we have added a new button with an `onclick` event listener to the button that will execute a browser alert using JavaScript. When we click the button, it will create the following browser alert notification:

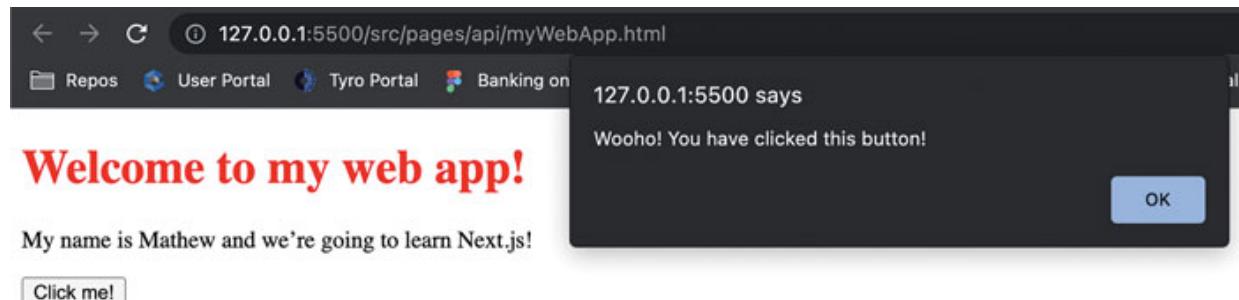


Figure 1.3: Browser alert

By combining these three building blocks, we can create powerful and interactive web applications that provide a great user experience.

Defining Next.js

Next.js is a popular open-source framework for building server-side rendered (SSR) and static site generated (SSG) React applications. Developed by Vercel, Next.js provides an intuitive and developer-friendly approach to building web applications, enabling developers to focus on building great user experiences without worrying about the underlying infrastructure.

With Next.js, developers can build dynamic and performant web applications that can run on any server or platform, thanks to its universal rendering capabilities. Next.js offers a range of features and benefits, including:

- **Server-side rendering (SSR) and static site generation (SSG)**

Next.js offers powerful server-side rendering capabilities that enable developers to create dynamic, interactive web applications that load quickly and provide great user experiences. Next.js also supports static site generation, allowing developers to generate static HTML files at build time that can be served quickly and efficiently.

- **Built-in tooling and automatic optimization**

Next.js includes a range of built-in tools and features that make it easy to optimize your application for performance and accessibility. With features like image optimization and automatic code splitting, Next.js helps to ensure that your application is fast, efficient, and accessible for all users.

- **Automatic code splitting and optimization**

Next.js automatically splits your code into smaller chunks and loads only the code that is required for each page, improving the initial load time and reducing the size of the JavaScript bundle.

- **Hybrid approach**

With Next.js, you can build hybrid applications that combine server-side rendering and client-side rendering, allowing you to take advantage of the benefits of both approaches.

Overall, Next.js is a powerful and flexible framework that enables developers to build high-quality, scalable web applications quickly and

efficiently.

- **Easy setup and deployment**

Next.js is easy to set up and deploy, allowing developers to get started quickly and focus on building their applications. With built-in support for hosting on Vercel, Next.js provides a seamless deployment experience that makes it easy to deploy and scale your application.

- **Community support and ecosystem**

Next.js has a large and active community of developers and contributors, who provide support, share knowledge, and contribute to the development of the framework. In addition, Next.js has a robust ecosystem of plugins, tools, and resources that can help developers build better and more efficient web applications.

Use cases for Next.js

Next.js is suitable for a wide range of web application development use cases, including:

- eCommerce applications
- Content-driven websites and blogs
- Social networking sites
- Web-based tools and dashboards
- Progressive web applications (PWAs)
- Mobile applications using React Native

With its flexibility, scalability, and ease of use, Next.js is a versatile framework that can be used to build a wide range of web applications.

In summary, Next.js is a powerful, flexible, and easy-to-use framework for building high-quality web applications using React. With its built-in support for server-side rendering and static site generation, automatic code splitting and optimization, and easy deployment and scaling, Next.js is an ideal choice for developers looking to build dynamic, performant, and scalable web applications.

Reasons to use Next.js for web application development

Next.js is a popular framework for building web applications using React. Here are some of the key reasons why you might want to consider using Next.js for your web application development:

- **Built-in server-side rendering**

One of the main benefits of using Next.js is its built-in support for SSR. SSR allows your application to render on the server before being sent to the client, which can improve the initial load time and provide better SEO. With Next.js, you don't need to set up a separate server or worry about managing the server-side rendering process, as it is all handled automatically by the framework.

- **Automatic code splitting and optimization**

Next.js comes with automatic code splitting and optimization features, which can help reduce the initial load time and improve the overall performance of your application. Code splitting allows you to split your code into smaller chunks, which are loaded on-demand, rather than all at once. This can help to reduce the amount of JavaScript that needs to be downloaded and parsed by the browser, which can speed up the initial load time. Next.js also supports image optimization and other performance optimizations out-of-the-box.

- **Easy static site generation**

Next.js also provides built-in support for SSG, which can be useful for building static websites, blogs, and other content-driven applications. SSG allows you to generate HTML pages at build-time, which can be served directly to the client, rather than being generated dynamically on the server. This can improve the performance and reduce the server load of your application.

- **Easy to set up and deploy**

Next.js is easy to set up and deploy, thanks to its built-in support for hosting on Vercel. Vercel provides a seamless deployment experience that makes it

easy to deploy and scale your application, without having to worry about managing servers or infrastructure.

- **Large and active community**

Next.js has a large and active community of developers and contributors, who provide support, share knowledge, and contribute to the development of the framework. This has led to the creation of many useful plugins, tools, and resources that can help developers to build better and more efficient web applications.

In summary, Next.js is a powerful and versatile framework for building web applications using React. With its built-in support for server-side rendering, automatic code splitting and optimization, easy static site generation, easy deployment, and large and active community, Next.js is an ideal choice for building high-quality, performant, and scalable web applications.

- **Improved developer experience**

Next.js provides a great developer experience, thanks to its intuitive and easy-to-use APIs and features. The framework comes with built-in support for many common web development tasks, such as routing, data fetching, and styling, which can help streamline the development process and reduce the time and effort required to build and maintain your application.

- **TypeScript support**

Next.js also provides built-in support for TypeScript, a statically typed superset of JavaScript that can help to improve code quality and catch errors early in the development process. TypeScript support is particularly useful for larger applications or teams, where the codebase can become complex and difficult to manage.

- **Flexible data fetching options**

Next.js provides flexible data fetching options, which can help simplify the process of fetching and managing data in your application. The framework supports both server-side and client-side data fetching, as well as incremental static regeneration, which allows you to update your static pages with new data without rebuilding the entire page.

- **Extensible and customizable**

Next.js is highly extensible and customizable, allowing you to add your own plugins, middleware, and configuration options to tailor the framework to your specific needs. This can help improve the flexibility and scalability of your application, and enable you to add new features and functionality as your application grows and evolves.

- **Built-in support for React**

Finally, Next.js provides built-in support for React, a popular JavaScript library for building user interfaces. React is known for its simplicity, performance, and flexibility, and is widely used in the web development community. Next.js provides a seamless integration with React, allowing you to build powerful and dynamic web applications using a familiar and popular toolset.

In summary, Next.js provides a range of benefits and features that make it an ideal choice for building high-quality, performant, and scalable web applications. With its improved developer experience, TypeScript support, flexible data fetching options, extensibility, and built-in support for React, Next.js is a powerful and versatile framework that can help you build better and more efficient web applications.

JavaScript basics for Next.js

Before diving into Next.js development, it's important to have a solid understanding of JavaScript basics. In this section, we'll cover some of the fundamental concepts of JavaScript that are essential for developing Next.js applications.

Variables and data types

Variables are used to store data values in JavaScript. There are three ways to declare a variable in JavaScript as follows:

- **var**
- **let**
- **const**

var is the old way of declaring variables in JavaScript, and it has some quirks that can cause issues. **let** and **const** were introduced in ES6 JavaScript

and are the preferred way of declaring variables in modern JavaScript.

Here is an example:

```
// Declare a variable using var  
var x = 10;  
  
// Declare a variable using let  
let y = 20;  
  
// Declare a variable using const  
const z = 30;  
  
// Trying to reassign a value to a const variable will result  
in an error  
// z = 40; // This will throw an error
```

JavaScript has several built-in data types, including:

- number (for numerical values)
- string (for text values)
- Boolean (for true/false values)
- null (for a null value)
- undefined (for an undefined value)
- object (for complex data structures)

Here is an example:

```
// Declare a number variable  
let a = 10;  
  
// Declare a string variable  
let b = "Hello, world!";  
  
// Declare a boolean variable  
let c = true;  
  
// Declare a null variable  
let d = null;  
  
// Declare an undefined variable  
let e;  
  
// Declare an object variable  
let f = { name: "Mathew", age: 28 };
```

Control flow statements

Control flow statements are used to control the flow of execution in JavaScript. The most common control flow statements are as follows:

- **if...else** statement
- **for** loop
- **while** loop
- **switch** statement

Here are examples of how each of these statements is used:

```
// If...else statement
let age = 20;

if (age >= 18) {
  console.log("You are an adult.");
} else {
  console.log("You are not yet an adult.");
}

// Output: You are an adult

// For loop
for (let i = 0; i < 5; i++) {
  console.log(i);
}

// Output: 0 1 2 3 4

// While loop
let i = 0;

while (i < 5) {
  console.log(i);
  i++;
}

// Output:
0 1 2 3 4

// Switch statement
let day = "Monday";
switch (day) {
```

```
case "Monday":  
    console.log("Today is Monday.");  
    break;  
case "Tuesday":  
    console.log("Today is Tuesday.");  
    break;  
default:  
    console.log("Today is another day.");  
    break;  
}  
  
// Output: Today is Monday
```

Functions

Functions are used to group a set of statements together and perform a specific task. In JavaScript, functions can be declared using the function keyword or using arrow function notation (`=>`).

Here is an example:

```
// Declare a function using function keyword  
function add(x, y) {  
    return x + y;  
}  
  
// Declare a function using arrow function notation  
const subtract = (x, y) => {  
    return x - y;  
};  
  
// Call the functions  
console.log(add(5, 10)); // Output: 15  
console.log(subtract(20, 5)); // Output: 15
```

Classes

Classes are used to create objects in JavaScript. In ES6, classes were introduced to make it easier to create objects and implement inheritance.

Here is an example:

```
class Person {
```

```

constructor(name, age) {
  this.name = name;
  this.age = age;
}

sayHello() {
  console.log(`Hello, my name is ${this.name} and I am
  ${this.age} years old.`);
}

// Create a new Person object
const mathew = new Person("Mathew", 28);

// Call the sayHello method
mathew.sayHello(); // Output: "Hello, my name is Mathew and I
am 28 years old."

```

Modules

Modules are used to organize code into reusable pieces. In Next.js, we use modules to organize our code and make it easier to share between different parts of our application.

Here is an example:

```

// Export a function from a file math.js
export function add(x, y) {
  return x + y;
}

// Import the function into another module
import { add } from "./math.js";

// Call the function
console.log(add(5, 10)); // Output: 15

```

Promises

Promises are used to handle asynchronous operations in JavaScript. They are a way to handle callback functions in a more readable and predictable way.

Here is an example of how to create a Promise in JavaScript:

```
// Create a new Promise
const promise = new Promise((resolve, reject) => {
  // Simulate an asynchronous operation
  setTimeout(() => {
    // Resolve the Promise
    resolve("Data successfully retrieved!");
  }, 2000);
});

// Call the Promise
promise.then((result) => {
  console.log(result); // Output: "Data successfully retrieved!"
});
```

Arrow functions

Arrow functions are a shorthand way of writing function expressions in JavaScript. They are a way to simplify the syntax of functions and make them easier to read.

Here is an example:

```
// Traditional function expression
const add = function(x, y) {
  return x + y;
}

// Arrow function expression
const add = (x, y) => x + y;
```

Destructuring

Destructuring is a way of extracting values from objects or arrays and assigning them to variables. It is a shorthand way of writing assignments and can make code more concise.

Here is an example:

```
// Destructuring an array
const [first, second, third] = [1, 2, 3];
console.log(first); // Output: 1

// Destructuring an object
```

```
const person = {
  name: "Mathew",
  age: 28
};
const { name, age } = person;
console.log(name); // Output: "Mathew"
```

Spread operator

The spread operator is a way of expanding an array or object into individual elements. It can be used to combine multiple arrays or objects into a single array or object.

Here is an example:

```
// Using the spread operator to combine arrays
const arr1 = [1, 2, 3];
const arr2 = [4, 5, 6];
const combined = [...arr1, ...arr2];
console.log(combined); // Output: [1, 2, 3, 4, 5, 6]

// Using the spread operator to copy an object
const person = {
  name: "Mathew",
  age: 28
};
const copy = { ...person };
console.log(copy); // Output: { name: "Mathew", age: 28 }
```

Async/Await

Async/await is a newer feature in JavaScript that simplifies working with promises. It allows you to write asynchronous code that looks and feels like synchronous code, making it easier to read and debug.

Here is an example of how to use async/await to handle a promise in JavaScript:

```
// Using async/await to handle a Promise
async function getData() {
  const response = await fetch('https://api.example.com/data');
```

```
const data = await response.json();
return data;
}
// Call the async function
const data = await getData();
console.log(data);
```

Template literals

Template literals are a way to write strings that include variables and expressions. They use backticks (`) instead of quotes and allow you to interpolate variables directly into the string.

Here is an example:

```
// Using template literals to interpolate a variable
const name = "Mathew";
const message = `Hello, ${name}!`;
console.log(message); // Output: "Hello, Mathew!"
```

Object-Oriented Programming (OOP)

Object-Oriented Programming is a programming paradigm that uses objects to represent real-world entities. It is a way of organizing code into reusable, modular components.

Here is an example:

```
// Using OOP to create a class
class Animal {
  constructor(name, species) {
    this.name = name;
    this.species = species;
  }
  speak() {
    console.log(` ${this.name} says hello!`);
  }
}
// Creating an instance of the Animal class
const dog = new Animal("Dottie", "Dog");
```

```
// Calling the speak method
dog.speak(); // Output: "Dottie says hello!"
```

By understanding these additional JavaScript concepts, you will be able to write more powerful and flexible code in your Next.js web applications. In the following chapters, we will explore how to apply these concepts specifically to building full-stack web applications with Next.js.

[Understanding server-side rendering \(SSR\) and client-side rendering \(CSR\)](#)

When building web applications with Next.js, it's important to understand the difference between SSR and CSR. Both approaches have their advantages and disadvantages, and it's important to choose the right one for your use case.

[Server-side rendering](#)

SSR is the traditional way of rendering web pages. With SSR, the server sends a fully rendered HTML page to the client in response to a request. This means that the client only needs to download and display the page, without needing to do any additional rendering or data fetching.

SSR can improve the initial load time of your web pages, because the client receives a complete page right away. It can also improve the SEO of your web pages, because search engines can more easily crawl and index fully rendered HTML pages.

Here's an example of using SSR with Next.js:

```
// A simple Next.js page that uses SSR
function HomePage({ data }) {
  return (
    <div>
      <h1>Hello, {data.name}!</h1>
      <p>{data.description}</p>
    </div>
  );
}

export async function getServerSideProps() {
```

```
// Fetch data from an external API
const response = await fetch('https://api.example.com/data');
const data = await response.json();

// Pass the data to the page component as props
return { props: { data } };
}

export default HomePage;
```

In this example, the `getServerSideProps` function is a special function in Next.js that allows you to fetch data and pass it to your page component as props. When the client requests this page, the server will run this function to fetch the data and render the page, then send the fully rendered HTML page to the client.

Client-side rendering

CSR is a more modern approach to rendering web pages. With CSR, the client downloads a minimal HTML page, then fetches data and renders the page on the client side using JavaScript.

CSR can improve the user experience of your web application, because the client can fetch and render data dynamically, without needing to refresh the page. It can also reduce the load on your server, because the server only needs to send the initial HTML page, and the client can handle all subsequent rendering and data fetching.

Here's an example of using CSR with Next.js:

```
// A simple Next.js page that uses CSR
function HomePage() {
  const [data, setData] = useState(null);
  useEffect(() => {
    // Fetch data from an external API
    async function fetchData() {
      const response = await
        fetch('https://api.example.com/data');
      const data = await response.json();
      setData(data);
    }
    fetchData();
  })
}
```

```

}, []);

if (!data) {
  return <div>Loading...</div>;
}

return (
  <div>
    <h1>Hello, {data.name}!</h1>
    <p>{data.description}</p>
  </div>
);
}

export default HomePage;

```

In this example, we are using React hooks to fetch data and render the page on the client side. When the client requests this page, the server sends a minimal HTML page, and the client runs the JavaScript code to fetch the data and render the page.

Hybrid rendering

In addition to SSR and CSR, Next.js also supports hybrid rendering, which is a combination of both approaches. With hybrid rendering, you can fetch data on the server and send a partially rendered page to the client, then continue rendering and fetching data on the client side.

Hybrid rendering can provide the best of both worlds: the fast initial load time and SEO benefits of SSR, and the dynamic and responsive user interface of CSR. However, it can also be more complex to implement and may require additional server-side configuration and optimization.

Here's an example of using hybrid rendering with Next.js:

```

// A simple Next.js page that uses hybrid rendering
function HomePage({ data }) {
  const [dynamicData, setDynamicData] = useState(null);

  useEffect(() => {
    // Fetch dynamic data on the client side
    async function fetchDynamicData() {

```

```

    const response = await
      fetch('https://api.example.com/dynamic-data');
    const dynamicData = await response.json();
    setDynamicData(dynamicData);
  }
  fetchDynamicData();
}, []);

return (
  <div>
    <h1>Hello, {data.name}!</h1>
    <p>{data.description}</p>
    {dynamicData && <p>{dynamicData.message}</p>}
  </div>
);
}

export async function getServerSideProps() {
  // Fetch static data from an external API
  const staticResponse = await
    fetch('https://api.example.com/static-data');
  const staticData = await staticResponse.json();
  // Pass the static data to the page component as props
  return { props: { data: staticData } };
}

export default HomePage;

```

In this example, we're using `getServerSideProps` to fetch static data on the server and send it to the client as props. We're also using React hooks to fetch dynamic data on the client side and update the page content dynamically.

In summary, when building web applications with Next.js, it's important to understand the difference between SSR and CSR, and to choose the right approach for your use case. Next.js also supports hybrid rendering, which can provide the benefits of both approaches. By understanding these concepts, you'll be able to build fast, dynamic, and SEO-friendly web applications with Next.js.

Setting up a development environment for Next.js

Setting up a development environment for Next.js is an important step toward building web applications with Next.js. In this section, we will guide you through the process of setting up a development environment for Next.js.

Step 1: Install Node.js and npm

The first step to setting up a development environment for Next.js is to install Node.js and npm. Node.js is a JavaScript runtime that allows you to run JavaScript on the server side, while npm is a package manager that allows you to install and manage dependencies for your project.

You can download and install Node.js from the official website at <https://nodejs.org>. Choose the appropriate version for your operating system and download it. Once the download is complete, follow the installation instructions to install Node.js.

Once you have installed Node.js, you can verify the installation by running the following commands in your terminal:



```
[→ ~ node -v
v18.16.1
[→ ~ npm -v
9.7.2
→ ~ ]
```

A screenshot of a terminal window on a dark background. It shows two command-line entries. The first entry is 'node -v' followed by the output 'v18.16.1'. The second entry is 'npm -v' followed by the output '9.7.2'. A cursor icon is visible at the bottom left, and a small gray square is positioned to the right of the second command's output.

Figure 1.4: Verifying the installation

These commands should output the versions of Node.js and npm that you have installed on your system.

Step 2: Create a new Next.js project

Once you have installed Node.js and npm, you can create a new Next.js project using the `create-next-app` command-line tool. This tool sets up a new Next.js project with all the necessary dependencies and configuration files.

To create a new Next.js project, open your terminal and run the following command:

```
npx create-next-app@latest
```

After running the command, you will be prompted with the following questions:

What is your project named? my-app

Would you like to use TypeScript? No / Yes

Would you like to use ESLint? No / Yes

Would you like to use Tailwind CSS? No / Yes

Would you like to use `src/` directory? No / Yes

Would you like to use App Router? (recommended) No / Yes

Would you like to customize the default import alias? No / Yes

What import alias would you like configured? @/*

This command will ask you some questions to bootstrap the project, which will create a new Next.js project in a directory called `my-app`. We have decided to use TypeScript instead of JavaScript in this example.

Step 3: Start the development server

Once you have created a new Next.js project, you can start the development server using the `npm run dev` command. This command starts a local development server that allows you to preview your Next.js application in the browser.

To start the development server, navigate to the project directory and run the following command in your terminal:

```
cd my-app  
npm run dev
```

```

○ → my-app git:(main) npm run dev
> my-app@0.1.0 dev
> next dev

ready - started server on 0.0.0.0:3000, url: http://localhost:3000
Attention: Next.js now collects completely anonymous telemetry regarding usage.
This information is used to shape Next.js' roadmap and prioritize features.
You can learn more, including how to opt-out if you'd not like to participate in this anonymous program, by visiting the following URL:
https://nextjs.org/telemetry

event - compiled client and server successfully in 1242 ms (170 modules)
wait - compiling...
event - compiled successfully in 63 ms (137 modules)

```

Figure 1.5: Successful local server startup

This will start the development server at `http://localhost:3000`. You can open this URL in your web browser to view your Next.js application.

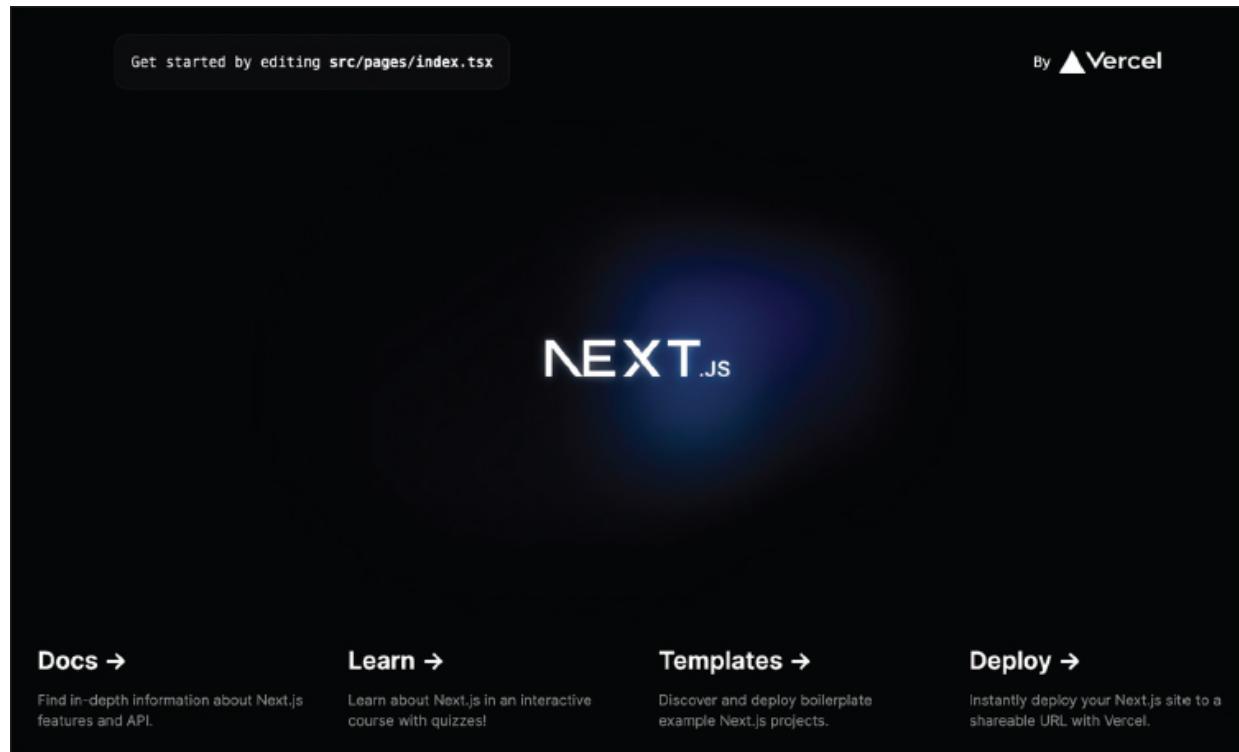


Figure 1.6: Next.js local server start page

Step 4: Install additional dependencies

Depending on the requirements of your Next.js application, you may need to install additional dependencies. You can do this using the `npm install` command.

For example, to install the `axios` library for making HTTP requests, you can run the following command in your terminal:

```
npm install axios
```

This will install the axios library and add it to your project's package.json file.

Setting up a development environment for Next.js is a crucial step in building web applications with Next.js. By following the steps outlined in this section, you can create a new Next.js project, start the development server, and install additional dependencies. With a fully functional development environment, you are ready to start building your own Next.js applications.

[Creating a simple Next.js application](#)

In this section, we will create a simple Next.js application from scratch. We will begin by setting up a new Next.js project using the `create-next-app` CLI tool. Then, we will create a basic **Hello World** application to familiarize ourselves with the structure of a Next.js application.

- **Setting up a new Next.js project**

Refer to the previous section on how to create a Next.js app from scratch.

Once the installation is complete, navigate to the project directory:

```
cd my-app
```

Now that we have our Next.js project set up, let's take a look at the structure of the project.

- **Understanding the structure of a Next.js project**

A typical Next.js project has the following structure:

```
my-app/
  .next/
  node_modules/
  src/
    pages/
    styles/
  public/
  package.json
```

The `.next` directory is generated by Next.js and contains the built files of the application. The `node_modules` directory contains all the dependencies installed by npm. The `pages` directory contains all the pages of the

application. The public directory contains all the static assets such as images, videos, and fonts. The styles directory contains all the CSS stylesheets used in the application. The package.json file contains the metadata about the project and the dependencies used.

Now that we have a basic understanding of the structure of a Next.js project, let's create our first page.

- **Creating a simple “Hello World” application**

In Next.js, a page is a React component that is exported as the default export of a file in the pages directory. To create a simple **Hello World** application, let us replace the boilerplate code in the index.tsx:

```
// src/pages/index.tsx

function Home() {
  return <h1>Hello World!</h1>
}

export default Home;
```

In this code, we have defined a new component called Home that returns a simple <h1> element with the text **Hello World!**. We have also exported this component as the default export of the file.

Now, if you run the development server with the following command:

```
npm run dev
```

You should be able to view the application by opening your browser and navigating to <http://localhost:3000/>. You should see the text **Hello World!** displayed on the page.

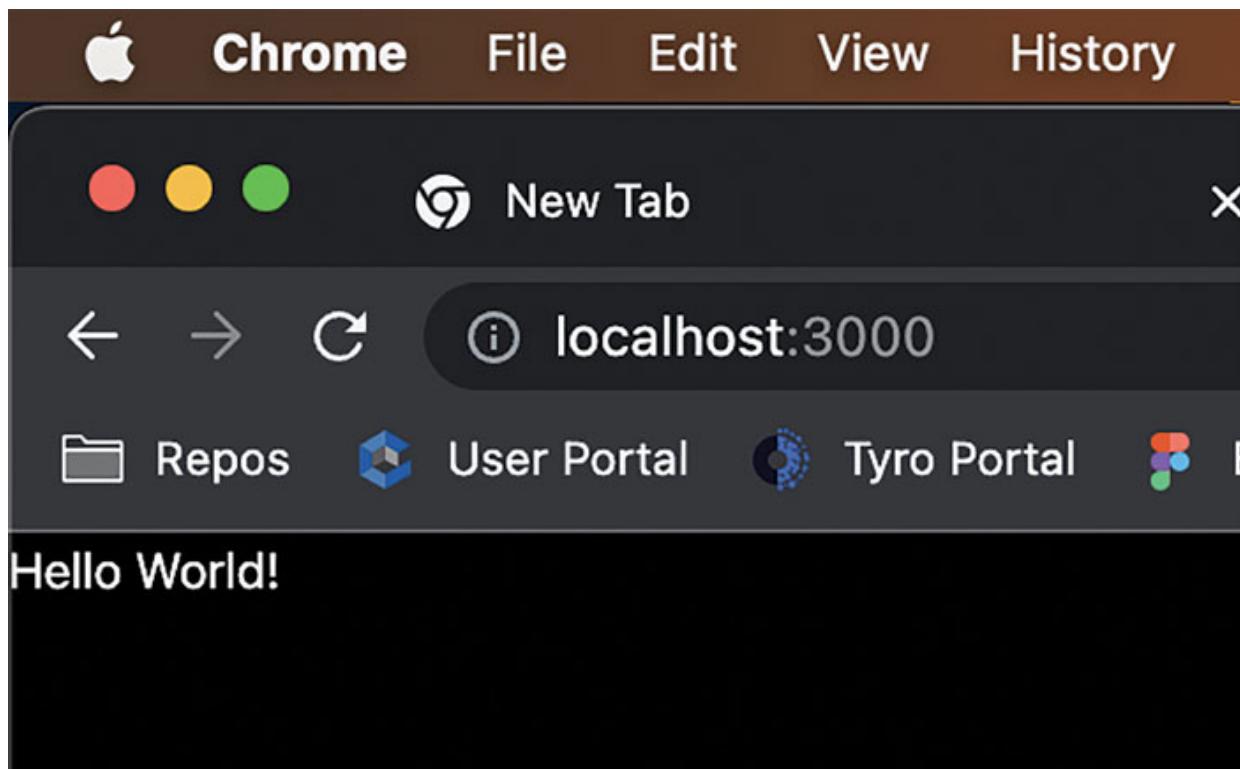


Figure 1.7: Next.js app running in the browser

Finally, you have successfully created a simple Next.js application!

Conclusion

In this chapter, we learned what web applications are, understood the basic workings of Next.js, its advantages, as well as the basic functionalities of HTML, CSS, and JavaScript. We also explored how easy it is to run a Next.js web application locally on our computer.

In the next chapter, we will recall the basics of React, which is the most popular JavaScript library that is used for building interactive web applications as well as cross-platform mobile apps.

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CHAPTER 2

Recall React

Introduction

React is a powerful JavaScript library used for building user interfaces. In this chapter, we will provide a refresher on the essential concepts of React, which are crucial for building robust web applications.

We will begin by introducing the basic building blocks of React applications: components. We will discuss how to create and use components in React and how they enable developers to build reusable UI elements. We will also cover JSX, a syntax extension of JavaScript that allows developers to write HTML-like code in their JavaScript files.

Next, we will delve into the important concepts of props and state in React. We will explain how props allow data to be passed between components, while a state is used to manage data that changes over time within a component. We will cover best practices for working with props and state, and how they can be used to build complex and interactive user interfaces.

Finally, we will discuss the lifecycle methods in React, which allow developers to handle certain events in a component's lifecycle. We will cover how to use these methods to control the behavior of a component and how they can be used to optimize performance and avoid bugs in React applications.

By the end of this chapter, you will have a solid understanding of the essential concepts of React and will be ready to start building robust and performant web applications using this powerful library.

Structure

In this chapter, the following topics will be covered:

- Introduction to React framework, including the virtual DOM and component-based architecture

- React component lifecycle methods and their usage
- JSX syntax and its differences from traditional HTML
- Handling events in React and passing data between components
- Working with React state and props, including data flow between components
- Introduction to React Hooks and their usage
- Basic concepts of asynchronous programming in JavaScript and how to use them in React

Introducing React

What is React, and why does it matter? React is a popular JavaScript library developed and maintained by Meta (formerly known as Facebook) for building user interfaces, particularly web applications. It was created to address the need for a more efficient and scalable way to handle complex user interfaces while providing excellent performance. React has gained immense popularity over the years because it enables developers to build reusable, modular components that are both easy to maintain and scale.

One of the main reasons React is so popular is its focus on simplicity and maintainability. By breaking down the user interface into small, self-contained components, React enables developers to easily understand and modify the code, even in large and complex applications. Additionally, React's performance optimizations, such as the virtual DOM, ensure that applications built with React are fast and responsive.

The virtual DOM and its benefits

The virtual DOM is one of the key features of React, and it's the primary reason for its exceptional performance. The virtual DOM is a lightweight in-memory representation of the actual DOM (Document Object Model) that is used to track changes to the UI. Whenever a change occurs, React updates the virtual DOM instead of the actual DOM, which can be a slow and expensive operation.

React uses a process called reconciliation to compare the current virtual DOM with the new one generated by a change in the state or props of a component. It then calculates the most efficient way to update the actual

DOM to match the new virtual DOM. This process minimizes the number of actual DOM updates, leading to significant performance improvements.

Consider the following example:

```
import React, { useState } from "react";
function Counter() {
  const [count, setCount] = useState(0);

  return (
    <div>
      <p>You clicked {count} times</p>
      <button onClick={() => setCount(count + 1)}>Click
        me</button>
    </div>
  );
}
export default Counter;
```

In this simple counter component, the state updates every time the button is clicked. React uses the virtual DOM to determine the minimal updates required for the actual DOM, ensuring optimal performance.

Component-based architecture in React

React's component-based architecture is a major factor in its popularity and maintainability. Components are self-contained, reusable pieces of code that represent a part of the user interface. They can be combined and nested to create complex UI structures.

There are two main principles behind React's component-based architecture as follows:

- **Single Responsibility Principle:** Each component should have a single responsibility or purpose. This makes it easier to understand, test, and maintain the code.
- **Composition:** Components can be composed together to build more complex UI structures. This allows developers to reuse components and create more maintainable code.

Here's a simple example of a component-based UI:

```
import React from "react";
import Header from "./Header";
import Content from "./Content";
import Footer from "./Footer";

function App() {
  return (
    <div>
      <Header />
      <Content />
      <Footer />
    </div>
  );
}

export default App;
```

In this example, the **App** component is composed of three other components: **Header**, **Content**, and **Footer**. Each of these components has its responsibility, making the overall application easier to maintain and understand.

Understanding functional and class components

React components can be written as functional components or class components. Before the introduction of Hooks in React 16.8, functional components were stateless and only used for presenting data, whereas class components were stateful and used for more complex logic. However, with the introduction of Hooks, functional components can now have state and perform side effects, making them more powerful and flexible.

Functional components are simpler and more concise than class components, making them the preferred choice for many developers. They are simply JavaScript functions that take props as input and return JSX to render the UI.

Here's an example of a functional component:

```
import React from "react";
function Welcome(props) {
  return <h1>Hello, {props.name}!</h1>;
```

```
}
```

```
export default Welcome;
```

In contrast, class components are JavaScript classes that extend the **React.Component** class. They have a **render()** method that returns JSX and can have local state and lifecycle methods.

Here's an example of a class component:

```
import React, { Component } from "react";
class Welcome extends Component {
  render() {
    return <h1>Hello, {this.props.name}!</h1>;
  }
}
export default Welcome;
```

While class components are still supported in React, the introduction of Hooks has made functional components more powerful and versatile. Hooks allow you to use state and other React features without writing a class, leading to cleaner and more readable code.

To illustrate the use of Hooks in functional components, let's convert the previous class component example into a functional component with the state:

```
import React, { useState } from "react";
function Welcome() {
  const [name, setName] = useState("John");

  const handleChange = (event) => {
    setName(event.target.value);
  };

  return (
    <div>
      <h1>Hello, {name}!</h1>
      <input type="text" value={name} onChange={handleChange} />
    </div>
  );
}
```

```
export default Welcome;
```

In this example, we use the **useState** Hook to manage the **name** state in the functional component. We also define a **handleChange** function to handle the input change event and update the state.

In conclusion, React's component-based architecture, virtual DOM, and emphasis on reusability make it a powerful and popular choice for building user interfaces. With the introduction of Hooks, functional components have become even more powerful and versatile, further solidifying React's position as a leading JavaScript library. As you continue to explore React and its features, you'll find that it provides an efficient and maintainable way to build complex and scalable web applications.

React component lifecycle methods and their usage

Let's explain the lifecycle methods of the React component and their benefits.

- **Overview of lifecycle methods**

Lifecycle methods are special methods in class components that allow you to run code at specific points during the component's lifecycle. They are essential for managing side effects, such as fetching data, updating the DOM, and handling events. The lifecycle methods can be grouped into three main phases: mounting, updating, and unmounting.

Note: With the introduction of Hooks, functional components can now perform similar tasks using **useEffect**. This section focuses on lifecycle methods for class components, but it's important to be aware of this alternative approach in functional components.

- **Mounting phase methods**

The mounting phase occurs when a component is being created and inserted into the DOM. There are two lifecycle methods associated with this phase:

- **constructor:** The constructor method is used to initialize the component's state and bind event handlers. It's called before the component is mounted.

Here's an example:

```
class MyComponent extends React.Component {  
  constructor(props) {  
    super(props);  
    this.state = { message: "Hello, World!" };  
    this.handleClick = this.handleClick.bind(this);  
  }  
}
```

- **componentDidMount**: This method is called immediately after the component is inserted into the DOM. It's the ideal place to fetch data, set up subscriptions, or perform other side effects.

Here's an example:

```
class MyComponent extends React.Component {  
  componentDidMount() {  
    console.log("Component has been mounted.");  
  }  
}
```

- **Updating phase methods**

The updating phase occurs when a component's state or props change, causing a re-render. There are two lifecycle methods associated with this phase:

- **shouldComponentUpdate**: This method is called before a re-render, allowing you to determine if the component should update based on changes in state or props. By default, it returns **true**. If you return **false**, the component won't update, and the remaining lifecycle methods won't be called.

Here's an example:

```
class MyComponent extends React.Component {  
  shouldComponentUpdate(nextProps, nextState) {  
    return this.props.someValue !== nextProps.someValue;  
  }  
}
```

- **componentDidUpdate**: This method is called immediately after a component has been updated. It's useful for performing side

effects, such as DOM manipulation or data fetching, in response to prop or state changes.

Here's an example:

```
class MyComponent extends React.Component {  
  componentDidUpdate(prevProps, prevState) {  
    if (this.props.someValue !== prevProps.someValue) {  
      console.log("someValue has changed.");  
    }  
  }  
}
```

- **Unmounting phase methods**

The unmounting phase occurs when a component is removed from the DOM. There is one lifecycle method associated with this phase:

- **componentWillUnmount**: This method is called immediately before the component is unmounted and destroyed. It's the perfect place to perform cleanup tasks, such as canceling network requests, removing event listeners, or clearing timers.

Here's an example:

```
class MyComponent extends React.Component {  
  componentWillUnmount() {  
    console.log("Component will unmount.");  
  }  
}
```

- **Error handling in lifecycle methods**

React provides lifecycle methods for error handling and displaying fallback UIs when an error occurs:

- **static getDerivedStateFromError**: This method is called when an error is thrown in a child component. It allows you to update the state to display a fallback UI.

Here's an example:

```
class MyComponent extends React.Component {  
  static getDerivedStateFromError(error) {  
    return { hasError: true };  
  }  
}
```

- ```
 }
 }

 - componentDidCatch: This method is called when an error is caught in a child component. It can be used to log the error or perform other side effects.
```

Here's an example:

```
class MyComponent extends React.Component {
 componentDidCatch(error, info) {
 console.log("Error caught:", error, info);
 }
}
```

Here's an example of using both error handling methods in a component:

```
class ErrorBoundary extends React.Component {
 constructor(props) {
 super(props);
 this.state = { hasError: false };
 }
 static getDerivedStateFromError(error) {
 return { hasError: true };
 }
 componentDidCatch(error, info) {
 console.log("Error caught:", error, info);
 }
 render() {
 if (this.state.hasError) {
 return <h1>Something went wrong!</h1>;
 }
 return this.props.children;
 }
}
// Usage:
<ErrorBoundary>
 <MyComponent />
</ErrorBoundary>
```

In this example, `ErrorBoundary` is a higher-order component that wraps around `MyComponent`. If an error occurs in `MyComponent`, the error boundary will catch it and display a fallback UI.

The following points explain when to use specific lifecycle methods:

- Use `constructor` for initializing state and binding event handlers. Avoid performing side effects in the constructor.
- Use `componentDidMount` for fetching data, setting up subscriptions, or performing other side effects that should happen when the component is first mounted.
- Use `shouldComponentUpdate` to optimize performance by preventing unnecessary re-renders based on specific prop or state changes.
- Use `componentDidUpdate` for side effects that should occur in response to prop or state changes, such as updating the DOM or fetching new data.
- Use `componentWillUnmount` for cleanup tasks, such as canceling network requests or removing event listeners.
- Use `getDerivedStateFromError` and `componentDidCatch` for handling errors in child components and displaying fallback UIs.

By understanding the different lifecycle methods and their appropriate use cases, you can effectively manage side effects, optimize performance, and handle errors in your React components. As you gain experience with React, you'll become more familiar with the nuances of each lifecycle method and how to best use them in your applications.

## **JSX syntax and its differences from traditional HTML**

JSX (JavaScript XML) is a syntax extension for JavaScript that allows you to write HTML-like code within your JavaScript code. It's not required to use React, but it's the recommended approach because it makes the code more readable and easier to understand. JSX is similar to HTML, but there are some key differences and additional features that make it more powerful and flexible.

## JSX syntax rules and best practices

Here are some basic rules and best practices for writing JSX:

- JSX must be enclosed in a single root element. If you have multiple elements, wrap them in a parent element like a `<div>` or a fragment `<>`:

```
// Correct
function MyComponent() {
 return (
 <>
 <h1>Title</h1>
 <p>Content</p>
 </>
);
}
```

```
// Incorrect
function MyComponent() {
 return (
 <h1>Title</h1>
 <p>Content</p>
);
}
```

- JSX tags can be self-closing if they don't have any children. Be sure to include a closing slash before the angle bracket, such as `<img />` or `<input />`:

```
function MyComponent() {
 return ;
}
```

- Attribute names in JSX use camelCase instead of kebab-case. For example, use `onClick` instead of `on-click` and `className` instead of `class`:

```
function MyComponent() {
 return (
 <button onClick={() => console.log("Clicked")}
 className="btn">
```

```
 Click me
 </button>
);
}
```

## Embedding JavaScript expressions in JSX

JSX allows you to embed JavaScript expressions using curly braces ({}). You can use this feature to display variables, perform calculations, and even render other components within your JSX.

Here's an example:

```
function Greeting(props) {
 const name = props.name;
 return <h1>Hello, {name}!</h1>;
}
```

## Handling conditional rendering and looping in JSX

Conditional rendering and looping are common tasks in React components. You can use JavaScript expressions in your JSX to handle these tasks as follows:

- For conditional rendering, use ternary operators or logical AND (`&&`) expressions:

```
function Greeting(props) {
 return (
 <div>
 {props.isLoggedIn ? (
 <h1>Welcome back, {props.name}!</h1>
) : (
 <h1>Please log in.</h1>
)}
 </div>
);
}
```

- For looping, use the `map` method to iterate over arrays and render elements:

```
function ListItems(props) {
 const items = props.items;

 return (

 {items.map((item) => (
 <li key={item.id}>{item.name}
))}

);
}
```

## Differences between JSX and HTML

While JSX looks similar to HTML, there are some key differences between the two:

- **Attribute names:** As mentioned earlier, JSX uses camelCase attribute names instead of kebab-case. For example, use `className` instead of `class` and `htmlFor` instead of `for`.
- **Style attribute:** In JSX, the `style` attribute expects a JavaScript object rather than a CSS string. Each CSS property should be written in camelCase.

```
function MyComponent() {
 const divStyle = {
 color: "blue",
 backgroundColor: "white",
 };
 return <div style={divStyle}>Hello, World!</div>;
}
```

- **Closing tags:** In JSX, all tags must be closed, even if they don't have any children. This is different from HTML, where some tags, like `<img>` and `<input>`, don't require closing tags. In JSX, these elements should be self-closing, with a forward slash before the closing angle bracket (for example, `<img />` and `<input />`).

```

// Correct
function MyComponent() {
 return (
 <div>

 <input type="text" name="username" />
 </div>
);
}

// Incorrect
function MyComponent() {
 return (
 <div>

 <input type="text" name="username">
 </div>
);
}

```

- **JavaScript expressions:** JSX allows you to embed JavaScript expressions using curly braces (`{}`). This feature is not available in HTML, where you must use template literals or other mechanisms to achieve similar functionality.
- **Custom components:** JSX allows you to create custom components that can be used in the same way as HTML elements. In HTML, you would need to use web components or other methods to achieve this.

In summary, JSX is a powerful and flexible syntax extension for JavaScript that allows you to write HTML-like code within your JavaScript code. By understanding its syntax rules, best practices, and differences from traditional HTML, you can effectively use JSX to create clean and maintainable React components. With the ability to embed JavaScript expressions, conditionally render content, and loop through arrays, JSX simplifies the process of building complex and dynamic user interfaces.

## [Handling events in React and passing data between components](#)

This section will explain how to manage events in React and pass data to components.

## React event handling basics

Handling events in React is similar to handling events in plain JavaScript. However, there are some differences and best practices to be aware of when working with events in React, including:

- **Event names:** In React, event names are written in camelCase, such as `onClick`, `onSubmit`, and `onMouseMove`.
- **Event handler:** You need to pass a function as the event handler, not a string. This function will be called when the event is triggered.

Here's an example:

```
function handleClick() {
 console.log("Button clicked!");
}

function MyComponent() {
 return <button onClick={handleClick}>Click me</button>;
}
```

## Synthetic events and event pooling

React uses a concept called Synthetic Events, which are wrappers around native browser events. This provides a consistent interface for handling events across different browsers and improves performance through event pooling. You can access the native event through the `nativeEvent` property on the Synthetic Event object.

Here's an example:

```
function handleClick(event) {
 console.log("Button clicked:", event.nativeEvent);
}

function MyComponent() {
 return <button onClick={handleClick}>Click me</button>;
}
```

## Binding event handlers to components

When using class components, it's essential to bind event handlers to the component instance to access `this` correctly. There are several ways to bind event handlers as follows:

- **Constructor binding**

```
class MyComponent extends React.Component {
 constructor(props) {
 super(props);
 this.handleClick = this.handleClick.bind(this);
 }

 handleClick() {
 console.log("Button clicked:", this);
 }

 render() {
 return <button onClick={this.handleClick}>Click
 me</button>;
 }
}
```

- **Arrow functions**

```
class MyComponent extends React.Component {
 handleClick = () => {
 console.log("Button clicked:", this);
 };

 render() {
 return <button onClick={this.handleClick}>Click
 me</button>;
 }
}
```

- **Inline arrow functions (use with caution, as it may have performance implications)**

```
class MyComponent extends React.Component {
 handleClick() {
 console.log("Button clicked:", this);
 }
```

```
 }

 render() {
 return <button onClick={() => this.handleClick()}>Click
 me</button>;
 }
 }
}
```

## [Passing data through props](#)

Props are the primary mechanism for passing data between components in React. They allow you to pass values from a parent component to a child component and render the child component with the provided data.

Here's an example:

```
function Greeting(props) {
 return <h1>Hello, {props.name}!</h1>;
}

function App() {
 return <Greeting name="John" />;
}
```

## [Using callback functions for parent-child communication](#)

To communicate from a child component back to a parent component, you can pass a callback function as a prop. The child component can then call this function when an event occurs, such as a button click.

Here's an example:

```
class ParentComponent extends React.Component {
 handleClick(name) {
 console.log("Button clicked in child component:", name);
 }

 render() {
 return <ChildComponent onClick={this.handleClick} />;
 }
}
```

```
function ChildComponent(props) {
 return <button onClick={() => props.onClick("Child")}>Click me</button>;
}
```

## Lifting state up and managing shared state

When multiple components need to share and modify the same data, it's a good practice to **lift the state up** to the nearest common ancestor. This means moving the state management to a higher-level component, which can then pass the data down to child components through props.

Here's an example:

```
class App extends React.Component {
 constructor(props) {
 super(props);
 this.state = { counter: 0 };
 this.incrementCounter = this.incrementCounter.bind(this);
 }

 incrementCounter() {
 this.setState((prevState) => ({ counter: prevState.counter + 1 }));
 }

 render() {
 return (
 <>
 <CounterDisplay counter={this.state.counter} />
 <CounterButton onClick={this.incrementCounter} />
 </>
);
 }
}

function CounterDisplay(props) {
 return <h1>Counter: {props.counter}</h1>;
}

function CounterButton(props) {
```

```
 return <button onClick={props.onClick}>Increment
 Counter</button>;
}
```

In this example, the `App` component manages the shared state (the counter value) and passes it down to the `CounterDisplay` and `CounterButton` components through props. The `incrementCounter` function is also passed down to the `CounterButton` component, allowing it to update the shared state.

In summary, handling events and passing data between components in React is a fundamental aspect of building dynamic user interfaces. By understanding React event handling basics, synthetic events, and event binding, you can effectively handle user interactions in your components. Additionally, learning to pass data through props and using callback functions for parent-child communication enables you to build complex and maintainable applications. Lastly, lifting state up and managing shared state helps you efficiently manage data that needs to be accessed and modified by multiple components.

## React state and props

Let's start working with React state and props, including data flow between components:

- **Understanding state in React components**

State in React components is a way to store and manage data that changes over time. Unlike props, which are read-only and passed down from parent components, state is local and mutable within the component. Stateful functional components can be created using the `useState` Hook.

- **Initializing and updating state**

To initialize a state in a functional component, you can use the `useState` Hook. It takes an initial value as an argument and returns an array with two elements: the current state value and a function to update the state. You can use array destructuring to assign the returned elements to variables:

```
import React, { useState } from 'react';
```

```
function Counter() {
 const [count, setCount] = useState(0);

 function increment() {
 setCount(count + 1);
 }

 return (
 <div>
 <p>Count: {count}</p>
 <button onClick={increment}>Increment</button>
 </div>
);
}
```

- **Handling state immutability and best practices**

State in React should be treated as immutable. This means that, instead of directly modifying the current state, you should create a new state object with the updated data. This practice helps prevent bugs and optimize performance, as React can efficiently compare the old and new state objects to determine if a re-render is necessary.

When updating state based on the current state, use a functional update by passing a function to the state updater:

```
function increment() {
 setCount((prevCount) => prevCount + 1);
}
```

- **Props and their role in component communication**

As mentioned earlier, props are the primary way to pass data between components in React. Props are read-only and allow parent components to pass values down to their children. Child components can then access the passed data through their props object:

```
function Greeting({ name }) {
 return <h1>Hello, {name}!</h1>;
}

function App() {
 return <Greeting name="John" />;
}
```

- **Validating props with PropTypes**

PropTypes is a library that allows you to specify the expected types of props for a component. It's a helpful tool for catching bugs and documenting your components' expected prop types. To use PropTypes, you need to import the library and define the expected prop types on your component:

```
import React from 'react';
import PropTypes from 'prop-types';

function Greeting({ name }) {
 return <h1>Hello, {name}!</h1>;
}

Greeting.propTypes = {
 name: PropTypes.string.isRequired,
};

export default Greeting;
```

- **Managing state and data flow with Context API**

In some cases, you may need to share state between components that are not directly connected through a parent-child relationship. The Context API is a built-in feature in React that allows you to share state across the component tree without manually passing props through multiple levels.

To use the Context API, you need to create a context using `React.createContext()` and wrap your component tree with a context provider. The context provider takes a `value` prop, which can be any data you want to share across the component tree:

```
import React, { useState, useContext } from 'react';
const ThemeContext = React.createContext();
function App() {
 const [theme, setTheme] = useState('light');

 return (
 <ThemeContext.Provider value={{ theme, setTheme }}>
 <Toolbar />
 </ThemeContext.Provider>
);
}
```

```

}

function Toolbar() {
 return <ThemeSwitch />;
}

function ThemeSwitch() {
 const { theme, setTheme } = useContext(ThemeContext);
 function toggleTheme() {
 setTheme((prevTheme) => (prevTheme === 'light' ? 'dark' :
 'light'));
 }
 return (<button onClick={toggleTheme}>
 Switch to {theme === 'light' ? 'dark' : 'light'} theme
 </button>);
}

```

In this example, the **App** component initializes the theme state and provides it to the **ThemeContext**. The **ThemeSwitch** component, nested within the **Toolbar** component, can then access and update the theme state using the **useContext** Hook, without the need to pass the theme and the updater function through props.

In summary, understanding state and props in React functional components is crucial for building dynamic and interactive applications. By using the **useState** Hook to initialize and update state, you can manage component data effectively. Adhering to best practices, such as treating state as immutable and using functional updates, helps prevent bugs and optimize performance. Props play a vital role in component communication, allowing you to pass data between components and validate their types with **PropTypes**. Finally, the Context API simplifies state management and data flow in more complex applications by sharing state across the component tree without the need for manual prop drilling.

## Introducing React Hooks and their usage

What are React Hooks and why use them? React Hooks are a set of functions introduced in React 16.8 that allow you to use state and other React features in functional components. Hooks provide a more

straightforward way to manage state and side effects in functional components without the complexity of class components. Some benefits of using Hooks include better code reuse, simpler code, and easier testing.

- **Using the useState Hook**

The **useState** Hook allows you to add state to functional components. It takes an initial state as an argument and returns an array with two elements: the current state and a function to update the state. You can use array destructuring to assign the returned elements to variables:

```
import React, { useState } from 'react';

function Counter() {
 const [count, setCount] = useState(0);

 function increment() {
 setCount(count + 1);
 }

 return (
 <div>
 <p>Count: {count}</p>
 <button onClick={increment}>Increment</button>
 </div>
);
}
```

- **Working with useEffect and its dependencies**

The **useEffect** Hook allows you to perform side effects, such as fetching data or updating the DOM, in functional components. It takes two arguments: a function containing the side effect and an optional dependency array. The side effect function runs after every render by default, but you can control when it runs by providing a dependency array. The effect will only run when one of the dependencies changes:

```
import React, { useState, useEffect } from 'react';

function UserProfile({ userId }) {
 const [user, setUser] = useState(null);

 useEffect(() => {
 async function fetchUser() {
```

```

 const response = await
 fetch('https://api.example.com/users/${userId}');
 const userData = await response.json();
 setUser(userData);
 }

 fetchUser();
}, [userId]);

return (
 <div>
 {user ? (
 <div>
 <h1>{user.name}</h1>
 <p>{user.email}</p>
 </div>
) : (
 <p>Loading...</p>
)}
 </div>
);
}

```

- **Implementing custom Hooks for reusable logic**

Custom Hooks are a powerful feature that allows you to create reusable logic across components. A custom Hook is simply a function that starts with the word **use** and contains other Hooks:

```

import { useState, useEffect } from 'react';
function useFetch(url) {
 const [data, setData] = useState(null);
 const [loading, setLoading] = useState(true);

 useEffect(() => {
 async function fetchData() {
 const response = await fetch(url);
 const jsonData = await response.json();
 setData(jsonData);
 setLoading(false);
 }
 })
}

```

```

 fetchData();
}, [url]);

return { data, loading };
}

function App() {
 const { data, loading } =
 useFetch('https://api.example.com/data');

 return (
 <div>
 {loading ? <p>Loading...</p> : <p>Data:
{JSON.stringify(data)}</p>}
 </div>
);
}

```

- **useContext and useReducer for advanced state management**

The **useContext** and **useReducer** Hooks can be used together to create advanced state management patterns similar to Redux. The **useContext** Hook allows you to access the nearest context value up the component tree, while the **useReducer** Hook manages complex state transitions using a reducer function:

```

import React, { createContext, useReducer, useContext }
from 'react';

const initialState = { count: 0 };

function reducer(state, action) {
 switch (action.type) {
 case 'increment':
 return { count: state.count + 1 };
 case 'decrement':
 return { count: state.count - 1 };
 default:
 throw new Error(`Unknown action type: ${action.type}`);
 }
}

const CounterContext = createContext();

```

```

function CounterProvider({ children }) {
 const [state, dispatch] = useReducer(reducer,
 initialState);
 return (
 <CounterContext.Provider value={{ state, dispatch }}>
 {children}
 </CounterContext.Provider>
);
}

function Counter() {
 const { state, dispatch } = useContext(CounterContext);
 return (
 <div>
 <p>Count: {state.count}</p>
 <button onClick={() => dispatch({ type: 'increment' })}>
 Increment
 </button>
 <button onClick={() => dispatch({ type: 'decrement' })}>
 Decrement
 </button>
 </div>
);
}

function App() {
 return (
 <CounterProvider>
 <Counter />
 </CounterProvider>
);
}

```

## Other built-in Hooks and their use cases

React offers several other built-in Hooks, each with specific use cases:

- **useMemo**: Optimizes performance by memoizing a value, which is recomputed only when its dependencies change. This Hook is useful

when working with computationally expensive functions or objects.

- **useCallback**: Similar to **useMemo**, but for memoizing functions. It returns a memoized version of the callback function that changes only if one of the dependencies has changed.
- **useRef**: Creates a mutable ref object that can be used to store values across renders without triggering a re-render. Common use cases include referencing DOM elements and storing the previous state.
- **useLayoutEffect**: Similar to **useEffect**, but it runs synchronously after all DOM mutations, ensuring that the effect and its cleanup are both run in the same frame. Use this Hook when you need to read the layout or measure the DOM before the browser paints.

In summary, React Hooks provide a powerful and straightforward way to manage state, side effects, and other React features in functional components. The built-in Hooks, such as **useState**, **useEffect**, **useContext**, and **useReducer**, cover a wide range of use cases, while custom Hooks enable the creation of reusable logic across components. Advanced state management patterns can be achieved using **useContext** and **useReducer**, and other built-in Hooks such as **useMemo**, **useCallback**, **useRef**, and **useLayoutEffect** offer additional functionality for various scenarios.

## [Asynchronous programming in JavaScript and its application in React](#)

Asynchronous programming is a programming paradigm that allows multiple tasks to run concurrently, without blocking the main execution thread. JavaScript is single-threaded, which means it can only execute one operation at a time. Asynchronous programming enables JavaScript to perform time-consuming tasks, such as fetching data from APIs or reading files, without freezing the user interface.

- **Callback functions and their limitations**

Callbacks are functions passed as arguments to other functions, which are then executed at a later time. Callbacks are the most basic form of handling asynchronous code in JavaScript:

```

function getData(callback) {
 setTimeout(() => {
 const data = 'Sample data';
 callback(data);
 }, 1000);
}

getData((data) => {
 console.log(data); // 'Sample data'
});

```

However, callbacks can lead to the infamous **callback hell** when dealing with multiple nested asynchronous operations, resulting in unreadable and hard-to-maintain code.

- **Promises and chaining**

Promises are a more advanced way to handle asynchronous code. A Promise represents a value that may be available in the future. Promises have three possible states: pending, fulfilled, or rejected. You can use the **then** method to attach callbacks that will be called when the Promise is fulfilled or the **catch** method to handle errors:

```

function getData() {
 return new Promise((resolve, reject) => {
 setTimeout(() => {
 const data = 'Sample data';
 resolve(data);
 }, 1000);
 });
}

getData().then((data) => {
 console.log(data); // 'Sample data'
});

```

Promises can be chained, allowing for more readable and maintainable code when dealing with multiple asynchronous operations.

- **Async/await syntax for cleaner asynchronous code**

Async/await is a modern syntax that makes working with asynchronous code even more straightforward. An **async** function

returns a Promise, and the `await` keyword is used to pause the execution of the function until the Promise is resolved:

```
async function fetchData() {
 const response = await
 fetch('https://api.example.com/data');
 const data = await response.json();
 console.log(data);
}

fetchData();
```

- **Integrating asynchronous code with React components**

To integrate asynchronous code in React functional components, you can use the `useEffect` Hook to fetch data or perform other side effects:

```
import React, { useState, useEffect } from 'react';

function DataDisplay() {
 const [data, setData] = useState(null);

 useEffect(() => {
 async function fetchData() {
 const response = await
 fetch('https://api.example.com/data');
 const jsonData = await response.json();
 setData(jsonData);
 }
 fetchData();
 }, []);

 return <div>{data ? <p>{JSON.stringify(data)}</p> :
 <p>Loading...</p>}</div>;
}
```

- **Error handling and best practices in asynchronous React code**

When working with asynchronous code in React, it's essential to handle errors properly. You can use `try/catch` blocks within async functions to catch errors and display appropriate error messages to the user:

```
import React, { useState, useEffect } from 'react';
```

```
function DataDisplay() {
 const [data, setData] = useState(null);
 const [error, setError] = useState(null);

 useEffect(() => {
 async function fetchData() {
 try {
 const response = await
 fetch('https://api.example.com/data');
 const jsonData = await response.json();
 setData(jsonData);
 } catch (err) {
 setError(err.message);
 }
 }
 })
}
```

Asynchronous programming is crucial for creating responsive and efficient applications in JavaScript and React. From callbacks to Promises and `async/await` syntax, JavaScript offers various ways to manage asynchronous code. In React, the `useEffect` Hook allows seamless integration of asynchronous operations within functional components. Proper error handling, such as using `try/catch` blocks, ensures a better user experience when dealing with real-world scenarios. By understanding and applying these concepts, you can create more robust and performant React applications that handle asynchronous operations gracefully.

## Conclusion

React provides a powerful and flexible framework for building modern web applications. Throughout these seven sections, we explored the core concepts of React, from its component-based architecture, JSX syntax, and state management, to event handling, lifecycle methods, and Hooks. Additionally, we delved into asynchronous programming techniques to create more responsive applications. By understanding these fundamental concepts and applying best practices, you can harness the full potential of React and develop efficient, maintainable, and scalable web applications.

In the upcoming chapter, *Next.js Fundamentals*, you will be introduced to the Next.js framework and its key advantages. We will guide you through

the installation and setup process, creating a new Next.js project, and understanding its folder structure. You'll learn about the essential role of pages in Next.js and how to create and render a basic page. Finally, we'll explore implementing CSS styling using CSS modules, a powerful feature for managing component styles. This chapter will equip you with the foundational knowledge necessary to build robust and scalable Next.js applications.

## Multiple choice questions

1. What is the primary purpose of the virtual DOM in React?
  - A. To improve performance by reducing direct DOM manipulations
  - B. To enable asynchronous programming
  - C. To simplify the syntax of JavaScript code
  - D. To replace the real DOM completely
2. What are the two types of components in React?
  - A. Synchronous and Asynchronous
  - B. Functional and Class
  - C. Stateful and Stateless
  - D. Parent and Child
3. What is the main difference between JSX and HTML?
  - A. JSX is a markup language, while HTML is a programming language
  - B. JSX allows embedding JavaScript expressions, while HTML does not
  - C. JSX cannot be used for styling, while HTML can
  - D. JSX requires a separate file for CSS, while HTML does not
4. What is the primary purpose of React Hooks?
  - A. To enable the use of state and other React features in functional components
  - B. To improve performance by reducing direct DOM manipulations

- C. To simplify the syntax of JavaScript code
  - D. To enable the use of class components
5. Which React Hook is used for performing side effects in functional components?
- A. useState
  - B. useEffect
  - C. useContext
  - D. useReducer
6. What is the primary advantage of using async/await syntax over Promises?
- A. Async/await allows for more performant code
  - B. Async/await makes asynchronous code easier to read and write
  - C. Async/await enables the use of state in functional components
  - D. Async/await eliminates the need for error handling
7. In which React Hook is the context API primarily used?
- A. useState
  - B. useEffect
  - C. useContext
  - D. useReducer
8. What is the primary role of props in React components?
- A. Managing state within a component
  - B. Enabling the use of state and other React features in functional components
  - C. Passing data and functions between components
  - D. Defining the structure and layout of a component
9. Which lifecycle method is called only once when a React component is mounted?
- A. componentDidMount
  - B. componentDidUpdate

- C. componentWillUnmount
  - D. componentDidCatch
10. Which of the following is NOT a valid state in a JavaScript Promise?
- A. Pending
  - B. Fulfilled
  - C. Rejected
  - D. Completed

## Answers

- 1. A
- 2. B
- 3. B
- 4. A
- 5. B
- 6. B
- 7. C
- 8. C
- 9. A
- 10. D

## CHAPTER 3

# Next.js Fundamentals

### Introduction

In this chapter, we delve into the fundamentals of the Next.js framework. We begin by introducing Next.js, a powerful React-based framework that offers unique features like server-side rendering (SSR), static site generation (SSG), and incremental static regeneration (ISR). We'll explore the advantages of using Next.js and compare it with other popular frameworks, while also shedding light on its practical applications in real-world projects.

Next, we'll guide you through the process of setting up your development environment, installing Next.js, and creating your first Next.js project. We'll help you understand the core structure of a Next.js project and explain how each folder and file contributes to your application.

As we delve deeper, we'll explain the critical role of pages in Next.js, how they are tied to routing, and the process of creating and rendering a basic page. Lastly, we'll introduce CSS Modules and demonstrate how to leverage them to style your Next.js application effectively. By the end of this chapter, you'll have a solid understanding of the basic workings of Next.js and will be well-equipped to start building your own Next.js applications.

### Structure

In this chapter, the following topics will be covered:

- Introduction to Next.js framework and its advantages
- Installing, setting up, and creating a new Next.js project
- Understanding the folder structure of a Next.js project
- Understanding the role of pages in **Next.js**
- Creating and rendering a basic page in **Next.js**

- Implementing CSS styling in `Next.js` using CSS Modules

## Introducing Next.js framework and its advantages

Next.js is a powerful, open-source, React-based framework for building server-side rendered and statically generated applications. Developed and maintained by Vercel, it's built with JavaScript and leverages the power of React, Node.js, and the JavaScript ecosystem. The framework is designed to provide an optimized user experience with features like automatic code splitting, pre-fetching, and hot code reloading.

Here is an example of a basic `Next.js` component:

```
// A basic Next.js component
function HomePage() {
 return <div>Welcome to Next.js!</div>
}
export default HomePage
```

## Advantages of using Next.js

Next.js offers several compelling features that make it a standout choice for modern web development. These features include:

- **Server-side rendering (SSR)**: Next.js renders pages on the server and sends them to the client as a complete HTML file. This feature accelerates initial page loads and improves SEO.
- **Static site generation (SSG)**: Next.js can generate static HTML at build time, reducing the need for a server. This feature is ideal for blog posts or documentation sites where content doesn't change frequently.
- **Incremental static regeneration (ISR)**: This is a blend of SSR and SSG. ISR allows you to create static pages that can be updated incrementally after the build process, providing optimal performance with up-to-date content.
- **Automatic routing**: Based on the file system in the `pages` directory, Next.js automatically routes your application, reducing manual routing setup.

- **API routes:** Next.js allows you to build your API routes alongside your pages, simplifying back-end development.

For example:

```
// An example of API route in Next.js
export default function handler(req, res) {
 res.status(200).json({ text: 'Hello from Next.js API
 route' })
}
```

- **Hot module reloading:** Next.js offers hot module reloading out of the box, providing immediate feedback during development.
- **Built-in CSS and Sass support:** Next.js has built-in support for CSS and Sass, and it also supports CSS-in-JS solutions like styled components or emotion.
- **TypeScript support:** Next.js supports TypeScript out of the box, allowing for strong typing in your projects.

## Comparing with other frameworks

Next.js stands out from other JavaScript frameworks such as Create React App (CRA) and Gatsby in several ways. While CRA is great for building single-page applications (SPAs), it lacks the SSR and SSG features of Next.js, which are critical for SEO and performance. Gatsby, on the other hand, emphasizes SSG but doesn't natively support SSR or ISR. Moreover, the automatic routing and API routes in Next.js make it a more comprehensive solution for full-stack development.

Here's an example:

```
// A dynamic route in Next.js
// pages/posts/[id].js
function Post({ post }) {
 // Render post...
}

export async function getServerSideProps(context) {
 const { id } = context.params
 // Fetch data based on id...
 return { props: { post } }
```

```
}

export default Post;
```

## Real-world use cases of Next.js

Many well-known companies use Next.js in their tech stacks due to its versatility and robust feature set. Companies like Netflix, Twitch, and Uber have leveraged the power of Next.js to build fast, scalable, and SEO-friendly web applications. These real-world uses validate the practicality and enterprise-readiness of the Next.js framework.

In summary, Next.js is a comprehensive framework that offers a blend of performance, developer experience, and flexibility. Whether you're building a small project or a large-scale enterprise application, Next.js has the tools and features to make the process efficient and enjoyable.

The broad feature set of Next.js reduces the need for additional configurations or plugins that might be necessary in other frameworks. Its server-side rendering capabilities allow for improved SEO, while static site generation and incremental static regeneration offer various options for optimizing performance based on your specific needs.

Here's an example of Static Site Generation in Next.js:

```
// Static Site Generation in Next.js
// pages/posts/[id].js
export async function getStaticPaths() {
 // Determine the paths at build time...
}

export async function getStaticProps({ params }) {
 // Fetch data based on params...
 return { props: { ... } }
}

export default function Post({ ... }) {
 // Render the post...
}
```

The built-in routing system simplifies page creation, and the native API route feature means you can handle backend functionality within the same framework, resulting in a seamless full-stack development experience.

In addition, Next.js provides out-of-the-box support for CSS and Sass, TypeScript, and popular CSS-in-JS solutions, eliminating the need to set up these features manually. This built-in functionality, coupled with the automatic hot code reloading, makes for an excellent developer experience.

In comparing Next.js to other popular frameworks like CRA and Gatsby, it's clear that Next.js offers a more comprehensive set of tools for building modern web applications. While CRA and Gatsby each have their strengths, the versatility of Next.js makes it a strong contender for many use cases.

The adoption of Next.js by prominent companies like Netflix, Uber, and Twitch further demonstrates its capabilities and practicality. These companies require highly performant, scalable, and reliable web applications, and their choice to use Next.js indicates the framework's ability to meet these requirements.

Whether you're just getting started with JavaScript development or you're a seasoned developer looking to streamline your workflow, Next.js offers an array of benefits that make it an excellent choice for your next project.

## **Installing and creating a new Next.js project**

In this section, we will look into the prerequisites for installing Next.js and analyze the folder structure of a Next.js application.

### **Prerequisites for installing Next.js**

Before we get started with Next.js, we need to make sure that the necessary tools are installed on our machine. Node.js and `npm` (node package manager) are crucial for setting up a Next.js project. Node.js is a JavaScript runtime that allows us to run JavaScript on our server, and npm is a package manager for Node.js. As of writing, the latest LTS versions of Node.js (v14.x.x or higher) and npm (v6.x.x or higher) are recommended.

You can check if you have Node.js and npm installed and view the versions by running the following commands in your terminal:

```
bash
node -v
npm -v
```

If you don't have Node.js installed, you can download it from the official Node.js website (<https://nodejs.org>).

## Installing Next.js

Once you have Node.js and `npm` installed, setting up a new Next.js application is a breeze, thanks to the `create-next-app` command, which sets up a new Next.js application with a default starter template.

In your terminal, navigate to the directory where you want your project to live and run the following command:

```
bash
npx create-next-app@latest my-next-app
```

In this command, `my-next-app` is the name of your new project. Replace it with the name you desire.

## Creating your first Next.js project

The `create-next-app` command creates a new directory with your project name, sets up the necessary files and folders, and installs the dependencies. It's essentially a ready-to-go Next.js application.

After the command completes, navigate into your new project directory:

```
bash
cd my-next-app
```

To start the development server, use the `npm run dev` command:

```
bash
npm run dev
```

Open your browser and go to `http://localhost:3000`. You should see your new Next.js application up and running!

## Understanding the initial setup

The 'create-next-app' command sets up a standard Next.js file structure as follows:

- **pages:** This directory contains your application's pages. Each file corresponds to a route based on its file name.

- **public**: This directory stores static files like images, which are served at the root ('/') URL path.
- **styles**: This directory contains global CSS files. The **globals.css** file is included by default and can be used for global styles.
- **package.json**: This file contains metadata about your project and its dependencies.

Here's the directory structure of a Next.js project:

```
bash
my-next-app
├── pages
│ ├── _app.js
│ ├── api
│ └── index.js
├── public
├── styles
│ ├── globals.css
│ └── Home.module.css
└── package.json
```

The ‘pages’ directory includes an **index.js** file, which corresponds to the ‘/’ route, and **\_app.js**, which is a custom App component used to initialize pages. You can override it to control page initialization or add global styles.

The **api** directory under **pages** is special — it’s where you can create backend functions directly in your Next.js app.

This initial setup provides a solid foundation for your Next.js projects, and you’ll learn more about each of these components as you progress in your Next.js journey.

## **Understanding the folder structure of a Next.js project**

Understanding the file and folder structure of a Next.js project is crucial as it will provide a better sense of the project’s organization and make development smoother.

## Overview of the folder structure

A newly created Next.js application has the following folder structure:

```
my-next-app
├── pages
│ ├── _app.js
│ ├── api
│ └── index.js
├── public
├── styles
│ ├── globals.css
│ └── Home.module.css
├── .gitignore
└── package.json
└── README.md
```

Let's go over each of these directories and files to better understand their roles.

## Exploring the ‘pages’ directory

The **pages** directory is one of the most important directories in a Next.js project. This is where you will add all the pages for your application. Each file inside this directory corresponds to a route based on its file name.

For example, if you create a **about.js** file inside the **pages** directory, it will be accessible at ‘<http://localhost:3000/about>’.

```
// pages/about.js
export default function About() {
 return <h1>About Us</h1>
}
```

The **pages** directory also includes the **\_app.js** file, which is a custom App component. This file allows you to override the default App component used to initialize pages. You can use this to keep state between pages, add global CSS, or add global layout.

The **api** directory inside **pages** is where you can create your API routes. Each file inside this directory corresponds to a route that can be used to create a full-fledged API.

```
// pages/api/hello.js
export default function handler(req, res) {
 res.status(200).json({ text: 'Hello' })
}
```

## Exploring the public directory

The **public** directory is where you can add static assets like images, fonts, or robots.txt file. These files will be served from the root ('/') URL path. For example, if you add a 'logo.png' file inside the 'public' directory, you can access it via 'http://localhost:3000/logo.png'.

This directory is also useful for files like **manifest.json**, **robots.txt**, and any other static files you want to add to the root of your domain.

## Exploring the styles directory

Next.js supports CSS imports out of the box. The **styles** directory is where you can add your CSS files. By default, Next.js configures your project to support CSS Modules, which allows you to import CSS directly into your JavaScript files.

For example, you can create a 'Button.module.css' file:

```
/* Button.module.css */
.button {
 padding: 10px 20px;
 background-color: #0070f3;
 color: #fff;
 border: none;
 border-radius: 5px;
}
```

And then import it in your component:

```
// pages/index.js
import styles from '../styles/Button.module.css'

export default function Home() {
 return <button className={styles.button}>Click Me</button>
}
```

The **globals.css** file is included by default and can be used for global styles. These styles will apply to all pages and components in your application. You can also use this file to import other CSS files as global.

## Other files

The **package.json** file contains metadata about your project and lists its dependencies. When you run **npm install <package>**, the package is added as a dependency

## Understanding the role of pages in Next.js

In Next.js, a page is a React Component that is associated with a route based on its file name in the **pages** directory. This concept is one of the foundational aspects of Next.js and understanding it is crucial for building applications using the framework.

## Introducing pages

In Next.js, each file in the **pages** directory becomes a route that automatically gets processed and rendered. Let's say you have a file **pages/about.js**, it will be accessible at '<http://localhost:3000/about>'.

Here is an example of a basic page:

```
// pages/about.js
export default function About() {
 return <h1>About Us</h1>
}
```

When you navigate to '/about', the 'About' function will be rendered.

- **Automatic routing**

Next.js follows a filesystem-based router built on the concept of pages. When a file is added to the **pages** directory, it's automatically available as a route.

The files and folders in the 'pages' directory mirror the routes' paths. For example, if you create a **pages/posts/first-post.js** file, it will be accessible at '/posts/first-post'.

- **Dynamic routes**

Next.js supports dynamic routes. If you create a file inside the ‘pages’ directory with square brackets (‘[]’) in the name, it will be treated as a dynamic route.

For example, **pages/posts/[id].js** will match **/posts/1**, **/posts/2**, and so on. You can access the dynamic part (id in this case) in your component using the **useRouter** hook from **next/router**:

```
// pages/posts/[id].js
import { useRouter } from 'next/router'
export default function Post() {
 const router = useRouter()

 return <h1>Post: {router.query.id}</h1>
}
```

- **Nested routes**

You can create nested routes by adding folders inside the **pages** directory. For example, if you create a **pages/posts/first-post.js** file, it will be accessible at **/posts/first-post**.

- **API routes**

Next.js allows you to create API routes. API routes are server-side routes where you can implement back-end logic, such as fetching data from a database or handling form submissions.

API routes are created by defining files inside the **pages/api** directory. Like the rest of the **pages** directory, the file system is the main API endpoint and files are associated with routes based on their file name.

For example, if you create a **pages/api/hello.js** file, it will be accessible at **/api/hello**:

```
// pages/api/hello.js
export default function handler(req, res) {
 res.status(200).json({ text: 'Hello' })
}
```

- **Error pages**

Next.js has a built-in 404 page, which is automatically served if a route is not found. You can customize the 404 page by creating a **pages/404.js** file:

```
// pages/404.js
export default function Custom404() {
 return <h1>404 - Page Not Found</h1>
}
```

In conclusion, pages in Next.js are the heart of the routing system. Understanding how to create and manage pages enables you to harness the power of Next.js to build dynamic, high-performing web applications.

## Creating and rendering a basic page in Next.js

As we have learned the role of pages in Next.js, let's walk through the process of creating and rendering a basic page.

As mentioned earlier, a page in Next.js is a React Component exported from a **.js**, **.jsx**, **.ts**, or **.tsx** file in the **pages** directory. Each page is associated with a route based on its file name.

- **Creating a new page**

Creating a new page in Next.js is as simple as creating a new file in the **pages** directory. Let's create a new **About** page for our application. In your project, create a new file at **pages/about.js** and add the following code:

```
// pages/about.js
export default function About() {
 return (
 <div>
 <h1>About Us</h1>
 <p>We are a team of dedicated developers building web
 applications with Next.js.</p>
 </div>
)
}
```

In the preceding code, we've created a functional component 'About' that returns a simple HTML structure. This component will be our **About** page.

- **Viewing the new page**

Now that you've created the new page, you can view it by navigating to 'http://localhost:3000/about' in your browser. You should see the 'About' page you just created.

- **Linking between pages**

One of the most common operations in a web application is navigating between pages. In Next.js, you can use the 'Link' component from the 'next/link' package to navigate between pages.

Let's create a **Link** to the 'About' page from our **Home** page. Open the **pages/index.js** file and update the content as follows:

```
// pages/index.js
import Link from 'next/link'

export default function Home() {
 return (
 <div>
 <h1>Home</h1>
 <p>Welcome to our website!</p>
 <Link href="/about">About Us</Link>
 </div>
)
}
```

In this code, we've imported the **Link** component from **next/link** and used it to link to the **About** page. The **href** attribute is used to specify the destination route of the link.

Now, when you navigate to **http://localhost:3000**, you'll see a link to the **About** page. Clicking this link will take you to the **About** page without a full page refresh, thanks to Next.js's automatic client-side navigation.

- **Understanding the rendering process**

When you request a page in a Next.js application, here's what happens under the hood:

1. **The server receives the request:** When you navigate to a route in your Next.js application, the server receives a request for that route.

2. **The server fetches the page's component:** Next.js then fetches the React Component for that route from the ‘pages’ directory.
3. **The server renders the page:** The component is rendered to HTML on the server. If your component fetches data in a `getServerSideProps` function (which we’ll discuss in later chapters), this data fetching happens during this step.
4. **The server sends the HTML response:** The HTML result is sent to the client, along with minimal JavaScript code for hydration.
5. **The page is interactive:** The JavaScript code runs on the client, **hydrating** the HTML into a fully interactive React application.

This process allows Next.js to provide fast initial load times and powerful features like server-side rendering and static site generation.

- **Recap**

In this section, you’ve learned how to create a new page in Next.js, how to view it, and how to link between different pages. You also gained an understanding of the rendering process in Next.js. With these basics, you can start building multi-page web applications using Next.js.

- **Creating a layout component**

Often, you might want to share components, like headers or footers, across multiple pages. Next.js doesn’t provide a built-in layout system, but creating your own is simple.

Let’s create a layout component that renders a navigation bar with links to the **Home** and **About** pages:

```
// components/Layout.js
import Link from 'next/link'
export default function Layout({ children }) {
 return (
 <div>
 <nav>
 <Link href="/">Home</Link>
 <Link href="/about">About</Link>
 </nav>
 </div>
)
}
```

```
 {children}
 </div>
)
}
```

In the **Layout** component, we're rendering a navigation bar and the children components passed to **Layout**.

Now, you can use this **Layout** component in your pages:

```
// pages/index.js
import Layout from '../components/Layout'
export default function Home() {
 return (
 <Layout>
 <h1>Home</h1>
 <p>Welcome to our website!</p>
 </Layout>
)
}

// pages/about.js
import Layout from '../components/Layout'
export default function About() {
 return (
 <Layout>
 <h1>About Us</h1>
 <p>We are a team of dedicated developers building web
 applications with Next.js.</p>
 </Layout>
)
}
```

With this setup, each page is wrapped with the **Layout** component, providing a consistent layout across pages.

Creating and rendering pages in Next.js is a straightforward process. By leveraging the framework's automatic routing and powerful rendering features, you can quickly create dynamic and performant web applications.

In the next section, we'll take a look at how you can style your Next.js application using CSS Modules.

## Implementing CSS styling in Next.js using CSS modules

Styling is an essential part of any web application. In Next.js, CSS can be imported directly into JavaScript files, thanks to built-in support for CSS and Sass. In this section, we'll focus on using CSS Modules, a CSS file in which all class names and animation names are scoped locally by default.

- **Introducing CSS Modules**

CSS Modules are CSS files where all class names and animation names are scoped locally by default. The key idea behind CSS Modules is that it ensures that all the styles for a single component:

- Live in one place (a **.module.css** file)
- Apply only to that component and nothing else

- **Creating a CSS module**

To create a CSS Module, you need to create a **.module.css** file. In your project's **styles** directory, create a new file named **About.module.css**:

```
/* About.module.css */
.container {
 margin: 20px;
 padding: 20px;
 border: 1px solid #ddd;
}
.title {
 color: #0070f3;
 font-size: 2em;
 margin-bottom: 10px;
}
.content {
 font-size: 1.2em;
 line-height: 1.6em;
}
```

In this file, we define three CSS classes: `container`, `title`, and `content`.

- **How to use a CSS module**

To use a CSS Module, you import it in a JavaScript file. The imported CSS Module can then be referenced as an object. Let's apply these styles to our **About** page:

```
// pages/about.js
import styles from '../styles/About.module.css'
import Layout from '../components/Layout'
export default function About() {
 return (
 <Layout>
 <div className={styles.container}>
 <h1 className={styles.title}>About Us</h1>
 <p className={styles.content}>We are a team of
 dedicated developers building web applications with
 Next.js.</p>
 </div>
 </Layout>
)
}
```

In this file, we import the CSS Module we created earlier and use the classes in our component. The styles are applied only to this component, even if other components use the same class names.

- **Composition and global classes**

CSS Modules allow you to compose styles, meaning you can use styles from other CSS Modules in your current one. It also supports global styles, which apply to your entire application.

Here's an example of using composition and global styles:

```
/* Global.module.css */
.title {
 color: #0070f3;
}

/* styles/About.module.css */
@import './Global.module.css';
```

```
.container {
 composes: title from './Global.module.css';
 font-size: 2em;
}
```

In this example, the **About.module.css** file imports styles from ‘Global.module.css’ and uses the **title** class in its **container** class.

CSS Modules provide a powerful and flexible way to style your Next.js applications. By scoping styles locally by default, CSS Modules ensure that styles don’t leak between components, helping you to avoid style conflicts and keep your styles organized.

## Conclusion

In this chapter, we’ve introduced Next.js, a robust framework that enhances React’s capabilities, and explored its key features and advantages. We’ve covered the installation and setup of a new Next.js project, understood the project structure, and dived deep into the role of pages. We’ve also walked through creating and rendering a basic page and learned to implement CSS styling using CSS Modules. With this foundational knowledge, you’re well-equipped to start building your own Next.js applications and to further explore this powerful framework’s advanced features.

In the upcoming chapter, “*Next 13 - Core Concepts*,” we will delve into the exciting new features and enhancements introduced in Next.js version 13. We’ll explore how these updates further optimize your development experience and improve your application’s performance. From the new Routing system and improvements to Edge Functions to Middleware and improvements in React Server Components, you’ll gain a comprehensive understanding of the current state of the framework, enabling you to make full use of its advanced capabilities.

## Multiple choice questions

1. What is Next.js?
  - A. A JavaScript library for building user interfaces
  - B. A CSS framework for styling web pages

- C. A full-fledged back-end framework
  - D. A React framework for building JavaScript applications
2. Which command is used to create a new Next.js application?
- A. `npm create-next-app`
  - B. `npm start-next-app`
  - C. `npx create-next-app`
  - D. `npx start-next-app`
3. What type of file represents a page in Next.js?
- A. A ‘.js’ or ‘.jsx’ file in the ‘pages’ directory
  - B. A ‘.css’ file in the ‘styles’ directory
  - C. A ‘.md’ file in the ‘markdown’ directory
  - D. A ‘.html’ file in the ‘public’ directory
4. How does Next.js handle routing?
- A. By manually defining routes in a ‘routes.js’ file
  - B. Automatically based on the ‘pages’ directory
  - C. By using the Express.js routing system
  - D. Next.js doesn’t handle routing
5. How can you navigate between pages in Next.js?
- A. By using the ‘<a>’ HTML element
  - B. By using the ‘navigate’ function from the ‘next/navigate’ package
  - C. By using the ‘Link’ component from the ‘next/link’ package
  - D. By using the ‘push’ method from the ‘next/router’ package
6. What happens when you request a page in a Next.js application?
- A. The browser downloads the entire application
  - B. The server sends the HTML of the requested page
  - C. The server sends the JavaScript code of the requested page
  - D. The browser renders the page from scratch
7. What is a CSS Module in Next.js?

- A. A CSS file in which all class names and animation names are scoped globally by default
  - B. A CSS file in which all class names and animation names are scoped locally by default
  - C. A JavaScript file in which all styles are defined as JavaScript objects
  - D. A CSS file that can be imported into a JavaScript file as a string
8. How do you apply a class from a CSS Module in a Next.js component?
- A. By using the ‘className’ attribute and the name of the class
  - B. By using the ‘style’ attribute and the name of the class
  - C. By using the ‘className’ attribute and referencing the class from the imported styles object
  - D. By using the ‘style’ attribute and referencing the class from the imported styles object
9. What is the purpose of the ‘Layout’ component in Next.js?
- A. To define the structure of a page
  - B. To share common components across multiple pages
  - C. To style a page
  - D. To handle data fetching for a page
10. Which of the following is NOT a feature of Next.js?
- A. Automatic routing
  - B. Local scope for CSS Modules
  - C. Client-side rendering
  - D. Automatic translation of JavaScript code to TypeScript

## Answers

1. D
2. C
3. A

- 4. B
- 5. C
- 6. B
- 7. B
- 8. C
- 9. B
- 10. D

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## CHAPTER 4

### Next.js 13

#### Introduction

In this chapter, we delve into the latest version of Next.js, v13, which was announced at the Next.js Conf 2022. Next.js 13 represents a significant evolution in the world of React frameworks, bringing forward novel concepts and tools that redefine the way developers build web applications. It is designed to streamline the development process, providing a rich set of features that make it easier to create scalable, performant, and SEO-friendly web applications. With the introduction of features like Server Components and TurboPack, Next.js 13 stands on the frontier of modern web development, pushing the boundaries of what's possible with React and JavaScript.

One of the key changes is the introduction of the ‘app’ router, a fundamental shift from the traditional ‘page` file structure. This new routing approach provides granular control over page transitions and enhances overall application performance. Moreover, Next.js 13 has revamped the way it handles images, leveraging a new generation of image optimization technology that enhances both speed and visual quality.

In essence, Next.js 13 is not just an update - it is a quantum leap that reimagines the very core of Next.js, ushering in a new era of web development. The following sections will delve into the specifics of these exciting new features, offering a comprehensive exploration of Next.js 13’s capabilities.

#### Structure

In this chapter, the following topics will be covered:

- Setting up a Next.js 13 app
- App Router

- Client and Server Components
- Routing
- Rendering
- Data fetching

## Setting up a Next.js 13 app

To download the latest version of Next.js (which is 13.4.3 as of May 2023), first, install Node.js on your system, and then type in the following command:

```
npx create-next-app@latest
```

You'll get the following prompts then:

```
What is your project named? my-app
Would you like to add TypeScript with this project? Y/N
Would you like to use ESLint with this project? Y/N
Would you like to use Tailwind CSS with this project? Y/N
Would you like to use the `src/ directory` with this project?
Y/N
What import alias would you like configured? `@/*`
```

After the prompts, create-next-app will create a folder with your project name and install the required dependencies.

If you open the package.json file, you will see the following scripts:

```
{
 "scripts": {
 "dev": "next dev",
 "build": "next build",
 "start": "next start",
 "lint": "next lint"
 }
}
```

These scripts refer to the different stages of developing a Next.js 13 application:

- **dev**: runs next dev to start Next.js in development mode.
- **build**: runs next build to build the application for production usage.

- **start**: runs next start to start a Next.js production server.
- **lint**: runs next lint to set up Next.js' built-in ESLint configuration.

Open the **layout.tsx** file in the app folder, and you'll see the following contents:

```
import './globals.css'
import { Inter } from 'next/font/google'
const inter = Inter({ subsets: ['latin'] })

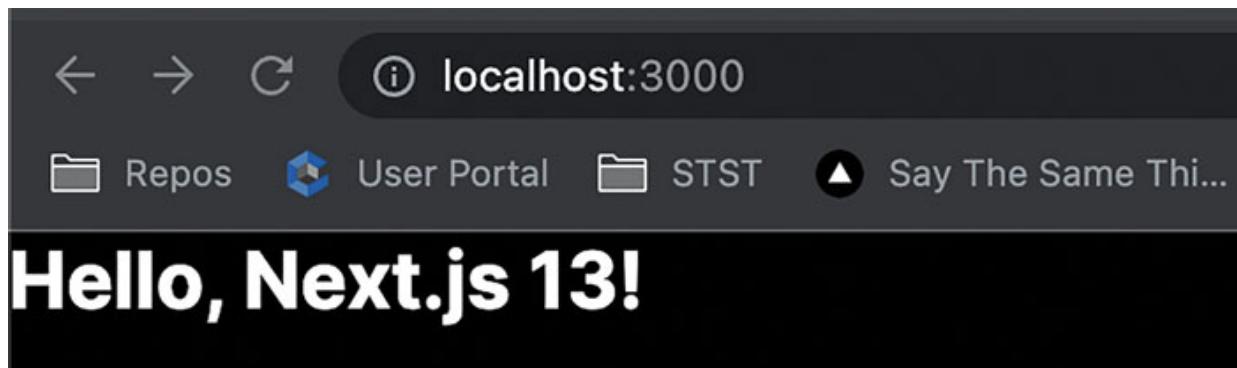
export const metadata = {
 title: 'Create Next App',
 description: 'Generated by create next app',
}

export default function RootLayout({
 children,
}: {
 children: React.ReactNode
}) {
 return (
 <html lang="en">
 <body className={inter.className}>{children}</body>
 </html>
)
}
```

Now open the **page.tsx** in the app folder and replace its contents with the following code:

```
export default function Page() {
 return <h1>Hello, Next.js 13!</h1>;
}
```

Type `npm run dev` in your console to start the development server and visit `http://localhost:3000` in your browser. You will see the following screen:



*Figure 4.1: localhost screen*

We have successfully set up a Next.js 13 application on our computer.

## App Router

Next.js 13 introduces a new App Router structure built on React Server Components, which supports nested routing, shared layouts, error handling, and loading states. The App Router works within a new folder named `app`, which can work alongside the `pages` directory. This helps to adopt the new App Router incrementally and allows the developer to adopt the new concepts at their own pace. In this chapter, we will focus only on learning the new features that were introduced with v13.

### **Folders and files**

In the App Router, folders are used to define routes. A route is a single path made up of nested folders that follow the hierarchy from the top-level root folder to the last leaf folder containing a `page.js` file. The `page.js` is used to define the UI displayed for that particular route. For example, if we visit the link <https://mathewdony.com/dashboard> in our browser for a Next.js 13 app, the application will render the UI from the `page.tsx` file located inside the `dashboard` folder in the `app` folder.

Here is the folder structure for `my-app`:

```
my-app
 +-- app
 +-- dashboard
 +-- page.tsx
```

### **File Conventions**

Next.js provides a set of special files for creating UI with specific behavior in nested routes. Let's have a look at the main ones that we need:

- **page.js**: It is used to render the UI of a route and make the path publicly accessible to a user.
- **layout.js**: It is used to create shared UI for a segment and its children. A layout wraps a page or child segment and can be used to render UI that is shared across multiple routes, such as a navigation menu or a header component.
- **loading.js**: It is used to create loading UI for a segment and its children. loading.js shows a loading UI while they load and works by wrapping a page or child segment in a React Suspense Boundary.
- **error.js**: It is used to create an error UI for a segment and its children. error.js shows the error UI if an error is caught and works by wrapping a page or child segment in a React Error Boundary.

## Client and server components

With the release of Next.js 13, a hybrid method for creating apps that uses both Server and Client Components was introduced. A React principle called “Server Components” seeks to design applications with zero JavaScript bundles and a server-driven mental model for modern user interfaces.

A Client Component is fetched from and rendered on the client (the browser), whereas a Server Component is fetched from and rendered on the server.

Now, let's examine a program without a Server Component. In this scenario, a server replies to a user's request for a web page by sending information to the browser. JavaScript is downloaded by the browser when it creates the web page. This implies that the browser, similar to npm packages, must install every piece of JavaScript required to create the web page. Due to all the request-response waterfalls, this may take a long time to load and provide a bad user experience.

A Server Component is useful in this situation. The browser only needs to download JavaScript files for Client Components, while a component is defined as a Server Component since the server builds the component and returns the rendered HTML for the Server Component. This can speed up browser rendering and enhance the user experience.

Next.js 13 provides us with a system where we can specify whether a component should be a Server or a Client Component at the component level.

In the newly introduced app directory in Next.js 13, all components are Server Components by default. This means that all the components and pages are rendered on the server, as long as you specify that the component should be rendered on the client side. Here's what a Server Component looks like in **Next.js 13**:

```
export default function Page() {
 return <h1>Hello, Next.js 13!</h1>;
}
```

You can see from the preceding code that it is just a normal React component, but it automatically becomes a Server Component as all components are Server Components by default in **Next.js 13**.

Next.js recommends using Server Components until you need to use Client Components. For example, React hooks, such as **useState()**, **useEffect()**, and **useContext()**, are only available on the client side. Furthermore, if you need to access browser-related things like **onClick** events, window, or browser API, you need to use the Client Component.

If we need to add a counter to our app, then we can import **useState** in our React component as follows:

```
import React, { useState } from "react";
export default function Page() {
 const [count, setCount] = useState(0);
 return <h1>Current Count: {count}</h1>;
}
```

But the preceding code will give us the following error message in the browser, as shown in [Figure 4.2](#):

```
Failed to compile

./app/page.tsx

ReactServerComponentsError:

You're importing a component that needs useState. It only works in a Client Component but none of its parents are marked with "use client", so they're Server Components by default.

,-[~/Users/mchittezhath/Downloads/my-app/app/page.tsx:1:1]
1 | import React, { useState } from "react";
:
2 |
3 | export default function Page() {
4 | const [count, setCount] = useState(0);
`-----

Maybe one of these should be marked as a client entry with "use client":
./app/page.tsx ⏺

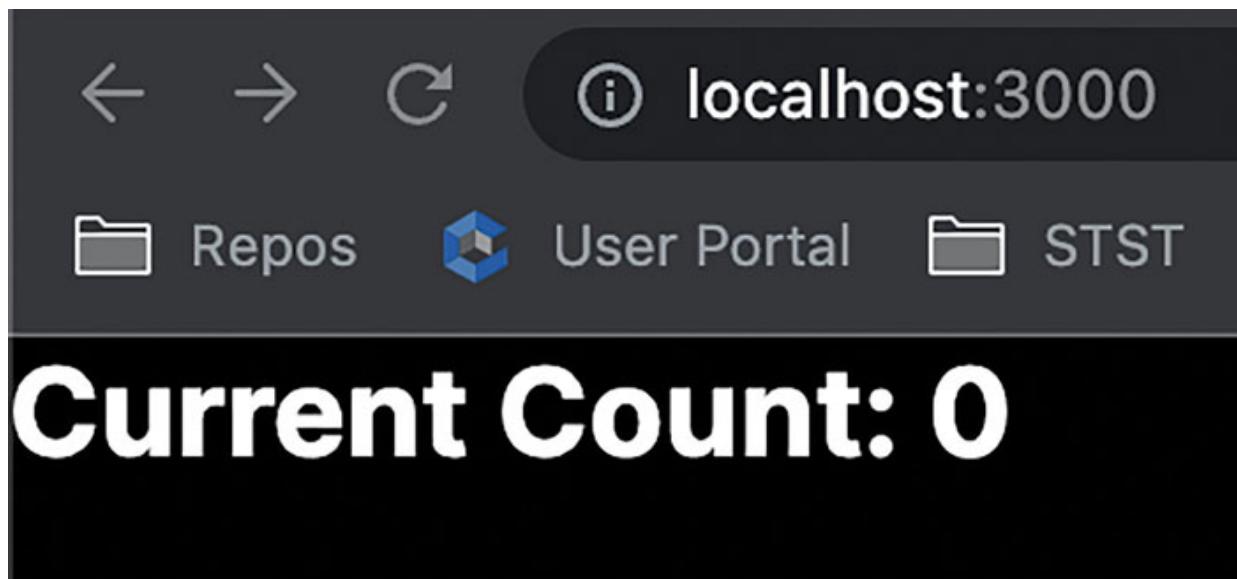
This error occurred during the build process and can only be dismissed by fixing the error.
```

*Figure 4.2: Error message*

To execute the preceding code, we need to convert our Server Component to a Client Component. This can be done by adding **use client** directive to the top of our component file as follows:

```
"use client";
import React, { useState } from "react";
export default function Page() {
 const [count, setCount] = useState(0);
 return <h1>Current Count: {count}</h1>;
}
```

This resolves the error and the app functions normally as follows:



*Figure 4.3: App functions normally after error resolution*

## Routing

Next.js uses a file system-based router in which each folder defines a route. Each folder represents a route segment that maps to a URL segment, and nested route can be created by nesting folders inside each other.

### **Dynamic routes**

While developing a web application, there are cases where the developer or user may not know the exact segment names ahead of time and want to create routes from dynamic data. In such cases, we can use Dynamic Segments that are resolved at request or pre-rendered at build time.

A dynamic segment in Next.js 13 can be created by wrapping a folder's name in square brackets.

For example, if you want to render dynamic data that should be retrieved from the URL segment, such as **app/blog/[slug]/page.js**, where [slug] is the Dynamic Segment for the blog posts, then you can write the page.js as follows:

```
export default function Page({ params }) {
 return <div>My Post with ID {params.slug}</div>;
}
```

If we visit the URL `app/blog/1234`, we will get the value `1234` inside the `params` prop, as demonstrated in the preceding example.

## Error handling

The `error.js` file convention allows a developer to handle runtime errors in nested routes. It can be used to automatically wrap a route and its nested children in a React Error Boundary. This enables developers to create an error UI tailored to that specific segment. A major advantage of the `error.js` file convention is that it allows error isolation without affecting the remaining parts of the app. An error UI can be easily added by creating an `error.js` file inside a route segment and exporting a React component.

## Middleware

We can execute code using middleware before a request has finished. The response may be modified based on the incoming request by rewriting, redirecting, changing the request or response headers, or simply responding.

# Rendering

A route can be statically or dynamically rendered in Next.js. In a static route, components are rendered on the server at build time. This work is cached and reused on subsequent requests, whereas, in a dynamic route, components are rendered on the server at request time.

## Static Rendering

Static rendering, which is the default rendering pattern for a Next.js app, improves performance because all the rendering work is done ahead of time and can be served from a Content Delivery Network (CDN) geographically closer to the user.

We can also opt into dynamic rendering by using a dynamic function or dynamic data fetching in a layout or page, which will cause Next.js to render the whole route dynamically at the time of the request.

## Dynamic rendering

Next.js will switch to dynamically rendering the whole route at request time if a dynamic function or `fetch()` request in no-caching mode is detected during static rendering. Any cached data requests can still be reused during

dynamic rendering. Dynamic data fetches are fetch requests with their cache option set to ‘no-store’ or revalidate to 0. We will explore more data fetching patterns in the next section.

## Data fetching

React and Next.js 13 introduced a new way to fetch and manage data in your application. The new data fetching system works in the app directory and is built on top of the `fetch()` Web API.

`fetch()` is a Web API used to fetch remote resources that returns a promise. React extends `fetch` to provide automatic request deduping, and Next.js extends the `fetch` options object to allow each request to set its own caching and revalidating.

### **async and await in Server Components**

The following code is an example of using `async` and `await` to fetch data in Server Components:

```
async function getData() {
 const res = await fetch('https://api.example.com/...');

 if (!res.ok) {
 // This will activate the closest `error.js` Error Boundary
 throw new Error('Failed to fetch data');
 }

 return res.json();
}

export default async function Page() {
 const data = await getData();

 return <p>{data}</p>;
}
```

### **Static data fetching**

By default, `fetch` will automatically **fetch** and **cache** data indefinitely:

```
fetch('https://...'); // cache: 'force-cache' is the default
```

### **Dynamic data fetching**

To fetch fresh data on every fetch request, use the cache: **no-store** option:

```
fetch('https://...', { cache: 'no-store' });
```

## Conclusion

In this chapter, we learned about Next.js 13, the latest version of the web framework, and explored its new key features and advantages. We've seen how it has adopted the app router, making it easy for developers to not worry about rendering and caching a Next.js application, as these cases are handled automatically by the framework. With all these new features, Next.js 13 has become the obvious choice for building a web application in 2023.

In the upcoming chapter, *Optimizing Next.js Applications*, we will learn about the different strategies that can be used to optimize a Next.js application, resulting in improved performance and a better developer experience. Next.js provides inbuilt components such as `<Image />` and `<Link />`, providing developers with numerous out-of-the-box capabilities to optimize their web applications.

## Multiple choice questions

1. Which is the command to start a Next.js development server locally?
  - A. next de
  - B. next build
  - C. next start
  - D. next lint
2. Which is the main directory in Next.js 13?
  - A. layout folder
  - B. pages directory
  - C. app router
  - D. public folder
3. What do you call a single path of nested folders?
  - A. Route
  - B. Page

- C. App
  - D. Folder
4. How is the file from which the UI is rendered for a route?
- A. error.js
  - B. loading.js
  - C. wait.js
  - D. page.js
5. What is the default type of a component in Next.js 13?
- A. Home Component
  - B. Server Component
  - C. App Component
  - D. Router Component
6. What is the directive to convert a Server Component to a Client Component?
- A. use client
  - B. use server
  - C. serve client
  - D. set client
7. Which file provides the React Error Boundary in Next.js 13?
- A. boundary.js
  - B. fault.js
  - C. error.js
  - D. error-boundary.js
8. What is the default behavior of fetch API in Next.js 13?
- A. Forced caching
  - B. Not caching
  - C. Incremental caching
  - D. Periodical caching

9. What is the command to build a Next.js app for production?

- A. build production
- B. next dev
- C. next build
- D. next run

10. Which is the convention to set a dynamic route path for ‘id’?

- A. {id}
- B. [id]
- C. (id)
- D. <id>

## Answers

1. A

2. C

3. A

4. D

5. B

6. A

7. C

8. A

9. C

10. B

## CHAPTER 5

# Optimizing Next.js Applications

## Introduction

As a savvy developer, you know that your Next.js applications need to be optimized for peak performance. Luckily, Next.js is an open-source framework that makes it easy to build blazing-fast, server-rendered React applications. With out-of-the-box features like automatic code splitting and static exporting, Next.js takes care of the heavy lifting, leaving you free to focus on creating scalable, high-performance apps that users will love. In this chapter, we'll explore the exciting world of Next.js, highlighting its many features and discussing why optimizing your Next.js apps is so important. So, buckle up and get ready to turbocharge your development skills!

## Structure

In this chapter, we will cover the following topics:

- Importance and benefits of optimizing the Next.js applications
- Adding metadata to pages using the head component
- Implementing static file serving in Next.js
- Understanding the use of the Next.js image component for image optimization
- Understanding Next.js architecture and how it works
- Configuring Next.js for optimal performance
- Implementing server-side rendering (SSR) and pre-rendering
- Code splitting and dynamic imports
- Caching and improving data fetching
- Analyzing and reducing bundle size
- Deployment strategies and best practices

- Monitoring and optimizing performance

## Importance and benefits of optimizing the Next.js applications

Optimizing Next.js applications is important for several reasons. First, it can improve the overall performance of the application, which can lead to better user engagement and retention. Second, it can reduce the load on the server, which can result in cost savings for the developer. Finally, optimizing Next.js applications can help to future-proof the application, ensuring that it remains scalable and maintainable over time.

There are several benefits of optimizing Next.js applications, including:

- **Improved performance:** Optimizing Next.js applications can help to improve the performance of the application, resulting in faster load times and a better user experience.
- **Reduced server load:** Optimizing Next.js applications can help to reduce the load on the server, which can result in cost savings for the developer.
- **Future-proofing:** Optimizing Next.js applications can help to future-proof the application, ensuring that it remains scalable and maintainable over time.
- **Increased developer productivity:** Optimizing Next.js applications can help to increase developer productivity, as it can help to identify and resolve performance issues more quickly.

## Adding metadata to pages using the head component

In this section, we will explore the syntax and usage of the Head component in Next.js. We will learn how to set the page title, define meta tags, add external stylesheets, and include JavaScript libraries. Additionally, we will cover best practices for structuring and organizing metadata to maximize its impact.

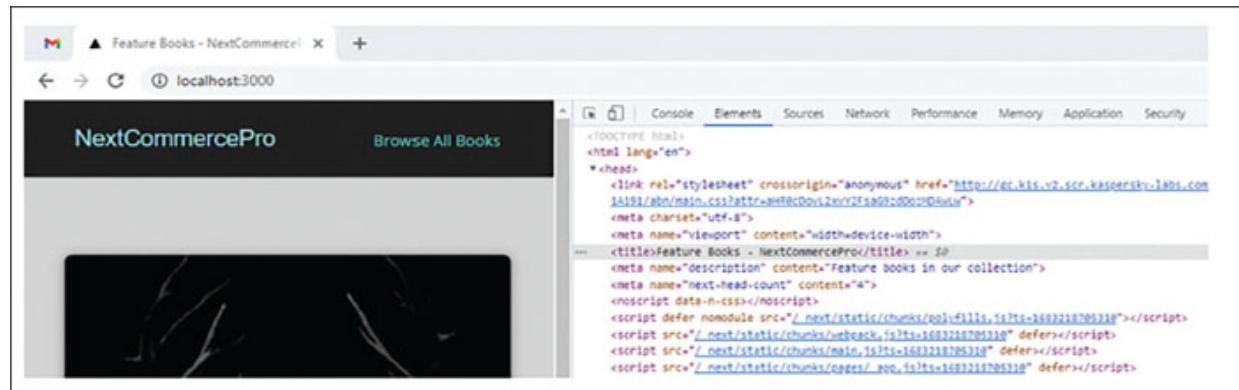
The Head component in Next.js allows you to define metadata for individual pages. Metadata includes elements like the title, description, and various tags

that enhance search engine optimization (SEO) and improve the display of pages when shared on social media platforms. By utilizing the Head component effectively, you can ensure that your web pages are well-represented across different platforms and achieve better visibility. To use the Head component, you need to import it from the **next/head** module.

Let's consider an example where we want to set the title and description for a specific page:

```
import Head from 'next/head';
function HomePage() {
 return (
 <div>
 <Head>
 <title> Feature Books - NextCommercePro</title>
 <meta name="description" content=" Feature books in our
 collection" />
 </Head>
 {/* Rest of the page content */}
 </div>
);
}
export default HomePage;
```

Figure 5.1 shows the Default Home page with meta and title:



*Figure 5.1: Default homepage*

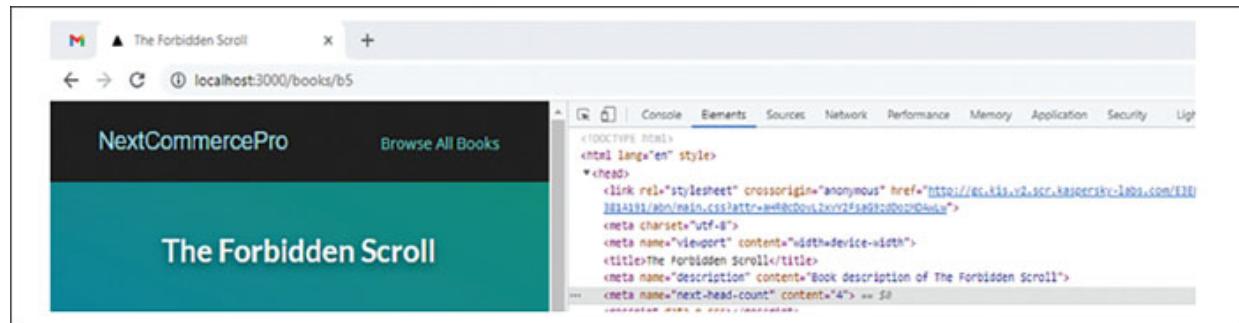
In the code snippet, we import the Head component from the 'next/head' module. Inside the HomePage component, we wrap the desired metadata elements within the Head component. In this case, we set the title to **My**

## Next.js App - Home and the meta description to Welcome to my Next.js application!

The Head component allows you to add various other metadata tags as well. For example, you can include Open Graph (OG) tags for better social media sharing:

```
import Head from 'next/head';
function BookPage({ book }) {
 return (
 <div>
 <Head>
 <title>{ book.title}</title>
 <meta name="description" content={ book.excerpt} />
 <meta property="og:title" content={ book.title} />
 <meta property="og:description" content={ book.excerpt} />
 <meta property="og:image" content={ book.thumbnail} />
 </Head>
 {/* Rest of the page content */}
 </div>
);
}
export default BookPage;
```

[Figure 5.2](#) depicts the Product detail page:



*Figure 5.2: Dynamic BookPage*

In this example, we pass the post object as a prop to the BookPage component. We use the post's data to dynamically set the title, description, and Open Graph (OG) tags. The og:title, og:description, and og:image tags are essential for social media platforms to display the correct title, description, and thumbnail image when the page is shared.

By using the Head component, you can easily set metadata for each page in your Next.js application, improving SEO and enhancing the visual representation of your pages on social media platforms. Remember to include relevant metadata, such as titles, descriptions, and OG tags, to ensure that your pages are effectively optimized for search engines and social sharing.

## [Implementing static file serving in Next.js](#)

When it comes to implementing static file serving in Next.js, different types of static files play a crucial role in web development, including images, CSS stylesheets, and JavaScript files. In this section, we will explore how to efficiently serve static files in your Next.js application. We'll cover various strategies and best practices to ensure optimal performance and seamless integration of static assets into your Next.js projects.

- **Serving images**

Images are an integral part of modern web development. In Next.js, you can serve images by following these steps:

- Create a folder named **public** in the root directory of your Next.js project.
- Place your image file, let's say **my-image.jpg**, inside the **public** folder.
- In your Next.js component, use the **<Image>** component from Next.js to display the image.

Here's an example:

```
import Image from 'next/image';
const MyComponent = () => {
 return (
 <div>
 <Image src="/my-image.jpg" alt="My Image" width={500}
 height={300} />
 </div>
);
};
export default MyComponent;
```

The `<Image>` component automatically optimizes and serves the image, providing benefits like lazy loading and responsive image rendering.

- **Serving CSS stylesheets**

When it comes to implementing static file serving in Next.js, CSS stylesheets are an essential part of the equation. They allow you to style your web pages and make them visually appealing. In this section, we will delve into how you can efficiently serve CSS stylesheets in your Next.js application.

To begin, let's assume you have a CSS file named `styles.css` that contains all the styles for your Next.js application. Here's an example of how you can serve this CSS file using Next.js:

- Create a folder named **public** in the root directory of your Next.js project. This folder will hold all your static files, including CSS stylesheets.
- Move the `styles.css` file into the **public** folder.
- In your Next.js component or layout file, import the CSS file using the `<link>` tag within the `<head>` section.

Here's an example:

```
import Head from 'next/head';
const MyComponent = () => {
 return (
 <div>
 <Head>
 <link rel="stylesheet" href="/styles.css" />
 </Head>
 {/* Your component content */}
 </div>
);
};
export default MyComponent;
```

- With the `<link>` tag, we specify the `rel` attribute as “**stylesheet**” to indicate that this is a stylesheet file. The `href` attribute points to the location of the CSS file relative to the root of your Next.js application. In this case, it's “`/styles.css`” because we placed the file in the **public** folder.

By following these steps, your Next.js application will efficiently serve the CSS stylesheet. The CSS rules defined in “`styles.css`” will be applied to the corresponding components and elements in your application.

It’s important to note that Next.js automatically handles caching and optimization of static files. When you make changes to the CSS file, Next.js will generate a new unique filename for the updated version, ensuring that clients receive the latest styles without relying on manual cache invalidation.

By adopting this approach, you can seamlessly integrate CSS stylesheets into your Next.js projects and ensure optimal performance by efficiently serving static files.

- **Serving JavaScript Files**

When it comes to serving JavaScript files in Next.js, you can follow a straightforward process to ensure efficient delivery and integration of these files into your application. Here’s a detailed explanation of serving JavaScript files in Next.js:

1. **Create a “public” folder:** Start by creating a folder named “`public`” in the root directory of your Next.js project if it doesn’t already exist. This folder will hold all your static files, including JavaScript files.
2. **Place JavaScript Files in the “public” folder:** Move your JavaScript files into the “`public`” folder. For example, let’s say you have a JavaScript file named “`script.js`.” Copy or move it to the “`public`” folder. The file structure should look as shown in [Figure 5.3](#):



*Figure 5.3: Public folder Structure*

3. **Include JavaScript Files in Your HTML:** To include the JavaScript file in your HTML, you can use the `<script>` tag. Next.js automatically serves any files placed in the “`public`”

folder as static files, and you can reference them by their relative path from the root of your Next.js application. In your HTML file or Next.js component, include the following code snippet to import the JavaScript file: `<script src="/script.js"></script>`

Here, the `src` attribute of the `<script>` tag points to the location of the JavaScript file relative to the root of your Next.js application. In this case, the file is named “script.js” and is located directly in the “public” folder.

4. **Utilizing JavaScript functionality:** Once the JavaScript file is included in your HTML or Next.js component, you can access and utilize the functionality it provides. The JavaScript code within “`script.js`” can contain various functions, event listeners, or other logic that you want to incorporate into your application.

For example, if “script.js” contains a function called “`myFunction`,” you can call it from your HTML or Next.js component using the following syntax:

```
<script src="/script.js"></script>
<script>
 myFunction(); // Call the function defined in
 script.js
</script>
```

By following these steps, Next.js will serve the JavaScript file as a static asset, allowing it to be efficiently delivered to the client’s browser. You can then utilize the JavaScript functionality within your application as needed.

It’s important to note that Next.js automatically handles caching and optimization of static files, including JavaScript files. If you make changes to the JavaScript file, Next.js will generate a new unique filename for the updated version, ensuring that clients receive the latest code without relying on manual cache invalidation.

By serving JavaScript files in this manner, you can seamlessly integrate dynamic functionality and interactivity into your Next.js application while ensuring optimal performance and efficient delivery of static assets.

## Understanding the use of the Next.js image component for image optimization

Images are an integral part of any modern web application, and optimizing them for performance is essential. In this section, we will delve into the Next.js Image component and its features for optimizing images in your Next.js applications. The Next.js Image component provides built-in image optimization techniques, such as automatic resizing, lazy loading, and responsive image delivery, to ensure efficient rendering and reduced page load times.

You will gain a comprehensive understanding of how to leverage this component to deliver efficient and visually appealing images in your Next.js projects. To use the Next.js Image component, you need to import it from the ‘next/image’ module.

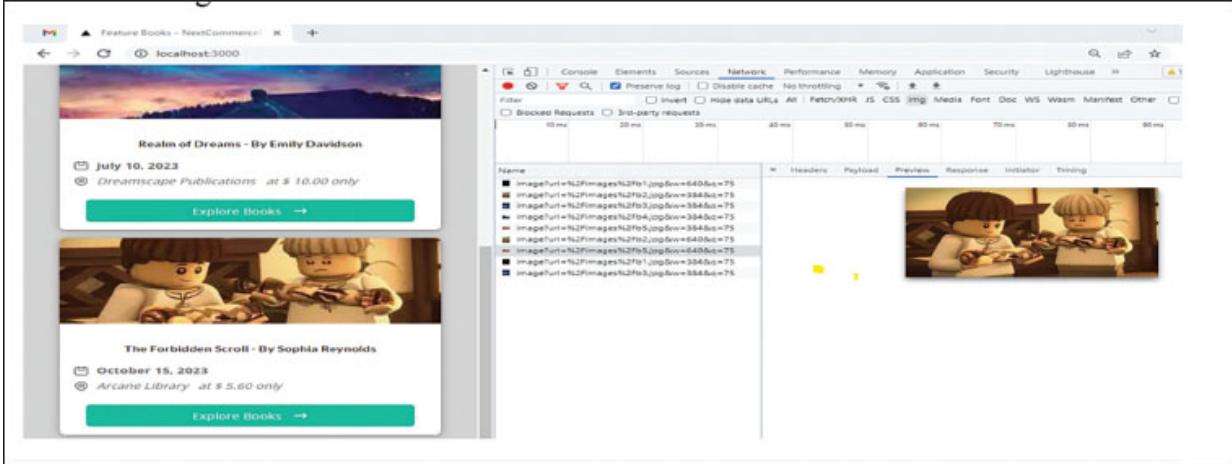
Let’s consider an example of using the Next.js Image component to display an optimized image:

```
import Image from 'next/image';
function HomePage() {
 return (
 <div>
 <Image src="/images/my-image.jpg" alt="My Image" width={800} height={600} />
 {/* Rest of the page content */}
 </div>
);
}
export default HomePage;
```

In the preceding code snippet, we import the Image component from the ‘next/image’ module. We use the Image component to display the image located at “/images/my-image.jpg”. We also provide the alt text for accessibility purposes. Additionally, we specify the desired width and height of the image using the width and height props.

The Next.js Image component automatically optimizes the image based on the provided dimensions. It generates multiple optimized versions of the image at build time, each tailored for different screen sizes and devices. The appropriate image is served to the client based on its viewport and device

characteristics, resulting in improved performance and reduced bandwidth usage ([Figure 5.4](#)).



**Figure 5.4:** Product list page or Book list page

The Next.js Image component supports several other properties that you can use to further optimize the image delivery:

- **layout:**

The layout property determines how the image should be laid out on the page. It can be set to “**responsive**” (default), “**fixed**”, or “**intrinsic**”. The “**responsive**” layout automatically sizes the image based on the container’s dimensions, while “**fixed**” and “**intrinsic**” enforce specific dimensions.

```
import Image from 'next/image';
function HomePage() {
 return (
 <div>
 <Image
 src="/images/my-image.jpg"
 alt="My Image"
 layout="responsive"
 width={800}
 height={600}
 />
 {/* Rest of the page content */}
 </div>
);
}
```

```
}

export default HomePage;
```

In the preceding example, we set the layout property to “**responsive**”. This allows the image to dynamically adjust its size based on the container’s dimensions, ensuring a responsive layout.

- **objectFit:**

The objectFit property determines how the image should be scaled and positioned within its container. It can be set to “**fill**” (default), “**contain**”, “**cover**”, “**none**”, or “**scale-down**”.

In the following example, we set the objectFit property to “**cover**”. This ensures that the image covers the entire container while maintaining its aspect ratio.

```
import Image from 'next/image';
function HomePage() {
 return (
 <div>
 <Image
 src="/images/my-image.jpg"
 alt="My Image"
 layout="fill"
 objectFit="cover"
 />
 {/* Rest of the page content */}
 </div>
);
}
export default HomePage;
```

- **objectPosition:**

The objectPosition property specifies the horizontal and vertical positioning of the image within its container. It takes values like “top”, “bottom”, “left”, “right”, “center”, or a combination of these.

```
import Image from 'next/image';
function HomePage() {
 return (
 <div>
```

```

<Image
 src="/images/my-image.jpg"
 alt="My Image"
 layout="fixed"
 width={500}
 height={300}
 objectFit="contain"
 objectPosition="top right"
/>
{/* Rest of the page content */}
</div>
);
}
export default HomePage;

```

In this example, we set the `objectPosition` property to “**top right**”. This positions the image at the top-right corner of the container.

- **loading:**

The `loading` property controls the lazy loading behavior of the image. It can be set to “**eager**” (default) to load the image immediately, or “**lazy**” to defer loading until the image enters the viewport.

```

import Image from 'next/image';

function HomePage() {
 return (
 <div>
 <Image
 src="/images/my-image.jpg"
 alt="My Image"
 loading="lazy"
 />
 {/* Rest of the page content */}
 </div>
);
}
export default HomePage;

```

In this example, we set the `loading` property to “**lazy**”, allowing the image to be loaded only when it enters the viewport, and improving

performance by reducing the initial page load time.

- **priority property**

The priority property in the Next.js Image component allows you to prioritize the loading of images, ensuring a better user experience for critical content. By setting a higher priority for certain images, you can make sure they are loaded first, reducing the perceived load time of important visual elements on your page.

Here's an example of how to use the priority property:

```
import Image from 'next/image';
function HomePage() {
 return (
 <div>
 <Image
 src="/images/my-image.jpg"
 alt="My Image"
 priority
 />
 {/* Rest of the page content */}
 </div>
);
}
export default HomePage;
```

In the preceding code snippet, we set the priority property to true for the image component. This indicates that the image should be given a higher priority during loading.

By setting the priority property, Next.js will prioritize the loading of the image, fetching it early in the page-loading process. This ensures that the image is available as soon as possible, improving the user experience by reducing the perceived load time for important visual elements.

It's important to note that the priority property should be used selectively for critical images that are essential for the initial rendering of your page. Using it for every image on the page may not provide significant benefits and could potentially impact the overall performance of your application.

In summary, the priority property in the Next.js Image component allows you to control the loading priority of images, ensuring a better user experience by loading critical content first.

By focusing on the three detailed topics mentioned above and providing an overview of the remaining subjects, this chapter aims to equip you with the necessary knowledge to leverage Next.js effectively and optimize your applications for superior performance.

## **Understanding Next.js Architecture and how it works**

We will provide a high-level overview of Next.js architecture, its key components, and how they interact to deliver powerful server-side rendered applications.

Next.js is a React framework that provides a comprehensive solution for building modern web applications with a focus on performance and developer experience. It combines the benefits of server-side rendering (SSR) and client-side rendering (CSR) to deliver fast and interactive user experiences.

Next.js follows a hybrid rendering approach, allowing you to choose between SSR and CSR based on your application's needs. Let's explore the architecture and how it works in more detail:

- **Server-side rendering (SSR)**

In server-side rendering, the server generates the HTML content for each page and sends it to the client. This means that the initial page load contains the fully rendered HTML, including the content fetched from APIs or databases. This approach provides several advantages, as follows:

- **Improved SEO:** Search engines can easily crawl and index the fully rendered HTML, leading to better search engine optimization.
- **Faster initial page load:** Since the server sends the pre-rendered HTML to the client, the user can see the content faster, even on slower connections.

- **Better performance for static content:** Static content is generated once on the server and can be cached for subsequent requests, reducing the load on the server.

To enable SSR in Next.js, you need to create a special type of file called a “page” in the pages directory. Each page file exports a React component that represents the content for that page. During the build process, Next.js pre-renders these pages and generates the corresponding HTML files.

- **Client-side rendering (CSR)**

In client-side rendering, the initial HTML sent by the server contains a minimal skeleton of the page, and the client-side JavaScript takes over to fetch data and render the content dynamically. This approach provides the following benefits:

- **Interactive user experience:** With CSR, you can build highly interactive applications that fetch and display data on the client-side without requiring full page reloads.
- **Real-time updates:** By fetching data asynchronously, you can update the UI in real-time without refreshing the entire page.

Next.js supports CSR through its powerful client-side routing system. When a user navigates to a different page within a Next.js application, only the necessary JavaScript and data are fetched, and the UI is updated without a full page reload.

- **Next.js architecture:** Next.js uses a serverless architecture, allowing you to deploy your application to serverless platforms like Vercel, AWS Lambda, or Netlify. This architecture automatically scales based on the incoming traffic, ensuring optimal performance and reducing infrastructure costs.

Next.js also provides various performance optimization features out of the box, such as automatic code splitting, static site generation (SSG), and incremental static regeneration (ISR). These features enable you to deliver optimized and fast-loading web applications.

Code example:

Here’s an example of a basic Next.js page component using SSR:

```
// pages/index.js
```

```
import React from 'react';
function HomePage({ data }) {
 return (
 <div>
 <h1>Welcome to Next.js!</h1>
 <p>{data}</p>
 </div>
);
}
export async function getServerSideProps() {
 // Fetch data from an API or database
 const res = await fetch('https://api.example.com/data');
 const data = await res.json();
 return {
 props: {
 data,
 },
 };
}
export default HomePage;
```

In this code, we have a simple Next.js page component called `HomePage`. It receives data as a prop and renders it on the page. The `getServerSideProps` function is a special Next.js function that runs on the server and fetches data from an API or database. The data is fetched, and it is passed as a prop to the `HomePage` component.

When a user requests the `HomePage`, Next.js will execute the `getServerSideProps` function on the server and fetch the data. The fetched data is then passed as props to the `HomePage` component, which renders the content on the page.

This is an example of SSR in Next.js. The server generates the fully rendered HTML with the fetched data and sends it to the client, resulting in a faster initial page load and improved SEO.

In addition to SSR, Next.js also supports CSR for dynamic content. You can use the `useEffect` hook or other mechanisms to fetch data on the client-side and update the UI without a full page reload.

Understanding the architecture and capabilities of both SSR and CSR in Next.js allows you to leverage the appropriate rendering method based on your application's requirements, balancing performance, interactivity, and SEO considerations.

## Configuring Next.js for optimal performance

We will touch upon various configuration options available in Next.js to fine-tune your application's performance. This overview will give you a starting point to optimize your Next.js projects.

To achieve optimal performance in your Next.js applications, there are several configuration options and best practices you can follow. This includes using a production-ready build, optimizing images, and implementing server-side caching. Let's explore each of these aspects in detail here:

- **Using a production-ready build:**

By default, when you run the Next.js development server, it uses a development build that includes features like hot module replacement and debugging tools. However, for optimal performance in production, it's recommended to use a production-ready build.

To create a production build, you can use the following command:

```
next build
```

This command generates an optimized and minified build of your Next.js application. You can then start the production server using:

```
next start
```

Using the production build removes unnecessary development-specific code and optimizations, resulting in faster load times and improved performance.

## Implementing server-side caching

We will briefly discuss the concepts of server-side rendering and pre-rendering in Next.js, highlighting their benefits and how to implement them in your applications.

Server-side caching can significantly improve the performance of your Next.js application by reducing the load on your server and improving response times. Next.js provides built-in support for server-side caching through various mechanisms:

- **Use `getServerSideProps` with caching:** The `getServerSideProps` function in Next.js can be configured to cache the server-rendered page for a specific duration. By setting the `revalidate` property, you can control how often the cache should be refreshed. This is useful for data that doesn't change frequently.
- **Implement external caching:** Next.js applications can benefit from utilizing external caching mechanisms such as CDN (Content Delivery Network) caching or proxy caching. These mechanisms cache the generated HTML or static assets at edge locations, closer to the user, resulting in faster response times.
- **Use caching plugins:** Next.js has a vibrant ecosystem of plugins that provide caching solutions tailored for different use cases. You can explore available caching plugins to further optimize the caching strategy in your application.

By implementing server-side caching, you can reduce the load on your server, improve response times, and deliver a faster user experience.

### Code example:

Here's an example of using the `getServerSideProps` function with caching in Next.js:

```
import React from 'react';
function HomePage({ data }) {
 return (
 <div>
 <h1>Welcome to Next.js!</h1>
 <p>{data}</p>
 </div>
);
}
export async function getServerSideProps() {
 const cacheSeconds = 60; // Cache for 60 seconds
 // Fetch data from an API or database
```

```
const res = await fetch('https://api.example.com/data');
const data = await res.json();
return {
 props: {
 data,
 },
 revalidate: cacheSeconds,
};
```

In the preceding code example, we have a basic Next.js page component called `HomePage`. It receives `data` as a prop and renders it on the page. The `getServerSideProps` function is a special Next.js function that runs on the server and fetches data from an API or database.

Within the `getServerSideProps` function, we define a variable `cacheSeconds` to set the duration for which the page should be cached (in this case, 60 seconds). The fetched data is returned in the `props` object along with the `revalidate` property set to the value of `cacheSeconds`.

By setting the `revalidate` property, Next.js will cache the server-rendered page and refresh the cache after the specified duration has elapsed. This helps reduce the load on the server by serving cached content for subsequent requests within the cache duration.

By implementing caching strategies like this, you can improve the performance of your Next.js application by reducing the need for frequent data fetching and server-side rendering.

Remember to adjust the caching duration (**cacheSeconds**) according to your specific use case and data update frequency.

Configuring Next.js for optimal performance involves using a production-ready build, optimizing images, and implementing server-side caching. These practices help ensure that your application delivers a fast and optimized user experience, enhancing performance and scalability.

## Code splitting and dynamic imports

This section will provide a brief introduction to code splitting and dynamic imports, and how they help reduce the initial bundle size and improve performance in Next.js. You will understand how these techniques can

enhance performance by loading only the necessary code for a particular page or feature.

Code splitting and dynamic imports are techniques used to break down a JavaScript bundle into smaller, more manageable chunks. By splitting the code and loading it on demand, you can reduce the initial bundle size and improve performance, especially for larger applications. [Chapter 6, Understanding Routing in Next.js](#), will delve into these concepts and provide hands-on examples to demonstrate their practical application.

Code splitting involves dividing your codebase into smaller pieces, or chunks, based on specific entry points or code dependencies. This allows you to load only the required code when it is needed, rather than loading everything upfront. The result is a smaller initial bundle size, which can significantly improve the time it takes for a user to see and interact with your application.

Dynamic imports are a key mechanism for implementing code splitting. They allow you to import modules asynchronously, at runtime, rather than statically at build time. By dynamically importing modules only when they are needed, you can optimize the loading of your application and reduce unnecessary network requests.

Here's an example of how code splitting and dynamic imports can be used in a Next.js application:

```
import React, { useState, useEffect } from 'react';
function HomePage() {
 const [data, setData] = useState(null);
 useEffect(() => {
 import('./api').then((module) => {
 module.getData().then((response) => {
 setData(response);
 });
 });
 }, []);
 return (
 <div>
 <h1>Welcome to Next.js!</h1>
 <p>{data}</p>
 </div>
);
}
```

```
);
}

export default HomePage;
```

In the preceding code snippet, the HomePage component uses dynamic imports to load an external module called api asynchronously. The api module contains a function called `getData()` that fetches some data. When the component mounts, the `useEffect` hook triggers the dynamic import, and once the module is loaded, it fetches the data using the `getData()` function and updates the state.

By dynamically importing the api module, you ensure that it is only loaded when the HomePage component is rendered, reducing the initial bundle size. This is especially beneficial if the api module is only used in a specific part of your application and is not needed on every page.

By applying code splitting and dynamic imports strategically throughout your application, you can optimize the loading and performance of your Next.js application. This technique helps reduce the initial bundle size, improve the interactive time, and provide a smoother user experience.

## Caching and improving data fetching

Caching plays a crucial role in improving the performance of data fetching in Next.js applications. By caching data, you can reduce the number of requests made to external APIs or databases, resulting in faster response times and an improved user experience.

Next.js provides several caching mechanisms that you can leverage:

- **Client-Side Caching:** Next.js supports client-side caching through the use of libraries like SWR (Stale-While-Revalidate) or React Query. These libraries handle caching, revalidation, and synchronization of data between components, allowing you to cache and reuse data across your application.

Example using SWR:

```
import useSWR from 'swr';
function UserProfile() {
 const { data, error } = useSWR('/api/user', fetcher);
 if (error) return <div>Error loading user data</div>;
 if (!data) return <div>Loading...</div>;
```

```

 return (
 <div>
 <h1>Welcome, {data.name}!</h1>
 <p>Email: {data.email}</p>
 </div>
);
 }

```

- **Server-side caching:** Next.js offers built-in server-side caching through the `getServerSideProps` and `getStaticProps` functions. By specifying a caching configuration in these functions, you can cache the server-rendered pages or static data for a specific duration. This reduces the load on your server and improves response times.

### **Example using `getServerSideProps`:**

```

export async function getServerSideProps(context) {
 const data = await fetchUserFromAPI();
 return {
 props: {
 data,
 },
 revalidate: 60, // Cache for 60 seconds
 };
}

```

- **External Caching:** You can also utilize external caching mechanisms like CDN (Content Delivery Network) caching or proxy caching. These mechanisms cache your API responses or static assets at edge locations, closer to the user, resulting in faster subsequent requests.

By implementing caching strategies appropriately, you can minimize the need for frequent data fetching and improve the overall performance of your Next.js application.

## **Analyzing and reducing bundle size**

We will briefly explore techniques to analyze and reduce the bundle size of your Next.js applications. This overview will introduce you to tools and

approaches that can help optimize your project's bundle size for better performance.

The bundle size of your Next.js application impacts the initial loading time and performance. Analyzing and reducing the bundle size is crucial to ensure a fast and smooth user experience. Here are some techniques to achieve this:

- **Code splitting:** Next.js supports automatic code splitting, where each page is bundled separately. This ensures that only the necessary code is loaded for each page, reducing the bundle size. You can also manually configure code splitting by using dynamic imports, as explained in the previous topic.
- **Tree shaking:** Tree shaking is a process where unused code is removed from the bundle during the build process. Next.js utilizes tools like webpack, which automatically performs tree shaking for your application. Make sure to write modular code and use ES modules to optimize tree shaking.
- **Minification:** Minification is the process of removing unnecessary characters like whitespace and comments from the code. Next.js performs minification by default in the production build, resulting in smaller bundle sizes.
- **Optimizing dependencies:** Analyze and optimize the dependencies used in your application. Consider using smaller alternative libraries or optimizing the configuration of existing dependencies to reduce the bundle size.
- **Deployment strategies and best practices:** Deploying a Next.js application efficiently is important to ensure its availability, scalability, and performance. Here are some deployment strategies and best practices:
  - **Serverless deployments:** Next.js applications are well-suited for serverless deployments, where your application is deployed to serverless platforms like Vercel, AWS Lambda, or Netlify. Serverless deployments offer automatic scaling, reduced infrastructure costs, and simplified deployment workflows.
  - **Continuous Integration and Deployment (CI/CD):** Implement a CI/CD pipeline to automate the deployment process. Tools like GitHub

Actions or Jenkins can be used to build and deploy your Next.js application whenever changes are pushed to the repository.

- **Performance monitoring:** Monitor the performance of your deployed application using tools like Lighthouse, New Relic, or Google Analytics. This helps identify performance bottlenecks and optimize your application for a better user experience.
- **Security considerations:** Implement security best practices like HTTPS, secure API integrations, and proper access control to protect your Next.js application and its data.
- **Scalability and load balancing:** Configure your deployment environment to scale horizontally by using load balancers and auto-scaling mechanisms. This ensures that your Next.js application can handle increased traffic without performance degradation.

By following these deployment strategies and best practices, you can ensure that your Next.js application is deployed efficiently and performs optimally.

## Deployment strategies and the best practices

We will provide an overview of various deployment strategies and best practices for Next.js applications. While not exhaustive, this section will give you insights into different options for deploying your Next.js projects in production environments.

Deploying a Next.js application efficiently is essential to ensure its availability, scalability, and performance. Here are some deployment strategies and best practices you can follow:

- **Serverless deployments:**

Next.js applications are well-suited for serverless deployments, where your application is deployed to serverless platforms like Vercel, AWS Lambda, or Netlify. Serverless deployments offer automatic scaling, reduced infrastructure costs, and simplified deployment workflows.

Example using Vercel:

Install Vercel CLI:

```
npm install -g vercel
```

Deploy your Next.js application:

## **vercel deploy**

- **Continuous integration and deployment (CI/CD):**

Implement a CI/CD pipeline to automate the deployment process. Tools like GitHub Actions or Jenkins can be used to build and deploy your Next.js application whenever changes are pushed to the repository.

- **Example using GitHub actions:**

Create a workflow file (for example, **.github/workflows/main.yml**) in your repository:

```
name: Deploy Next.js App
on:
 push:
 branches:
 - main
jobs:
 deploy:
 runs-on: ubuntu-latest
 steps:
 - name: Checkout code
 uses: actions/checkout@v2
 - name: Install dependencies
 run: npm install
 - name: Build and deploy
 uses: vercel/actions@v21
 with:
 args: "deploy"
```

- **Performance monitoring:** Monitor the performance of your deployed application using tools like Lighthouse, New Relic, or Google Analytics. This helps identify performance bottlenecks and optimize your application for a better user experience.
- **Security considerations:** Implement security best practices like using HTTPS, securing API integrations, and implementing proper access control to protect your Next.js application and its data.
- **Scalability and load balancing:** Configure your deployment environment to scale horizontally by using load balancers and auto-

scaling mechanisms. This ensures that your Next.js application can handle increased traffic without performance degradation.

Example load balancing using AWS Elastic Load Balancer:

1. Create an Elastic Load Balancer in AWS.
2. Configure the load balancer to distribute traffic across multiple instances of your Next.js application.
3. Set up auto-scaling to automatically add or remove instances based on traffic.

By following these deployment strategies and best practices, you can ensure that your Next.js application is deployed efficiently, performs optimally, and is secure. These practices enable seamless scalability and provide a smooth user experience for your application's users.

## Monitoring performance

We will touch upon the importance of monitoring and optimizing performance in Next.js applications. This overview will highlight key performance metrics and introduce you to tools and practices for tracking and improving the overall performance of your Next.js projects.

- **Lighthouse:** Lighthouse is an open-source tool from Google that audits the performance, accessibility, SEO, and best practices of web pages. It provides detailed reports and suggestions for improving performance. You can run Lighthouse audits on your Next.js application to identify performance bottlenecks and areas for improvement.
- **Real user monitoring (RUM):** RUM tools like Google Analytics or New Relic capture performance metrics and user interactions in real-time. They provide insights into how your application performs in the wild and help you identify performance issues experienced by real users.

Example using Lighthouse:

```
Install Lighthouse CLI
npm install -g lighthouse
Run Lighthouse audit on your Next.js application
```

lighthouse http://your-nextjs-app-url

- **Performance optimization**

Some features of performance optimization are explained here:

- **Code Splitting:** As mentioned earlier, Next.js supports automatic code splitting, which allows you to load only the necessary code for each page. By analyzing your application's dependencies and optimizing code splitting, you can reduce the bundle size and improve initial load times.
- **Image Optimization:** Next.js provides the Image component, which optimizes and delivers images efficiently. By leveraging the Image component, you can reduce image file sizes, lazy-load images, and serve responsive images based on the device's screen size.
- **Server-Side Caching:** Next.js allows you to cache server-rendered pages or static data using functions like `getServerSideProps` or `getStaticProps`. By implementing appropriate caching strategies, you can reduce server load and improve response times.
- **Performance Budgeting:** Define performance budgets for your Next.js application, specifying thresholds for metrics like bundle size, network requests, and page load time. Regularly monitor these metrics and ensure that your application stays within the defined performance thresholds.

Example optimizing image loading with the Next.js Image component:

```
import Image from 'next/image';
function MyComponent() {
 return (
 <div>
 <h1>Welcome to My Component</h1>
 <Image src="/path/to/image.jpg" alt="Image description"
 width={500} height={300} />
 </div>
);
}
```

In this example, the Next.js Image component is used to load and optimize an image. You provide the path to the image, alt text for accessibility, and the desired width and height. Next.js automatically optimizes the image by generating multiple sizes and formats, and it serves the most appropriate version based on the device and screen size, reducing the file size and improving performance.

By monitoring performance using tools like Lighthouse and implementing performance optimization techniques like code splitting, image optimization, server-side caching, and performance budgeting, you can ensure that your Next.js application delivers an optimal user experience in production. Regularly monitor performance metrics and make iterative improvements to continually enhance the performance of your application.

## Conclusion

Are you ready to take your Next.js applications to the next level? Optimizing your Next.js applications is vital to creating lightning-fast, efficient, and highly engaging web applications. Throughout this chapter, we've covered a plethora of essential optimization strategies, including adding metadata to pages, implementing static file serving, and utilizing the Next.js image component for image optimization.

We've also delved into the Next.js architecture and how to configure it for optimal performance. From implementing server-side rendering (SSR) and pre-rendering, to code splitting and dynamic imports, caching and improving data fetching, and analyzing and reducing bundle size, we've got you covered.

Furthermore, we've discussed deployment strategies and best practices, as well as monitoring and optimizing performance. With these techniques, you can ensure your Next.js applications deliver a seamless, high-quality user experience while optimizing performance and reducing load times.

You can start implementing these optimization strategies today, and take your Next.js applications to the next level!

In the next chapter, we'll be diving into Next.js file-based routing. Routing is a crucial aspect of any web application, and Next.js makes it a breeze with its intuitive and flexible file-based routing system.

## Multiple choice questions

1. What is the purpose of adding metadata to pages in Next.js?
  - A. To improve SEO
  - B. To enhance user experience
  - C. To optimize page load times
  - D. All of the above
2. Which component is used to add metadata to pages in Next.js?
  - A. Title
  - B. Header
  - C. Meta
  - D. Head
3. What is the purpose of implementing static file serving in Next.js?
  - A. To improve SEO
  - B. To enhance user experience
  - C. To optimize page load times
  - D. All of the above
4. What is the purpose of the Next.js image component?
  - A. To reduce image file sizes
  - B. To improve SEO
  - C. To enhance user experience
  - D. To make images load faster
5. What is server-side rendering (SSR) in Next.js?
  - A. Rendering pages on the client-side
  - B. Rendering pages on the server-side and sending the HTML to the client
  - C. Pre-rendering pages at build time
  - D. None of the above

## Answers

1. D
2. D
3. C
4. D
5. B

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# CHAPTER 6

## Understanding Routing in Next.js

### Introduction

Routing is like the backbone of a web application, ensuring seamless navigation and a delightful user experience. In the world of Next.js, routing becomes a breeze with its built-in router, which takes care of all the heavy lifting when it comes to moving between pages and handling dynamic routes. So, fasten your seatbelts as we embark on an exciting journey through the realm of Next.js routing.

### Structure

The topics covered in this chapter are as follows:

- Understanding the role of Next.js router
- Understanding the Next.js Link component and its usage
- Navigating between pages in Next.js using the router
- Working with dynamic routes in Next.js

Overall, this chapter aims to provide a comprehensive understanding of how routing works in Next.js. It covers the fundamentals of the Next.js router, navigation between pages, handling dynamic routes, and utilizing the Link component for efficient client-side navigation.

### Understanding the role of Next.js router

This section provides an overview of the Next.js router and its significance in handling client-side navigation. The Next.js router is responsible for managing the application's routes and rendering the appropriate components based on the requested URL.

The Next.js router plays a vital role in managing the routing within a Next.js application. It is responsible for handling the navigation between

different pages based on the URLs and rendering the appropriate components accordingly. The Next.js router builds upon React Router, a popular client-side routing library, and adds additional features and optimizations specific to Next.js.

To better understand the role of the Next.js router, let's consider an example scenario. Suppose we have a Next.js application with three pages: **Home**, **About**, and **Contact**. Each page has its own URL and corresponding component. The URLs for these pages are as follows:

```
Home: "/home"
About: "/about"
Contact: "/contact"
```

When a user enters the URL of our application in the browser, the Next.js router is responsible for matching the URL with the defined routes and rendering the appropriate component.

For instance, if a user enters “**/about**” in the browser’s address bar and hits Enter, the Next.js router detects the “**/about**” URL and renders the About component, which corresponds to that route. The router handles this process seamlessly, ensuring that the correct component is displayed to the user without a full-page refresh.

The Next.js router also supports nested routes, allowing us to create more complex page structures. For example, we could have a nested route for a blog post page:

```
Blog Post: "/blog/[slug]"
```

In this case, the [slug] represents a dynamic parameter that can be any value. The Next.js router can extract the value of the slug parameter from the URL and pass it as a prop to the corresponding component.

Overall, the Next.js router simplifies the process of managing routes and rendering components based on the current URL. It provides a seamless navigation experience within a Next.js application.

Example usage:

To define routes in Next.js, we create individual files inside the page’s directory. For example, we can create a file named **pages/about.js** to define the About page route. Inside the **about.js** file, we would export a React component that represents the About page:

```
// pages/about.js
import React from "react";
const About = () => {
 return (
 <div>
 <h1>About Page</h1>
 <p>This is the About page content. </p>
 </div>
);
};
export default About;
```

Similarly, we can create files for other pages such as Home and Contact, each exporting their respective React components.

With the Next.js router in place, we can navigate between these pages using the `<Link>` component. For instance, to navigate from the home page to the **About** page, we can use the following code:

```
// pages/index.js (Home page)
import React from "react";
import Link from "next/link";
const Home = () => {
 return (
 <div>
 <h1>Home Page</h1>
 <p>Welcome to the Home page.</p>
 <Link href="/about">
 <a>Go to About page
 </Link>
 </div>
);
};
export default Home;
```

In this code snippet, the `<Link>` component is used to create a link to the About page (“`/about`”). When the user clicks on the “Go to About page” link, the Next.js router handles the navigation and renders the About component without a full-page refresh.

The Next.js router makes it easy to define routes and navigate between pages, providing a seamless user experience within a Next.js application.

In the latest Next.js version 13+, the routing structure has undergone a slight adjustment. Here's the updated folder structure with a brief description:

- app
- about
  - page.js # Now Maps to "/about"
- products
  - [productId]
    - page.js # Now Maps to "/products/:productId"

This structure showcases the hierarchy within the **app** directory. Notably, the “**about**” page and the “**products**” route are now housed within their respective folders. Importantly, the files within these folders, such as **page.js**, have been optimized to directly align with specific URL routes. This refinement enhances the overall organization and user-friendliness of the routing system in Next.js, promoting a more streamlined and intuitive approach to web application development.

## **Understanding the Next.js Link component and its usage**

The Next.js Link component is a powerful tool for creating client-side navigation links within a Next.js application. It provides an optimized way to handle navigation, ensuring fast page transitions and preserving the application state. This section explains the usage of the Link component and its various properties and options.

The Next.js Link component is a built-in feature that enables client-side navigation between pages within a Next.js application. It provides a simple and optimized way to create links, ensuring fast page transitions and preserving the application state. Here is an explanation of the Link component's properties, along with a code example to demonstrate its usage:

- **href (string or object):**

The href property specifies the destination URL of the link. It can be a string representing a static route or an object containing dynamic route parameters.

```
import Link from 'next/link';
// Static route
<Link href="/about">
 <a>About
</Link>

// Dynamic route with parameters
<Link href="/users/[id]" as="/users/1">
 <a>User Profile
</Link>
```

- **as (string, optional):**

The “as” property is used combined with dynamic routes to specify the actual URL that will be displayed in the browser’s address bar. It is only required when using dynamic routes.

- **replace (boolean, optional):**

The replace property determines whether the navigation should replace the current page in the browser history or add a new entry. By default, it is set to false, meaning a new entry will be added.

```
<Link href="/contact" replace>
 <a>Contact
</Link>
```

- **scroll (boolean or string, optional):**

The scroll property controls the scroll behavior when the link is clicked. It can be set to true to scroll to the top of the page, false to preserve the current scroll position, or a string value to scroll to a specific element ID on the destination page.

```
<Link href="/blog" scroll={true}>
 <a>Blog
</Link>
```

- **shallow (boolean, optional):**

The shallow property enables shallow routing, which means the page component won’t be re-rendered if only the query parameters change.

It is useful when you want to update the URL without fetching new data or re-running the page's initial props.

```
<Link href="/products" shallow>
 <a>Products
</Link>
```

- **prefetch (boolean, optional):**

The prefetch property enables automatic pre-fetching of the linked page's data in the background. It can improve the user experience by reducing the loading time when the linked page is visited.

```
<Link href="/dashboard" prefetch>
 <a>Dashboard
</Link>
```

The Link component wraps around the anchor () tag, providing the necessary functionality for client-side navigation. It handles click events and prevents the default browser navigation behavior.

By using the Link component, Next.js optimizes the navigation process and leverages its built-in capabilities to enhance the user experience. It enables smooth transitions between pages, improves performance, and allows developers to take advantage of advanced features like dynamic routing and prefetching.

- **passHref (boolean, optional):**

The passHref property, when set to true, passes the href property to the underlying  tag. This is useful when you need to apply additional properties or custom styling to the anchor tag.

```
<Link href="/profile" passHref>
 Profile
</Link>
```

- **active (boolean, optional):**

The active property allows you to apply a specific style or class to the link when it matches the current route. This can be helpful for highlighting the active link in a navigation menu.

```
<Link href="/about" active={true}>
 <a>About
</Link>
```

- **onClick (function, optional):**

The onClick property lets you define a custom function to be executed when the link is clicked. This can be useful for performing additional actions or triggering events before the navigation occurs.

```
const handleClick = () => {
 // Perform additional actions before navigation
 console.log('Link clicked');
};

<Link href="/contact" onClick={handleClick}>
 <a>Contact
</Link>
```

- **Linking to external URLs:**

In addition to internal navigation, the Link component can also be used to create links to external URLs. Simply provide the full URL as the href property, and Next.js will handle the redirection accordingly.

```
<Link href="https://www.example.com">
 <a>External Link
</Link>
```

The Next.js Link component simplifies the process of creating navigation links within a Next.js application. It ensures efficient client-side navigation, handles dynamic routes, and provides options for customization and optimization. By leveraging the Link component, you can create a seamless and intuitive user experience while building your Next.js web application.

## [Navigating between pages in Next.js using the router](#)

Here, the chapter explains how to navigate between different pages within a Next.js application using the router. Next.js provides a simple and intuitive API to handle navigation, allowing developers to programmatically navigate to different routes and pass data between pages. Navigating between pages in Next.js is facilitated by the Next.js router, which allows for seamless client-side navigation. The `useRouter` hook is a built-in Next.js hook that provides access to the router object, enabling you to

programmatically navigate between pages. Here's an explanation of the process, along with a code example.

- **Import the useRouter hook:**

In your Next.js component, import the **useRouter** hook from the `next/router` module.

```
import { useRouter } from 'next/router';
```

- **Access the router object:**

Call the **useRouter** hook within your component to get access to the router object.

```
const router = useRouter();
```

- **Perform navigation:**

Use the methods provided by the router object to navigate between pages. The most common method is `push`, which allows you to navigate to a new page.

```
const handleNavigation = () => {
 router.push('/about');
};
```

You can also use other methods like `replace` to replace the current page in the browser history or `back` to navigate back to the previous page.

- **Handle navigation events:**

Next.js provides various events that you can listen to when navigation occurs. For example, you can listen for the **routeChangeStart** event to perform actions before a route change, or the **routeChangeComplete** event to perform actions after a route change.

```
useEffect(() => {
 const handleRouteChangeStart = () => {
 // Actions to perform before route change
 };
 const handleRouteChangeComplete = () => {
 // Actions to perform after route change
 };
 router.events.on('routeChangeStart',
 handleRouteChangeStart);
```

```
router.events.on('routeChangeComplete',
 handleRouteChangeComplete);
return () => {
 router.events.off('routeChangeStart',
 handleRouteChangeStart);
 router.events.off('routeChangeComplete',
 handleRouteChangeComplete);
};
}, []);
```

Here are a few more details about the `useRouter` hook and its properties in Next.js:

- **query (object):**

The `query` property of the `router` object contains the parsed query string parameters from the URL. It allows you to access and retrieve query parameters passed to the current page.

```
// URL: /products?id=123
console.log(router.query.id); // Output: 123
```

- **pathname (string):**

The `pathname` property represents the current URL pathname, excluding the query parameters. It provides the path of the current page within the application.

```
console.log(router.pathname); // Output: /products
```

- **route (string):**

The `route` property returns the current matched route pattern. It represents the route associated with the current page.

```
console.log(router.route); // Output: /products
```

- **basePath (string):**

The `basePath` property returns the base path of the application. It represents the portion of the URL that is common to all pages in the application.

```
console.log(router basePath); // Output: /
```

- **isFallback (boolean):**

The **isFallback** property indicates whether the current page is being statically generated as a fallback. It can be useful for rendering fallback content during the fallback state.

```
if (router.isFallback) {
 return <div>Loading...</div>;
}
events (EventEmitter):
```

The events property provides an **EventEmitter** object that emits events related to route changes. You can use it to listen for various events, such as route change start, route change complete, and route change error.

```
router.events.on('routeChangeStart', () => {
 console.log('Route change started');
});
```

Remember to subscribe to events using **router.events.on()** and clean up the event listeners using **router.events.off()**.

- **push (method):**

The **push** method of the router object allows you to navigate to a new page programmatically. You can provide the destination URL as a string parameter to the **push** method.

```
const handleNavigation = () => {
 router.push('/about');
};
```

- **replace (method):**

The **replace** method is similar to push, but it replaces the current page in the browser history instead of adding a new entry. It can be useful for implementing a back button or when you don't want the current page to be accessible through the browser's back button.

```
const handleNavigation = () => {
 router.replace('/about');
};
```

- **back (method):**

The **back** method allows you to navigate back to the previous page in the browser's history. It is equivalent to the browser's back button

functionality.

```
const handleNavigation = () => {
 router.back();
};
```

- **prefetch (method):**

The **prefetch** method allows you to prefetch and cache the resources (HTML, JavaScript, CSS, and so on.) of a specific page in the background. Prefetching can improve performance by preloading the required assets before the user navigates to the page.

```
const prefetchPage = () => { router.prefetch('/about'); };
```

- **isReady (boolean):**

The **isReady** property indicates whether the router object is ready and all initial values (such as query parameters) have been populated. It can be useful for conditional rendering based on the router's readiness.

```
if (!router.isReady) {
 return <div>Loading...</div>;
}
```

The **useRouter** hook and its properties in Next.js provide powerful functionality for handling navigation, accessing query parameters, programmatically manipulating the URL, and prefetching resources. By utilizing these capabilities, you can create dynamic and interactive Next.js applications with efficient client-side navigation and optimized page loading.

## Working with dynamic routes in Next.js

Next.js supports dynamic routes, which are routes that include parameters or placeholders in the URL. This section explores how to define and work with dynamic routes in Next.js. It covers concepts such as route parameters, accessing dynamic data within components, and generating dynamic routes based on data.

Working with dynamic routes in Next.js allows you to create pages that can accept dynamic parameters as part of the URL. This enables you to build flexible and reusable components that can render different content based on the provided parameters. Here's an explanation of working with dynamic

routes in Next.js, along with a code example that demonstrates the usage of the `Link` component and the `useRouter` hook for dynamic routing:

- **Defining a dynamic route**

To define a dynamic route in Next.js, you need to create a file inside the `pages` directory with square brackets ([ ]) in the file name. The portion within the square brackets represents the dynamic parameter.

For example, if you have a dynamic route for displaying a product with an ID, you would create a file named `[productId].js` inside the `pages` directory.

- **Linking to a dynamic route**

The `Link` component in Next.js allows you to navigate between pages. To link to a dynamic route, you need to provide the dynamic parameter as a property to the `href` attribute of the `Link` component.

```
import Link from 'next/link';
const ProductList = () => {
 return (
 <div>
 <Link href="/products/1">
 <a>Product 1
 </Link>
 <Link href="/products/2">
 <a>Product 2
 </Link>
 {/* ... */}
 </div>
);
};
export default ProductList;
```

In the preceding example, the `Link` component is used to create links to different product pages by providing the dynamic parameter (for example, `/products/1`, `/products/2`) as the `href` value.

- **Accessing dynamic parameter**

To access the dynamic parameter in the dynamic route's component, you can use the `useRouter` hook provided by Next.js.

```

import { useRouter } from 'next/router';
const ProductDetail = () => {
 const router = useRouter();
 const { productId } = router.query;
 return (
 <div>
 <h1>Product Detail: {productId}</h1>
 {/* ... */}
 </div>
);
}
export default ProductDetail;

```

In the preceding example, the **useRouter** hook is used to get access to the router object. The **router.query** object contains the dynamic parameter, which can be accessed using object destructuring (for example, **const { productId } = router.query**). You can then use the dynamic parameter (productId in this case) to fetch and display the relevant product details.

Working with dynamic routes in Next.js allows you to build pages that can handle different parameters, providing a flexible and reusable way to display content based on the dynamic values. The Link component simplifies navigation to dynamic routes, while the **useRouter** hook enables access to the dynamic parameter within the component.

## [Conclusion: Unveiling the Beauty of Next.js Routing](#)

The chapter on *Understanding Routing in Next.js* is a comprehensive guide that explores essential routing concepts and techniques, providing developers with a solid foundation to navigate and handle routes within Next.js applications. It covers the fundamentals of the Next.js router, page navigation, dynamic route handling, the Link component, **useRouter** hook, and file-based routing. By understanding the router's role, developers gain insights into how page navigation is managed, and how different routes are mapped to their corresponding components. The usage of the Link component simplifies the creation of anchor tags for page transitions,

ensuring optimized client-side navigation while preserving server-rendering benefits. Dynamic routes allow for handling routes with dynamic parameters, building flexible and reusable components that render different content based on the provided parameters. The `useRouter` hook grants access to the router object, providing various properties and methods for working with routing. File-based routing simplifies the organization of routes by mapping the file structure to the URL structure. This chapter equips developers with the knowledge to navigate between pages, handle dynamic routes, utilize the `Link` component for optimized client-side navigation, and leverage the `useRouter` hook to enhance routing control and interactivity, creating dynamic, interactive, and seamless routing experiences in their Next.js applications.

Please refer to the GitHub repository *Building-Scalable-Web-Applications-with-Next.js-and-React* for [Chapters 5](#) and [6](#). This repository features a small, 2-page application that demonstrates a book list and book details, incorporating dynamic routing and optimization techniques. You can use this repository as a valuable reference for your development purposes.

## Multiple choice questions

1. What is the Next.js router?
  - A. A tool for server-side rendering in Next.js applications
  - B. A component for client-side navigation in Next.js applications
  - C. A mechanism for handling routing in Next.js applications
  - D. A feature for organizing file structure in Next.js applications
2. What is the purpose of the `Link` component in Next.js?
  - A. To simplify the creation of anchor tags for page transitions
  - B. To handle dynamic parameters in routes
  - C. To grant access to the router object and provide properties and methods for working with routing
  - D. To organize file structure in Next.js projects
3. What are dynamic routes in Next.js?
  - A. Routes that are only available on the server-side

- B. Routes that handle dynamic parameters such as IDs or slugs
  - C. Routes that are mapped to the file structure in the pages directory
  - D. Routes that use the `useRouter` hook for enhanced control and interactivity
4. What is the `useRouter` hook in Next.js?
- A. A tool for server-side rendering in Next.js applications
  - B. A component for client-side navigation in Next.js applications
  - C. A mechanism for handling routing in Next.js applications
  - D. A powerful tool that grants access to the router object and provides various properties and methods for working with routing
5. What is file-based routing in Next.js?
- A. A feature for organizing file structure in Next.js projects
  - B. A tool for client-side navigation in Next.js applications
  - C. A mechanism for handling routing in Next.js applications
  - D. A feature for server-side rendering in Next.js applications

## Answers

- 1. C
- 2. A
- 3. B
- 4. D
- 5. A

## CHAPTER 7

# State Management in Next.js

### Introduction

State management is a crucial aspect of building web applications, particularly in complex and dynamic applications. In Next.js, state management plays an important role in managing data, user interface, and other components of an application. State management refers to the techniques and tools used to manage the data and state of an application in a way that is efficient, scalable, and easy to maintain.

Next.js offers several options for state management, including React state, Redux, and React context. Each of these options has its pros and cons, and choosing the right one depends on the specific needs and requirements of the application. In this chapter, we will review each of these state management options and discuss their benefits and drawbacks. We will also guide you on when to use each one and how to implement them in a Next.js application.

We will begin by discussing the basics of state management in Next.js, including why it's important and how it can improve the performance and scalability of an application. We will then delve into the different state management options available in Next.js, including React state, Redux, and React context, and compare their strengths and weaknesses.

The chapter will then provide detailed instructions on how to implement state management using React state, including the use of hooks such as `useState` and `usememoContext`. We will also discuss how to set up the Redux store, define actions and reducers, and connect components to the store.

Furthermore, we will explore how to implement state management using React context, including creating context, defining providers and consumers, and using context in components. We will provide best practices for managing state in Next.js applications, including avoiding common pitfalls and optimizing performance.

Finally, we will share case studies and examples of how to implement state management in Next.js applications. These examples will cover real-world scenarios and best practices for handling complex state.

By the end of this chapter, readers will have a clear understanding of the different state management options available in Next.js, their benefits and drawbacks, and how to implement them effectively in their applications.

## Structure

In this chapter, we will cover the following topics:

- Introduction to state management in Next.js and its importance
- Review of the different state management options available in Next.js
- Pros and cons of each state management option and when to use each one
- How to implement state management using React state, including how to use hooks such as `useState` and `useContext`
- Best practices for managing state in Next.js applications, including avoiding common pitfalls and optimizing performance
- How to implement state management using Redux, including setting up the store, defining actions and reducers, and connecting components to the store
- How to implement state management using React context, including creating context, defining providers and consumers, and using context in components
- Case studies and examples of how to implement state management in Next.js applications, including real-world scenarios and best practices for handling complex states

## Introducing state management in Next.js and its importance

When building web applications, managing the state becomes a crucial task. State refers to the data and information that determines how a user interface behaves and appears at any given moment. It includes things like user inputs, server responses, and the current state of various components.

In Next.js, state management is essential because it helps us organize and handle this data effectively. It allows us to maintain consistency, synchronize different parts of our application, and update the user interface in response to changes in data or user interactions.

Imagine you're creating a shopping cart feature for an e-commerce website using Next.js. The state of the cart includes items, quantities, and the total price. Without proper state management, you might encounter issues like items disappearing from the cart, incorrect quantities, or inconsistent prices. State management ensures that such problems are minimized and provides a seamless and reliable user experience.

But **why is state management important specifically in Next.js?** Next.js is a powerful framework for building server-rendered and static websites. It offers features like server-side rendering (SSR), automatic code splitting, and fast page transitions. These features bring numerous benefits, but they also introduce complexity when it comes to managing state.

Next.js applications often have multiple pages with different components, each with its own state requirements. As users navigate through the application, data needs to be shared across pages and components, requiring careful state management to ensure consistent behavior and performance.

Effective state management in Next.js can enhance the performance and scalability of your application. It allows you to handle complex data flows, avoid unnecessary re-renders, and optimize the usage of network and server resources. It also simplifies debugging and maintenance, as the state is organized in a structured manner and can be easily tracked and modified.

By adopting proper state management techniques in Next.js, you can build robust and maintainable applications that provide a seamless and interactive user experience.

In the following sections of this chapter, we will explore the various state management options available in Next.js, compare their strengths and weaknesses, and provide practical examples and best practices for implementing state management effectively.

## Different state management options available in Next.js

In Next.js, there are several state management libraries available that can be used in conjunction with React to handle state effectively. These libraries provide various approaches and features for managing state in your Next.js applications. Here are some of the popular state management libraries used in React with Next.js:

- **Redux:** Redux is a predictable state container that helps manage the state of your application in a centralized manner. It follows a unidirectional data flow and provides a global store to hold the state. Redux is widely used and has a large community, making it a popular choice for managing complex state in Next.js applications.
- **React Context:** React Context is a built-in feature in React that allows you to create and share state across components without having to pass props manually. It provides a way to pass data through the component tree without explicitly passing it through every level. React Context is a lightweight option for state management in smaller applications or for sharing data between components with a few levels of nesting.
- **MobX:** MobX is a simple and scalable state management library that emphasizes automatic observability and fine-grained reactivity. It allows you to create observable objects, which can be used to track changes and trigger re-rendering of components when the state updates. MobX integrates well with React and provides an intuitive API for managing state in Next.js applications.
- **Zustand:** Zustand is a lightweight state management library that leverages React hooks and the Context API. It offers a simple and functional approach to state management, with a focus on performance and a minimalistic setup. Zustand is a good choice for smaller to medium-sized applications that require a lightweight and easy-to-use state management solution.
- **Recoil:** Recoil is a state management library specifically designed for React applications. It provides a simple and efficient way to manage state that is shared across components. Recoil uses atoms and selectors to define and access state, and it offers features like asynchronous selectors and built-in support for derived state.

These are just a few examples of state management libraries available for Next.js applications. Each library has its own set of features, advantages, and

community support. Depending on the specific requirements and complexity of your project, you can choose the most suitable library for managing the state in your Next.js application.

A review of the six popular state management options available in React Next.js, along with a comparison as shown in [Table 7.1](#):

| State Management Option                                                             | Key Features                                        | Scalability                             | Learning Curve          | Community Support                        |
|-------------------------------------------------------------------------------------|-----------------------------------------------------|-----------------------------------------|-------------------------|------------------------------------------|
|    | React state<br>Built-in to React                    | Suitable for smaller apps               | Easy to learn           | Strong community support                 |
|    | Centralized global state management                 | Highly scalable                         | Moderate learning curve | Large community and extensive ecosystem  |
|    | Provides shared state to nested components          | Limited scalability                     | Easy to learn           | Part of React ecosystem                  |
|   | Automatic observability and fine-grained reactivity | Highly scalable                         | Easy to learn           | Active community and good documentation  |
|  | Lightweight, functional state management            | Suitable for small to medium-sized apps | Easy to learn           | Growing community and simplicity-focused |
|  | State management for React with atoms and selectors | Suitable for medium-sized apps          | Easy to learn           | Developing community and React-specific  |

*Table 7.1: Various state management options*

Please note that the scalability and learning curve are subjective and may vary depending on the complexity of your application and your familiarity with the chosen state management option. It's important to consider your specific project requirements, team expertise, and community support when making a decision.

Each option offers different trade-offs, and the choice depends on factors such as the size of your application, the complexity of your state management needs, and the preferences of your development team. Take time to evaluate these options and consider the strengths and weaknesses of each to find the best fit for your Next.js project.

## Pros and cons of state management options

*Table 7.2* shows the pros and cons of each state management option, and when to use each one:

| State Management Option | Pros                                                                                                | Cons                                                                                                 | When to Use                                                                                                                    |
|-------------------------|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <b>React state</b>      | Built-in to React, no additional setup required Simple and intuitive API for local component state  | Limited to local component state Not suitable for managing complex or shared state                   | Small applications with localized state needs                                                                                  |
| <b>Redux</b>            | Centralized global state management Predictable state updates Large ecosystem and community support | Requires setup and boilerplate code Moderate learning curve                                          | Large applications with complex state management needs, or when time-travel debugging and extensive tooling are desired        |
| <b>React Context</b>    | Provides shared state to nested components Avoids prop drilling Part of React ecosystem             | Limited scalability for large applications May have performance overhead in deeply nested components | Medium-sized applications with moderate state sharing requirements or when simplicity and integration with React are important |
| <b>MobX</b>             | Automatic observability and fine-grained reactivity Highly scalable Easy to learn                   | May require additional setup for React integration May have a learning curve for advanced concepts   | Applications requiring highly scalable and reactive state management, with a preference for simplicity and ease of use         |
| <b>Zustand</b>          | Lightweight and functional state management Easy to learn                                           | May have limited tooling and community support                                                       | Small to medium-sized applications that prioritize simplicity, performance, and a minimalistic approach                        |
| <b>Recoil</b>           | State management for React with atoms and selectors Easy to learn                                   | Relatively new and evolving library Developing community                                             | Applications built with React that require flexible and efficient state management, especially for medium-sized projects       |

*Table 7.2: Pros and cons of each state management option*

## Implementing state management with React state and the use of hooks

Let's learn how to implement state management using React state, and how to use hooks such as **useState** and **useContext**.

**useState** is a built-in hook in React that allows you to add state to functional components. It provides a way to manage and update state within a component without needing to use class components.

To implement state management using **useState**, you can follow these steps:

- Import the necessary dependencies:

```
import React, { useState } from 'react';
```

- Define and initialize the state using `useState`:

```
const [state, setState] = useState(initialValue);
```

`state` represents the current value of the state variable.

`setState` is a function used to update the state.

`initialValue` is the initial value you want to assign to the state.

- Use the state in your components:

```
return (
 <div>
 <p>Current state value: {state}</p>
 <button onClick={() => setState(newValue)}>Update
 State</button>
 </div>
);
```

- Access the state value using `{state}` in JSX.

To update the state, call `setState` with the new value you want to assign (`newValue`).

Here's a complete example to illustrate the implementation:

```
import React, { useState } from 'react';
const MyComponent = () => {
 const [count, setCount] = useState(0);
```

```
const incrementCount = () => { setCount(count + 1); };
};

return (
<div>
<p>Count: {count}</p>
<button onClick={incrementCount}>Increment</button>
</div>
);
};

export default MyComponent;
```

In this example, **count** is the state variable managed using **useState** to keep track of a count value. The `incrementCount` function updates the `count` state by incrementing it. The component renders the current count value and a button to trigger the increment.

By following these steps, you can easily implement state management using **useState** in your functional components. Remember that state-managed using

**useState** is local to the component in which it is declared.

**useContext** is a built-in hook in React that allows you to access the value of a context object. It provides a way to consume context values in functional components without the need for wrapping components with context consumers.

To implement state management using **useContext**, you can follow these steps:

- Create a context object using **React.createContext()**:

```
const MyContext = React.createContext();
```

- Wrap your component or components with the context provider and provide a value:

```
return (
<MyContext.Provider value={contextValue}>
 {/* Your components here */}
</MyContext.Provider>
);
```

`contextValue` represents the value you want to share within the context.

Consume the context value in your components using `useContext`:

```
const contextValue = useContext(MyContext);
`contextValue` will contain the value provided by the context.
```

Here's a complete example to illustrate the implementation:

```
import React, { useContext } from 'react'; const
MyContext = React.createContext(); const
ParentComponent = () => {
 const contextValue = 'Hello from context'; return (
 <MyContext.Provider value={contextValue}>
 <ChildComponent />
 </MyContext.Provider>
);
};

const ChildComponent = () => {
 const contextValue = useContext(MyContext); return (
 <div>
 <p>Context Value: {contextValue}</p>
 </div>
);
};
export default ParentComponent;
```

In this example, the **ParentComponent** wraps the **ChildComponent** with the context provider, providing the context value **Hello from context**. The '**ChildComponent**' consumes the context value using `useContext` and renders it.

By following these steps, you can implement state management using **useContext** to share and consume context values within your functional components. Remember to adjust the code according to your specific use cases and component structure.

## **Best practices for managing state in Next.js applications**

When managing state in Next.js applications, there are several best practices to follow in order to avoid common pitfalls and optimize performance. Here

are some key practices to consider:

- **Minimize global state:** It's generally recommended to minimize the use of global state as much as possible. Global state can introduce complexity and make it harder to reason about the flow of data in your application. Instead, strive for localized state management within individual components or smaller scoped contexts.
- **Use local component state:** Utilize React's built-in state management capabilities, such as `useState`, to manage local component state. This is ideal for managing state that is specific to a particular component and doesn't need to be shared across multiple components.
- **Choose appropriate state management libraries:** If you have complex state management requirements or need to share state across multiple components, consider using state management libraries like Redux or MobX. These libraries provide advanced features for managing state and can help with organizing and scaling your application's state management.
- **Normalize state shape:** Normalize your state structure to keep it simple and organized. This involves breaking down complex data structures into separate entities and storing them in a normalized form. Normalization improves performance and simplifies data retrieval and manipulation.
- **Avoid unnecessary re-renders:** Optimize your components to avoid unnecessary re-renders by using techniques like memoization and `React.memo`. Memoization helps prevent expensive computations or calculations from being repeated on every render, while `React.memo` can prevent the re-rendering of components when their props haven't changed.
- **Use immutability:** Immutable data helps in optimizing performance by allowing React to efficiently determine if a component needs to be re-rendered. Avoid directly mutating state objects and instead create new copies or use immutable data structures like Immutable.js or Immer.
- **Use react context sparingly:** React Context is a powerful tool for sharing state across components, but it can impact performance if used excessively. Use context judiciously and consider whether alternatives

like props drilling or state lifting might be more appropriate for your specific use case.

- **Optimize API requests:** When fetching data from APIs, implement techniques such as caching, debouncing, or pagination to minimize unnecessary requests and improve performance. Consider using libraries like SWR or React Query that provide data fetching and caching capabilities specifically designed for React applications.
- **Performance monitoring:** Monitor your application's performance using tools like Lighthouse, Chrome DevTools, or performance profiling libraries. Identify and address any bottlenecks or performance issues related to state management.
- **Testing and refactoring:** Write comprehensive unit tests for your state management code to ensure correctness and maintainability. Regularly review and refactor your state management code to keep it clean, organized, and optimized.

By following these best practices, you can effectively manage the state in your Next.js applications while optimizing performance and avoiding common pitfalls. Remember that the specific needs of your application may vary, so always consider the context and requirements of your project when implementing state management solutions.

## Implementing state management using Redux in Next.js Application

**Redux** is a state management library commonly used with JavaScript frameworks like React and Next.js. It provides a predictable way to manage the state of an application by enforcing a strict set of principles and patterns. Redux follows a unidirectional data flow, making it easier to understand and debug how state changes occur.

The three principles of Redux are:

- Single source of truth: Redux promotes the idea of having a single source of truth for the state of your application. The entire state is stored in a centralized object called the Redux store. This allows all components in your application to access and update the state consistently and predictably.

- State is read-only and immutable: In Redux, the state is treated as read-only, meaning you cannot directly modify it. Instead, you dispatch actions to describe state changes. These actions are plain JavaScript objects that contain information about what happened in your application. Reducers, pure functions in Redux, take the current state and the dispatched action as input and return a new state object, without modifying the original state. This immutability ensures that the state remains predictable, helps with efficient change detection, and enables features like time-travel debugging.
- Changes are made with pure functions: Redux relies on pure functions called reducers to update the state. Reducers take the current state and an action and return a new state. They don't have side effects or directly interact with external resources. By adhering to pure functions, Redux makes state changes predictable and testable. It also enables modular and reusable code, as reducers can be composed to handle different parts of the state.

## Flux

Flux is an architectural pattern introduced by Facebook that complements React's component-based architecture. Flux addresses the challenges of managing state in large-scale applications. It enforces a unidirectional flow of data and promotes a clear separation of concerns.

Flux consists of several key components:

- **Actions:** Actions describe events or user intents and contain the data associated with the event. They are triggered by user interactions or system events.
- **Dispatcher:** The Dispatcher is responsible for receiving actions and dispatching them to registered stores. It acts as a central hub in the Flux architecture.
- **Stores:** Stores hold the application state and business logic. They receive actions from the Dispatcher and update their state accordingly. Stores are responsible for determining how the state should change in response to actions.
- **Views:** Views represent the user interface components of your application. They retrieve data from the Stores and render the user

interface based on the state.

- Flux enforces a unidirectional flow of data, where actions flow through the Dispatcher to the Stores, which then update the state. The Views listen to changes in the state and re-render as needed.

## Combining Redux and Flux

Redux and Flux share similar concepts and principles, making them compatible for combining in state management. Redux can be seen as an implementation of the Flux architecture, where Redux's store replaces the role of Flux's stores, and Redux's reducers replace Flux's stores' logic.

In a combined approach of Redux and Flux, you can use Redux as the underlying state management library and follow Redux's principles of single source of truth, immutability, and pure reducers. The unidirectional data flow and separation of concerns provided by Flux can be integrated with Redux to enhance the organization and scalability of your application's state management.

Here's a step-by-step explanation of how you can combine Redux and Flux:

- Use Redux as the state management library: Set up Redux in your Next.js application by creating a Redux store, defining reducers to handle state updates, and connecting your components to the Redux store using React Redux's `connect` function.
- Adopt Flux's unidirectional data flow: While Redux already follows a unidirectional data flow, you can further enhance it by adopting Flux's pattern. Actions are dispatched from your components to the Redux store, which updates the state using reducers. The updated state is then propagated to the components, triggering re-renders.
- Utilize Flux's separation of concerns: Take advantage of Flux's separation of concerns by organizing your Redux reducers based on specific domains or features in your application. Each reducer can handle a specific portion of the state, similar to how Flux's stores manage different parts of the application data.
- Combine actions and reducers: Create actions in Redux to describe state changes, just as you would in Flux. Dispatch these actions to the Redux store, which in turn invokes the corresponding reducers. The

reducers handle the actions and update the state accordingly, following the principles of immutability and pure functions.

By combining Redux and Flux, you can benefit from Redux's powerful state management capabilities while leveraging Flux's clear data flow and separation of concerns. This combination helps you maintain a single source of truth for your application's state, ensure immutability and predictable state updates, and organize your state management logic in a modular and scalable manner.

Remember, while Redux and Flux can be combined, it's essential to consider the complexity and needs of your application. If your application is relatively small or doesn't require extensive state management, using Redux alone may suffice. However, for larger and more complex applications, combining Redux with Flux can provide an effective solution for managing state in a structured and maintainable way.

[Figure 7.1](#) shows the basic flowchart illustrating the basic flow of data in Flux and Redux

- The User View represents the user interface components of your application.
- User interactions in the view trigger Actions. Actions describe user intents or system events.
- Actions are dispatched to the Dispatcher.
- The Dispatcher acts as a central hub for receiving actions and dispatching them to registered Stores in Flux, or to the Reducers in Redux.
- In Flux, Stores hold the application state and business logic. In Redux, Reducers are pure functions that update the state based on the dispatched action.
- Once the Stores (Flux) or Reducers (Redux) update their state, they emit a change event.
- The User View listens to the change events emitted by the Stores (Flux) or subscribes to the Store (Redux) and updates its display based on the new state.

Both Flux and Redux follow a unidirectional flow of data, where Actions trigger state changes through the Dispatcher (Flux) or Reducers (Redux).

The state is updated in the Stores (Flux) or Store (Redux), and the User View reflects the changes by re-rendering.

Note that Flux and Redux have some differences in how they handle state management, such as the presence of Actions and Dispatcher in Flux and the introduction of Reducers in Redux. Nevertheless, both Flux and Redux aim to provide a clear and structured approach to managing the state in complex applications.



*Figure 7.1: Illustrating the basic flow of data in Flux and Redux*

To implement state management using Redux with Flux in a simple Next.js application, you can follow these steps:

Step 1: Set up a Next.js project

Start by setting up a basic Next.js project using your preferred method. You can use the Next.js CLI or create a new project manually. Make sure you have the necessary dependencies installed.

## Step 2: Install Redux and related packages

In your project directory, install the necessary packages for Redux and Flux integration. Run the following command:

```
npm install redux react-redux redux-thunk
```

## Step 3: Create the Redux store

In your project, create a new file called `store.js`. This file will contain the configuration for your Redux store. Add the following code:

```
import { createStore, applyMiddleware } from 'redux'; import
thunk from 'redux-thunk';
// Import your reducers here
import rootReducer from './reducers';
const store = createStore(rootReducer, applyMiddleware(thunk));
export default store;
```

Make sure you have your reducers defined in separate files within the **reducers** directory.

## Step 4: Define your reducers

Create separate files for each of your reducers in the `reducers` directory. Each reducer file should export a function that takes the current state and an action as parameters, and returns a new state. For example,

```
// Example reducer in counterReducer.js const initialState = {
count: 0,
};

const counterReducer = (state = initialState, action) => {
switch (action.type) { case 'INCREMENT':
return { ...state, count: state.count + 1 }; case 'DECREMENT':
return { ...state, count: state.count - 1 }; default:
return state;
}
};
export default counterReducer;
```

## Step 5: Create your actions

Create separate files for your actions in the `actions` directory. Each file should export action creator functions that return an action object. For example,

```
// Example actions in counterActions.js
export const increment = () => ({
 type: 'INCREMENT',
});
export const decrement = () => ({ type: 'DECREMENT',
});
```

#### Step 6: Combine reducers

In your `reducers` directory, create an `index.js` file to combine all your reducers into a single root reducer. For example,

```
// reducers/index.js
import { combineReducers } from 'redux';
import counterReducer from './counterReducer';
const rootReducer = combineReducers({ counter: counterReducer,
});
export default rootReducer;
```

#### Step 7: Create your components

Create React components that will use the Redux store and dispatch actions. For example,

```
// Example component in Counter.js
import React from 'react';
import { connect } from 'react-redux';
import { increment, decrement } from
'./actions/counterActions';

const Counter = ({ count, increment, decrement }) => {
 return (
 <div>
 <h1>Count: {count}</h1>
 <button onClick={increment}>Increment</button>
 <button onClick={decrement}>Decrement</button>
 </div>
);
};

const mapStateToProps = (state) => ({ count:
 state.counter.count,
```

```
});

const mapDispatchToProps = { increment,
decrement,
};

export default connect(mapStateToProps, mapDispatchToProps)
(Counter);
```

## Step 8: Set up your Next.js pages

Create a Next.js page where you want to render your Redux-connected components. Import the components and use them in your page. For example,

```
// pages/index.js
import React from 'react';
import Counter from '../components/Counter'; const HomePage =
() => {
return (
<div>
<h1>Redux with Flux Example</h1>
<Counter />
</div>
);
};
export default HomePage;
```

Step 9: Wrap your Next.js app with Redux provider In the pages/\_app.js file, wrap your Next.js app with the Redux Provider component and provide the Redux store created in Step 3. For example,

```
// pages/_app.js
import { Provider } from 'react-redux'; import store from
'../store';
function MyApp({ Component, pageProps }) { return (
<Provider store={store}>
<Component {...pageProps} />
</Provider>
);
}
export default MyApp;
```

## Step 10: Run your Next.js app

Start your Next.js development server and navigate to the page where you have used the Redux-connected component. You should now see the counter component with buttons to increment and decrement the count.

That's it! You have implemented state management using Redux with Flux in a simple Next.js application. Redux provides the single source of truth and state management capabilities, while Flux's principles of actions, dispatcher, and stores are integrated into the Redux architecture.

You can add more actions, reducers, and components as needed, following the same patterns. This approach allows you to manage the state of your Next.js application effectively and handle complex state interactions with ease.

## Redux Thunk

Redux Thunk is a middleware for Redux, which is a popular state management library in JavaScript. It allows you to write action creators that return functions instead of plain action objects. This enables you to perform asynchronous operations, such as API calls, inside your action creators before dispatching the actual actions.

### **Why is Redux Thunk needed?**

In Redux, actions are typically plain objects with a type and a payload. However, there are scenarios where you might need to perform asynchronous operations, like fetching data from an API, before dispatching an action. Redux Thunk provides a way to handle such asynchronous operations and dispatch actions at the appropriate time.

### **Implementing Redux Thunk with code example:**

To use Redux Thunk, you need to set it up in your Redux store and create thunk action creators.

#### 1. Setup Redux Thunk middleware:

```
import { createStore, applyMiddleware } from 'redux';
import thunk from 'redux-thunk';
import rootReducer from './reducers';
```

```
const store = createStore(rootReducer,
applyMiddleware(thunk)); export default store;
```

Here, we import the **thunk** middleware and apply it to the store using **applyMiddleware** from Redux. **rootReducer** represents your combined reducers.

## 2. Create thunk action creators:

**Thunk** action creators are functions that can dispatch actions and perform async operations. Here's an example:

```
// actions.js
import axios from 'axios'; export const fetchData = () => {
return async (dispatch) => {
dispatch({ type: 'FETCH_DATA_REQUEST' }); try {
const response = await
axios.get('https://api.example.com/data'); dispatch({ type:
'FETCH_DATA_SUCCESS', payload: response.data });
} catch (error) {
dispatch({ type: 'FETCH_DATA_FAILURE', payload:
error.message });
}
};
};
```

In this example, **fetchData** is a thunk action creator that fetches data from an API. It returns a function that receives the `dispatch` function as an argument. Inside this function, you can dispatch multiple actions to represent the different stages of the asynchronous operation.

## 3. Dispatch thunk action creators:

To dispatch a thunk action creator, you need to use the **dispatch** function provided by Redux. Here's an example of how you can dispatch the **fetchData** thunk action creator:

```
// component.js
import React, { useEffect } from 'react';
import { useDispatch, useSelector } from 'react-redux';
import { fetchData } from './actions';
const Component = () => {
const dispatch = useDispatch();
```

```

const data = useSelector((state) => state.data);
useEffect(() => {
 dispatch(fetchData());
}, [dispatch]);
// Render the component using the fetched data
// ...
return <div>{data}</div>;
};
export default Component;

```

In this example, we use the **useDispatch** hook from the react-redux library to get access to the **dispatch** function. We then dispatch the **fetchData** thunk action creator inside a **useEffect** hook to trigger the API call when the component mounts.

That's a basic overview of Redux Thunk and how to implement it. It allows you to handle asynchronous operations within your Redux actions and manage the state accordingly.

**Note:** [Chapter 12, Developing a CRUD Application with Next.js](#), covers a complete implementation of Redux and Flux in our application, providing a powerful state management solution. Follow along to learn how to set up the Redux store, define actions and reducers, and connect components for efficient data flow.

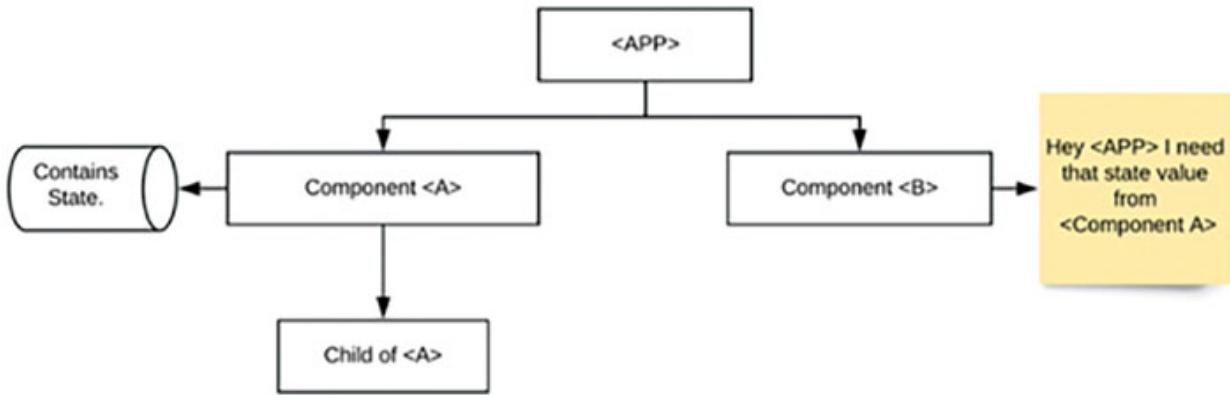
## Implementing state management using React context in a simple Next.js application

React context is a feature in React that allows you to share data between components without passing props explicitly at every level of the component tree. It provides a way to create a global state that can be accessed by any component within its tree.

When it comes to state management, react context can be used as a basic form of state management. It allows you to define a central state and provides a Sure, here's a simplified breakdown of the topic “Context API in React with Hooks”:

Problem Visualization:

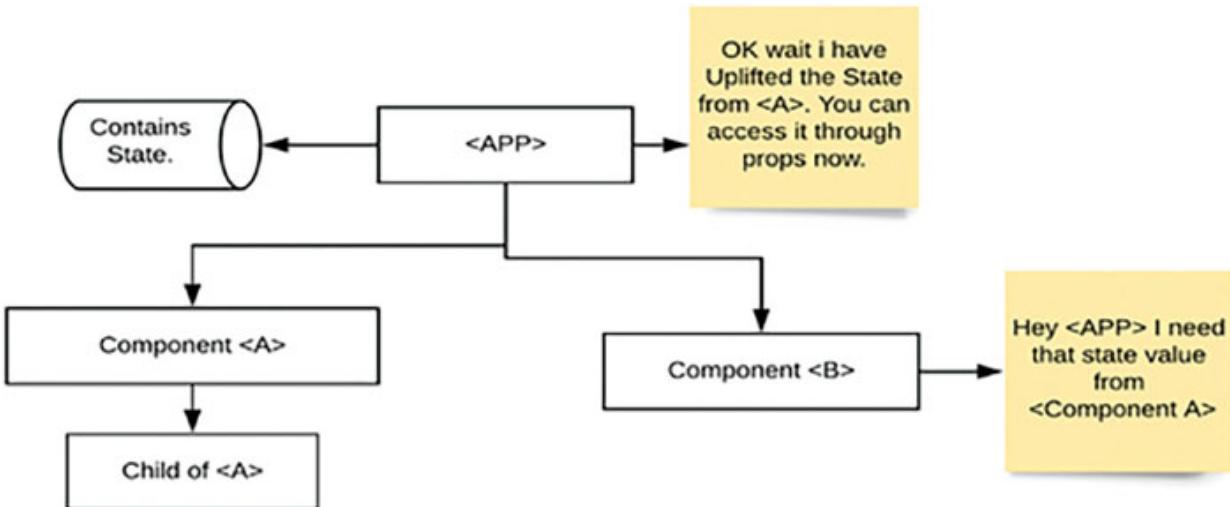
- Imagine you have two components, A and B, both inside the main APP component.
- Component B needs a state value from Component A.
- Directly passing this value is tricky due to their component structure.



*Figure 7.2: Explain the problem statement*

### Solution 1: Uplifting State:

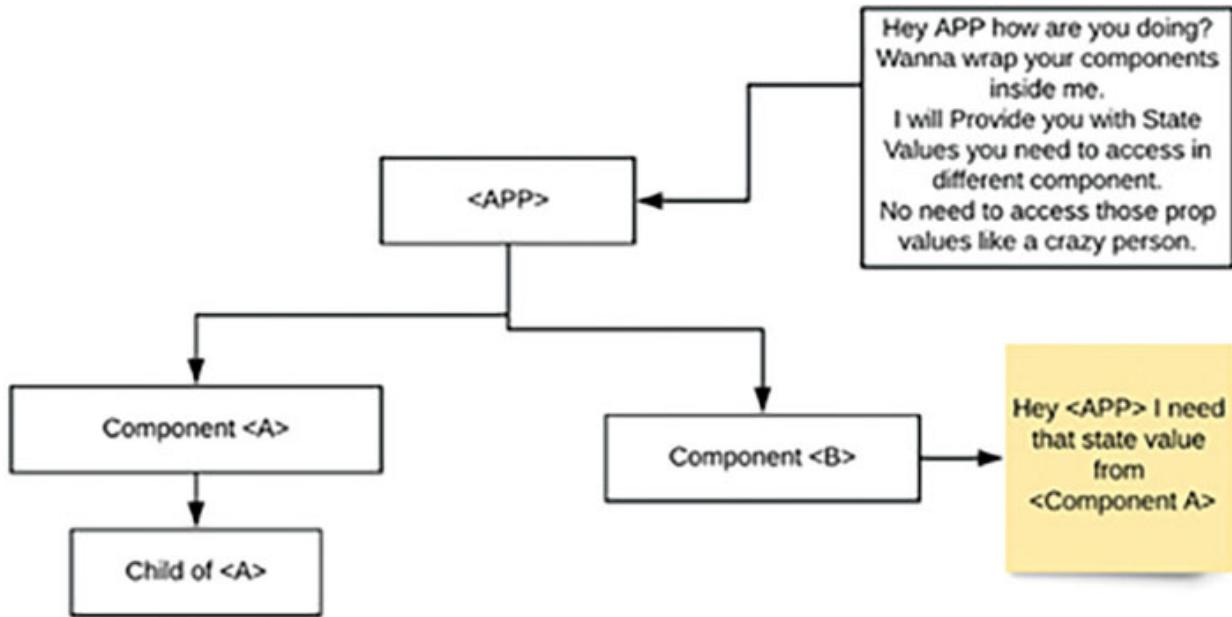
- Move the required state from Component A to the parent APP component.
- This solves the immediate problem, but it's not practical for larger apps.



*Figure 7.3: Explain Uplifting state*

### Solution 2: Context API:

- Context API provides a way to create global variables shared across components.
- It's an alternative to manual prop passing (prop drilling).
- Best used when data needs to be accessible by many components at different nesting levels.



*Figure 7.4: Solution where Context API comes into the picture*

### Creating Context API:

- Set up directory structure with Parent APP, Component A, and Component B.
- Create a file named **Context.js** with code to create a context using **createContext**.

### Creating a Provider:

- Extract **Provider** from the created context.
- Create an `AppProvider` component that provides values to consuming components.
- Inside **AppProvider**, set up state using **useState** for the data you want to share.
- Wrap your Parent Component (APP) with **AppProvider**.

### Consuming the Context:

- Import **AppContext** and **useContext** into the component where you want to consume the context.
- Use the **useContext** hook to access the context values.

Tips for Context Usage:

- Don't replace local state with context; use local state whenever possible.
- Changing context values causes re-renders in components using that context.
- Avoid wrapping the entire app with the context provider; use it in the smallest necessary parent.

In Summary:

- Use **createContext** to make the Context.
- Extract **Provider** from the context.
- Wrap the Parent component with the Provider.
- Consume context using **useContext** hooks.

Context API simplifies sharing data between components without prop drilling, but use it wisely and avoid overuse. mechanism for updating and accessing that state across different components.

This flow represents the basic flow of data in React context. It outlines the steps involved in creating the context, setting up the provider, defining actions, consuming the context, accessing and updating the state, and re-rendering components.

To implement state management using React context in a simple Next.js application, you can follow these steps:

Step 1: Set up a Next.js project

Start by setting up a basic Next.js project using your preferred method. You can use the Next.js CLI or create a new project manually. Make sure you have the necessary dependencies installed.

Step 2: Create a new context file

Create a new file called **AppContext.js** in your project. This file will contain the setup for your React context. Add the following code:

```

// AppContext.js
import React, { createContext, useState } from 'react';
// Create the context
export const AppContext = createContext();
// Create a provider component
export const AppProvider = ({ children }) => {
 const [state, setState] = useState({
 // Define your initial state here
 count: 0,
 });
 // Define any actions to update the state
 const increment = () => {
 setState((prevState) => ({
 ...prevState,
 count: prevState.count + 1,
 }));
 };
 const decrement = () => {
 setState((prevState) => ({
 ...prevState,
 count: prevState.count - 1,
 }));
 };
 // Provide the state and actions to the children components
 return (
 <AppContext.Provider value={{ state, increment, decrement }}>
 {children}
 </AppContext.Provider>
);
};

```

### Step 3: Wrap your Next.js app with the AppProvider

In the „\_app.js“ file in the „pages“ directory, wrap your Next.js app with the `AppProvider` component from the **AppContext.js** file. For example,

```

// pages/_app.js
import { AppProvider } from '../AppContext';
function MyApp({ Component, pageProps }) {

```

```
return (
<AppProvider>
<Component {...pageProps} />
</AppProvider>
);
}

export default MyApp;
```

#### Step 4: Create your components

Create React components that will use the state managed by the context. Import the **AppContext** and use the **useContext** hook to access the state and actions. For example:

```
// components/Counter.js
import React, { useContext } from 'react'; import {
AppContext } from '../AppContext'; const Counter =
() => {
const { state, increment, decrement } = useContext(AppContext);
return (
<div>
<h1>Count: {state.count}</h1>
<button onClick={increment}>Increment</button>
<button onClick={decrement}>Decrement</button>
</div>
);
};
export default Counter;
```

#### Step 5: Set up your Next.js pages

Create a Next.js page where you want to render your context-connected components. Import the components and use them in your page. For example,

```
// pages/index.js
import React from 'react';
import Counter from '../components/Counter';
const HomePage = () => { return (
<div>
<h1>React Context Example</h1>
```

```
<Counter />
</div>
);
};

export default HomePage;
```

That's it! You have implemented state management using React context in a simple Next.js application. The **AppProvider** component wraps your app, providing the state and actions to all the components nested within it. The `Counter` component consumes the state and actions from the context and uses them to manage and display the count.

You can add more context files, actions, and components as needed, following the same patterns. React context provides a straightforward and efficient way to manage state in your Next.js application without the need for external dependencies like Redux.

#### Step 6: Access the context outside of components (optional)

If you need to access the context outside of components, such as in utility functions or custom hooks, you can use the **useContext** hook as well. For example:

```
// utils/Helper.js
import { useContext } from 'react';
import { AppContext } from '../AppContext';
const Helper = () => {
 const { state, increment, decrement } = useContext(AppContext);
 // Use the state and actions here
 // ...
 return <div>...</div>;
};
export default Helper;
```

#### Step 7: Run your Next.js app

Start your Next.js development server and navigate to the page where you have used the context-connected component. You should now see the counter component with buttons to increment and decrement the count.

That's it! You have successfully implemented state management using React context in a simple Next.js application. React context allows you to share state and actions across components without the need for prop drilling. It

simplifies the process of managing and updating shared state in your application.

Remember that as your application grows, you might need more advanced features like middleware, async actions, or complex state management. In such cases, you can consider using Redux or other state management libraries.

However, for smaller applications with simpler state requirements, react context can be a lightweight and effective solution.

**Note:** Check out the sample code for [Chapter 7](#) in the GitHub repository *Building-Scalable-Web-Applications-with-Next.js-and-React*, to explore practical examples and implementations related to the chapter's content.

## Case studies and examples

In this section, we will see how state management can be implemented in real-world scenarios in Next.js applications. Let's explore five case studies along with the best practices for handling complex state:

- E-commerce shopping cart:
  - Scenario: Imagine you're building an e-commerce website with a shopping cart feature.
  - Implementation: To manage the shopping cart state, you can use Redux or React context. Store the cart items, quantities, and total price in the global state. Implement actions and reducers to handle adding, removing, or updating items in the cart. Connect relevant components to the state management solution to display and update the cart.
  - Best practices:
    - Normalize the cart state structure to efficiently handle a large number of items.
    - Optimize rendering using selectors or memoization techniques to prevent unnecessary re-renders of cart-related components.
    - Implement persistence to save the cart state, allowing users to return to their cart even after closing the browser.

- Social media feed:
  - Scenario: Suppose you're building a social media application with a feed of posts from different users.
  - Implementation: For managing the feed state, you can utilize React state or React context. Store the posts and their metadata in the component's state or context. Implement functions to handle actions such as adding new posts, deleting posts, or updating post likes and comments. Render the feed components based on the state data.
  - Best practices:
    - Consider pagination or infinite scrolling techniques to efficiently handle a large amount of data in the feed.
    - Use asynchronous actions or API calls to fetch and update posts, ensuring a seamless user experience.
    - Implement caching mechanisms to improve performance, avoiding redundant API calls for the same posts.
- Implementing Redux for a weather app:
  - Scenario: Developing a weather application that displays weather information for different locations.
  - Implementation: Use Redux to manage the weather data state. Store the weather information, such as temperature, conditions, and location, in the Redux store. Implement actions and reducers to fetch and update the weather data. Connect the relevant components to the store using the react-redux library.
  - Best practices:
    - Structure the Redux store with normalized data to efficiently manage and update weather information.
    - Utilize middleware like Redux Thunk or Redux Saga to handle asynchronous actions, such as fetching weather data from an API.
    - Leverage selectors to compute derived data from the store, reducing unnecessary computations and optimizing performance.

- Implementing React context for user authentication:
  - Scenario: Building an application with user authentication functionality.
  - Implementation: Use React context to manage the user authentication state. Store the user information, such as the username and authentication token, in the context. Implement context providers and consumers to handle user login, logout, and authentication checks. Access the authentication state throughout the application using useContext hook.
  - Best practices:
    - Use context sparingly and only for globally shared state that is truly necessary.
    - Implement authentication logic in a separate module or custom hook for reusability and maintainability.
    - Consider using third-party libraries like react-router to handle protected routes based on authentication state.
- Implementing React state for a To-Do list:
  - Scenario: Building a simple to-do list application.
  - Implementation: Use React state to manage the list of tasks. Store the tasks as an array in the component's state. Implement functions to add new tasks, mark tasks as completed, and delete tasks. Use the useState hook to manage the state and update the list based on user actions.
  - Best practices:
    - Break down the state into smaller, manageable pieces to avoid unnecessary re-renders.
    - Use immutability when updating the state to ensure predictable behavior and prevent bugs.
    - Consider using the useEffect hook to persist the to-do list in local storage, allowing users to access their list even after closing the browser.

In these case studies, implementing state management with Redux or React context offers centralized and efficient solutions for handling complex state

in Next.js applications. By following the best practices, such as normalizing state structures, optimizing rendering with selectors or memoization, and implementing persistence or caching, you can ensure smooth performance and effective management of complex state.

Remember to adapt these approaches to your specific application requirements and consider the needs of your project when implementing state management solutions.

## Conclusion

This chapter extensively explored the fundamental aspects of state management in Next.js applications and emphasized its significance. It began with an introduction to state management in Next.js, highlighting its crucial role in developing robust web applications.

A comprehensive review of various state management options in Next.js was conducted, including React state, Redux, and React context. The strengths and weaknesses of each option were discussed to aid in making informed decisions based on specific requirements.

Best practices for effective state management were emphasized throughout the chapter, encompassing the avoidance of common pitfalls and performance optimization. These guidelines enable developers to streamline the state management process in Next.js applications.

Implementation techniques for state management using React state were explored, including the utilization of hooks such as useState and useContext. This knowledge empowers developers to effectively manage state within components.

The implementation of state management using Redux was also covered, encompassing the setup of the store, definition of actions and reducers, and integration with components. This comprehensive walkthrough equips developers with the skills to leverage Redux for advanced state management in Next.js applications.

Additionally, the chapter addressed state management using React context, covering the creation of context, definition of providers and consumers, and usage within components. This understanding enables developers to leverage React context effectively.

Real-world case studies and examples were examined to reinforce understanding and demonstrate practical implementations of state management in Next.js applications. These scenarios showcased best practices for handling complex state, providing valuable insights to developers.

The next chapter will focus on introducing REST and GraphQL APIs in the context of Next.js applications. It will explain their concepts and showcase their usage for building robust and flexible web applications with Next.js.

## **Multiple choice questions**

1. What is the purpose of state management in a Next.js application?
  - A. To handle user authentication
  - B. To manage application routing
  - C. To efficiently manage and share data across components
  - D. To improve code organization and maintainability
2. Which state management option is built-in and provided by React itself?
  - A. Redux
  - B. React state
  - C. React context
  - D. MobX
3. Which state management option is based on the Flux architecture pattern?
  - A. Redux
  - B. React state
  - C. React context
  - D. MobX
4. What is the main advantage of using React context for state management?
  - A. Centralized state management with a predictable data flow

- B. Built-in support for time-travel debugging
  - C. Simplicity and ease of use
  - D. High performance and efficient updates
5. When is Redux typically recommended as a state management option in Next.js?
- A. For small and simple applications
  - B. When dealing with complex state and data flow
  - C. When server-side rendering is a requirement
  - D. When real-time data updates are needed

## Answers

- 1. C
- 2. B and C
- 3. A
- 4. C
- 5. B

**Note:** These questions are designed to test general knowledge about state management in Next.js. It's important to refer to the specific content and concepts covered in your learning materials for accurate answers.

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## CHAPTER 8

# Restful and GraphQL API Implementation

## Introduction

In the world of web development, APIs (Application Programming Interfaces) are essential for building robust applications. They enable seamless communication and data exchange between software systems. This chapter explores the significance of APIs in modern web development.

In this chapter, we will introduce APIs and highlight their importance as bridges between applications, providing access to external functionalities. We will discuss the differences between RESTful and GraphQL APIs and their benefits for informed API design. Practical implementation covers setting up RESTful APIs in Next.js and creating endpoints for CRUD operations. We will also explore setting up GraphQL APIs in Next.js with Apollo Server, building powerful API endpoints for precise data retrieval.

Integration with Next.js applications focuses on server-side rendering, improving the user experience with faster page loads. Error handling and best practices for API security and authentication are also discussed.

Throughout the chapter, practical examples and tips enhance the reader's understanding. By the end, you will have a comprehensive understanding of APIs in Next.js development. Let's unlock the power of APIs in web development!

## Structure

In this chapter, we will cover the following topics:

- Introduction to APIs and their importance in modern web development
- Understanding the differences between RESTful and GraphQL APIs
  - Setting up and configuring a RESTful API in Next.js
  - Setting up and configuring a GraphQL API in Next.js using popular frameworks like Apollo Server

- Building RESTful and GraphQL API endpoints for CRUD operations (Create, Read, Update, Delete)
- Integrating the API endpoints with the Next.js
- Handling errors and exceptions in API calls
- Best practices for API security and authentication in Next.js applications

## Introduction to APIs and their importance in modern web development

An API can be thought of as a set of rules and protocols that defines how software components should interact. It specifies the methods, data formats, and endpoints that developers can use to request and exchange information between applications.

### **Types of APIs:**

- **Web APIs:** These APIs are designed to allow communication between web-based systems. They use HTTP (Hypertext Transfer Protocol) as the underlying protocol and commonly provide data in formats like JSON (JavaScript Object Notation) or XML (eXtensible Markup Language).
- **Service APIs:** These APIs are exposed by various software services, allowing developers to access specific functionalities of those services. For example, a payment gateway service may provide an API that developers can use to process payments in their applications.

### **APIs importance in modern web development:**

- **Integration:** APIs enable different applications to seamlessly integrate and share data, functionalities, and services. This integration allows developers to leverage existing platforms and services to enhance their applications quickly.
- **Efficiency:** APIs promote code reuse and modularity. Instead of building everything from scratch, developers can use APIs to access pre-built functionalities, which saves time and effort.
- **Scalability:** APIs facilitate the scalability of applications. Developers can leverage external services or platforms to handle tasks like storage, authentication, or payment processing, freeing up resources to focus on core application features.

- **Collaboration:** APIs promote collaboration between developers and teams. By exposing specific functionalities through APIs, developers can work on different components simultaneously, ensuring faster development cycles.

How do APIs work?

When a developer wants to interact with an API, they make a request to a specific endpoint (URL) using the appropriate HTTP method (GET, POST, PUT, DELETE, and so on). The API processes the request, performs the necessary actions, and returns a response with the requested data or a status indicating the success or failure of the operation.

## API protocols and architectures

API protocols and architectures refer to the standards and frameworks that govern the design, communication, and interaction patterns of APIs. Here are some commonly used API protocols and architectures:

- REST (Representational State Transfer): REST is a widely adopted architectural style for designing networked applications. RESTful APIs use HTTP methods (GET, POST, PUT, DELETE, and so on) to interact with resources identified by URLs (Uniform Resource Locators). REST APIs emphasize stateless communication, scalability, and separation of concerns. They are commonly used in web development and follow principles like resource-oriented design, statelessness, and uniform interface.
- SOAP (Simple Object Access Protocol): SOAP is a protocol for exchanging structured information in web services using XML. SOAP APIs define message formats, operations, and contracts using XML-based contracts described by WSDL (Web Services Description Language). SOAP is known for its extensive features, support for complex data types, security, and transactional capabilities. It is commonly used in enterprise-level integrations and service-oriented architectures.
- gRPC (Google Remote Procedure Call): gRPC is a high-performance, language-agnostic framework developed by Google. It uses Protocol Buffers (protobuf) for defining services and messages. gRPC APIs enable efficient and cross-platform communication between services through remote procedure calls (RPC). gRPC is known for its speed, support for bidirectional streaming, flow control, and authentication. It is often used in microservices architectures and distributed systems.
- GraphQL: GraphQL is an open-source query language and runtime for APIs. It allows clients to request specific data by constructing flexible and

precise queries. Unlike REST, where the server determines the shape of the response, GraphQL puts control in the hands of the client. GraphQL APIs provide a single endpoint and return only the data requested by the client, reducing over-fetching and under-fetching of data. GraphQL is commonly used in scenarios where flexibility, efficient data retrieval, and client-driven data requirements are essential.

These are some of the widely used API protocols and architectures. Each protocol has its own strengths and use cases, and the choice depends on factors such as the nature of the application, performance requirements, compatibility with existing systems, and developer preferences.

In this chapter, you will gain a comprehensive understanding of these two popular API types: REST and GraphQL APIs. We will discuss their characteristics, use cases, and how to implement and consume APIs of each type. This knowledge will enable you to make informed decisions when choosing between REST and GraphQL based on your project requirements and optimize your API design and integration strategies.

## **RESTful versus GraphQL APIs**

The following table explains the difference between RESTful and GraphQL APIs:

|                     | <b>RESTful APIs</b>                                              | <b>GraphQL APIs</b>                                                                          |
|---------------------|------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Data Fetching       | Fetches multiple resources using multiple endpoints              | Fetches data from a single endpoint, allowing clients to specify exactly what data they need |
| Over-fetching       | Common occurrence where clients receive more data than needed    | Eliminates over-fetching by allowing clients to request only the required fields             |
| Under-fetching      | Requires multiple requests to retrieve related data              | Solves under-fetching issue by allowing clients to request nested data in a single query     |
| Versioning          | Often requires versioning to introduce breaking changes          | No need for versioning as the structure of the response can be controlled by the client      |
| Endpoint Structure  | Resource-based, with different endpoints for different resources | Single endpoint that handles all data queries, mutations, and subscriptions                  |
| Request Flexibility | Limited flexibility as the server determines the response format | Highly flexible, as the client specifies the data requirements in the query                  |
| Caching             | Supports caching at the endpoint level                           | Caching can be challenging due to                                                            |

|                         |                                                                  |                                                                                                     |
|-------------------------|------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
|                         |                                                                  | dynamic queries and unpredictable data requirements                                                 |
| Complexity Management   | May become complex when dealing with nested or related resources | Provides simplicity in querying related data and avoids complexity through precise data selection   |
| Client-Server Agreement | Server determines the structure and format of responses          | Client decides the structure and format of responses by specifying the fields it needs              |
| Learning Curve          | Relatively easier to understand and implement                    | Requires additional learning and understanding of the GraphQL query language and resolver functions |
| Ecosystem Maturity      | Well-established with a mature ecosystem and tooling             | Growing ecosystem with evolving tooling, but not as mature as RESTful APIs                          |

*Table 8.1: The difference between RESTful and GraphQL APIs*

## Setting up and configuring a RESTful API in Next.js

To set up and configure a RESTful API in Next.js with different HTTP methods (GET, POST, PUT, PATCH, and DELETE), you can follow the steps given here:

### **Step 1:** Set up a new Next.js project

- Create a new directory for your project and navigate to it using a terminal or command prompt.
- Initialize a new Next.js project by running the following command:

```
npx create-next-app
```

This will set up a basic Next.js project in the current directory.

### **Step 2:** Create an API route

- Inside your project directory, create a new directory called `pages/api`.
- In the `api` directory, create a new JavaScript file, such as `example.js`. This file will represent your API route.

### **Step 3:** Define API routes for different HTTP methods:

#### **1. GET Method: Retrieves data from a server.**

In `example.js`, define the API route for the GET method. For example:

```
export default function handler(req, res) {
 if (req.method === 'GET') {
```

```

 // Logic for handling GET requests
 res.status(200).json({ message: 'GET request received.' });
} else {
 // Handle other HTTP methods
 res.status(405).json({ message: 'Method Not Allowed' });
}
}

```

## 2. POST Method: Sends data to a server to create a new resource.

To handle a POST request, add the following code to `example.js`:

```

export default function handler(req, res) {
 if (req.method === 'POST') {
 // Logic for handling POST requests
 const data = req.body;
 res.status(200).json({ message: 'POST request received.', data });
 } else {
 // Handle other HTTP methods
 res.status(405).json({ message: 'Method Not Allowed' });
 }
}

```

Note: For the POST method, you need to parse the request body to access the data. You can use `body-parser` or the built-in `express.json()` middleware to achieve this.

## 3. PUT Method: Sends data to a server to update an existing resource.

For the PUT method, you can use the following code:

```

export default function handler(req, res) {
 if (req.method === 'PUT') {
 // Logic for handling PUT requests
 const { id } = req.query; // Access dynamic URL parameter
 const data = req.body;
 res.status(200).json({ message: `PUT request received for ID: ${id}`, data });
 } else {
 // Handle other HTTP methods
 res.status(405).json({ message: 'Method Not Allowed' });
 }
}

```

In this example, the PUT method expects a dynamic URL parameter `id` to identify the resource being updated.

**PATCH:** Sends data to a server to partially update an existing resource, modifying only the specified fields or properties without affecting the rest of the resource.

The main difference between PUT and PATCH methods is as follows:

- **PUT:** The PUT method is used to completely replace an existing resource with a new representation. When sending a PUT request, the entire updated resource is typically sent in the request payload. This means that any fields not included in the request payload will be removed or reset to their default values. PUT is generally used for full updates and is idempotent, meaning that making the same PUT request multiple times will have the same outcome.
- **PATCH:** The PATCH method is used to partially update an existing resource. Instead of sending the entire resource, a PATCH request typically includes only the specific fields or properties that need to be modified. This allows for more granular updates without affecting the rest of the resource. PATCH is used for partial updates and is not necessarily idempotent, meaning that making the same PATCH request multiple times may have different outcomes.

In summary, PUT is used for complete updates by replacing the entire resource, while PATCH is used for partial updates by modifying specific fields or properties of an existing resource.

#### 4. **DELETE Method: Sends a request to a server to delete a specific resource.**

For the DELETE method, you can use the following code:

```
export default function handler(req, res) {
 if (req.method === 'DELETE') {
 // Logic for handling DELETE requests
 const { id } = req.query; // Access dynamic URL parameter
 res.status(200).json({ message: `DELETE request received for
ID: ${id}` });
 } else {
 // Handle other HTTP methods
 res.status(405).json({ message: 'Method Not Allowed' });
 }
}
```

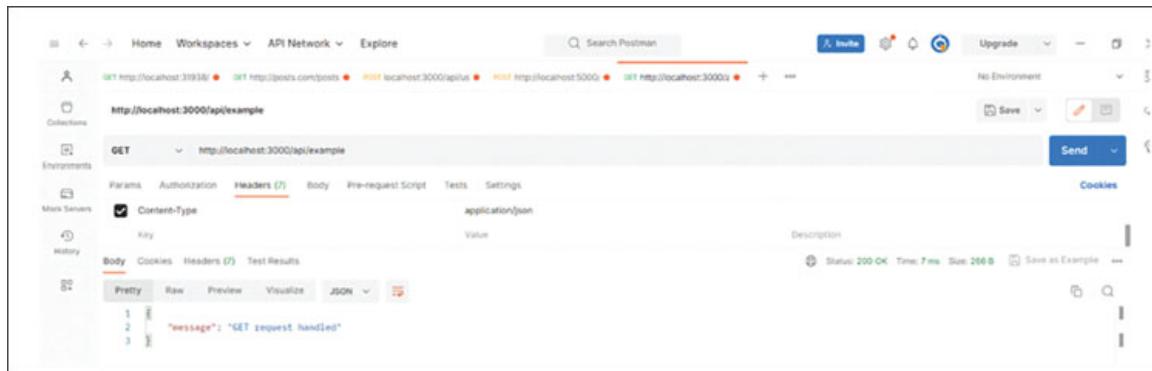
In this example, the DELETE method expects a dynamic URL parameter `id` to identify the resource being deleted.

#### Step 4: Test the API routes

Start the Next.js development server by running the following command in your project directory:

```
npm run dev
```

Use a tool like Postman or cURL to send requests to your API routes. For example, you can send a GET request to `http://localhost:3000/api/example` or a POST please refer [Figure 8.1](#):



*Figure 8.1: Postman call API call*

## Setting up and configuring a GraphQL API in Next.js using Apollo Server

In a GraphQL API, the three basic components include queries, mutations, and resolvers.

- **Query:** A query in GraphQL is used to request data from the server. It follows a specific structure defined by the GraphQL schema and allows clients to specify the exact fields and relationships they want to retrieve. Queries are executed in parallel, and the response matches the shape of the query.
- **Mutation:** A mutation in GraphQL is used to modify data on the server. It enables clients to perform create, update, or delete operations on resources. Like queries, mutations are defined in the GraphQL schema and have their own structure. Mutations are typically used when making changes that have side effects on the server.
- **Resolver:** A resolver is a function that is responsible for resolving a query or mutation in GraphQL. It acts as the link between the API and the

underlying data sources. Resolvers are defined for each field in the schema and contain the logic to fetch or manipulate the requested data. They are executed to fulfill the client's request and return the corresponding data.

Overall, queries are used to retrieve data, mutations are used to modify data, and resolvers handle the execution of these requests and provide the requested data or perform the necessary actions.

To set up and configure a GraphQL API in Next.js using Apollo Server, you can follow these steps:

### Step 1: Set up a new Next.js project

- Create a new directory for your project and navigate to it using a terminal or command prompt.
- Initialize a new Next.js project by running the following command:

```
npx create-next-app
```

This will set up a basic Next.js project in the current directory.

### Step 2: Install required dependencies

- In your project directory, install the necessary packages for GraphQL and Apollo Server by running the following command:

```
npm install apollo-server-micro graphql
```

### Step 3: Create an API route for GraphQL

- Inside your project directory, create a new directory called `pages/api`.
- In the `api` directory, create a new JavaScript file, such as `graphql.js`. This file will represent your GraphQL API route.

### Step 4: Define GraphQL schema and resolvers

1. In **graphql.js**, define the GraphQL schema using the `makeExecutableSchema` function from the `graphql-tools` package. For example,

```
import { ApolloServer, gql } from 'apollo-server-micro';
const typeDefs = gql`
 type Book {
 id: ID!
 title: String!
 author: String!
 }
`
```

```
type Query {
 books: [Book!]!
 book(id: ID!): Book
}
type Mutation {
 addBook(title: String!, author: String!): Book!
 updateBook(id: ID!, title: String, author: String): Book
 deleteBook(id: ID!): Book
}
`;
const books = [
 { id: '1', title: 'Book 1', author: 'Author 1' },
 { id: '2', title: 'Book 2', author: 'Author 2' },
];
const resolvers = {
 Query: {
 books: () => books,
 book: (parent, args) => books.find((book) => book.id === args.id),
 },
 Mutation: {
 addBook: (parent, args) => {
 const newBook = { id: String(books.length + 1), ...args };
 books.push(newBook);
 return newBook;
 },
 updateBook: (parent, args) => {
 const index = books.findIndex((book) => book.id === args.id);
 if (index >= 0) {
 const updatedBook = { ...books[index], ...args };
 books[index] = updatedBook;
 return updatedBook;
 }
 return null;
 },
 deleteBook: (parent, args) => {
 const index = books.findIndex((book) => book.id === args.id);
 if (index >= 0) {
```

```

 const deletedBook = books[index];
 books.splice(index, 1);
 return deletedBook;
 }
 return null;
},
},
};

const apolloServer = new ApolloServer({ typeDefs, resolvers });
let handler;
async function getHandler() {
 if (!handler) {
 await apolloServer.start();
 handler = apolloServer.createHandler({ path: '/api/graphql' });
 }
 return handler;
}
export default async function graphqlHandler(req, res) {
 const apolloHandler = await getHandler();
 return apolloHandler(req, res);
}
export const config = {
 api: {
 bodyParser: false,
 },
};

```

## 1. Importing necessary dependencies:

- a. `ApolloServer` and `gql` are imported from `apollo-server-micro`. `ApolloServer` is used to create an instance of the Apollo Server, and `gql` is used to define the GraphQL schema.

## 2. Defining the GraphQL schema:

- a. The schema is defined using the `gql` tag function. It specifies the types and operations available in the API.
- b. In this schema, there are three types: `Book`, `Query`, and `Mutation`.
- c. The `Book` type represents a book object and has three fields: `id` (ID type), `title` (String type), and `author` (String type).

- d. The `Query` type defines the available queries. It has two fields: `books` (returns an array of `Book` objects) and `book` (takes an `id` argument and returns a single `Book` object).
- e. The `Mutation` type defines the available mutations. It has three fields: `addBook` (takes `title` and `author` arguments and returns a new `Book` object), `updateBook` (takes `id`, `title`, and `author` arguments and returns the updated `Book` object), and `deleteBook` (takes an `id` argument and returns the deleted `Book` object).

### 3. Defining the resolver functions:

- a. The `books` array holds a few book objects as sample data.
- b. The resolver functions define how the GraphQL operations are resolved.
- c. For the `Query` type, the resolver functions for `books` and `book` simply return the corresponding data from the `books` array based on the provided arguments.
- d. For the `Mutation` type, the resolver functions for `addBook`, `updateBook`, and `deleteBook` handle the addition, updating, and deletion of book data respectively. They update the `books` array accordingly and return the relevant data.

### 4. Creating an instance of Apollo Server:

- a. An instance of `ApolloServer` is created with the defined `typeDefs` and `resolvers`.

### 5. Setting up the serverless function handler:

- a. The `getHandler` function is defined to lazily create and return the Apollo Server handler.
- b. The `graphqlHandler` function is the main entry point for the serverless function.
- c. It calls `getHandler` to get the Apollo Server handler and passes the incoming `req` and `res` objects to it.
- d. The handler is then returned.

### 6. Exporting the serverless function and configuration:

- a. The `graphqlHandler` function is exported as the default function to be used as the serverless function.

- b. The `config` object is exported to configure the API, setting `bodyParser` to `false` to disable automatic parsing of the request body.
7. Overall, this code sets up a GraphQL API using Apollo Server Micro, defines a schema with queries and mutations for managing a list of books, and provides resolver functions to handle the logic of querying, adding, updating, and deleting book data.

## Step 5: Test the GraphQL API

1. Start the Next.js development server by running the following command in your project directory:

```
npm run dev
```

2. Open your browser and navigate to `http://localhost:3000/api/graphql`. You should see the GraphQL Playgroun interface.
3. Use the Playgroun interface to send queries and mutations to your GraphQL API. For example, you can send the following queries and mutations:

- o **Query: Get all books**

```
query {
 books {
 id
 title
 author
 }
}
```

- o **Mutation: Add a new book**

```
mutation {
 addBook(title: "The Great Gatsby", author: "F.
 Scott Fitzgerald")
 {
 id
 title
 author
 }
}
```

- o **Mutation: Update a book**

```
mutation {
```

```

updateBook(id: "bookId", title: "New Title",
 author: "New Author"
) {
 id
 title
 author
}

```

Replace `bookId` with the actual ID of the book you want to update.

- **Mutation: Delete a book**

```

mutation {
 deleteBook(id: "bookId") {
 id
 title
 author
 }
}

```

Replace `bookId` with the actual ID of the book you want to delete.

You can use the preceding queries and mutations in the GraphQL Playground interface to interact with your GraphQL API and perform actions like adding, updating, and deleting books. Please refer to [figures 8.2 and 8.3](#).

The screenshot shows the GraphQL Playground interface with a successful query execution. The query is:

```

query {
 books {
 id
 title
 author
 }
}

```

The response is:

```

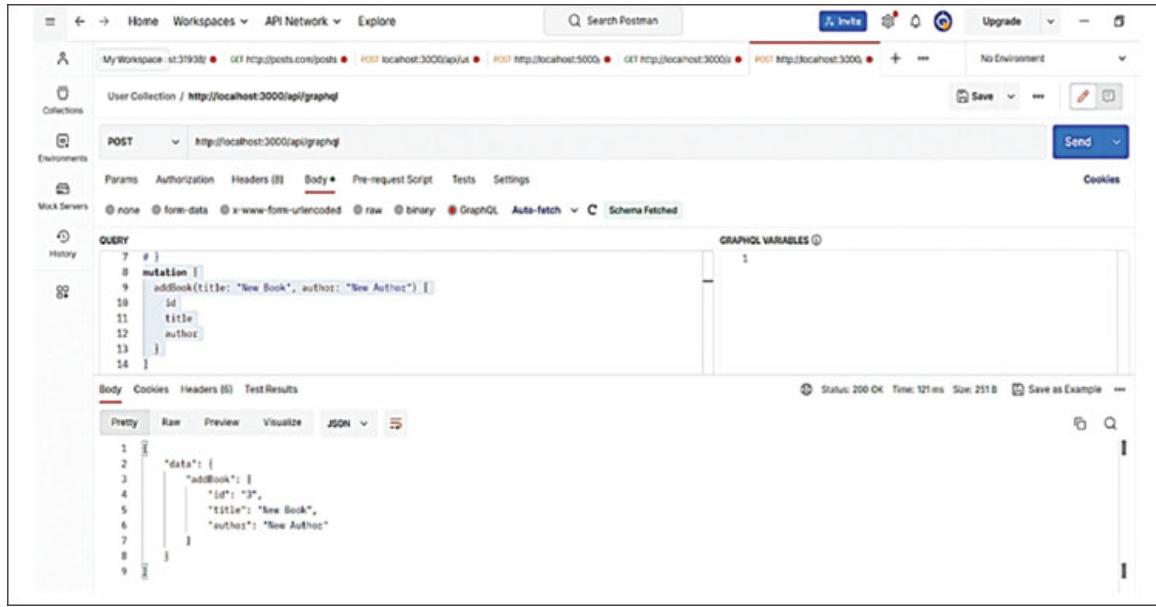
{
 "data": [
 {
 "id": "1",
 "title": "Book 1",
 "author": "Author 1"
 },
 {
 "id": "2",
 "title": "Book 2",
 "author": "Author 2"
 }
]
}

```

The interface includes tabs for Body, Cookies, Headers (empty), and Test Results. The Body tab is selected, showing the query text. The Test Results tab shows the JSON response. The status bar at the bottom indicates Status: 200 OK, Time: 430 ms, Size: 296 B.

**Figure 8.2:** Fetch data from graphQL api

[Figure 8.3](#) shows the add data form graphQL api:



**Figure 8.3:** Add data form graphQL api

By convention, GraphQL queries should be sent as POST requests because the query complexity and data requirements can vary significantly. POST requests also allow for sending larger payloads and more complex query structures.

However, GraphQL also supports GET requests for simple queries that only retrieve data without any side effects. In a GET request, the query is typically passed as a URL parameter.

To use GET requests with GraphQL, you need to modify the server configuration and client implementation accordingly. On the server side, you would configure your GraphQL server to accept GET requests and handle them appropriately. On the client side, you would construct the GraphQL query as a URL parameter and include it in the GET request.

It's important to note that using GET requests for complex or mutation queries is generally discouraged due to limitations on request size and potential security concerns. POST requests are the recommended method for most GraphQL interactions.

So, while it's true that GraphQL queries can work with both POST and GET methods, it is advisable to use POST requests for most GraphQL operations and only use GET requests for simple read-only queries when necessary.

## [Integrating the API endpoints with Client Side in Next.js](#)

Before integrating REST APIs with Next.js, you need to understand how to use the SWR hook in Next.js. Additionally, to integrate GraphQL APIs, you can utilize the Apollo Client library. Let me explain each library separately, along with their properties, using a short code example.

The SWR (Stale-While-Revalidate) hook in Next.js is a built-in data-fetching library that simplifies data fetching, caching, and synchronization between the client and server. It provides an intuitive way to handle real-time data updates and optimize the performance of your application. Here's a breakdown of the SWR hook's properties and their usage:

**useSWR** (key: string, fetcher: Function, options?: Config): This is the main function of the SWR hook used to fetch and manage data. It takes three parameters:

- key: A unique identifier for the data being fetched. It can be a URL, an API endpoint, or any other string representing the data source.
- fetcher: A function responsible for making the actual API call and returning the response. The fetcher function can be asynchronous and should typically return the fetched data in a specific format, such as JSON.
- options (optional): An object that allows you to configure additional behavior and options for the SWR hook. It includes properties such as revalidateOnMount, revalidateOnFocus, revalidateOnReconnect, refreshInterval, and more.

Here's an example demonstrating the usage of the SWR hook:

```
import useSWR from 'swr';
const fetcher = (url) => fetch(url).then((res) => res.json());
const MyComponent = () => {
 const { data, error } = useSWR('/api/data', fetcher);
 if (error) return <div>Error loading data</div>;
 if (!data) return <div>Loading...</div>;
 return <div>{data.message}</div>;
};
```

In the preceding example, we use useSWR to fetch data from the /api/data endpoint using the fetcher function. The data and error variables capture the result of the API call, which can be rendered accordingly in the component.

- data: The data property holds the fetched data. Initially, it will be undefined or the default value specified in the **useSWR** hook.
- error: If an error occurs during the data fetching process, the error property will contain the error details. You can check this property to handle error

cases appropriately.

- `mutate(data?, shouldRevalidate?, options?)`: The `mutate` function allows you to manually mutate the data. You can use it to update the data or trigger a revalidation. It accepts three optional parameters.
  - `data`: The new data to be set. If provided, it will update the `data` property.
  - `shouldRevalidate`: A boolean indicating whether a revalidation should be triggered after data mutation. By default, it's set to true.
  - `options`: Additional options for the mutation, such as `revalidate` and `noRevalidate`.
- `revalidate()`: The `revalidate` function triggers a revalidation of the data, making a new API call to fetch the latest data.
- `isValidating`: The `isValidating` property is a boolean that indicates whether the SWR hook is currently validating (fetching) the data. It can be used to show loading spinners or other indicators while data is being fetched.

These properties and functions provide powerful control over data fetching and updating in your Next.js application.

**Apollo Client:** Apollo Client is a powerful GraphQL client that simplifies data fetching and management in Next.js applications. It provides features like caching, local state management, and real-time subscriptions. Here's a breakdown of Apollo Client's properties and their usage:

### 1. Setting up Apollo Client in Next.js:

To use Apollo Client in Next.js, you'll need to install the necessary packages:

```
npm install @apollo/client graphql
```

Once installed, you can create an instance of Apollo Client with the required configuration, typically in a separate file:

```
import { ApolloClient, InMemoryCache } from '@apollo/client';
const client = new ApolloClient({
 uri: 'https://localhost:3000.com/graphql', // replace with
 your GraphQL API endpoint
 cache: new InMemoryCache(),
});
export default client;
```

In the preceding example, we create an instance of Apollo Client with the appropriate GraphQL API endpoint (`uri`) and an `InMemoryCache` for data caching. You can customize the configuration based on your requirements.

## 2. Apollo Provider in Next.js:

Next.js provides the `ApolloProvider` component to wrap your application and provide the Apollo Client instance to all components in the hierarchy. You can typically set it up in your `pages/\_app.js` file:

```
import { ApolloProvider } from '@apollo/client';
import client from '../path/to/apolloClient';
function MyApp({ Component, pageProps }) {
 return (
 <ApolloProvider client={client}>
 <Component {...pageProps} />
 </ApolloProvider>
);
}
export default MyApp;
```

By wrapping your app with `ApolloProvider` and passing the `client` instance, all components in your application can access and utilize Apollo Client for data fetching and management.

## 3. Querying data with Apollo Client:

To fetch data from a GraphQL API using Apollo Client, you can use the `useQuery` hook provided by `@apollo/client`. Here's an example:

```
import { gql, useQuery } from '@apollo/client';
const GET_USERS = gql`query {
 users {
 id
 name
 }
}`;
function MyComponent() {
 const { loading, error, data } = useQuery(GET_USERS);
 if (loading) return <div>Loading...</div>;
 if (error) return <div>Error loading data</div>;
 return (

 {data.users.map((user) => (
 <li key={user.id}>{user.name}
))}

);
}
```

```

);
}
```

In the preceding example, we define a GraphQL query using the `gql` tag from `@apollo/client`. The `useQuery` hook is then used to fetch data based on the `GET\_USERS` query. The `loading` property indicates if the data is still being fetched, the `error` property captures any errors that occur during the process, and the `data` property contains the fetched data.

#### 4. Mutation with Apollo Client:

Apollo Client provides the `useMutation` hook to handle mutations (data modifications) in GraphQL. Here's an example:

```
import { gql, useMutation } from '@apollo/client';
const ADD_USER = gql`
mutation AddUser($input: UserInput!) {
 addUser(input: $input) {
 id
 name
 }
}`
function MyComponent() {
 const [addUser, { loading, error, data }] =
 useMutation(ADD_USER);
 const handleAddUser = async () => {
 try {
 const { data } = await addUser({
 variables: {
 input: {
 name: "John Doe",
 },
 },
 });
 console.log(data);
 } catch (error) {
 console.error(error);
 }
 };
 if (loading) return <div>Loading...</div>;
 if (error) return <div>Error adding user</div>;
 return (
```

```

 <div>
 <button onClick={handleAddUser}>Add User</button>
 </div>
);
}

```

In the preceding example, we define a GraphQL mutation using the `gql` tag from `@apollo/client`. The `useMutation` hook is used to handle the `ADD_USER` mutation. It returns a function `addUser` that can be called to trigger the mutation. The result of the mutation, including loading, error, and data, is captured in the respective variables.

In the `handleAddUser` function, we call the `addUser` function and provide the necessary variables required by the mutation. In this case, we're adding a user with the name "John Doe". The response data can be accessed and utilized accordingly.

## 5. Apollo Client Cache:

Apollo Client utilizes a cache to store and manage fetched data. The cache allows for efficient data retrieval and synchronization. By default, Apollo Client uses the `InMemoryCache` implementation, which provides powerful caching capabilities.

You can customize the cache behavior based on your requirements. For example, you can modify cache options, define custom cache resolvers, or even implement client-side data manipulation.

These are some of the key aspects of using Apollo Client in Next.js. Apollo Client offers many more features and capabilities, including local state management, subscriptions, and error handling. It provides a comprehensive solution for working with GraphQL in your Next.js applications, simplifying data fetching, caching, and manipulation.

**To integrate the REST API endpoints in a Next.js application using the SWR (Stale-While-Revalidate) hook, you can follow these steps:**

1. Install the required dependencies:

```
npm install swr
```

2. Create a new file, `api.js`, to handle the API requests using the `fetch` function or any HTTP library of your choice. This file will contain functions for each API endpoint:

```

export const fetchTodos = async () => {
 const response = await fetch('/api/todos');
 const data = await response.json();

```

```

 return data;
};

export const createTodo = async (todo) => {
 const response = await fetch('/api/todos', {
 method: 'POST',
 headers: {
 'Content-Type': 'application/json',
 },
 body: JSON.stringify(todo),
 });
 const data = await response.json();
 return data;
};

export const updateTodo = async (id, todo) => {
 const response = await fetch(`api/todos/${id}`, {
 method: 'PUT',
 headers: {
 'Content-Type': 'application/json',
 },
 body: JSON.stringify(todo),
 });
 const data = await response.json();
 return data;
};

export const deleteTodo = async (id) => {
 const response = await fetch(`api/todos/${id}`, {
 method: 'DELETE',
 });
 const data = await response.json();
 return data;
};

```

3. In your Next.js component, import the necessary dependencies and use the SWR hook to fetch and manage the data from the API endpoints:

```

import useSWR from 'swr';
import { fetchTodos } from './api';
const TodoList = () => {
 const { data: todos, error } = useSWR('/api/todos',
 fetchTodos);
 if (error) {

```

```

 return <p>Error: {error.message}</p>;
 }
 if (!todos) {
 return <p>Loading...</p>;
 }
 return (
 <div>
 <h1>Todo List</h1>

 {todos.map((todo) => (
 <li key={todo.id}>{todo.title}
)))

 </div>
);
}
export default TodoList;

```

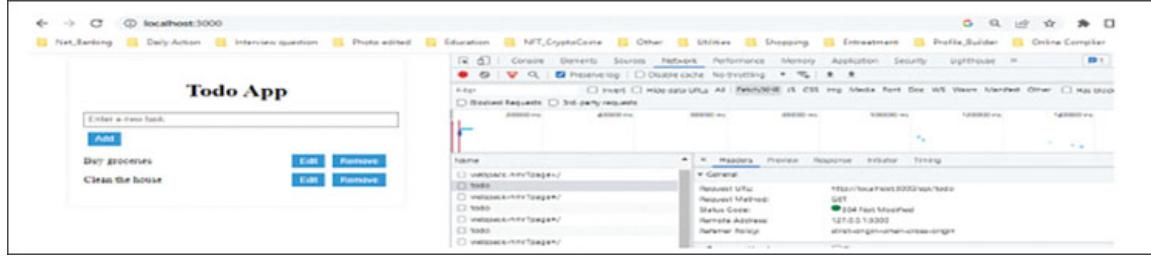
4. Update your API endpoints in the `pages/api/todos.js` file to handle the respective requests:

```

export default function handler(req, res) {
 if (req.method === 'GET') {
 // Handle GET request to fetch all todos
 const todos = [
 { id: 1, title: 'Todo 1' },
 { id: 2, title: 'Todo 2' },
 // ...
];
 res.status(200).json(todos);
 } else if (req.method === 'POST') {
 // Handle POST request to create a new todo
 // ...
 } else if (req.method === 'PUT') {
 // Handle PUT request to update a todo
 // ...
 } else if (req.method === 'DELETE') {
 // Handle DELETE request to delete a todo
 // ...
 }
}

```

- Now, you can use the `TodoList` component in your Next.js application, and it will automatically fetch and update the TODOs using the SWR hook.



**Figure 8.4:** sample UI consume RestFull api

Remember to start your Next.js application (`npm run dev`) to see the changes in action. Make sure you have the required imports and files in the appropriate locations for the code to work properly. Please refer [Figure 8.4](#):

Note: The provided GitHub repository contains code examples related to the book *Building Scalable Web Applications with Next.js and React*. Specifically, the code in the “**chapter\_8\_API\_DEMO**” branch demonstrates API integration in a Next.js application.

**To consume the GrahQL API using Apollo Client in a Next.js application, you'll need to install the necessary dependencies and set up the Apollo Client configuration. you can follow these steps:**

- Install the required dependencies:

```
npm install apollo-boost graphql
```

- Create a new file, `apolloClient.js`, to configure the Apollo Client:

```
import { ApolloClient, InMemoryCache } from 'apollo-boost';
const client = new ApolloClient({
 uri: '/api/graphql',
 cache: new InMemoryCache(),
});
export default client;
```

- Create a new page in the `pages` directory, for example, `books.js`, to fetch and display the books:

```
import { gql, useQuery } from '@apollo/client';
import client from '../apolloClient';
const GET_BOOKS = gql`query GetBooks {
 books {
 id
```

```

 title
 author
 }
};

export default function BooksPage() {
const { loading, error, data } = useQuery(GET_BOOKS, { client
});
if (loading) {
 return <p>Loading...</p>;
}
if (error) {
 return <p>Error: {error.message}</p>;
}
const { books } = data;
return (
 <div>
 <h1>Books</h1>
 {books.map((book) => (
 <div key={book.id}>
 <h2>{book.title}</h2>
 <p>{book.author}</p>
 </div>
))}
 </div>
);
}

```

4. Update the **graphqlHandler** in the API route file, `api/graphql.js`, to handle CORS headers and enable introspection:

```

import { ApolloServer, gql } from 'apollo-server-micro';
const typeDefs = gql`
type Book {
 id: ID!
 title: String!
 author: String!
}
type Query {
 books: [Book!]!
 book(id: ID!): Book
}

```

```

...Mutation definitions...
const books = [
 { id: '1', title: 'Book 1', author: 'Author 1' },
 { id: '2', title: 'Book 2', author: 'Author 2' },
];
const resolvers = {
 Query: {
 books: () => books,
 book: (parent, args) => books.find((book) => book.id ===
 args.id),
 },
 // ...Mutation resolvers...
};
const apolloServer = new ApolloServer({
 typeDefs,
 resolvers,
 introspection: true,
});
export const config = {
 api: {
 bodyParser: false,
 },
};
export default apolloServer.createHandler({ path:
 '/api/graphql' });

```

5. Now, you can visit the `books` page in your Next.js application to see the list of books fetched from the API.

Remember to start your Next.js application (`npm run dev`) to see the changes in action. Make sure you have the required imports and files in the appropriate locations for the code to work properly.

## Handling errors and exceptions in API calls

In Next.js, handling errors and exceptions in API calls involves implementing error handling logic on both the server-side and client-side. Here's a general approach you can follow:

1. Server-Side Error Handling:

- In your API route handler (`pages/api/your-api-route.js`), wrap your code inside a try-catch block.
- Catch any potential errors that may occur during the API call.
- Return an appropriate error response using the `res.status()` and `res.json()` methods. For example:

```
export default async function handler(req, res) {
 try {
 // API code here
 res.status(200).json({ message: 'Success' });
 } catch (error) {
 res.status(500).json({ message: 'Internal Server Error' });
 }
}
```

## 2. Client-Side Error Handling:

- In your client-side code (React component), handle any errors or exceptions that may occur during the API call.
- Use a `try-catch` block or `Promise.catch()` to catch any errors thrown during the API call.
- You can display error messages to the user or perform appropriate actions based on the error received.
- Here's an example of handling errors in a Next.js client-side component using `fetch`:

```
import { useState } from 'react';
export default function MyComponent() {
 const [error, setError] = useState(null);
 const fetchData = async () => {
 try {
 const response = await fetch('/api/your-api-route');
 if (!response.ok) {
 throw new Error('Request failed');
 }
 // Process the response data
 } catch (error) {
 setError('An error occurred');
 }
 };
}
```

```

 return (
 <div>
 {error && <p>{error}</p>}
 <button onClick={fetchData}>Fetch Data</button>
 </div>
);
 }

```

### 3. Handling Errors with SWR:

SWR is a popular data fetching library for Next.js that provides built-in error handling capabilities.

```

import useSWR from 'swr';
const MyComponent = () => {
 const { data, error } = useSWR('/api/your-api-route',
 fetcher);
 if (error) {
 // Handle the error
 return <p>Error: {error.message}</p>;
 }
 // Handle loading and success states
 if (!data) {
 return <p>Loading...</p>;
 }
 // Render the data
 return <div>Data: {data}</div>;
};

```

In the preceding example, the `useSWR` hook is used to fetch data from the specified API route (`/api/your-api-route`) using the `fetcher` function. The `data` and `error` variables provided by SWR are then used to handle the different states of the API call.

### 4. Handling Errors with Apollo Client:

If you're using Apollo Client for GraphQL API calls in Next.js, you can handle errors using the `useQuery` and `useMutation` hooks provided by Apollo.

```

import { useQuery, gql } from '@apollo/client';
const GET_DATA = gql`
 query GetData {
 // Your query definition here
 }

```

```

const MyComponent = () => {
 const { data, loading, error } = useQuery(GET_DATA);
 if (loading) {
 return <p>Loading...</p>;
 }
 if (error) {
 // Handle the error
 return <p>Error: {error.message}</p>;
 }
 // Render the data
 return <div>Data: {data}</div>;
};

```

In preceding example, the `useQuery` hook is used to fetch data using the `GET\_DATA` GraphQL query. The `data`, `loading`, and `error` variables provided by Apollo are then used to handle the different states of the API call.

These examples demonstrate how to handle errors and exceptions in API calls using SWR and Apollo Client in Next.js. You can customize the error handling logic based on your specific requirements and error response structures.

## Best practices for API security and authentication in Next.js applications

Securing APIs and implementing authentication in Next.js applications involves following best practices to protect sensitive data and prevent unauthorized access. Here are some recommended practices for API security and authentication in Next.js applications:

- Use HTTPS: Always serve your Next.js application over HTTPS to encrypt communication between the client and server, ensuring data confidentiality and integrity.
- Implement Proper Authentication:
  - Use a secure authentication mechanism such as JSON Web Tokens (JWT) or OAuth.
  - Implement strong password hashing algorithms like bcrypt to securely store user passwords.
  - Use session management techniques to handle user sessions and store session data securely (for example, using secure cookies with HttpOnly and Secure flags).

- Employ mechanisms like rate limiting and account lockouts to prevent brute-force attacks.
- Protect Sensitive Data:
  - Avoid storing sensitive information, such as passwords or API keys, in plain text. Instead, use secure storage solutions like environment variables or a secure key management system.
  - Use encryption when storing or transmitting sensitive data, especially in databases or API responses.
- Validate and Sanitize User Input:
  - Apply input validation and sanitization to prevent common vulnerabilities such as cross-site scripting (XSS) and SQL injection attacks.
  - Utilize libraries or frameworks that offer built-in validation and sanitization mechanisms.
- Implement Role-Based Access Control (RBAC):
  - Define roles and permissions for different user types.
  - Restrict access to certain API endpoints or actions based on user roles and permissions.
- Protect Against Cross-Site Request Forgery (CSRF):
  - Implement CSRF protection mechanisms, such as using CSRF tokens or same-site cookies, to prevent unauthorized requests from malicious websites.
- Secure API Keys and Secrets:
  - Safeguard API keys, tokens, and other secrets by storing them in secure storage solutions (e.g., environment variables) and avoid committing them to version control.
- Enable CORS (Cross-Origin Resource Sharing):
  - Configure CORS headers appropriately to restrict access to your API from unauthorized domains and prevent cross-origin attacks.
- Regularly Update Dependencies:
  - Keep your Next.js application and its dependencies up to date to benefit from security patches and bug fixes.

- Conduct Security Audits and Testing:
  - Regularly perform security audits, code reviews, and vulnerability scanning to identify and address potential security vulnerabilities.
  - Conduct thorough penetration testing and security assessments to uncover any weaknesses in your application's security.

Remember that security is an ongoing process, and it's essential to stay updated on the latest security practices, vulnerabilities, and best practices to ensure the ongoing security of your Next.js application and its APIs.

## Conclusion

Learning how to implement APIs in Next.js can greatly enhance your ability to build powerful and interactive web applications. By understanding the fundamentals of API development and integrating them into your Next.js projects, you can unlock the potential for seamless data communication and exchange.

To solidify your understanding, it's beneficial to explore practical examples. By working on a practical example, you can gain hands-on experience in setting up and configuring APIs in Next.js. This example could involve creating API endpoints to handle CRUD operations related to particles, such as creating new particles, retrieving particle data, updating existing particles, and deleting particles.

By following tutorials and documentation specific to Next.js and popular frameworks like Apollo Server, you can learn how to implement both RESTful and GraphQL APIs efficiently. You will discover how to define the necessary schemas and resolvers, handle server-side rendering, and effectively manage errors and exceptions.

Throughout this process, you will gain insights into the best practices for API security and authentication.

By applying these principles and gaining hands-on experience with practical examples, you will become proficient in implementing APIs within your Next.js applications. This knowledge will empower you to build robust and scalable web applications that leverage the power of APIs to provide dynamic and interactive experiences for your users.

In the next chapter, we will explore how to save data in SQL and NoSQL databases within the context of Next.js applications. Storing data is a crucial aspect of most web applications, and understanding the differences between SQL

and NoSQL databases can help you make informed decisions about which type of database to use based on your project's requirements.

## **Multiple choice questions**

1. Which of the following is an important benefit of using APIs in web development?
  - A. Enhancing user interface design
  - B. Enabling seamless communication between systems
  - C. Optimizing database performance
  - D. Increasing server processing speed
2. Which API architectural style provides a flexible and efficient way to query and mutate data?
  - A. RESTful API
  - B. SOAP API
  - C. GraphQL API
  - D. RPC API
3. Which framework can be used to set up and configure GraphQL APIs in Next.js?
  - A. Express.js
  - B. Apollo Server
  - C. Django
  - D. Laravel
4. Which approach does RESTful API follow for handling CRUD operations?
  - A. Command-query separation
  - B. Event-driven architecture
  - C. Resource-based approach
  - D. Middleware pattern
1. What are some best practices for securing and authenticating APIs in Next.js applications?
  - A. Using HTTPS, implementing proper authentication mechanisms like JWT or OAuth, protecting sensitive data, and regular security audits

- B. Using HTTP, storing sensitive data in plain text, and relying on client-side validation
- C. Enabling CORS protection, using environment variables for API keys, and avoiding input validation
- D. Using OAuth only for authentication, storing secrets in the application code, and never updating dependencies

## Answer:

1. B
2. C
3. B
4. C
5. A

I hope you enjoyed this mini quiz! APIs are a fascinating aspect of web development, and understanding their importance, architectural styles, and best practices can significantly enhance your skills in building robust Next.js applications.

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## CHAPTER 9

# Using Different Types of Databases

### Introduction

In this chapter, we will delve into the world of databases and explore how they can be utilized in Next.js applications. Databases play a crucial role in web development, acting as the backbone for storing, retrieving, and managing data.

To begin, we will provide an overview of databases and their significance in web development. Understanding the fundamentals of databases will set the stage for exploring the various types of databases available. We will introduce you to relational databases, NoSQL databases, and even delve into graph databases, highlighting their unique characteristics and use cases.

Selecting the right database for your application is essential, as each type has its own strengths and weaknesses. We will guide you through the decision-making process, considering factors such as data structure, scalability, and performance.

Once you've made your choice, we will help you set up a database connection in Next.js. We'll cover the steps involved in connecting popular databases like MongoDB, MySQL, and PostgreSQL to your Next.js application, allowing you to leverage their functionalities seamlessly.

Next, we will explore the common operations you'll perform with databases, focusing on Create, Read, Update, and Delete (CRUD) operations. You will learn how to interact with the selected database, manipulate data, and retrieve information using Next.js.

Handling database errors and implementing effective debugging techniques is another crucial aspect we will address. Troubleshooting common issues and adopting best practices for error handling will ensure the smooth operation of your Next.js application.

Database security is of paramount importance, and we will provide you with best practices to safeguard your data. We'll discuss techniques for

securing your database, protecting sensitive information, and preventing common vulnerabilities.

Furthermore, we will dive into the realm of data modeling and schema design. You will gain insights into designing efficient database structures, creating relationships between entities, and optimizing queries for improved performance.

Finally, we will touch upon scaling your database to meet the demands of a growing user base. We will discuss strategies for enhancing performance and ensuring high availability, allowing your application to handle increased traffic and user interactions effectively.

Throughout this chapter, we will present practical examples and use cases to illustrate the concepts discussed. By the end, you will be equipped with the knowledge and tools necessary to leverage different types of databases within your Next.js applications, empowering you to build modern and robust web applications. So, let's embark on this database journey together and unlock the power of data in Next.js!

## **Structure**

In this chapter, we will cover the following topics:

- Setting up a database connection in Next.js
- Using the popular databases in Next.js such as MongoDB, MySQL
- CRUD operations with the selected database
- Handling database errors and debugging techniques
- Database security best practices
- Data modelling and schema design
- Scaling the database for performance and high availability

## **Quick Overview of Database Management System**

A Database Management System (DBMS) is a software system that allows users to store, organize, and manage large amounts of data efficiently. It provides a structured and centralized approach to handle data, making it easier to access, retrieve, modify, and delete information.

## **Key Components of a DBMS:**

- **Data:** DBMS manages different types of data, such as text, numbers, images, videos, and so on, which are stored in various formats and structures.
- **Database:** A database is a collection of related data that is organized and stored in a structured manner. It consists of tables, views, indexes, and other objects that define the structure and relationships of the data.
- **Database Schema:** The database schema defines the logical and physical structure of the database. It describes the tables, their attributes (columns), data types, constraints, and relationships with other tables.
- **Data Manipulation Language (DML):** DML is a language that allows users to retrieve, insert, update, and delete data in the database. Common DML statements include SELECT, INSERT, UPDATE, and DELETE.
- **Data Definition Language (DDL):** DDL is a language used to define and manage the database structure. It includes statements such as CREATE, ALTER, and DROP, which are used to create tables, modify their structure, or delete them.
- **Query Optimization:** DBMS optimizes the execution of queries to improve performance and efficiency. It analyses the query, evaluates different execution plans, and chooses the most efficient approach to retrieve the data.
- **Transaction Management:** DBMS ensures the ACID properties of transactions. ACID stands for Atomicity (transactions are treated as a single unit of work), Consistency (ensures data integrity), Isolation (transactions are executed in isolation from each other), and Durability (once a transaction is committed, its changes are permanent).
- **Concurrency Control:** DBMS handles concurrent access to the database by multiple users or processes. It ensures that data integrity is maintained when multiple transactions are executed simultaneously. Techniques like locking, timestamping, and multisession concurrency control are used to manage concurrency.
- **Security and Authorization:** DBMS provides mechanisms to control access to the database and ensure data security. It includes user

authentication, authorization, and privileges management to protect sensitive data from unauthorized access.

- **Backup and Recovery:** DBMS facilitates backup and recovery of data in case of system failures, data corruption, or human errors. It allows users to create backups, restore data to a previous state, and perform recovery operations to minimize data loss.

## Types of DBMS:

- **Relational DBMS (RDBMS):** The most widely used type, where data is organized in tables with predefined relationships between them. Examples include MySQL, Oracle Database, and Microsoft SQL Server.
- **Object-Oriented DBMS (OODBMS):** These systems store data in the form of objects, allowing inheritance, encapsulation, and polymorphism. They are suited for complex data structures. Examples include MongoDB and Apache Cassandra.
- **Hierarchical DBMS:** Data is organized in a tree-like structure, where each record has a parent-child relationship. It was popular in the early days but has been largely replaced by other models.
- **Network DBMS:** Similar to hierarchical DBMS, but with a more flexible structure. It allows records to have multiple parent and child records, creating complex relationships.
- **NoSQL DBMS:** NoSQL (Not Only SQL) databases are designed to handle large-scale, unstructured, and diverse data. They provide high scalability, performance, and flexibility. Examples include MongoDB, Cassandra, and Redis.
- **NewSQL DBMS:** NewSQL databases combine the scalability and performance of NoSQL with the ACID properties of traditional relational databases. They aim to address the limitations of traditional RDBMS in handling high volumes of data and concurrent users. NewSQL systems provide distributed architectures and efficient parallel processing while maintaining transactional consistency. Examples include Google Spanner, Cockroach DB, and TiDB.

## Benefits of Using a DBMS:

- **Data Centralization:** A DBMS allows users to store data in a centralized location, providing a unified view of the data for different applications and users. This eliminates data redundancy and inconsistency.
- **Data Sharing:** DBMS enables multiple users to access and share data simultaneously. It provides controlled access and ensures data integrity through concurrency control mechanisms.
- **Data Security:** DBMS includes features such as user authentication, access control, and encryption to protect sensitive data from unauthorized access, ensuring data security and compliance with regulations.
- **Data Integrity:** DBMS enforces data integrity constraints, such as primary key constraints and referential integrity, to maintain the accuracy and consistency of data.
- **Data Consistency:** DBMS ensures that data remains consistent and valid even during concurrent access and updates. ACID properties guarantee that transactions are executed reliably and maintain data integrity.
- **Data Scalability:** DBMS provides mechanisms to handle large amounts of data efficiently. It allows scaling horizontally by adding more servers or nodes to distribute the data and workload.
- **Data Recovery:** DBMS supports backup and recovery mechanisms to prevent data loss in the event of system failures, disasters, or human errors. It allows restoring the database to a previous state or point-in-time recovery.
- **Data Independence:** DBMS provides data independence by separating the logical structure of the database (schema) from the physical storage details. This allows modifications to the database schema without affecting the applications that use the data.
- **Data Querying and Reporting:** DBMS offers query languages (for example, SQL) and tools to perform complex data queries, generate reports, and extract useful insights from the data.
- **Improved Performance:** DBMS optimizes query execution, indexing, and caching techniques to enhance performance and

response times. It utilizes query optimization algorithms to choose the most efficient execution plans.

- **Data Maintenance:** DBMS provides tools for managing and maintaining the database, such as data backup, recovery, indexing, and performance tuning. It simplifies administrative tasks and reduces the effort required for database management.

In summary, a Database Management System (DBMS) is a crucial software system that provides efficient and reliable management of data. It offers a structured approach to store, organize, manipulate, and retrieve data while ensuring data integrity, security, and scalability. DBMS plays a vital role in modern applications and organizations by enabling effective data management and supporting critical business operations.

**Please note that this chapter will focus specifically on two types of Database Management Systems (DBMS): Relational DBMS (RDBMS) with MySQL and NoSQL DBMS with MongoDB. We will explore the features, advantages, and use cases of these two popular systems to provide a comprehensive understanding of their capabilities. Other types of DBMS will not be covered in this chapter.**

## **Relational Database Management Systems**

A Relational Database Management System (RDBMS) is a software system that manages relational databases. It provides a structured way to store, organize, and retrieve data based on a predefined schema. MySQL is one of the most popular RDBMS(s) and is widely used for web applications.

Relational databases are based on the relational model, which organizes data into tables consisting of rows and columns. Each table represents an entity or a relationship between entities. In MySQL, tables are created with a specific schema that defines the structure and data types of the columns.

Normalization is the process of designing a database schema to eliminate redundancy and ensure data integrity. It involves breaking down large tables into smaller, related tables and establishing relationships between them using primary and foreign keys. Normalization helps to reduce data redundancy, improve data consistency, and facilitate efficient data retrieval.

There are several normal forms in database normalization, including:

- **First Normal Form (1NF):** Ensures that each column in a table contains atomic values (indivisible and cannot be further divided).
- **Second Normal Form (2NF):** Builds on 1NF and requires that each non-key column in a table is functionally dependent on the entire primary key.
- **Third Normal Form (3NF):** Builds on 2NF and requires that each non-key column in a table is dependent only on the primary key and not on other non-key columns.
- **Boyce-Codd Normal Form (BCNF):** A stricter form of 3NF that eliminates all functional dependencies between non-key columns.
- **Fourth Normal Form (4NF):** Ensures that there are no multi-valued dependencies within a table.

Now let's discuss OLAP (Online Analytical Processing) and OLTP (Online Transaction Processing):

### **OLAP:**

OLAP is a category of software and technology used for complex analysis and reporting on large volumes of data. It focuses on providing business intelligence and decision support capabilities. OLAP databases are designed for read-intensive operations and complex analytical queries. They typically store aggregated data in a multidimensional structure, known as a data cube, which allows for fast querying and slicing and dicing of data from different perspectives.

### **OLTP:**

OLTP, on the other hand, is a category of software and technology used for managing and processing day-to-day transactional operations of an organization. OLTP databases are designed for high-speed data processing, transactional consistency, and concurrent access. They support operations such as inserting, updating, and deleting small amounts of data in real-time. MySQL, being an RDBMS, is commonly used for OLTP applications where data consistency and real-time transaction processing are crucial.

## **NoSQL Database Management Systems**

NoSQL (Not Only SQL) is a type of database management system that deviates from the traditional relational model used in RDBMS like MySQL. MongoDB is a popular example of a NoSQL DBMS, and let's explore its characteristics and context in detail:

- **Document-Oriented Model:**

NoSQL databases, including MongoDB, use a document-oriented model for data storage. Instead of tables with rows and columns, MongoDB stores data in flexible, self-describing documents. These documents are typically represented in JSON-like (BSON) format, allowing for the storage of nested structures and dynamic schemas.

- **Schema Flexibility:**

Unlike the fixed schema structure of RDBMS, NoSQL databases like MongoDB provide schema flexibility. Each document can have its own structure, allowing you to store varying types of data in the same collection. This flexibility simplifies the development process, especially in scenarios where data schemas evolve over time.

- **Scalability and High Performance:**

NoSQL databases are designed to scale horizontally, meaning they can distribute data across multiple servers or nodes to handle high data volumes and traffic. MongoDB, in particular, excels in scalability, offering automatic sharding capabilities to distribute data and queries across a cluster of machines. It provides high performance for both read and write operations, making it suitable for large-scale applications.

- **Replication and High Availability:**

MongoDB supports replica sets, which are clusters of database nodes that maintain copies of the same data. Replica sets offer data redundancy and high availability, ensuring that the system remains operational even in the event of node failures. MongoDB uses automatic failover mechanisms to elect a new primary node and maintain continuous service.

- **Querying and Indexing:**

MongoDB provides a flexible and powerful query language for retrieving data, known as the MongoDB Query Language (MQL).

MQL supports a wide range of querying capabilities, including filtering, sorting, aggregation, and geospatial queries. MongoDB also supports indexing, allowing you to optimize query performance by creating indexes on specific fields.

- **Use Cases and Context:**

MongoDB is particularly well-suited for use cases where flexibility, scalability, and real-time data processing are crucial. It is commonly used in scenarios such as content management systems, real-time analytics, logging and monitoring systems, and user profile management. Additionally, MongoDB's document model makes it easier to integrate with modern web development frameworks and languages.

### Difference between SQL vs NoSQL DBMS:

| Aspect             | SQL (Relational Database)                                                          | NoSQL (Non-relational Database)                                                                                     |
|--------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Data Structure     | Structured, tabular data with fixed schema.                                        | Flexible, semi-structured or unstructured data with dynamic schema.                                                 |
| Schema             | Requires predefined schema with strict structure.                                  | Schema-less or flexible schema that can evolve over time.                                                           |
| Query Language     | SQL (Structured Query Language) is used for defining and manipulating data.        | Query languages specific to each NoSQL database (for example, MongoDB uses a query language similar to JavaScript). |
| Scalability        | Vertical scaling (scaling hardware resources of a single server).                  | Horizontal scaling (adding more servers to distribute the load).                                                    |
| Data Relationships | Supports complex relationships between tables using foreign keys.                  | Primarily designed to handle denormalized data with minimal or no relationships.                                    |
| ACID Compliance    | ACID properties (Atomicity, Consistency, Isolation, Durability) are maintained.    | May sacrifice some ACID properties for improved scalability and performance (for example, eventual consistency).    |
| Transactions       | Strong support for transactions (grouping multiple operations into a single unit). | Varies across NoSQL databases, with some offering limited or no transaction support.                                |
| Data Integrity     | Enforces strict data integrity constraints (for example, primary                   | Relies on application logic to maintain data integrity.                                                             |

|           |                                                                                                                   |                                                                                                                                                                              |
|-----------|-------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           | keys, foreign keys).                                                                                              |                                                                                                                                                                              |
| Storage   | Typically uses a fixed schema and stores data in tables.                                                          | Various storage formats, including key-value, document, columnar, or graph-based models.                                                                                     |
| Use Cases | Well-suited for structured, relational data with complex queries and transactions (for example, banking systems). | Ideal for handling large volumes of semi-structured or unstructured data, rapid prototyping, and scenarios with changing requirements (for example, social media analytics). |

*Table 9.1: SQL vs NoSQL DBMS*

## Setting up a database connection in Next.js

To set up a database connection in Next.js with MongoDB and MySQL, you'll need to install the necessary packages and configure the connection settings. Here's a step-by-step guide for each database:

1. Installing the required packages:

```
npm install mongodb mysql
```

2. Create a separate file to handle the database connections. For MongoDB, create a file named `mongodb.js`, and for MySQL, create a file named `mysql.js`.

In `mongodb.js`, import the `mongodb` package and define the connection settings:

```
const { MongoClient } = require('mongodb');
const uri = 'mongodb://localhost:27017'; // Replace with your MongoDB connection URI
const dbName = 'your-database-name'; // Replace with your database name
const client = new MongoClient(uri, {
 useNewUrlParser: true,
 useUnifiedTopology: true,
});
async function connectMongoDB() {
 try {
 await client.connect();
 console.log('Connected to MongoDB');
```

```

 const db = client.db(dbName);
 return db;
 } catch (error) {
 console.error('Error connecting to MongoDB', error);
 throw error;
 }
}

module.exports = connectMongoDB;

```

In mysql.js import the `mysql` package and define the connection settings:

```

const mysql = require('mysql');
const connection = mysql.createConnection({
 host: 'localhost', // Replace with your MySQL host
 user: 'your-username', // Replace with your MySQL
 username
 password: 'your-password', // Replace with your MySQL
 password
 database: 'your-database-name', // Replace with your
 database name
});

connection.connect((error) => {
 if (error) {
 console.error('Error connecting to MySQL', error);
 throw error;
 }
 console.log('Connected to MySQL');
});

```

```

module.exports = connection;

```

3. In your Next.js code, import the respective database files and use the connections as needed. For example, create a file named `pages/index.js` and include the following code:

```

import { useEffect } from 'react';
import connectMongoDB from '../mongodb';
import connectionMySQL from '../mysql';
export default function HomePage() {

```

```

useEffect(() => {
 async function fetchData() {
 const db = await connectMongoDB();

 // Perform MongoDB operations here
 // Example: const collection = db.collection('your-
 collection');
 // Example: const data = await
 collection.find().toArray();

 connectionMySQL.query('SELECT * FROM your-table',
 (error, results, fields) => {
 if (error) {
 console.error('Error querying MySQL', error);
 throw error;
 }

 // Process the MySQL query results here
 });
 }
 fetchData();
}, []);

return (
 <div>
 {/* Your page content */}
 </div>
);
}

```

Remember to replace the placeholder values (like `your-database-name`, `your-username`, `your-password`, and so on) with your actual database connection details.

With this setup, you'll have a Next.js page that connects to both MongoDB and MySQL databases. The `fetchData` function is executed when the component mounts, allowing you to perform database operations and process the results as needed.

There are multiple third-party libraries available for working with databases in JavaScript and Node.js, such as Mongoose, Sequelize, TypeORM, and

PrismORM. These libraries provide Object-Relational Mapping (ORM) functionality and simplify database interactions.

While Mongoose is specifically designed for MongoDB, Sequelize primarily focuses on SQL databases (MySQL, PostgreSQL, SQLite, MSSQL). TypeORM, on the other hand, supports various databases, including PostgreSQL, MySQL, SQLite, MSSQL, and Oracle.

However, if you prefer a library that handles both SQL and NoSQL databases, TypeORM is an excellent choice. TypeORM is versatile and allows you to work with different database types using a unified API. It provides a consistent and intuitive approach for working with various databases, making it convenient if you need to switch between SQL and NoSQL databases within the same project.

PrismORM is not as widely known or popular as all other libraries mentioned. However, if it meets your specific requirements and you find it suitable for your project, you can explore its features and evaluate its capabilities.

Ultimately, the choice of database library depends on the specific needs of your project, your familiarity with the library, and the databases you are working with. Consider the factors such as supported databases, ORM functionality, ease of use, community support, and active development when selecting the appropriate library for your project. The following table compares common three libraries which help to work with databases.

| Feature                         | Mongoose (MongoDB)                   | Sequelize (MySQL, PostgreSQL, SQLite, MSSQL) | TypeORM (Various databases)              |
|---------------------------------|--------------------------------------|----------------------------------------------|------------------------------------------|
| Supported Databases             | MongoDB                              | MySQL, PostgreSQL, SQLite, MSSQL, and more   | PostgreSQL, MySQL, SQLite, MSSQL, Oracle |
| ORM Functionality               | Yes                                  | Yes                                          | Yes                                      |
| Object-Relational Mapping (ORM) | Yes                                  | Yes                                          | Yes                                      |
| Schema Definition               | Schema-based (with Mongoose Schemas) | Model-based (with Sequelize Models)          | Decorator-based (with Entity Classes)    |
| Query Language                  | MongoDB Query Language (MQL)         | SQL                                          | SQL                                      |
| Connection Pooling              | No (managed by                       | Yes                                          | Yes                                      |

|                                        | MongoDB driver) |             |                      |
|----------------------------------------|-----------------|-------------|----------------------|
| Support for Associations/Relationships | Yes             | Yes         | Yes                  |
| Support for Migrations                 | No              | Yes         | Yes                  |
| Active Development                     | Yes             | Yes         | Yes                  |
| Popularity                             | Widely used     | Widely used | Increasingly popular |

**Table 9.2: Difference between Mongoose, Sequelize and TypeORM**

## CRUD operations with the selected database

CRUD operations refer to the basic operations performed on a database: Create, Read, Update, and Delete. In the context of Next.js, you can use the TypeORM library to handle these operations with both SQLite and MongoDB databases. To establish a localhost connection, you need to configure the database settings in your Next.js application.

A step-by-step explanation of how to perform CRUD operations using TypeORM with SQLite and MongoDB in Next.js:

### **Step 1: Set up a Next.js project**

Create a new Next.js project by running the following command in your terminal:

```
npx create-next-app my-next-app
```

### **Step 2: Install dependencies**

Navigate to your project directory and install the required dependencies:

```
cd my-next-app
npm install next typeorm sqlite3 mongodb
```

### **Step 3: Create database connection**

Create a new folder called `config` in the root directory of your project. Inside the `config` folder, create a file called `database.ts`. This file will contain the database connection settings.

For SQLite:

```
const { ConnectionOptions } = require("typeorm");
```

```

const sqliteConfig = {
 type: "sqlite",
 database: "./data/database.sqlite",
 synchronize: true,
 logging: true,
 entities: [
 // Add your entity classes here
],
};

module.exports = sqliteConfig;
export default sqliteConfig;
const { ConnectionOptions } = require("typeorm");

const mongoConfig = {
 type: "mongodb",
 host: "localhost",
 port: 27017,
 database: "mydatabase",
 synchronize: true,
 logging: true,
 entities: [
 // Add your entity classes here
],
};

module.exports = mongoConfig;

```

## Step 4: Define entity classes

Create a new folder called `entities` in the root directory of your project. Inside the `entities` folder, create entity classes representing your data model. These classes will define the structure of your tables or collections.

For example, let's create a `User` entity:

```

const { Entity, Column, PrimaryGeneratedColumn } =
require("typeorm");

@Entity()
class User {
 @PrimaryGeneratedColumn()

```

```
id;

@Column()
name;

@Column()
email;

// Add other properties and relationships as needed
}

module.exports = User;
```

## Step 5: Implement CRUD operations

In the root directory of your project, create a folder called `pages`. Inside the `pages` folder, create a file for each CRUD operation: `create.tsx`, `read.tsx`, `update.tsx`, and `delete.tsx`. These files will handle the respective operations.

For example, in `create.js`, you can implement the logic to create a new user:

```
import { useState } from "react";
import { createConnection, getConnection } from "typeorm";
import sqliteConfig from "../config/database";

export default function CreateUser() {
 const [name, setName] = useState("");
 const [email, setEmail] = useState("");

 const handleSubmit = async (event) => {
 event.preventDefault();

 try {
 const connection = await createConnection(sqliteConfig);
 const userRepository = connection.getRepository(User);

 const newUser = userRepository.create({ name, email });
 await userRepository.save(newUser);

 await connection.close();

 console.log("User created successfully!");
 } catch (error) {
```

```

 console.error("Error creating user:", error);
 }
};

return (
 <form onSubmit={handleSubmit}>
 <input
 type="text"
 value={name}
 onChange={(event) => setName(event.target.value)}
 placeholder="Name"
 />
 <input
 type="email"
 value={email}
 onChange={(event) => setEmail(event.target.value)}
 placeholder="Email"
 />
 <button type="submit">Create User</button>
 </form>
);
}

```

Similarly, you can implement the logic for read, update, and delete operations by connecting to the database, retrieving the appropriate repository, and performing the required operations.

## **Step 6: Run the Next.js application**

To start your Next.js application and test the CRUD operations, run the following command in your terminal:

```
npm run dev
```

Open your browser and navigate to `http://localhost:3000/create` to create a new user. You can create additional pages for other CRUD operations and test them as well.

Note: Ensure that you have a running SQLite server or a MongoDB instance on your local machine, depending on the database you're using.

Make sure the database credentials and connection details match the ones specified in the configuration file.

That's it! You have now implemented CRUD operations with SQLite and MongoDB in Next.js using the TypeORM library. You can extend this example to handle more complex data models and operations as needed.

## Handling database errors and debugging techniques

In Next.js, handling database errors and debugging techniques involve ensuring proper error handling when interacting with databases and employing effective debugging practices to identify and resolve issues. Here's a detailed explanation of how you can approach these tasks:

- **Error Handling:**
  - a. **Connect to the Database:** To interact with a database in Next.js, you typically use a library like Prisma, Sequelize, or Mongoose. These libraries provide mechanisms for connecting to the database and executing queries. Ensure that you establish a connection to the database before attempting any operations.
  - b. **Query Execution:** When executing database queries, it's essential to handle potential errors. Most database libraries provide mechanisms to catch and handle errors returned by the database server. For example, with Prisma, you can use `try-catch` blocks or promise-based error handling to catch and handle errors.
  - c. **Error Messages:** When an error occurs during database operations, it's crucial to provide meaningful error messages to aid in debugging. Include relevant information like the type of error, query being executed, and any relevant data involved. Logging the error messages to a central system like a log file or a monitoring service can help track issues.
  - d. **Graceful Error Handling:** In Next.js, you can implement error boundaries using Error Boundary Components or the `getDerivedStateFromError` method. These techniques allow you to catch errors within components and display fallback UIs

instead of crashing the entire application. You can display an error page or a specific error message to users and log the error details for further investigation.

- **Debugging Techniques:**

- a. **Logging:** Logging is an essential technique for debugging database-related issues. Utilize logging libraries like Winston, Pino, or the built-in `console.log` statements to output relevant information during runtime. Log important details such as query execution times, results, and error messages to track down issues.
- b. **Debugging Tools:** Next.js provides powerful development tools like the Next.js DevTools browser extension and the built-in React Developer Tools. These tools enable you to inspect components, examine props, and monitor network requests. You can use them to identify any potential issues with your database queries or data flow.
- c. **Query Optimization:** If you encounter performance issues with database queries, it's crucial to optimize them. You can use tools like the database's query analyzer or profiler to identify slow or inefficient queries. Check for missing indexes, redundant joins, or suboptimal query patterns. Adjusting indexes or rewriting queries can significantly improve performance.
- d. **Code Review:** Involve other developers in reviewing your code, especially when dealing with complex database operations. Peer code reviews can help identify logical errors, potential race conditions, or suboptimal code patterns that might cause bugs or impact performance.
- e. **Unit Testing:** Write unit tests for your database-related code using frameworks like Jest or Mocha. Test different scenarios, including both successful and erroneous queries. This practice helps ensure that your code behaves as expected and catches any issues early in the development process.

**Let's explore handling database errors and debugging techniques in Next.js with a code example using TypeORM.**

- 1. **Handling Database Errors:**

Assuming you're using TypeORM as the ORM (Object-Relational Mapping) library in your Next.js project, you can handle database errors in the following way:

```
``` const { getRepository } = require('typeorm');
const { User } = require('../entities/User');

async function getUserById(id) {
  try {
    const userRepository = getRepository(User);
    const user = await userRepository.findOne(id);

    if (!user) {
      throw new Error('User not found');
    }

    return user;
  } catch (error) {
    console.error('Error retrieving user:', error);
    throw new Error('Failed to retrieve user');
  }
}
```

In this example, we import the `getRepository` function from TypeORM to retrieve the repository for the `User` entity. We then use the repository to find a user by their ID. If the user is not found, we throw a custom error. Any other database errors encountered are caught in the `catch` block, logged, and re-thrown with a generic error message.

2. Debugging Techniques:

Now let's explore debugging techniques in Next.js with TypeORM:Logging:

```
```const { getRepository } = require('typeorm');
const { User } = require('../entities/User');

async function getUserById(id) {
 try {
 const userRepository = getRepository(User);
 const user = await userRepository.findOne(id);

 if (!user) {
```

```

 throw new Error('User not found');
 }

 console.log('Retrieved user:', user);

 return user;
} catch (error) {
 console.error('Error retrieving user:', error);
 throw new Error('Failed to retrieve user');
}
}

```

In this updated example, we added a `console.log` statement to output the retrieved user. This helps in inspecting the data and verifying if the correct user is being fetched. You can customize the logging statements based on your debugging needs.

### 3. Debugging Tools:

Next.js provides powerful development tools and browser extensions for debugging, including React Developer Tools and Next.js DevTools. These tools allow you to inspect components, examine props, and monitor network requests. You can use them to identify any potential issues with your components or data flow.

### 4. Query Optimization:

```

``` const { getRepository } = require('typeorm');
const { User } = require('../entities/User');

async function getUsersWithPosts() {
    try {
        const userRepository = getRepository(User);
        const users = await userRepository.find({ relations:
            ['posts'] });
        return users;
    } catch (error) {
        console.error('Error retrieving users:', error);
        throw new Error('Failed to retrieve users');
    }
}
```

```

In this example, we fetch users along with their associated posts using TypeORM's `relations` option. This simplifies the retrieval of related data, but if the query becomes slow due to a large number of users or posts, you can optimize it further by using pagination, eager loading, or applying additional filters.

## 5. Unit Testing:

Unit testing is crucial to catch errors and ensure the correctness of your code. Here's an example using the Jest testing framework:

```
const { getRepository } = require('typeorm');
const { User } = require('../entities/User');
const { getUserById } = require('./user');
jest.mock('typeorm');
describe('getUserById', () => {
 test('returns a user when the database query is
 successful', async () => {
 const mockUser = { id: 1, name: 'John Doe' };
 const findOneMock =
 jest.fn().mockResolvedValue(mockUser);
 getRepository.mockReturnValueOnce({
 findOne: findOneMock,
 });

 const user = await getUserById(1);

 expect(user).toEqual(mockUser);
 expect(findOneMock).toHaveBeenCalledTimes(1);
 expect(findOneMock).toHaveBeenCalledWith(1);
 });

 test('throws an error when the user is not found', async
() => {
 const findOneMock =
 jest.fn().mockResolvedValue(undefined);
 getRepository.mockReturnValueOnce({
 findOne: findOneMock,
 });
 });
});
```

```
 await expect(getUserById(1)).rejects.toThrow('User not found');
 expect(findOneMock).toHaveBeenCalledTimes(1);
 expect(findOneMock).toHaveBeenCalledWith(1);
 });
});
`
```

In this unit test example, we mock the `getRepository` function and the `findOne` method from TypeORM using Jest's mocking capabilities. We simulate both a successful query and a query that returns `undefined` (user not found). This ensures that the `getUserById` function behaves as expected and handles database errors appropriately.

By employing these techniques, you can handle database errors effectively and debug issues in your Next.js application using TypeORM, ensuring smooth operation and a better user experience.

## Database security best practices in Next.js

When it comes to database security best practices in Next.js, there are several key considerations to keep in mind. Let's explore them in detail:

### **1. Protecting Database Credentials:**

- Store database credentials securely, such as using environment variables or a secure secrets management solution.
- Avoid hardcoding credentials in your source code, configuration files, or version control repositories.
- Restrict access to sensitive files and ensure appropriate permissions are set.

### **2. Implementing User Authentication and Authorization:**

- Use secure authentication mechanisms, such as password hashing and salting, to protect user credentials.
- Implement proper authorization and access controls to ensure that users can only access the data they are authorized to view or modify.

- Validate and sanitize user inputs to prevent common security vulnerabilities like SQL injection attacks.

### **3. Encryption and Data Protection:**

- Implement Transport Layer Security (TLS) to encrypt data transmitted between your application and the database.
- Consider implementing encryption at rest to protect sensitive data stored in the database.
- Utilize encryption libraries or built-in encryption functions provided by your database system.

### **4. Regular Updates and Patching:**

- Keep your database system and associated libraries up to date with the latest security patches and updates.
- Monitor security advisories and promptly apply patches to address any identified vulnerabilities.

### **5. Input Validation and Query Parameterization:**

- Validate and sanitize user inputs to prevent malicious data from being executed as part of database queries.
- Use parameterized queries or prepared statements to avoid SQL injection attacks.
- Leverage database query builders or ORMs (Object-Relational Mappers) that handle query parameterization automatically.

### **6. Auditing and Logging:**

- Enable logging and auditing features provided by your database system to track and monitor database activity.
- Regularly review and analyze database logs to identify any suspicious activities or potential security breaches.

### **7. Limiting Database Access:**

- Grant only the necessary privileges to database users, following the principle of least privilege.

- Avoid using privileged database accounts for regular application operations.
- Implement strong password policies and enforce password complexity rules.

## **8. Regular Backups and Disaster Recovery:**

- Perform regular backups of your database to ensure data integrity and availability.
- Store backups securely and test the restoration process periodically.
- Have a disaster recovery plan in place to quickly recover from any data breaches or loss.

## **9. Secure Deployment and Hosting:**

- Utilize secure hosting platforms or infrastructure that offer strong security measures and compliance standards.
- Follow secure deployment practices, such as using secure protocols (for example, HTTPS) and deploying on hardened servers.

## **10. Regular Security Assessments and Testing:**

- Conduct regular security assessments and penetration testing to identify vulnerabilities in your database and application.
- Use security testing tools to scan for common vulnerabilities and misconfigurations.
- Involve security experts to perform comprehensive security audits of your application and database infrastructure.

Remember, database security is a continuous process, and it's important to stay updated with the latest security practices, vulnerabilities, and recommendations from the database system you are using.

## **Data modeling and schema design**

Data modeling and schema design involve designing the structure and relationships of the data to be stored in a database. TypeORM is an object-

relational mapping (ORM) library that simplifies working with databases in TypeScript and JavaScript.

Here are the key terms and concepts to understand:

- **Entity:**

An entity represents a database table or collection in TypeORM. It is defined as a TypeScript class decorated with the `@Entity()` decorator. Each entity corresponds to a row/document in the database table/collection.

- **Column:**

A column represents a field or attribute of an entity. It is defined using the `@Column()` decorator. Columns store data values, such as strings, numbers, booleans, or dates.

- **Primary Key:**

The primary key uniquely identifies each row/document in an entity. It ensures that each entry is uniquely identifiable. In TypeORM, primary keys are defined using the `@PrimaryGeneratedColumn()` decorator, and they often use auto-incrementing numbers.

- **Relationships:**

Relationships define how entities are related to each other. TypeORM supports various types of relationships, including:

- One-to-One: One entity is associated with another entity in a one-to-one relationship.
- One-to-Many: One entity is associated with multiple entities in a one-to-many relationship.
- Many-to-One: Multiple entities are associated with one entity in a many-to-one relationship.
- Many-to-Many: Multiple entities are associated with multiple entities in a many-to-many relationship.

These relationships are established using decorators like `@OneToOne()`, `@OneToMany()`, `@ManyToOne()`, and `@ManyToMany()`.

- **Migration:**

Migration is a way to manage database schema changes over time. When your application evolves and the database schema needs to be updated, migrations help you make those changes while preserving existing data. TypeORM provides tools to create, run, and manage migrations.

- **Querying:**

Querying is the process of retrieving data from the database based on specific criteria. TypeORM offers a query builder that allows you to construct queries using a chain of methods and conditions. This makes it easier to build complex queries without writing raw SQL statements.

- **Transactions:**

Transactions ensure the atomicity and consistency of database operations. A transaction groups a set of database operations into a single unit, which either succeeds as a whole or fails. It ensures that if any part of the transaction fails, all changes are rolled back, maintaining data integrity.

- **ORM (Object-Relational Mapping):**

ORM is a programming technique that maps objects in an application to tables in a relational database. It simplifies database operations by allowing developers to work with objects and perform CRUD operations without writing SQL queries explicitly.

TypeORM is an ORM library that provides a set of tools and features to map entities, define relationships, perform database operations, and handle migrations in an application.

In summary, data modeling and schema design with TypeORM involve creating entities, defining columns and relationships, managing migrations for schema changes, querying data using the query builder, and ensuring transactional integrity. These concepts help you design efficient, scalable, and maintainable database structures for your applications.

Let's dive into data modeling and schema design with TypeORM, covering all types of operations, including CRUD (Create, Read, Update, Delete) operations, querying, transactions, and migrations.

1. Setting up TypeORM:

Start by installing the necessary dependencies using npm or yarn:

```
``` npm install typeorm reflect-metadata
```

```

## 2. Configuration:

Create a `typeorm.config.js` file in the project's root directory to define the database connection parameters. For example, here's a configuration for a PostgreSQL database:

```
module.exports = {
 type: "postgres",
 host: "localhost",
 port: 5432,
 username: "your_username",
 password: "your_password",
 database: "your_database",
 synchronize: true,
 logging: true,
 entities: ["src/entities/**/*.ts"],
 migrations: ["src/migrations/**/*.ts"],
 subscribers: ["src/subscribers/**/*.ts"],
 cli: {
 entitiesDir: "src/entities",
 migrationsDir: "src/migrations",
 subscribersDir: "src/subscribers",
 },
};
```

```

3. Entity Creation:

Create entity classes using TypeScript and decorate them with TypeORM decorators. Let's consider an example of a blog application with two entities: User and Post. Each user can have multiple posts, and each post belongs to a user.

```
import { Entity, PrimaryGeneratedColumn, Column,
ManyToOne, ManyToOne, JoinColumn } from 'typeorm';
@Entity()
export class User {
  @PrimaryGeneratedColumn()
  id: number;
}
```

```

```

@Column()
name: string;
@OneToMany(() => Post, post => post.user)
posts: Post[];
}

@Entity()
export class Post {
 @PrimaryGeneratedColumn()
 id: number;
 @Column()
 title: string;
 @Column({ type: 'text' })
 content: string;
 @ManyToOne(() => User, user => user.posts)
 @JoinColumn({ name: 'user_id' })
 user: User;
}

```

In this example, the `@Entity()` decorator marks the class as a TypeORM entity. The `@PrimaryGeneratedColumn()` decorator defines the primary key of the entity. The `@Column()` decorator specifies columns in the table, and `@OneToMany()` and `@ManyToOne()` decorators establish relationships between the User and Post entities.

#### 4. Database Connection:

Create a connection to the database using the TypeORM configuration and entity classes. Here's an example:

```

```import { createConnection } from 'typeorm';
import { User } from './entities/User';
import { Post } from './entities/Post';

async function connectToDatabase() {
    try {
        const connection = await createConnection();
        console.log('Connected to the database');

        // Additional application logic goes here

        await connection.close();
    }
}
```

```

```

 console.log('Connection closed');
 } catch (error) {
 console.error('Error connecting to the database:',
 error);
 }
}

connectToDatabase();
```

```

5. CRUD Operations:

TypeORM simplifies CRUD operations using its EntityManager. Here are examples of each operation:

- Creating a new user and saving it to the database:

```

```
const user = new User();
user.name = 'John Doe';
await connection.manager.save(user);
console.log('User saved:', user);
```

```

- Retrieving all users from the database:

```

```
const users = await connection.manager.find(User);
console.log('All users:', users);
```

```

- Updating a user:

```

```
const user = await connection.manager.findOne(User, {
 id: 1 });
user.name = 'Updated Name';
await connection.manager.save(user);
console.log('User updated:', user);
```

```

- Deleting a user:

```

```
const user = await connection.manager.findOne(User,
{ id: 1 });
await connection.manager.remove(user);
```

```

```
    console.log('User deleted');
    ````
```

## 6. Querying:

TypeORM provides a powerful query builder for complex querying. Here's an example:

```
const users = await connection.manager
 .createQueryBuilder(User, 'user')
 .leftJoinAndSelect('user.posts', 'post')
 .where('user.id = :userId', { userId: 1 })
 .getMany();

console.log('User and their posts:', users);
````
```

This query fetches a user with their associated posts using a left join.

7. Transactions:

TypeORM supports transactions to ensure atomicity and consistency. Here's an example:

```
``` const queryRunner = connection.createQueryRunner();
await queryRunner.connect();
await queryRunner.startTransaction();

try {
 const user = new User();
 user.name = 'Jane Smith';

 await queryRunner.manager.save(user);

 const post = new Post();
 post.title = 'New Post';
 post.content = 'Lorem ipsum dolor sit amet';

 post.user = user;
 await queryRunner.manager.save(post);
 await queryRunner.commitTransaction();
 console.log('Transaction committed');

} catch (error) {
 await queryRunner.rollbackTransaction();
 console.log('Transaction rolled back');
```

```
 } finally {
 await queryRunner.release();
 }
}
```

This example demonstrates a transaction that saves a new user and a post associated with that user. If any operation fails, the transaction is rolled back.

## 8. Migrations:

**TypeORM** simplifies database schema migrations. Here's an example of creating and running a migration:

```
typeorm migration:create -n CreateUserTable
```

``This command generates a new migration file. Edit the generated file to define the necessary changes.

```
import {MigrationInterface, QueryRunner} from "typeorm";
export class CreateUserTable1612345678901 implements
MigrationInterface {
 public async up(queryRunner: QueryRunner): Promise<void>
 {
 await queryRunner.query(`CREATE TABLE "user" (
 "id" SERIAL NOT NULL,
 "name" character varying NOT NULL,
 CONSTRAINT "PK_3dd8bfc97e4a77c70971591bdcb" PRIMARY
 KEY ("id")
)
 `);
 }
 public async down(queryRunner: QueryRunner): Promise<void> {
 await queryRunner.query(`DROP TABLE "user"`);
 }
}
```

To run the migration:

```
typeorm migration:run
```

These examples provide an overview of data modeling and schema design with TypeORM, covering various operations such as CRUD, querying,

transactions, and migrations. TypeORM's documentation offers more details on advanced features and customization options.

## Scaling the database for performance and high availability

Scaling a database for performance and high availability involves optimizing the database infrastructure to handle increased workload and ensuring that the database remains accessible even in the event of failures. Here's a detailed explanation for novice users:

- **Database Scaling:**

Database scaling refers to the process of increasing the capacity and capabilities of a database system to handle growing data volumes and user requests. There are two primary types of scaling:

- Vertical Scaling (Scaling up): In vertical scaling, the database server is upgraded with more powerful hardware resources such as CPU, memory, or storage to handle increased load. It involves upgrading the existing server or migrating to a more powerful one.
- Horizontal Scaling (Scaling out): Horizontal scaling involves adding more database servers to distribute the workload across multiple machines. It is achieved by using techniques like database sharding or replication.

- **Performance Optimization:**

To improve database performance, consider the following techniques:

- Indexing: Create appropriate indexes on frequently queried columns to speed up data retrieval operations.
- Query Optimization: Analyze and optimize database queries to minimize their execution time. This may involve rewriting queries, using appropriate join strategies, or optimizing the data model.
- Caching: Implement a caching layer to store frequently accessed data in memory, reducing the need for database queries.

- Denormalization: In some cases, denormalizing the database schema (reducing the number of joins) can improve performance by reducing the complexity of queries.
  - Partitioning: Partition large tables into smaller, more manageable chunks based on specific criteria (for example, range, list, or hash). This allows for better data distribution and faster access.
- **High Availability:**

High availability ensures that the database remains accessible even in the face of failures. Key techniques for achieving high availability include:

    - Replication: Maintain multiple copies of the database on different servers. Replication can be synchronous (real-time) or asynchronous (delayed), depending on the desired level of data consistency and performance.
    - Failover: Implement mechanisms to automatically switch to a standby server if the primary server fails. This requires continuous monitoring of the database's health and the ability to quickly redirect incoming traffic.
    - Load Balancing: Distribute incoming requests across multiple database servers to evenly distribute the workload. Load balancers monitor server health and direct traffic to available resources.
    - Disaster Recovery: Create regular backups of the database and store them in off-site locations. In the event of a major failure or disaster, these backups can be used to restore the database to a previous state.
    - Redundancy: Use redundant components such as power supplies, network connections, and storage devices to minimize single points of failure.

- **Monitoring and Optimization:**

Continuously monitor the performance and health of the database system. This involves tracking metrics such as CPU usage, memory utilization, disk I/O, and network traffic. Analyze these metrics to identify bottlenecks and areas for optimization. Regularly review and

fine-tune the database configuration based on the observed performance patterns.

In conclusion, scaling a database for performance and high availability involves optimizing the database infrastructure, implementing performance-enhancing techniques, ensuring data redundancy, and maintaining failover mechanisms to keep the database accessible and reliable even during periods of high demand or failures.

## Conclusion

This chapter provided a comprehensive exploration of databases and their role in Next.js applications. We began by understanding the fundamentals of databases and their significance in web development. We then delved into different types of databases, including relational, NoSQL, and graph databases, highlighting their unique characteristics and use cases. The decision-making process for selecting the right database was discussed, considering factors such as data structure, scalability, and performance.

Once the database type was chosen, the chapter guided readers through the process of setting up a database connection in Next.js, specifically focusing on popular databases like MongoDB, MySQL, and PostgreSQL. The common operations performed with databases, such as CRUD operations, were explained, showcasing how to interact with the selected database, manipulate data, and retrieve information using Next.js.

Furthermore, the chapter addressed crucial aspects such as handling database errors, implementing effective debugging techniques, and ensuring database security. Best practices for troubleshooting common issues, securing sensitive information, and preventing vulnerabilities were provided.

Data modeling and schema design were explored to help readers design efficient database structures, create relationships between entities, and optimize queries for enhanced performance.

Lastly, strategies for scaling databases to meet the demands of a growing user base were discussed, ensuring high availability and improved performance. Practical examples and use cases were presented throughout the chapter to illustrate the concepts discussed.

By acquiring the knowledge and tools presented in this chapter, readers are now empowered to leverage different types of databases within their Next.js applications, enabling them to build modern and robust web applications that harness the power of data. So, let's embark on this database journey together and unlock the full potential of Next.js!

In the next chapter, we will dive into the fascinating world of rendering in Next.js applications. We will explore the different rendering techniques, such as server-side rendering (SSR), client-side rendering (CSR), and static site generation (SSG), understanding their benefits and use cases.

## **Multiple choice questions**

1. Which of the following is not a type of database discussed in this chapter?
  - A. Relational database
  - B. NoSQL database
  - C. Graph database
  - D. Blockchain database
2. What factors should be considered when selecting the right database for an application?
  - A. Data structure, scalability, and performance
  - B. User interface design and color schemes
  - C. Marketing strategies and target audience
  - D. Website responsiveness and loading speed
3. Which databases are mentioned as popular options for connecting with Next.js?
  - A. MongoDB, MySQL, and PostgreSQL
  - B. SQLite, Redis, and Firebase
  - C. Oracle, DB2, and Informix
  - D. Cassandra, Couchbase, and DynamoDB
4. What do CRUD operations stand for?

- A. Create, Render, Update, Delete
  - B. Copy, Rename, Upload, Download
  - C. Create, Read, Update, Delete
  - D. Compile, Run, Upload, Debug
5. Which aspect is addressed in this chapter regarding database security?
- A. Building user authentication systems
  - B. Implementing front-end form validation
  - C. Preventing SQL injection attacks
  - D. Optimizing database queries

## Answers

- 1. D
- 2. A
- 3. A
- 4. C
- 5. C

By exploring terms like CRUD operations, SQL, NoSQL, ACID, and API, readers were able to reinforce their understanding of these concepts and grasp the foundational principles of database management. These interactive questions allowed readers to solidify their knowledge and enhance comprehension. The MCQs served as a valuable tool for assessing readers' understanding and retention of key concepts, preparing them to apply their knowledge in real-world scenarios.

## CHAPTER 10

# Understanding Rendering in Next.js Applications

## Introduction

In the world of web development, rendering plays a crucial role in delivering dynamic and interactive content to users. Two popular rendering techniques, client-side rendering, and server-side rendering, have emerged as essential approaches for creating web applications. In this chapter, we will explore these rendering methods and their significance in the context of Next.js applications.

To begin, we will provide a comprehensive overview of client-side rendering and server-side rendering, delving into their fundamental concepts and highlighting their key differences. By understanding the core principles behind each approach, you will gain a solid foundation for making informed decisions when it comes to rendering strategies.

Next, we will explore why server-side rendering is a critical aspect of Next.js applications. We will examine how server-side rendering can improve performance, enhance search engine optimization, and elevate the overall user experience. Through real-world examples and practical insights, we will illustrate the benefits of leveraging server-side rendering within the Next.js framework.

However, client-side rendering also has its merits, particularly in scenarios where dynamic content and interactivity are paramount. We will explore the different scenarios where client-side rendering shines and demonstrate how it can be effectively implemented in Next.js applications. From dynamic client-side rendering to optimal usage, this chapter will equip you with the knowledge needed to leverage client-side rendering capabilities in Next.js.

To assist you in making informed decisions, we will discuss the best practices for choosing between client-side and server-side rendering in Next.js applications. We will explore the factors to consider when selecting

the appropriate rendering strategy and provide guidelines to optimize rendering performance.

Topics covered in this chapter include understanding the basics of client-side rendering and server-side rendering, the benefits and drawbacks of each approach, Next.js's approach to rendering, server-side rendering with Next.js, client-side rendering with Next.js, dynamic client-side rendering with Next.js, when to use client-side rendering versus server-side rendering, and best practices for using these rendering techniques in Next.js applications.

By the end of this chapter, you will have a comprehensive understanding of client-side and server-side rendering, and how they can be effectively employed in Next.js applications. Armed with this knowledge, you will be able to make informed decisions and optimize the rendering performance of your Next.js projects. So, let's dive in and explore the fascinating world of rendering in Next.js!

## Structure

In this chapter, we will cover the following topics:

- Understanding the basics of client-side rendering and server-side rendering
- Benefits and drawbacks of client-side and server-side rendering
- Next.js's approach to client-side and server-side rendering
- Server-side rendering with Next.js
- Client-side rendering with Next.js
- Dynamic client-side rendering with Next.js
- When to use client-side rendering and when to use server-side rendering
- Best practices for using client-side and server-side rendering in Next.js applications

## Understanding rendering in Next.js

Next.js is a popular React framework that simplifies the process of building server-side rendered (SSR) and statically rendered web applications. It

provides an intuitive way to handle rendering by offering a hybrid approach.

With Next.js, you have the flexibility to choose between different rendering methods based on your project's requirements. You can opt for client-side rendering (CSR), where the page is initially rendered on the client side using JavaScript. This approach provides interactivity but may result in slower initial page loading.

Next.js also supports server-side rendering (SSR), where the page is rendered on the server and sent to the client as fully rendered HTML. SSR provides better performance and SEO benefits, as the content is readily available to search engines.

Another option is static site generation (SSG), where pages are pre-rendered as static HTML files during the build process. This approach offers excellent performance, as there is no server-side processing during runtime. SSG is suitable for websites with content that doesn't change frequently, like blogs or documentation sites.

Next.js combines the best of both SSR and SSG, allowing you to choose the rendering strategy on a per-page basis. This flexibility empowers developers to create highly optimized, fast, and SEO-friendly web applications.

Let's understand the basics of client-side rendering, server-side rendering and static site generation:

- Client-Side Rendering (CSR):

Client-side rendering involves loading a basic HTML page from the server and then using JavaScript to dynamically fetch and render data on the client's browser. The client-side rendering process typically involves making API requests to retrieve data and updating the DOM (Document Object Model) with the received data. This approach allows for a more interactive and dynamic user experience, as the content can be updated without refreshing the entire page. However, it places a heavier load on the client's device, as the browser needs to handle both rendering and data fetching.

- Server-Side Rendering (SSR):

Server-side rendering, on the other hand, involves generating the HTML content on the server itself and sending the pre-rendered HTML to the client's browser. In SSR, the server processes the request, retrieves the necessary data, and generates a complete HTML page that includes the requested content. This pre-rendered HTML is then sent to the client, reducing the client's device load. SSR is beneficial for search engine optimization (SEO) as the content is readily available for search engine crawlers. However, it can be slower for the initial page load compared to CSR since the server needs to process the request and generate the HTML.

- Static site generation (SSG):

Static Site Generation (SSG) is a website rendering technique where web pages are pre-rendered at build time and served as static HTML files to clients. With SSG, the content is generated once during the build process and does not require any server-side processing during runtime. This approach offers several advantages, such as improved performance, lower server load, and enhanced security. It also enables better search engine optimization (SEO), as search engines can easily crawl and index the static pages. SSG is commonly used for websites with content that doesn't frequently change, such as blogs, documentation sites, and marketing pages.

Key differences between CSR and SSR:

- Initial page load: SSR provides a fully rendered HTML page from the server, enabling faster initial rendering, whereas CSR requires additional requests and processing on the client-side.
- SEO: SSR is more SEO-friendly as search engines can easily crawl and index the pre-rendered HTML, whereas CSR requires additional efforts to make content discoverable by search engines.
- Performance: CSR can provide a faster and more interactive experience once the initial page is loaded, as subsequent updates can be handled on the client-side without requiring a full page reload. SSR may have a longer initial load time but provides a better user experience for slower devices or poor network conditions.
- Code complexity: CSR requires more client-side JavaScript code for data fetching and rendering, while SSR shifts this responsibility to the

server-side, reducing the complexity on the client.

Table 10.1 presents the difference between SSR and CSR:

| Feature                | Server-Side Rendering (SSR)                                         | Client-Side Rendering (CSR)                                           |
|------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------|
| Rendering Process      | Pre-rendering of HTML on the server                                 | Rendering and data fetching on the client-side using JS               |
| Initial Load Time      | Faster initial rendering                                            | Slower initial rendering due to additional requests                   |
| SEO                    | SEO-friendly as content is readily available for indexing           | Requires additional SEO efforts for search engine discoverability     |
| Performance            | Better user experience on slower devices or poor network conditions | Faster and more interactive experience once initial page is loaded    |
| Code Complexity        | Less client-side JavaScript code                                    | More client-side JavaScript code                                      |
| Data Fetching          | Limited or no additional API requests required                      | Additional API requests for data fetching and rendering               |
| Development Complexity | Server handles rendering, reducing client-side complexity           | Client handles rendering, increasing client-side complexity           |
| Caching                | Easier to implement server-side caching                             | Caching requires additional client-side logic                         |
| Use Cases              | Content-heavy websites, SEO-focused applications                    | Interactive and dynamic applications, Single-Page Applications (SPAs) |
| Frameworks             | Next.js, Nuxt.js (Vue.js)                                           | React, Angular, Vue.js, Ember.js, and so on.                          |

**Table 10.1: CSR vs SSR**

Please note that the usage of SSR or CSR depends on various factors and requirements of your specific application. It's common to use a combination of both techniques within a single application, leveraging the benefits of each approach where they are most suitable. Frameworks like Next.js provide the flexibility to choose between SSR and CSR based on specific components or routes within the application.

## **Benefits and drawbacks of CSR and SSR**

CSR and SSR have their respective benefits and drawbacks, and understanding them can help developers make informed decisions based on their specific use cases. Let's explore the advantages and disadvantages of each rendering approach in detail:

### **Benefits of CSR:**

- Enhanced User Experience: CSR enables smooth and interactive user experiences by allowing dynamic content updates without refreshing the entire page. It provides a more app-like feel as users can interact with the application in real-time.
- Improved Performance After Initial Load: Once the initial HTML, CSS, and JavaScript are loaded, subsequent updates and data fetching can occur asynchronously without the need for full page reloads. This can lead to faster response times and a seamless user experience.
- Rich Front-End Interactions: CSR is well-suited for applications that heavily rely on client-side interactivity and dynamic content, such as real-time dashboards, collaborative tools, or social media feeds.

### **Drawbacks of CSR:**

- Slower Initial Load Time: CSR requires downloading the initial JavaScript bundle and making additional API requests to fetch data. This can lead to slower initial page load times compared to server-side rendering.
- SEO Challenges: Search engine crawlers may face difficulties in indexing and understanding client-rendered content. Additional measures like server-side rendering of critical pages or using techniques like prerendering may be necessary to ensure proper SEO.
- Increased Client-Side Complexity: CSR requires more client-side code to handle data fetching, rendering, and state management. This complexity can make development and debugging more challenging.

### **Benefits of SSR:**

- Faster Initial Page Load: SSR sends pre-rendered HTML from the server, resulting in faster initial page load times. This is particularly

advantageous for content-heavy websites or applications where quick loading is crucial.

- SEO-Friendly: Search engines can easily crawl and index the pre-rendered HTML, making SSR beneficial for better SEO. It ensures that content is readily available for search engines to understand and rank.
- Graceful Degradation: SSR gracefully handles scenarios where JavaScript is disabled or not supported by the client's device or browser, ensuring that users can still access and view the content.

### **Drawbacks of SSR:**

- Increased Server Load: SSR puts a heavier load on the server, as it needs to generate the HTML for each request. This can impact server performance and scalability, especially under high traffic or resource-intensive applications.
- Limited Client-Side Interactivity: SSR relies on server-generated HTML, which means that certain types of interactivities that require client-side processing may be limited compared to CSR.
- Development Complexity and Server-Side Logic: SSR requires developers to handle rendering logic on the server-side, which may require additional server-side coding and configuration compared to CSR.

It's important to note that a hybrid approach, using both CSR and SSR selectively based on specific components or routes, can be employed to leverage the benefits of each rendering approach while mitigating their drawbacks. Frameworks like Next.js provide hybrid rendering options, offering flexibility and optimization possibilities.

## **Next.js's approach to CSR and SSR**

Next.js is a popular React framework that provides an opinionated approach to CSR and SSR. It simplifies the process of implementing both rendering strategies, offering developers a powerful toolset for building efficient web applications. Let's explore Next.js's approach to CSR and SSR in detail:

- **Server-Side Rendering (SSR) with Next.js:**

Next.js makes server-side rendering straightforward by allowing developers to write components that can be rendered on the server. When a request is made to a Next.js application, the server fetches the required data and renders the component on the server. The resulting HTML is then sent to the client for display. This approach provides several benefits:

- SEO Optimization: Next.js's SSR enables search engine crawlers to easily discover and index content, enhancing search engine optimization.
  - Faster Initial Load: By pre-rendering pages on the server, Next.js delivers a complete HTML page to the client, resulting in faster initial load times.
  - Graceful Degradation: SSR ensures that pages are accessible even when JavaScript is disabled, providing a better user experience for a wider range of devices.
- **Client-Side Rendering (CSR) with Next.js:**

Next.js also supports CSR, allowing components to be rendered on the client-side using JavaScript. This approach is suitable for scenarios where dynamic content and interactivity are paramount. Next.js leverages React's capabilities for client-side rendering, enabling the efficient updating of components without reloading the entire page. Some benefits of CSR with Next.js include:

- Enhanced User Experience: CSR enables real-time updates and interactivity, providing a more engaging user experience.
- Dynamic Content: Next.js allows components to fetch data on the client-side, making it easy to render dynamic content and handle user interactions.
- Code Splitting and Lazy Loading: Next.js offers built-in code splitting and lazy loading capabilities, optimizing performance by only loading the required components when needed.

### **Hybrid Rendering with Next.js:**

Next.js provides a hybrid rendering approach that allows developers to choose between SSR and CSR on a per-page or per-component basis. This

flexibility enables developers to strike a balance between performance, interactivity, and SEO requirements.

By default, Next.js uses SSR for the initial page load, allowing faster rendering and improved SEO. Subsequent navigation within the application can then use CSR, ensuring a smooth and interactive user experience.

Next.js also optimizes the rendering process by utilizing techniques like automatic code splitting, intelligent caching, and incremental static regeneration. These features help improve performance and ensure efficient rendering of content.

In summary, Next.js simplifies the implementation of both SSR and CSR by providing a framework that seamlessly integrates server-side and client-side rendering. It offers flexibility in choosing the appropriate rendering approach based on specific requirements, making it a powerful tool for building efficient and performant web applications.

## SSR with Next.js

A detailed explanation with code examples of the functions used to achieve SSR with Next.js:

### 1. `getServerSideProps`:

The `getServerSideProps` function allows you to fetch data on the server and pass it as props to your components. It runs on every request and fetches the data dynamically. Here's an example:

```
import React from 'react';
function HomePage({ data }) {
 return (
 <div>
 <h1>Welcome to my Next.js app!</h1>
 <p>Data from API: {data}</p>
 </div>
);
}

export async function getServerSideProps() {
 const res = await fetch('https://api.example.com/data');
 const data = await res.json();
```

```
return {
 props: {
 data,
 },
};

export default HomePage;
```
```

In the preceding example, the `getServerSideProps` function fetches data from an API endpoint (`<https://api.example.com/data>`). The fetched data is passed as a prop (`data`) to the `HomePage` component, which can then be rendered with the server-rendered data.

2. `getStaticProps`:

The `getStaticProps` function enables server-side rendering with static generation. It fetches data at build time and generates static HTML pages. The generated HTML is then reused on each request, providing better performance. Here's an example:

```
```import React from 'react';
function HomePage({ data }) {
 return (
 <div>
 <h1>Welcome to my Next.js app!</h1>
 <p>Data from API: {data}</p>
 </div>
);
}

export async function getStaticProps() {
 const res = await fetch('https://api.example.com/data');
 const data = await res.json();

 return {
 props: {
 data,
 },
 };
}
```

```
export default HomePage;
```

```

In the preceding example, the `getStaticProps` function fetches the data from the API endpoint at build time. The data is then passed as a prop (`data`) to the `HomePage` component, and Next.js generates a static HTML page that includes the fetched data.

3. `getStaticPaths`:

The `getStaticPaths` function is used for dynamic routing and server-side rendering with static generation. It defines the possible paths for dynamic routes and specifies the data to pre-render. Here's an example:

```
import React from 'react';
function Post({ post }) {
  return (
    <div>
      <h1>{post.title}</h1>
      <p>{post.content}</p>
    </div>
  );
}
export async function getStaticPaths() {
  const res = await fetch('https://api.example.com/posts');
  const posts = await res.json();
  const paths = posts.map((post) => ({
    params: { slug: post.slug },
  }));
  return {
    paths,
    fallback: false,
  };
}
export async function getStaticProps({ params }) {
  const res = await
    fetch(`https://api.example.com/posts/${params.slug}`);
  const post = await res.json();
  return {

```

```
    props: {
      post,
    },
  };
}
export default Post;
```
```

In this example, the `getStaticPaths` function fetches a list of posts from an API endpoint (`<https://api.example.com/posts>`) and maps each post to its respective `slug` parameter. The `paths` object is returned with the list of paths.

The `getStaticProps` function fetches the post data based on the dynamic `slug` parameter and returns it as props. The `Post` component receives the `post` prop and renders the title and content of the post.

These functions (`getServerSideProps`, `getStaticProps`, and `getStaticPaths`) enable server-side rendering in Next.js. They allow you to fetch data dynamically, generate static HTML pages, and pre-render dynamic routes, providing efficient and flexible rendering options for your Next.js applications.

## [Client-side rend to CSR with Next.js](#)

CSR in Next.js allows you to render components on the client-side, meaning the initial HTML is minimal, and the content is generated and rendered dynamically in the browser. Here's a detailed explanation with a code example of client-side rendering with Next.js:

### **1. Component Rendering:**

In Next.js, you can create React components in the **pages** directory and they will be automatically rendered on the client-side. Here's an example of a simple client-side rendered component:

```
import React from 'react';
function HomePage() {
 return (
 <div>
 <h1>Welcome to my Next.js app!</h1>
 </div>
);
}
export default HomePage;
```

```

 <p>This page is client-side rendered.</p>
 </div>
);
}
export default HomePage;
```

```

In the preceding example, we have a functional component `HomePage` that renders some static content. This component will be rendered on the client-side when the page is accessed.

2. Dynamic Data Fetching:

Client-side rendering in Next.js allows you to fetch data from APIs or external sources dynamically. You can use various approaches such as `useEffect`, `useState`, or external libraries like `axios` or `fetch` to fetch data on the client-side. Here's an example of fetching data on the client-side:

```

import React, { useEffect, useState } from 'react';
function HomePage() {
  const [data, setData] = useState(null);

  useEffect(() => {
    const fetchData = async () => {
      const res = await
        fetch('https://api.example.com/data');
      const data = await res.json();
      setData(data);
    };
    fetchData();
  }, []);

  return (
    <div>
      <h1>Welcome to my Next.js app!</h1>
      {data && <p>Data from API: {data}</p>}
    </div>
  );
}
export default HomePage;

```

```

In the updated example, we use the `useState` hook to manage the `data` state, and the `useEffect` hook to fetch data from an API (`https://api.example.com/data`). The fetched data is stored in the state and rendered in the component.

### 3. Interactivity and Client-side Updates:

Client-side rendering in Next.js allows for interactive components that can update and render dynamically based on user interactions or events. You can use various event handlers, state management libraries like `Redux` or `React Context`, or even Next.js' built-in `Link` component for client-side navigation. Here's an example of an interactive client-side rendered component:

```
``import React, { useState } from 'react';
function HomePage() {
 const [count, setCount] = useState(0);

 const handleIncrement = () => {
 setCount(count + 1);
 };

 return (
 <div>
 <h1>Welcome to my Next.js app!</h1>
 <p>Count: {count}</p>
 <button onClick={handleIncrement}>Increment</button>
 </div>
);
}
export default HomePage;
````
```

In the preceding example, we use the `useState` hook to manage the `count` state. When the “**Increment**” button is clicked, the `handleIncrement` function is called, updating the `count` state and re-rendering the component with the updated value.

Client-side rendering in Next.js provides flexibility and interactivity, allowing you to fetch data dynamically and update components based on

user actions. It is suitable for scenarios where dynamic content and interactivity are paramount, such as real-time updates or complex user interfaces.

Dynamic client-side rendering

To achieve dynamic CSR and SSR together in Next.js, you can use a combination of both approaches based on your specific use case. Here's an explanation of how you can achieve dynamic client-side rendering with Next.js, utilizing both SSR and CSR:

- Server-Side Rendering (SSR):

For initial page load or when SEO is crucial, you can leverage server-side rendering. With SSR, the server generates the HTML with the initial data, ensuring search engines can index the content and users can see the fully rendered page even without JavaScript enabled.

- Client-Side Rendering (CSR):

For dynamic updates or interactivity, you can utilize client-side rendering. CSR allows you to fetch and update data on the client-side without reloading the entire page, resulting in a more responsive user experience. This approach is suitable for scenarios where real-time updates, user interactions, or dynamic content rendering are required.

To achieve both SSR and CSR, you can follow these steps:

Step 1: Implement SSR:

Use the `getServerSideProps` function in your Next.js pages to fetch data on the server-side and pass it as props to your components. This allows you to render the page with initial data before sending it to the client.

```
```export async function getServerSideProps() {
 // Fetch data from an API or perform any server-side
 operations
 const data = await fetchData();

 // Return the data as props
 return {
 props: {
 data,
```

```
 },
};

}

```

```

Step 2: Implement CSR:

For dynamic updates or interactivity, you can use client-side rendering techniques. You can fetch data using `useEffect` or other client-side data fetching libraries like `axios` or `fetch`.

```
import React, { useEffect, useState } from 'react';

function MyComponent() {
  const [data, setData] = useState(null);

  useEffect(() => {
    const fetchData = async () => {
      const res = await fetch('https://api.example.com/data');
      const data = await res.json();
      setData(data);
    };
    fetchData();
  }, []);

  // Render your component with the fetched data
  return <div>{data && <p>Data: {data}</p>}</div>;
}
```

```

By combining SSR and CSR, you can achieve a hybrid rendering approach with Next.js. This enables you to provide initial server-rendered content for SEO and performance, while also incorporating dynamic client-side updates for interactivity and real-time data. This combination allows for a flexible and optimal user experience.

Choosing between CSR and SSR depends on various factors and the specific requirements of your application. Here's a detailed explanation of when to use each rendering approach:

### 1. Client-Side Rendering (CSR):

Use client-side rendering when:

- Dynamic Content: If your application heavily relies on dynamic content that needs to be fetched and updated frequently, CSR is a suitable choice. It allows you to fetch data on the client-side and update the UI without reloading the entire page.
- Interactivity: When you need to provide a highly interactive user experience with real-time updates, such as live chats, collaborative editing, or interactive data visualization, CSR is a preferred option. It allows for seamless interactions and immediate feedback to user actions.
- Single-Page Applications (SPAs): If you are building a single-page application where the entire application logic resides on the client-side, CSR is often the default approach. It enables smooth navigation and transitions between different views without full page reloads.
- Mobile Apps and Progressive Web Apps (PWAs): When developing mobile apps or PWAs, CSR can provide a native-like experience with smooth transitions, offline capabilities, and efficient resource usage.

## 2. Server-Side Rendering (SSR):

Use server-side rendering when:

- SEO and Initial Page Load: If search engine optimization (SEO) is crucial for your application or you want to provide fully rendered content to users even with JavaScript disabled, SSR is recommended. It ensures that search engines can crawl and index your pages effectively and users can see the content immediately.
- Performance and Time-to-Interactive: SSR can provide faster time-to-interactive as the server sends pre-rendered HTML to the client. This reduces the time required for the initial page load and enhances perceived performance, especially for content-rich pages.
- Security and Data Protection: When dealing with sensitive data, SSR can offer better security by keeping the data on the server-side. It reduces the risk of exposing sensitive information to the client-side JavaScript code.

- Compatibility: SSR ensures your application works across a wide range of devices, browsers, and user settings, as it relies less on client-side JavaScript execution.
- Social Media Sharing: If social media sharing is an important aspect of your application, SSR ensures that shared links display meaningful content and metadata, improving the overall sharing experience.

It's important to note that you can also combine SSR and CSR in hybrid approaches, where some pages are server-rendered while others are rendered on the client-side. Next.js, for example, offers flexibility in choosing the appropriate rendering strategy for each page.

Ultimately, the decision between CSR and SSR depends on the specific requirements, trade-offs, and goals of your application. Analysing factors such as content dynamics, interactivity, SEO, performance, security, and compatibility will help you determine the most suitable rendering approach.

In the dynamic realm of Next.js 13+, developers harness the power of directives to fine-tune code execution on both the server and client sides. This chapter delves into the use of two pivotal directives, `use server` and `use client`, exploring their role in server-side rendering (SSR) and client-side rendering (CSR) for improved performance and streamlined code organization.

## Section 1: Understanding Directives

### 1.1 Introducing Next.js Directives

In the context of Next.js, directives such as `use server` and `use client` act as markers for code, designating whether it should execute exclusively on the server or client side. This strategic use of directives optimizes the overall functionality and responsiveness of Next.js applications.

## Section 2: Leveraging `use server` Directive

### 2.1 Purpose of `use server`

The `use server` directive plays a pivotal role in streamlining server-side code execution. By employing this directive, developers can exclude designated code from the client-side bundle. This exclusion contributes to a leaner bundle size, subsequently enhancing the initial page load performance.

Example:

```
```javascript
// server-side.js
'use server';

async function fetchData() {
  const response = await
    fetch('https://jsonplaceholder.typicode.com/posts/1');
  const data = await response.json();
  return data;
}

export default fetchData;
```
```

Developers must exercise caution when using `use server` to ensure that the marked code executes exclusively on the server, with results seamlessly integrated into the client's response.

### Section 3: Harnessing `use client` Directive

#### 3.1 Role of `use client`

Conversely, the `use client` directive enables the identification of code intended solely for client-side execution. This code is included in the client-side bundle, empowering developers to interact with the Document Object Model (DOM) and respond to user events.

Example:

```
```javascript
// client-side.js
'use client';

const handleClick = () => {
  const element = document.getElementById('button');
  element.textContent = 'Clicked!';
};

const button = document.getElementById('button');
button.addEventListener('click', handleClick);
```
```

With `use client`, functions and event listeners execute exclusively on the client, post page load, enhancing the interactive elements of the application.

## Section 4: Code Organization and Performance Benefits

### 4.1 Strategic Code Partitioning

By judiciously implementing `use server` and `use client` directives, developers can effectively partition their code into server-side and client-side components. This not only enhances code organization but also optimizes performance, contributing to a seamless user experience in Next.js applications.

## Section 5: Default Configuration in `next.config.json`

### 5.1 Configuration for Default Behavior

To streamline the usage of directives in a Next.js project, developers can configure the `next.config.json` file. The following example demonstrates how to enable server-side actions by default.

```
```javascript
/** @type {import('next').NextConfig} */
const nextConfig = {
  experimental: {
    serverActions: true,
  },
}
module.exports = nextConfig;
```
```

This configuration ensures that server-side actions are enabled by default, offering a cohesive and efficient development experience with Next.js.

## **Best practices for using CSR and SSR in Next.js applications**

When working with CSR and SSR in Next.js applications, it's important to follow certain best practices to ensure optimal performance, maintainability, and user experience. Here are some key best practices for using CSR and SSR in Next.js:

- Code Separation:

Maintain a clear separation between client-side and server-side code. Use the appropriate Next.js functions like `getServerSideProps`,

`getStaticProps`, and `useEffect` to handle server-side rendering and client-side rendering logic separately. This helps in understanding and managing the flow of data and rendering on both the client and server.

- Choose the Right Rendering Strategy:

Evaluate your application requirements and choose the appropriate rendering strategy. Use SSR when you need SEO optimization, initial page load performance, or when handling sensitive data. Use CSR when you need dynamic content, interactivity, or real-time updates. Consider using a hybrid approach that combines SSR and CSR for different parts of your application.

- Lazy Loading and Code Splitting:

Implement lazy loading and code splitting techniques to optimize the loading time and improve performance. Split your code into smaller chunks and load them on demand, reducing the initial bundle size. Use tools like dynamic imports, React.lazy, and dynamic routing in Next.js to achieve code splitting and load components only when needed.

- Caching and Memoization:

Utilize caching mechanisms to improve performance and reduce unnecessary server requests. Implement server-side caching techniques like caching responses from APIs, database queries, or expensive computations. Additionally, use client-side caching mechanisms like memoization or client-side state management libraries to avoid unnecessary re-renders and optimize the client-side rendering process.

- Handling Loading and Error States:

Consider the loading and error states in your application. Show loading spinners or placeholders while fetching data on the client-side or server-side. Handle error cases gracefully by displaying error messages or fallback content to provide a better user experience and handle edge cases effectively.

- Performance Monitoring and Optimization:

Monitor the performance of your application using tools like Lighthouse, PageSpeed Insights, or Web Vitals. Optimize your code, reduce unnecessary re-renders, and minimize the payload size to improve the performance of both CSR and SSR. Use techniques like

image optimization, lazy loading of assets, and minimizing the number of external dependencies.

- Testing and Debugging:

Write tests to cover different scenarios and edge cases for both CSR and SSR components. Use tools like React Testing Library or Jest for testing. Additionally, use browser developer tools, Next.js debug mode, and server logs to debug issues related to rendering, data fetching, or performance.

- Documentation and Team Collaboration:

Document your rendering strategies, data flow, and component behavior to facilitate collaboration among team members. Clearly define the responsibilities of CSR and SSR components and provide guidelines on when to use each approach. Document any custom configurations or server-side logic that may affect rendering.

By following these best practices, you can optimize the rendering performance, maintainability, and user experience of your Next.js application when using both client-side and server-side rendering.

## Conclusion

Client-side rendering and server-side rendering are two crucial techniques in web development for delivering dynamic and interactive content. This chapter explored the fundamental concepts and key differences between these rendering methods. Server-side rendering was highlighted as a critical aspect of Next.js applications due to its ability to improve performance, enhance search engine optimization, and elevate user experience. However, client-side rendering also has its merits, especially in scenarios requiring dynamic content and interactivity. The chapter discussed the different scenarios where client-side rendering shines and provided insights on its effective implementation in Next.js applications. Best practices for choosing between client-side and server-side rendering in Next.js applications were also discussed, along with guidelines to optimize rendering performance. By understanding these rendering techniques and their application in Next.js, developers can make informed decisions and optimize rendering performance in their projects.

In the next chapter, *Securing App with Next Auth*, we will delve into the realm of authentication and security in Next.js applications. This chapter will guide you through the implementation of Next Auth, a powerful third-party authentication library. By leveraging Next Auth, you will be able to streamline the authentication process and seamlessly integrate various authentication providers, including popular ones like Google, Facebook, Twitter, and more. Join us as we explore the world of secure authentication in Next.js and learn how to enhance the security of your applications with Next Auth.

## Multiple choice questions

1. What are the two popular rendering techniques discussed in the chapter?
  - A. Front-end rendering and back-end rendering
  - B. Client-side rendering and server-side rendering
  - C. Static rendering and dynamic rendering
  - D. Local rendering and cloud rendering
2. Which rendering technique is critical for Next.js applications?
  - A. Client-side rendering
  - B. Server-side rendering
  - C. Static rendering
  - D. Dynamic rendering
3. What are the benefits of SSR in Next.js applications?
  - A. Improved performance and enhanced user experience
  - B. Increased interactivity and dynamic content
  - C. Better search engine optimization and reduced load times
  - D. All of the above
4. In which scenarios does client-side rendering excel in Next.js applications?
  - A. When performance is a top priority

- B. When dynamic content and interactivity are paramount
  - C. When search engine optimization is crucial
  - D. When server-side rendering is not supported
5. What are the best practices for choosing between client-side and server-side rendering in Next.js applications?
- A. Always choose client-side rendering for better performance
  - B. Always choose server-side rendering for improved SEO
  - C. Consider factors such as performance requirements and content interactivity
  - D. Rely on default rendering settings without customization

## **Answers**

- 1. B
- 2. B
- 3. D
- 4. B
- 5. C

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## CHAPTER 11

### Securing App with Next Auth

In the ever-evolving landscape of web applications, ensuring robust authentication and security measures is of paramount importance. In this chapter, we will delve into the realm of authentication and security in Next.js applications, focusing on the implementation of Next Auth, a powerful third-party authentication library that simplifies the authentication process across various providers.

To kickstart our exploration, we will begin with an introduction to authentication and security. We will discuss the fundamental concepts, highlighting the significance of secure user authentication and protecting sensitive data. By understanding the core principles behind authentication and security, you will gain valuable insights into the importance of incorporating these practices into your Next.js applications.

Next, we will dive into Next Auth, an invaluable tool for simplifying the authentication process. We will provide an overview of Next Auth, exploring its features, benefits, and how it seamlessly integrates into Next.js applications. Whether you're working with popular authentication providers like Google, Facebook, Twitter, or custom providers, Next Auth offers a unified and streamlined approach.

Practical implementation is the key, so we will guide you through the process of setting up Next Auth in your Next.js application. You will learn the necessary steps and configurations to get started with Next Auth, ensuring smooth integration with your application.

Expanding upon the versatility of Next Auth, we will explore the implementation of different authentication providers. You will discover how to leverage Next Auth's capabilities to authenticate users using various providers, allowing your application to accommodate a wide range of user preferences.

However, authentication is only one aspect; protecting your application's pages and API routes is equally crucial. We will demonstrate how to secure

your pages and API routes using authentication mechanisms provided by Next Auth. You will learn how to restrict access to sensitive areas of your application, granting only authenticated users the privilege to interact with these resources.

Finally, we will delve into best practices for authentication and security in Next.js applications. We will discuss essential considerations, such as handling session management, mitigating common security vulnerabilities, and maintaining user trust. By adhering to these best practices, you will fortify your Next.js application's authentication and security measures, ensuring a safe and trustworthy user experience.

Throughout the chapter, we will cover topics including an introduction to authentication and security, an overview of Next Auth, setting up Next Auth in a Next.js application, implementing different authentication providers, protecting pages and API routes with authentication, and best practices for authentication and security in Next.js applications.

By the end of this chapter, you will have the knowledge and practical know-how to incorporate Next Auth into your Next.js applications, effectively securing your app and providing a seamless authentication experience for your users. So, let's dive in and explore the world of authentication and security with Next Auth!

## Structure

In this chapter, we will cover the following topics:

- Introduction to authentication and security
- Overview of Next Auth
- Setting up Next Auth in a Next.js application
- Implementing different authentication providers
- Protecting pages and API routes with authentication
- Best practices for authentication and security in Next.js applications

## Introduction to authentication and security

Authentication, authorization, and security are fundamental components of web development that work together to ensure the integrity, confidentiality,

and availability of data and resources. Let's explore each concept in detail and understand their significance in the context of web development.

- **Authentication**

Authentication is the process of verifying the identity of a user or system. It involves providing credentials, such as a username and password, to prove that you are who you claim to be. The primary goal of authentication is to ensure that only authorized individuals or systems can access specific resources or perform certain actions.

In web development, authentication typically involves the following steps:

- **User registration:** Users create an account by providing necessary information such as username, email address, and password. This information is usually stored securely in a database.
- **User login:** Users authenticate themselves by entering their credentials, typically a username/email and password combination. The entered credentials are validated against the stored information in the database. If the credentials match, the user is granted access.
- **Multi-factor authentication (MFA):** MFA adds an extra layer of security by requiring users to provide additional authentication factors, such as a one-time password (OTP) sent to their mobile device, in addition to their username and password.

- **Authorization**

Authorization is the process of determining what actions or resources a user is allowed to access after successful authentication. Once a user's identity is verified, authorization mechanisms define the user's permissions and restrictions within the application.

In web development, authorization involves:

- **Role-based access control (RBAC):** RBAC assigns roles to users based on their responsibilities or privileges. Each role has a set of permissions associated with it. By assigning users to specific roles, you can control their access to different features or sections of the application.

- **Access control lists (ACL):** ACL provides more granular control over individual resources or actions by defining specific permissions for each user or role. With ACL, you can determine fine-grained access rights, allowing or denying access to specific resources.

- **Security**

Security encompasses measures taken to protect web applications and systems from various threats, vulnerabilities, and attacks. It involves implementing safeguards to maintain the confidentiality, integrity, and availability of data and resources.

In web development, security considerations include:

- **Input validation and sanitization:** Validating and sanitizing user input helps prevent common security vulnerabilities like cross-site scripting (XSS) and SQL injection attacks. By ensuring that user input adheres to expected formats and removing malicious or unexpected data, you can mitigate these risks.
- **Secure communication:** Secure communication protocols such as HTTPS (HTTP over SSL/TLS) encrypt data transmitted between the client and the server, preventing eavesdropping and tampering. Properly configuring SSL/TLS certificates is crucial to establish a secure connection.
- **Data protection:** Sensitive data, such as passwords or personal information, should be stored securely using techniques like hashing and encryption. Hashing one-way encrypts passwords, making them irreversible, while encryption ensures data is only accessible with the proper decryption keys.
- **Security headers:** HTTP response headers, such as Content Security Policy (CSP), Strict-Transport-Security (HSTS), and X-XSS-Protection, help mitigate security risks and protect against common web vulnerabilities by defining browser behavior and enforcing security policies.
- **Regular security updates:** Keeping web applications and their dependencies up to date with the latest security patches and fixes is essential. Updates often address known vulnerabilities and security flaws, ensuring the application remains protected.

- **Security testing:** Regular security assessments, such as penetration testing and vulnerability scanning, can identify potential weaknesses in the application. By proactively identifying and addressing security issues, you can enhance the overall security posture of the system.

In summary, authentication, authorization, and security are essential pillars of web development. Proper implementation of authentication ensures the verification of user identities, authorization controls user access based on roles or permissions, and security measures protect against various threats and vulnerabilities. By incorporating these elements effectively, web developers can create robust and secure applications.

## Overview of Next Auth

Next Auth is an open-source authentication library for JavaScript applications, primarily used in the context of web development. It provides a simple and flexible way to implement various authentication methods, such as email/password, social logins (Google, Facebook, Twitter, and so on), and external identity providers (OAuth, OpenID Connect).



*Figure 11.1*

The goal of Next Auth is to simplify the authentication process and provide a standardized solution for handling user authentication in JavaScript-based projects, particularly those built with frameworks like Next.js. It abstracts away the complexities of implementing authentication from scratch, allowing developers to focus on building the core functionality of their applications.

**Key features of Next Auth include the following:**

- **Authentication Providers**

NextAuth.js supports various authentication providers, allowing users to authenticate using their existing accounts from platforms like GitHub, Google, Facebook, Twitter, and more. It provides a unified API for working with different providers, making it easy to switch between them or combine multiple providers.

- **Session Management**

NextAuth.js handles session management for authenticated users. It automatically manages session tokens, sets up secure HTTP-only cookies, and provides hooks and utilities for accessing session information in your Next.js components and pages.

- **Serverless API Routes**

NextAuth.js integrates with Next.js' API routes to handle authentication requests. It provides a special route (`/api/auth/[...nextauth].js`) that handles authentication flows, including authentication provider callbacks, token refresh, and more. This API route is where you configure the authentication options and define custom behavior.

- **Customization and Extensibility**

NextAuth.js allows you to customize and extend its functionality according to your specific requirements. You can customize the UI components, add custom authentication flows, implement authorization checks, and even extend the authentication providers to support your authentication systems.

- **Middleware and Callbacks**

NextAuth.js offers a flexible middleware system and callback hooks that allow you to inject custom logic at various stages of the authentication flow. This enables you to add custom checks, modify user data, enforce additional security measures, and integrate with external services.

- **Authentication Hooks**

NextAuth.js provides React hooks and server-side functions to access authentication-related data in your Next.js components and API routes. These hooks include **useSession** for retrieving session information,

**signIn** for initiating authentication flows, and **getSession** for server-side usage.

- **Security**

NextAuth.js follows security best practices and includes built-in protections against common attack vectors, such as cross-site request forgery (CSRF) and cross-site scripting (XSS) attacks. It also supports secure token storage, cookie encryption, and other security features.

NextAuth.js is highly regarded for its simplicity, flexibility, and compatibility with Next.js. It abstracts away much of the complexity involved in implementing authentication, allowing developers to focus on building secure and user-friendly authentication systems in their Next.js applications. It has a growing community and extensive documentation, making it easier to get started and find support for various authentication scenarios.

Overall, NextAuth simplifies the process of implementing user authentication in JavaScript applications by providing a well-documented and customizable solution. It reduces the development time and effort required for building secure and reliable authentication systems, enabling developers to focus on other aspects of their projects.

Let's explore an overview of NextAuth.js and how it can be used to achieve authentication and authorization in a Next.js application:

## 1. Installation and Configuration

To get started with NextAuth.js, you need to install it as a dependency in your Next.js project. You can do this using npm or yarn:

```
npm install next-auth
...
```

After installation, you need to create a `'[...nextauth].js` file in the root of your Next.js project. This file serves as the NextAuth.js configuration file, where you define authentication providers, callbacks, and other settings.

## 2. Authentication Providers

NextAuth.js supports a wide range of authentication providers out of the box, including:

- **OAuth providers:** Google, Facebook, GitHub, Twitter, and so on.

- **Database providers:** MongoDB, MySQL, PostgreSQL, and so on.
- **JWT (JSON Web Token) providers:** Custom JWT authentication.

You can configure one or more authentication providers by specifying their respective credentials and options in the configuration file. For example, to enable authentication with Google, you would add a Google provider with your client ID and client secret.

### 3. Authentication Callbacks and Functions

NextAuth.js provides callback functions that allow you to customize the authentication flow and handle user data. These include:

- **signIn:** Executed when a user signs in. You can use this callback to fetch or create user data and return it to be stored in the session.
- **signOut:** Executed when a user signs out. You can perform any necessary cleanup tasks here.
- **getSession:** Retrieves the user session data and provides it to pages or API routes. You can customize the session data and include additional information if needed.

You can define these callbacks in the configuration file to tailor the authentication flow to your application's requirements.

### 4. Authorization and Access Control

NextAuth.js provides built-in support for RBAC and defining authorization rules. In the `get Session` callback, you can enrich the user session data with authorization information such as roles or permissions. This allows you to implement fine-grained access control in your Next.js application by checking the user's session data and determining whether they have the required permissions to access certain pages or perform specific actions.

### 5. Session Management and Storage

NextAuth.js manages user sessions by storing session data either in cookies or a database. By default, it uses secure HTTP-only cookies to store session information, ensuring that session data is encrypted and tamper-proof. However, you can also configure it to use a database for session storage, which allows for more flexibility and scalability.

## 6. Customization and Theming

NextAuth.js offers various customization options, allowing you to tailor the authentication experience to match your application's design and branding. You can customize the login page, add additional form fields, and define custom error pages.

## 7. Additional Features

NextAuth.js provides several additional features to enhance authentication and authorization, including:

- **Passwordless authentication:** Supports email-based login flows, where users receive magic links or one-time passwords (OTPs) to authenticate.
- **Webhooks:** Allows you to trigger events or perform custom actions based on authentication events, such as user creation or sign-in.
- **Integrations:** NextAuth.js integrates seamlessly with Next.js and popular frameworks like React and TypeScript.

In conclusion, NextAuth.js simplifies the implementation of authentication and authorization in Next.js applications. With its wide range of authentication providers, flexible callbacks, and built-in access control features, it provides a robust foundation for securing your Next.js application.

## Setting up Next Auth in a Next.js application

Setting up Next Auth in a Next.js application involves several steps, including installing the necessary packages, configuring the NextAuth.js library, and integrating it into your application. NextAuth.js is a flexible authentication library that provides support for various authentication providers, such as OAuth, JWT, email/password, and more.

Here's a step-by-step guide on how to set up NextAuth in a Next.js application:

### **Step 1: Install the required packages**

Start by creating a new Next.js application or opening an existing one. Open your terminal and navigate to the project directory. Install the following

packages:

```
npm install next-auth
npm install axios
npm install react-hook-form
```

## Step 2: Create a NextAuth.js configuration file



*Figure 11.2*

Next, create a new file in your project's root directory called `next-auth.config.js`. This file will contain the configuration for NextAuth.js.

Here's an example configuration:

```
import NextAuth from 'next-auth'
import Providers from 'next-auth/providers'
const options = {
 // Configure one or more authentication providers
 providers: [
 Providers.GitHub({
 clientId: 'YOUR_GITHUB_CLIENT_ID',
 clientSecret: 'YOUR_GITHUB_CLIENT_SECRET',
 }),
 Providers.Google({
 clientId: 'YOUR_GOOGLE_CLIENT_ID',
 clientSecret: 'YOUR_GOOGLE_CLIENT_SECRET',
 }),
 // Add more authentication providers here
],
 // Optional configuration options
}
```

```

session: {
 jwt: true,
},
callbacks: {
 async signIn(user, account, profile) {
 // Custom sign-in logic
 return true
 },
 async redirect(url, baseUrl) {
 // Custom redirect logic
 return baseUrl
 },
 async session(session, user) {
 // Custom session data
 session.user.id = user.id
 return session
 },
 async jwt(token, user, account, profile, isNewUser) {
 // Custom JWT token logic
 return token
 },
},
// More configuration options...
}

export default (req, res) => NextAuth(req, res, options)

```

In this example, we're using GitHub and Google as authentication providers. You'll need to replace 'YOUR\_GITHUB\_CLIENT\_ID', 'YOUR\_GOOGLE\_CLIENT\_ID' and 'YOUR\_GITHUB\_CLIENT\_SECRET', 'YOUR\_GOOGLE\_CLIENT\_SECRET' with your actual GitHub and Google client credentials. You can also add more authentication providers, such as LinkedIn or Facebook, by including their configuration objects inside the `providers` array.

Let's go through the key aspects of this configuration file:

## Authentication Providers

The providers property is an array where you can configure one or more authentication providers. In this example, we've configured GitHub and Google as providers, each with its own configuration object, such as `Providers.GitHub` and `Providers.Google`. You'll need to replace '`YOUR_GITHUB_CLIENT_ID`', '`YOUR_GITHUB_CLIENT_SECRET`', '`YOUR_GOOGLE_CLIENT_ID`', and '`YOUR_GOOGLE_CLIENT_SECRET`' with your actual client credentials for each provider.

## Session Configuration

The session property configures the session behavior. In this example, we've enabled JWT by setting `jwt: true`. This allows NextAuth.js to issue and manage JWTs for authenticated users. You can customize other session options, such as session database adapters, session `maxAge`, and more.

## Callbacks

The callbacks property allows you to define custom logic at various stages of the authentication flow. In this example, we've defined several callback functions as follows:

- **signIn**

This function is called when a user successfully signs in. You can use it to perform additional actions, such as saving the user's data in your database.

- **redirect**

This function determines the URL to redirect the user after authentication. You can customize the redirect logic based on the user's role or other conditions.

- **session**

This function allows you to customize the session object before it's serialized and sent to the client. You can add or modify properties in the session object.

- **jwt**

This function allows you to customize the JWT token payload. You can add additional claims or modify the token based on the user's information.

## Additional Configuration Options

The options object provides more configuration options that you can explore in the NextAuth.js documentation. These options include specifying the database adapter, specifying custom pages for sign-in/sign-out, overriding default pages, configuring email providers, and more.

Finally, the configuration file exports a function that receives the req and res objects. This function is used by NextAuth.js to handle authentication requests.

### Step 3: Create an API route for NextAuth

Next, create a new file called `pages/api/auth/[...nextauth].js`. This file will handle the authentication requests. Paste the following code into the file:

```
import NextAuth from 'next-auth'
import Providers from 'next-auth/providers'

const options = {
 providers: [
 Providers.GitHub({
 clientId: 'YOUR_GITHUB_CLIENT_ID',
 clientSecret: 'YOUR_GITHUB_CLIENT_SECRET',
 }),
 // Add more authentication providers here
],
}

export default (req, res) => NextAuth(req, res, options)
```

Make sure to replace the GitHub client credentials with your own.

### Step 4: Set up authentication pages

Next, create a new directory called `pages/auth` and create two files inside it: `signin.js` and `signout.js`. These files will handle the authentication-related pages.

Here's an example code for `signin.js`:

```
import { signIn } from 'next-auth/client'
export default function SignIn() {
 return (
 <>
```

```
<h1>Sign In</h1>
<button onClick={() => signIn('github')}>
 Sign in with GitHub
</button>
</>
)
}
```

In this example, we're using the `signIn` function from the `next-auth/client` package to initiate the authentication flow with GitHub. You can add more authentication providers and buttons as needed.

## Step 5: Use NextAuth in your application

Finally, you can start using NextAuth in your Next.js application. Open your desired page/component and import the `useSession` hook from the `next-auth/client` package.

Here's an example:

```
import { useSession } from 'next-auth/client'

export default function MyPage() {
 const [session, loading] = useSession()

 if (loading) {
 return <p>Loading...</p>
 }

 if (!session) {
 return <p>Please sign in</p>
 }

 return <p>Welcome, {session.user.name
}</p>
}
```

In this example, we're using the `useSession` hook to check if a user is authenticated. If the `session` object is not available, it means the user is not authenticated and we display a "Please sign in" message. Otherwise, we display a welcome message with the user's name.

That's it! You have successfully set up NextAuth in your Next.js application. You can now customize the authentication flow, add more authentication

providers, and handle user sessions as needed. Make sure to refer to the NextAuth.js documentation for more advanced configuration options and usage examples.

## **Implementing different authentication providers**

Implementing different authentication providers with NextAuth.js allows you to offer multiple options for users to authenticate and sign in to your application. NextAuth.js provides built-in support for various authentication providers, including OAuth providers like GitHub, Google, Facebook, Twitter, and more, as well as email/password authentication and JWT authentication.

Here's a detailed explanation of implementing different authentication providers with NextAuth.js:

### **1. OAuth Providers**

OAuth providers allow users to sign in to your application using their existing accounts from popular platforms. To implement an OAuth provider:

#### **a. Install the necessary packages**

For example, to implement GitHub authentication, you would need to install the `next-auth/providers` package:

```
npm install next-auth/providers
```

#### **b. Import the provider and add it to the NextAuth.js configuration**

In the NextAuth.js configuration file (`next-auth.config.js`), import the provider from the `next-auth/providers` package and include it in the `providers` array. Provide the required client ID and client secret for the provider:

```
import Providers from 'next-auth/providers'
const options = {
 providers: [
 Providers.GitHub({
 clientId: 'YOUR_GITHUB_CLIENT_ID',
 clientSecret: 'YOUR_GITHUB_CLIENT_SECRET',
 }),
],
}
```

```
// Add more OAuth providers here
],
}
// Rest of the NextAuth.js configuration
```

### c. Configure the provider on the provider's platform

Each OAuth provider requires some configuration on their platform side. For example, to implement GitHub authentication, you need to set up a GitHub OAuth application and provide the generated client ID and client secret in the NextAuth.js configuration.

## 2. Email/Password Authentication:

NextAuth.js supports email/password authentication out of the box. Users can sign in with their email and password combination. To implement email/password authentication:

### a. Enable email/password authentication in the NextAuth.js configuration

In the NextAuth.js configuration file, enable the email/password provider by adding it to the `providers` array:

```
import Providers from 'next-auth/providers'
const options = {
 providers: [
 Providers.Email({
 server: {
 host: 'YOUR_SMTP_HOST',
 port: 'YOUR_SMTP_PORT',
 auth: {
 user: 'YOUR_SMTP_USERNAME',
 pass: 'YOUR_SMTP_PASSWORD',
 },
 },
 from: 'YOUR_EMAIL_ADDRESS',
 }),
],
}
// Rest of the NextAuth.js configuration
```

### b. Configure the SMTP server details

Specify the details of your SMTP server, such as the host, port, authentication credentials, and the email address from which to send verification and password reset emails.

## 3. JWT Authentication

NextAuth.js also supports JWT authentication, where you can issue and validate JWTs for users. This allows you to implement custom authentication systems or integrate with other services that use JWTs. To implement JWT authentication:

### a. Enable JWT authentication in the NextAuth.js configuration

In the NextAuth.js configuration file, enable JWT authentication by providing the required options:

```
const options = {
 providers: [],
 // Rest of the NextAuth.js configuration
 jwt: {
 secret: 'YOUR_JWT_SECRET',
 },
}
```

### b. Define your own JWT signing and verification logic

You need to define custom functions for signing and verifying JWT tokens. These functions receive the user object and should return a JWT token or validate the received token, respectively. You can use libraries like `jsonwebtoken` for this purpose.

## 4. Custom Providers

NextAuth.js allows you to create custom authentication providers to integrate with your own authentication systems or third-party services that are not supported out of the box. To implement a custom provider:

### a. Create a custom provider file

Create a JavaScript file for your custom provider, for example, `myCustomProvider.js`. In this file, define the necessary functions for authentication and user data retrieval. For example:

```
import { Account, Provider } from 'next-auth/providers'
```

```

const MyCustomProvider = (options) => {
 return {
 id: 'my-custom-provider',
 name: 'My Custom Provider',
 type: 'oauth',
 version: '1.0',
 scope: 'read:profile',
 accessTokenUrl:
 'https://mycustomprovider.com/oauth2/token',
 authorizationUrl:
 'https://mycustomprovider.com/oauth2/auth',
 profileUrl:
 'https://mycustomprovider.com/api/profile',
 clientId: options.clientId,
 clientSecret: options.clientSecret,

 async profile(profile, tokens) {
 // Retrieve user data from the profile and tokens
 return {
 id: profile.id,
 name: profile.name,
 email: profile.email,
 image: profile.image,
 }
 },
 // Additional provider methods...
 }
}

export default MyCustomProvider

```

**b. Import and add the custom provider to the NextAuth.js configuration**

In the NextAuth.js configuration file, import the custom provider and include it in the `providers` array, passing any required options:

```

import MyCustomProvider from './myCustomProvider'
const options = {
 providers: [

```

```
MyCustomProvider({
 clientId: 'YOUR_CUSTOM_PROVIDER_CLIENT_ID',
 clientSecret: 'YOUR_CUSTOM_PROVIDER_CLIENT_SECRET',
},
 // Other providers...
],
}
// Rest of the NextAuth.js configuration
```

### c. Implement the necessary provider methods

In the custom provider file, you'll need to implement the necessary methods like `accessToken`, `refreshToken`, and `profile`. These methods handle the authentication flow, retrieving access tokens, refreshing tokens, and extracting user data from the provider's API.

**Note:** Custom providers require additional setup and configuration specific to the provider you're integrating with. Refer to the provider's documentation for detailed instructions on setting up and configuring the custom provider.

By implementing different authentication providers, you can give your users the flexibility to choose their preferred method of authentication, whether it's through popular platforms, email/password, or custom authentication systems. NextAuth.js abstracts away much of the complexity of working with different providers, making it easier to implement and manage authentication in your Next.js application.

## Protecting pages and API routes with authentication

In Next.js, you can protect pages and API routes by implementing authentication mechanisms. Authentication ensures that only authenticated and authorized users can access certain pages or API endpoints. While there are several approaches you can take to achieve this in Next.js, we will describe a common method using sessions and cookies.

Here are the steps:

- 1. Set up server-side session management:** Next.js provides a built-in API for server-side session management using a package called **next-iron-session**. You can install it by running **npm install next-iron-session**. This package allows you to securely and efficiently store session data.
- 2. Create an authentication endpoint:** In your Next.js project, create an API route specifically for handling authentication requests, such as `'/api/auth'`. This endpoint will handle user login, logout, and session creation.

Here's an example of how you can implement the authentication endpoint:

```
// api/auth.js
import { ironSession } from 'next-iron-session';
async function handler(req, res) {
 if (req.method === 'POST') {
 // Validate user credentials
 const { username, password } = req.body;
 const isValid = await validateCredentials(username, password);

 if (isValid) {
 // Create session and store user information
 req.session.set('user', { username });
 await req.session.save();
 res.status(200).json({ success: true });
 } else {
 res.status(401).json({ error: 'Invalid credentials' });
 }
 } else if (req.method === 'DELETE') {
 // Destroy session on logout
 await req.session.destroy();
 res.status(200).json({ success: true });
 } else {
 res.status(405).end(); // Method not allowed
 }
}

export default ironSession(handler, {
```

```
password: process.env.SESSION_PASSWORD,
cookieName: 'session',
cookieOptions: {
 secure: process.env.NODE_ENV === 'production',
},
});
```

In this example, the /api/auth endpoint handles POST requests for login and DELETE requests for logout. It validates the user credentials and creates/destroys the session accordingly using next-iron-session.

3. **Implement user authentication logic:** In the authentication endpoint, you will need to implement the logic to validate user credentials, typically by checking against a user database or an external authentication service (for example, OAuth). If the credentials are valid, you create a session and store relevant user information in it.
4. **Create a middleware to check authentication:** Implement a middleware function that checks if the user is authenticated before accessing protected pages or API routes. You can create a file called `authMiddleware.js` with the following code:

```
// authMiddleware.js
import { ironSession } from 'next-iron-session';
const withAuth = (handler) => {
 return ironSession(async (req, res) => {
 const user = req.session.get('user');

 if (!user) {
 res.status(401).json({ error: 'Unauthorized' });
 } else {
 req.user = user;
 return handler(req, res);
 }
 }, {
 password: process.env.SESSION_PASSWORD,
 cookieName: 'session',
 cookieOptions: {
 secure: process.env.NODE_ENV === 'production',
 },
 });
};
```

```
};

export default withAuth;
```

This middleware function checks if the user is authenticated by verifying if the session contains the user information. If the user is authenticated, it allows access to the protected page or API route; otherwise, it returns a 401 Unauthorized error.

5. **Secure pages and API routes:** To protect a specific page or API route, wrap the corresponding component or handler with the `withAuth` middleware.

Here are examples for a protected page and API route:

```
// pages/dashboard.js
import withAuth from '../path/to/authMiddleware';
const DashboardPage = ({ user }) => {
 // Protected page content
};
export default withAuth(DashboardPage);

// pages/api/protected.js
import withAuth from '../../path/to/authMiddleware';
const protectedHandler = (req, res) => {
 // Protected API route logic
};
export default withAuth(protectedHandler);
```

By wrapping the ``DashboardPage`` component and ``protectedHandler`` with ``withAuth``, they are protected, and only authenticated users can access them. If a user is not authenticated, they will receive a 401 Unauthorized error.

6. **Implement login and logout functionality:** Use the login and logout functionality mentioned earlier to authenticate users and manage their sessions. You can redirect them to the login page if they are not authenticated.

By following these steps, you can secure pages and API routes in Next.js by implementing authentication middleware using server-side sessions. The middleware checks for authentication before granting access to protected resources.

# Best practices for authentication and security in Next.js applications

Implementing strong authentication and security practices is crucial for ensuring the integrity and confidentiality of data in Next.js applications. Here are some best practices to follow when it comes to authentication and security in Next.js applications:

## **1. Use Strong Authentication Mechanisms**

- Implement secure authentication protocols such as OAuth 2.0 or JWT for user authentication.
- Enforce strong password policies, including complexity requirements, password hashing, and salting.
- Consider implementing MFA to add an extra layer of security.

## **2. Implement Authorization and Access Control**

- Use RBAC or ACL to control user permissions and restrict access to sensitive resources or actions.
- Validate user roles or permissions on the server side to prevent unauthorized access.

## **3. Securely Store User Credentials**

- Hash and salt passwords using strong cryptographic algorithms such as bcrypt or Argon2.
- Avoid storing sensitive information like passwords or API keys in plain text.
- Consider using secure credential management systems like AWS Secrets Manager or environment variables.

## **4. Protect Against Cross-Site Scripting (XSS) Attacks**

- Implement input validation and sanitization to prevent malicious user input from being executed as code.
- Use security libraries like `DOMPurify` to sanitize user-generated content before rendering it on the client side.

## **5. Prevent CSRF Attacks**

- Use CSRF tokens and validate them on the server side to prevent malicious requests from external sites.
- Include anti-CSRF protection mechanisms like SameSite cookies and CSRF headers.

## 6. Implement Transport Layer Security (TLS)

- Use HTTPS to ensure encrypted communication between the client and the server, protecting sensitive data from interception or tampering.
- Obtain and configure SSL/TLS certificates to establish secure connections.

## 7. Sanitize and Validate User Input

- Implement server-side input validation to ensure that user input adheres to expected formats and limits.
- Use libraries like `Joi` or `validator.js` to validate user input for specific data types or patterns.

## 8. Regularly Update Dependencies and Patches

- Stay updated with the latest versions of Next.js and its dependencies to benefit from security fixes and patches.
- Monitor security advisories and apply patches promptly to address known vulnerabilities.

## 9. Implement Rate Limiting and Security Headers

- Enforce rate limiting to prevent brute-force attacks and excessive resource consumption.
- Set security headers like CSP, HSTS, and X-XSS-Protection to mitigate common web vulnerabilities.

## 10. Conduct Regular Security Audits and Testing

- Perform security audits and penetration testing to identify vulnerabilities in your application.
- Conduct regular code reviews and security assessments to ensure best practices are followed.

## 11. Educate Users and Maintain Audit Logs

- Educate users about best security practices, such as using strong passwords and being cautious about phishing attempts.
- Maintain logs of authentication and security-related events for auditing and analysis.

By following these best practices, you can enhance the authentication and security of your Next.js applications and protect against common vulnerabilities and threats.

## Conclusion

This chapter has provided a comprehensive exploration of authentication and security in Next.js applications, with a specific focus on Next Auth. We began by emphasizing the importance of robust authentication and security measures in web applications. Understanding the fundamental concepts of authentication and security is crucial for implementing these practices effectively.

Next Auth was introduced as a powerful third-party authentication library that simplifies the authentication process across various providers. We explored its features, benefits, and seamless integration with Next.js applications. Practical implementation was emphasized, and step-by-step guidance was provided for setting up Next Auth in a Next.js application.

The chapter further discussed the implementation of different authentication providers and demonstrated how to protect pages and API routes using Next Auth's authentication mechanisms. Best practices for authentication and security in Next.js applications were also highlighted, covering topics such as session management, mitigating security vulnerabilities, and maintaining user trust.

In summary, this chapter equipped readers with the necessary knowledge and practical skills to incorporate Next Auth into their Next.js applications, ensuring secure and seamless authentication experiences for users. By following the best practices outlined, developers can fortify their applications and provide a safe environment for users to interact with their resources.

In the next chapter, we will delve into the setup and configuration of a Next.js project for developing a CRUD application. We will explore how to handle routing, create pages, and implement the basic structure of the

application. Additionally, we will learn about Next.js data fetching methods and how to integrate a database to perform CRUD operations efficiently.

## **Multiple Choice Questions**

1. What is the focus of this chapter?
  - A. Database management in Next.js applications
  - B. Performance optimization in Next.js applications
  - C. Authentication and security in Next.js applications
  - D. UI design principles in Next.js applications
2. Which authentication library is discussed in this chapter?
  - A. Passport.js
  - B. Firebase Authentication
  - C. Next Auth
  - D. Okta Authentication
3. What is the benefit of using Next Auth?
  - A. It simplifies the authentication process across various providers
  - B. It provides advanced UI components for Next.js applications
  - C. It offers built-in database management capabilities
  - D. It enables real-time data synchronization
4. What is one of the topics covered in this chapter?
  - A. Machine learning algorithms in Next.js applications
  - B. Localization and internationalization in Next.js applications
  - C. Responsive web design in Next.js applications
  - D. Protecting pages and API routes with authentication
5. What is the purpose of discussing best practices in this chapter?
  - A. To highlight the drawbacks of using Next Auth
  - B. To showcase alternative authentication libraries
  - C. To provide guidance on ensuring secure authentication and user trust

D. To introduce upcoming features in Next.js

## Answers

1. C
2. C
3. A
4. D
5. C

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## CHAPTER 12

# Developing a CRUD Application with Next.js

### Introduction

In this chapter, we will delve into the exciting world of building a CRUD (Create, Read, Update, Delete) application using Next.js, a popular and powerful React framework for server-side rendering and static site generation. We will leverage the capabilities of Next.js to develop a fully functional To-do application, allowing users to create, manage, update, and delete their tasks effortlessly.

To power our application's backend, we will integrate Supabase, a modern and open-source alternative to traditional databases. Supabase combines the simplicity and scalability of PostgreSQL with a real-time and reactive data API. By using Supabase, we can easily handle data storage and retrieval, as well as handle real-time updates seamlessly.

Throughout this chapter, we will explore the key concepts and techniques required to build a robust CRUD application. We will start by setting up our development environment, ensuring that we have all the necessary tools and dependencies installed. Next, we will create a new Next.js project, configuring it to work seamlessly with Supabase.

We will take a hands-on approach and guide you through the process of designing the application's user interface using React components and Next.js's built-in styling capabilities. You will learn how to create forms for user input, display dynamic data, and implement navigation between different pages of the application.

Moving forward, we will dive into the core functionality of our To-do application. We will implement the necessary logic to create new tasks, retrieve existing tasks from the database, update task status, and delete tasks. We will also explore how to handle validation and error handling to ensure a smooth user experience.

By the end of this chapter, you will have a deep understanding of how to leverage the power of Next.js and Supabase to develop a feature-rich CRUD application. You will have the skills to build similar applications with different data models and extend the functionality to suit your specific requirements. So, let's dive in and get started on this exciting journey of building a CRUD application with Next.js and Supabase!

## Structure

In this chapter, the following topics will be covered:

- Introduction to CRUD applications and how they work
- Setting up a Next.js development environment and creating a new project
- Creating a database schema for the CRUD application and setting up a database connection
- Creating the user interface for the CRUD application using React and Next.js, including creating components and styling them with CSS
- Deploying the application to a production server

## Setting up your development environment

### **Prerequisites:**

- Node 16.8 or later
- macOS, Windows (including WSL), or Linux OS
- npm (a package manager)
- Visual Studio Code
- GitHub account

Now, we will download the latest version of Next.js. Open your terminal and enter the following command:

```
npx create-next-app@latest
```

You will get the following prompts then:

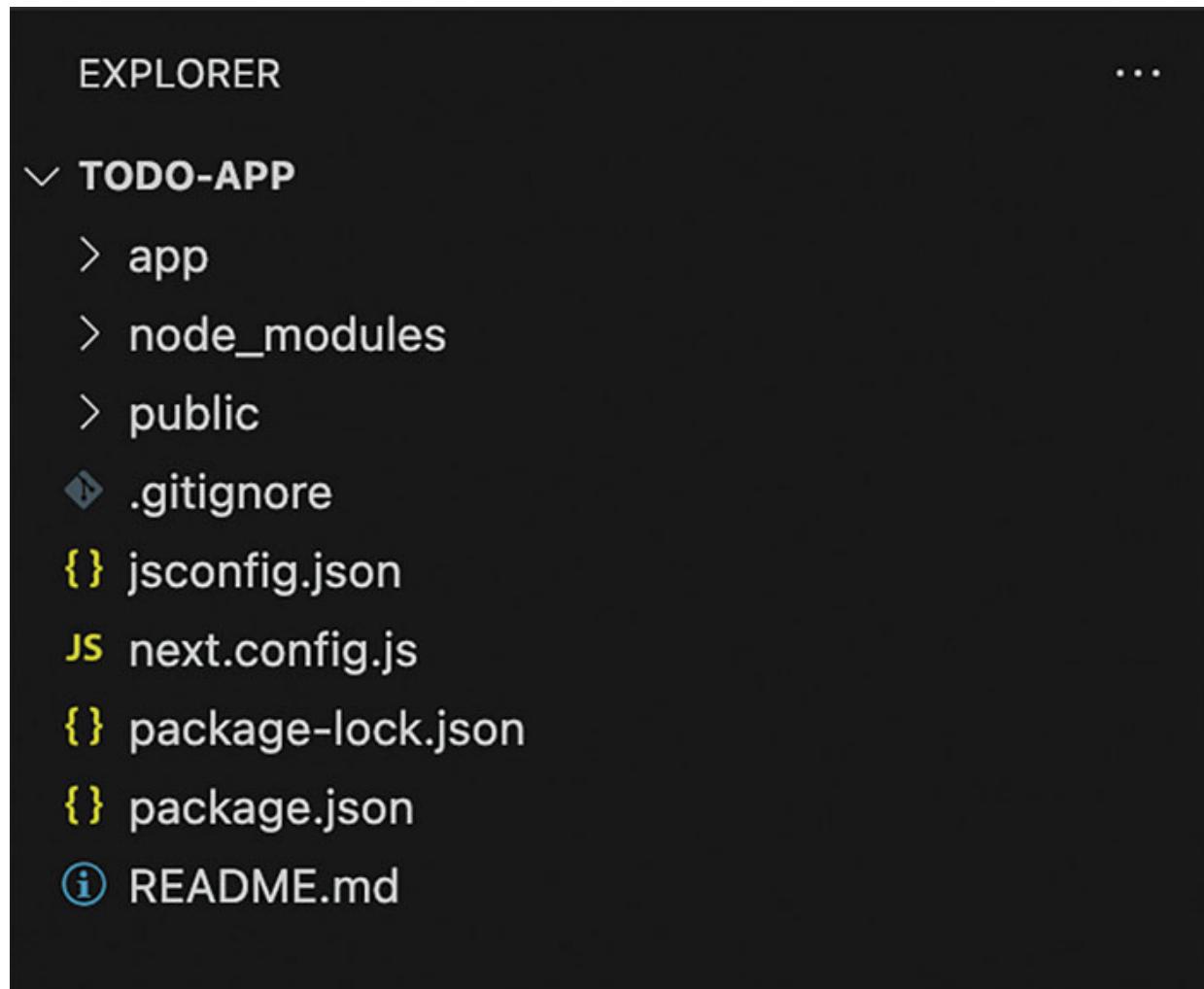
```
What is your project named? todo-app
```

```
Would you like to use TypeScript? No / Yes
```

```
Would you like to use ESLint? No / Yes
Would you like to use Tailwind CSS? No / Yes
Would you like to use `src/` directory? No / Yes
Would you like to use App Router? (recommended) No / Yes
Would you like to customize the default import alias? No / Yes
```

Name your project as **todo-app** like the preceding example or choose any name you wish. You can select **No** as the option for the remaining questions but answer **Yes** to the question about using App router, which was a new feature introduced in Next.js 13.

Now, open Visual Studio Code and navigate to the newly created folder. You should see the following file structure:

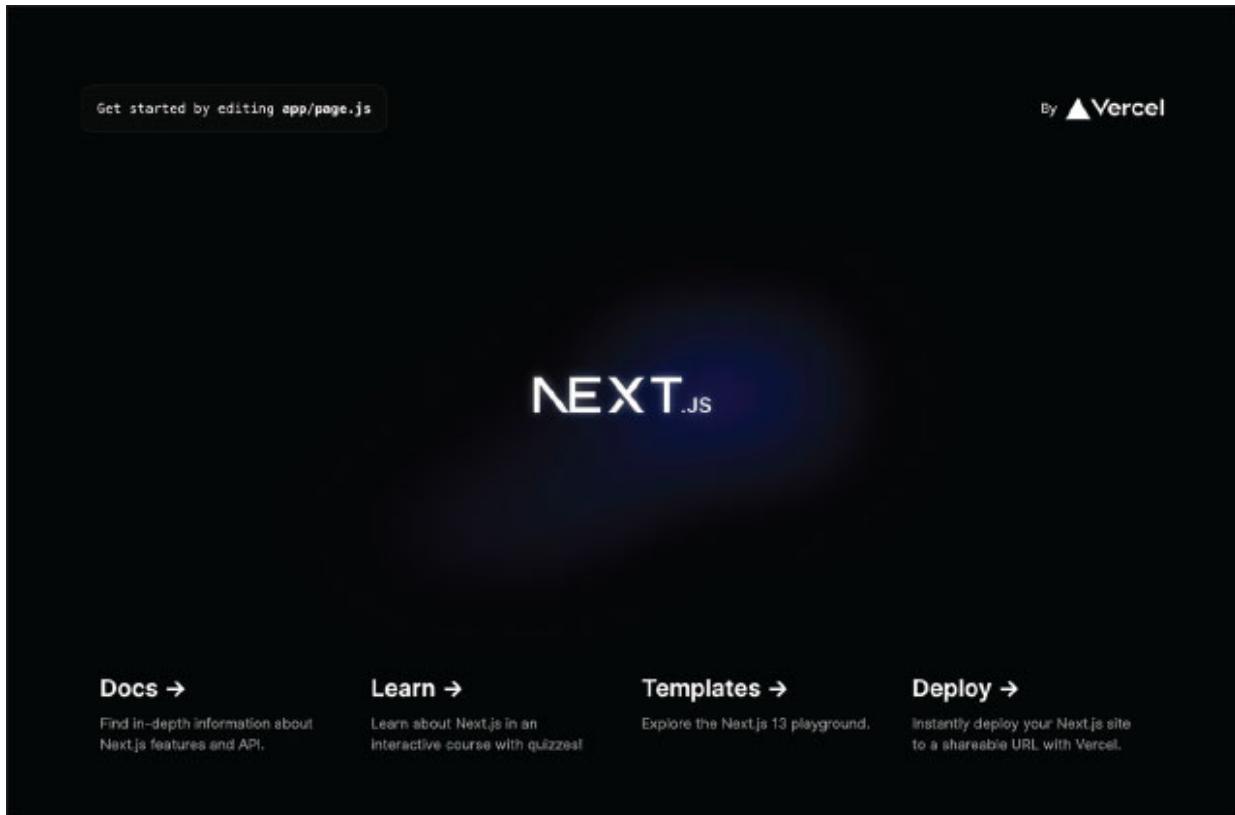


*Figure 12.1: App folder structure*

Now, enter the following command in the terminal:

```
npm run dev
```

And visit `http://localhost:3000` in the browser. You should see the following screen:



*Figure 12.2: Next.js app default screen*

As we bootstrapped our Next app using the `create-next-app` command, let's clear some boilerplate code from some files to get something like this:

### app/globals.css

```
* {
 box-sizing: border-box;
 padding: 0;
 margin: 0;
}

html,
body {
 max-width: 100vw;
 overflow-x: hidden;
```

```
}
```

```
body {
```

```
 background: black;
```

```
 color: white;
```

```
}
```

## app/layout.js

```
import './globals.css'
```

```
import { Inter } from 'next/font/google'
```

```
const inter = Inter({ subsets: ['latin'] })
```

```
export const metadata = {
```

```
 title: 'To-Do app',
```

```
 description: 'Created using Next.js 13',
```

```
}
```

```
export default function RootLayout({ children }) {
```

```
 return (
```

```
 <html lang="en">
```

```
 <body className={inter.className}>{children}</body>
```

```
 </html>
```

```
)
```

```
}
```

## app/page.module.css

```
.main {
```

```
 display: flex;
```

```
 flex-direction: column;
```

```
 gap: 40px;
```

```
 align-items: center;
```

```
 padding: 6rem;
```

```
 min-height: 100vh;
```

```
}
```

```
.go-button {
```

```
 background: green;
```

```
 padding: 10px;
```

```
}
```

## app/page.js

```
import styles from "./page.module.css";
import Link from "next/link";

export default function Home() {
 return (
 <main className={styles.main}>
 <h1>To-Do app</h1>
 <p>This is an app created using Next.js 13</p>
 <Link href="/" className={styles['go-button']}>Let's Go!
 </Link>
 </main>
);
}
```

Congratulations! Next.js has been successfully set up on your computer for local development. It should appear as shown in [Figure 12.3](#):

# To-Do app

This is an app created using Next.js 13

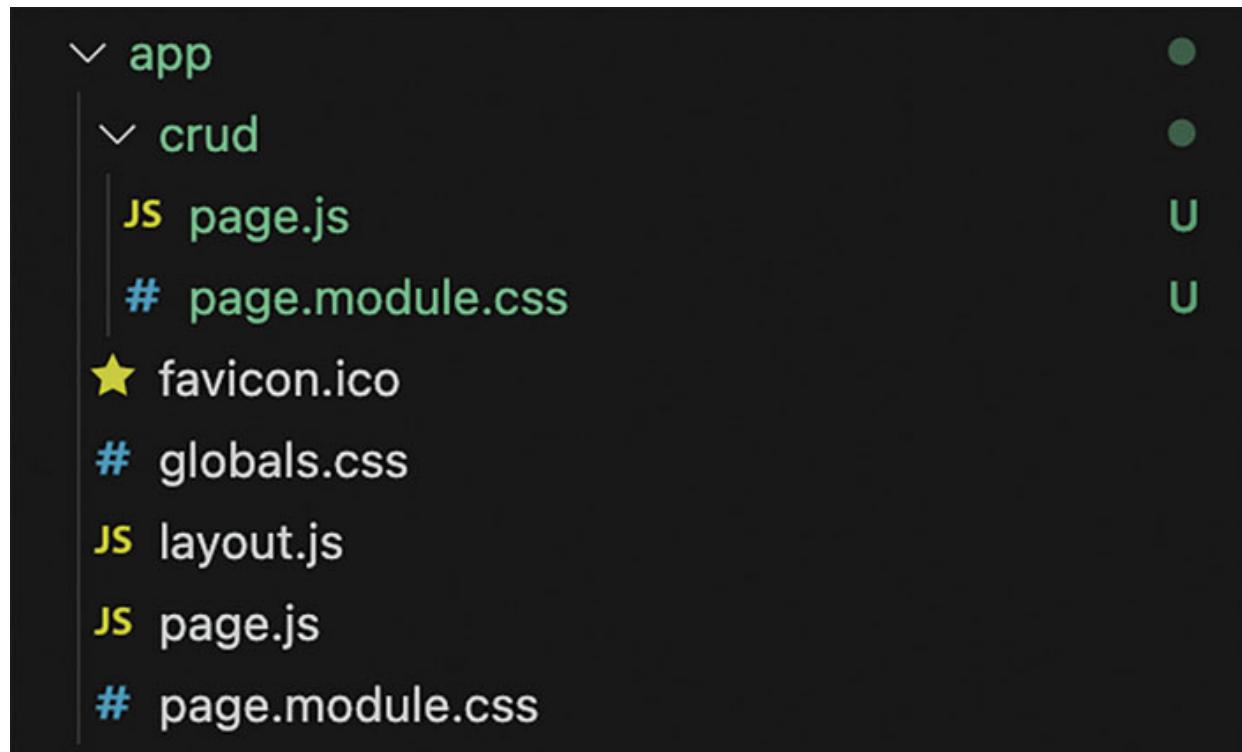
Let's Go!

*Figure 12.3: To-Do app*

## Displaying To-Do items (Read)

We have created the landing page for our app, which users will see when they visit the home page. When a user clicks the ‘Let’s Go’ button, we will redirect them to the main page of the app where they can do CRUD operations.

We will now create a new **crud** folder inside the **app** folder and create a **page.js** to render the UI for the **crud** route, and a **page.module.css** file to write its CSS.



A screenshot of a file explorer interface. On the left, there is a tree view of a directory structure. The root directory is 'app', which contains a 'crud' folder. Inside 'crud', there are two files: 'page.js' (highlighted in yellow) and '# page.module.css' (highlighted in blue). Below 'crud', there are three more files: 'favicon.ico' (marked with a yellow star icon), '# globals.css', and 'layout.js'. There are also two additional '# page.module.css' files located at the bottom level, one next to 'globals.css' and one next to 'layout.js'. The right side of the interface shows small green circular icons with letters 'U' or 'C' inside, likely indicating file status or type.

*Figure 12.4: New folders and files added*

The contents of **page.js** in the **crud** folder will be as follows:

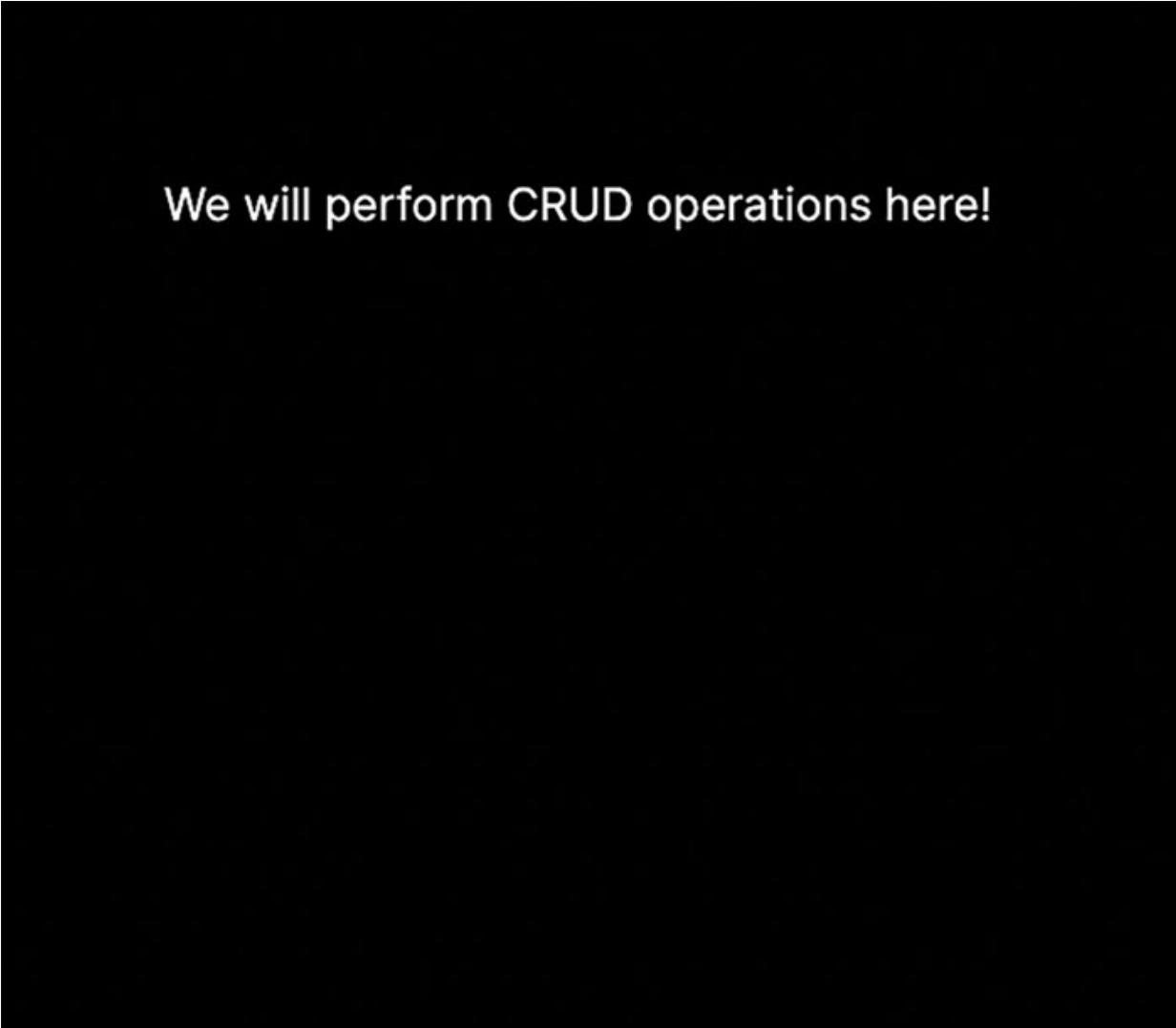
```
import styles from "./page.module.css";
export default function Crud() {
 return (
 <div className={styles.main}>
 <p>We will perform CRUD operations here!</p>
 </div>
);
}
```

## page.module.css

```
.main {
 display: flex;
 flex-direction: column;
 gap: 40px;
 align-items: center;
 padding: 6rem;
 min-height: 100vh;
}

.go-button {
 background: green;
 padding: 10px;
}
```

If we navigate to <http://localhost:3000/crud>, we will now see the following screen:



We will perform CRUD operations here!

*Figure 12.5: Output on screen*

We will change the Link component's href in the app/page.js file to:

```
<Link href="/crud" className={styles['go-button']}>Let's Go!
</Link>
```

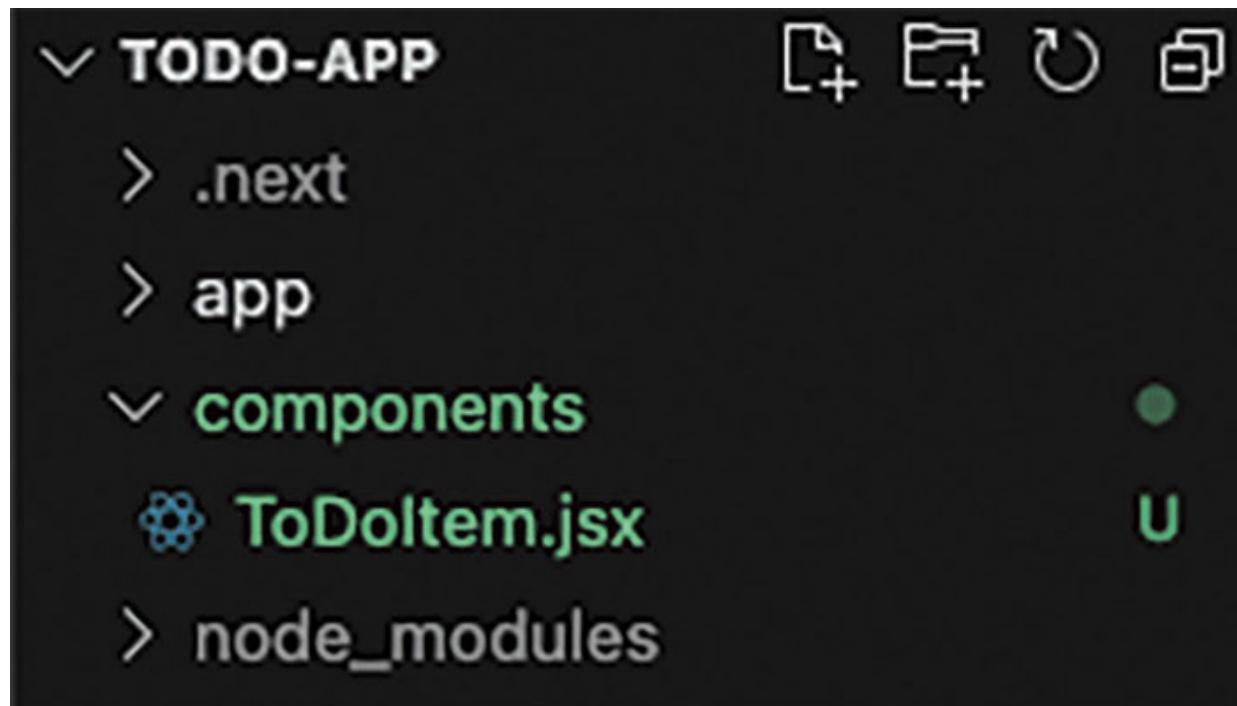
So, when a user clicks this link, they will be directed to the preceding **crud** route that we just created.

Now, we will edit the page.js in the /crud route to build our app. As the first step, we will create a static array of elements (that contains To-Do items) and render them on the screen:

```
const items = ["Go to the gym", "Buy groceries", "Pickup mail"];
```

The preceding items array contains a list of To-Do items, which we will try to render on the screen.

We will create a new **components** folder at the root level and create a **ToDoItem** component inside it. It will receive an **item** prop that contains the name of the ToDo item:



*Figure 12.6: Added ToDoItem.jsx file*

```
const ToDoItem = ({ item }) => {
 return <p>{item}</p>;
};

export default ToDoItem;
```

Change **crud/page.js** to:

```
import styles from "./page.module.css";
import TodoItem from "@/components/ToDoItem";
export default function Crud() {
 const items = ["Go to the gym", "Buy groceries", "Pickup mail"];

 return (
 <div className={styles.main}>
```

```
<h2>To-Do items</h2>

 {items.map((item) => (
 <TodoItem item={item} />
)));

</div>
);
}
```

# To-Do items

Go to the gym  
Buy groceries  
Pickup mail

*Figure 12.7: Rendered ToDo items*

You can now see that we are rendering the ToDo items from the array.

Next, let us polish the UI of the ToDo item list. To do this, we will install a UI library called Material UI. It has many pre-built UI React components and utilities. Run the command `npm install @mui/material @emotion/react @emotion/styled @mui/icons-material` to install

Material UI and its icon pack We will add a checkbox to mark items as completed and add a delete button for each item:

### components/ToDoItem.jsx

```
"use client";

import React from "react";
import styles from "./TodoItem.module.css";
import ListItem from "@mui/material/ListItem";
import ListItemButton from "@mui/material/ListItemButton";
import ListItemIcon from "@mui/material/ListItemIcon";
import Checkbox from "@mui/material/Checkbox";
importListItemText from "@mui/material/ListItemText";
import DeleteIcon from "@mui/icons-material/Delete";

const ToDoItem = ({ item, key }) => {
 const [checked, setChecked] = React.useState([0]);
 const handleToggle = (value) => () => {
 const currentIndex = checked.indexOf(value);
 const newChecked = [...checked];
 if (currentIndex === -1) {
 newChecked.push(value);
 } else {
 newChecked.splice(currentIndex, 1);
 }
 setChecked(newChecked);
 };
 return (
 <ListItem className={styles.item} key={key}>
 <ListItemButton onClick={handleToggle(key)}>
 <ListItemIcon>
 <Checkbox
 checked={checked.indexOf(key) !== -1}
 tabIndex={-1}
 className={styles.checkbox}
 />
 </ListItemIcon>
 <ListItemText primary={item} />
 </ListItemButton>
 </ListItem>
);
}
```

```
</ListItemButton>
<ListItemIcon>
<DeleteIcon className={styles.delete} />
</ListItemIcon>
</ListItem>
);
};

export default ToDoItem;
```

### **components/ToDoItem.module.css**

```
// CSS styles.item {
background: black;
margin-bottom: 20px;
}

.checkbox {
color: white;
}

.delete {
color: rgb(235, 81, 81);
}
```

### **crud/page.js**

```
// Component that renders the Todo items
"use client";

import styles from "./page.module.css";
import TodoItem from "@/components/ToDoItem";
import List from "@mui/material/List";

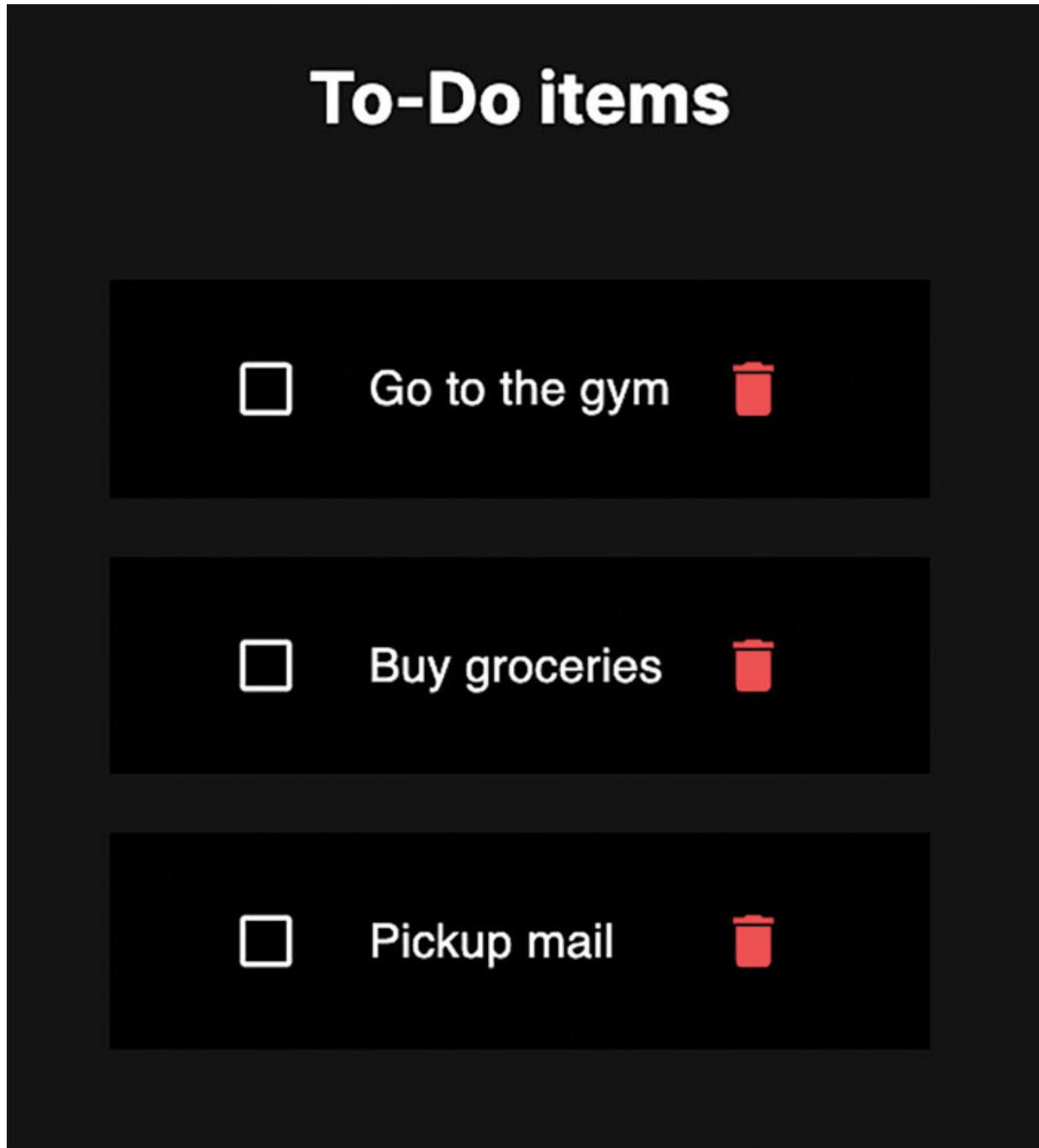
export default function Crud() {
const items = ["Go to the gym", "Buy groceries", "Pickup mail"];

return (
<div className={styles.main}>
<h2>To-Do items</h2>
<List>
{items.map((item, index) => (
```

```
<TodoItem item={item} key={index} />
))}
</List>
</div>
);
}
```

You will notice that we wrote a “use client” directive at the top of the files. This is used to specify that it’s a client component since we are using the external client library, Material UI.

The previous changes will render the following UI:



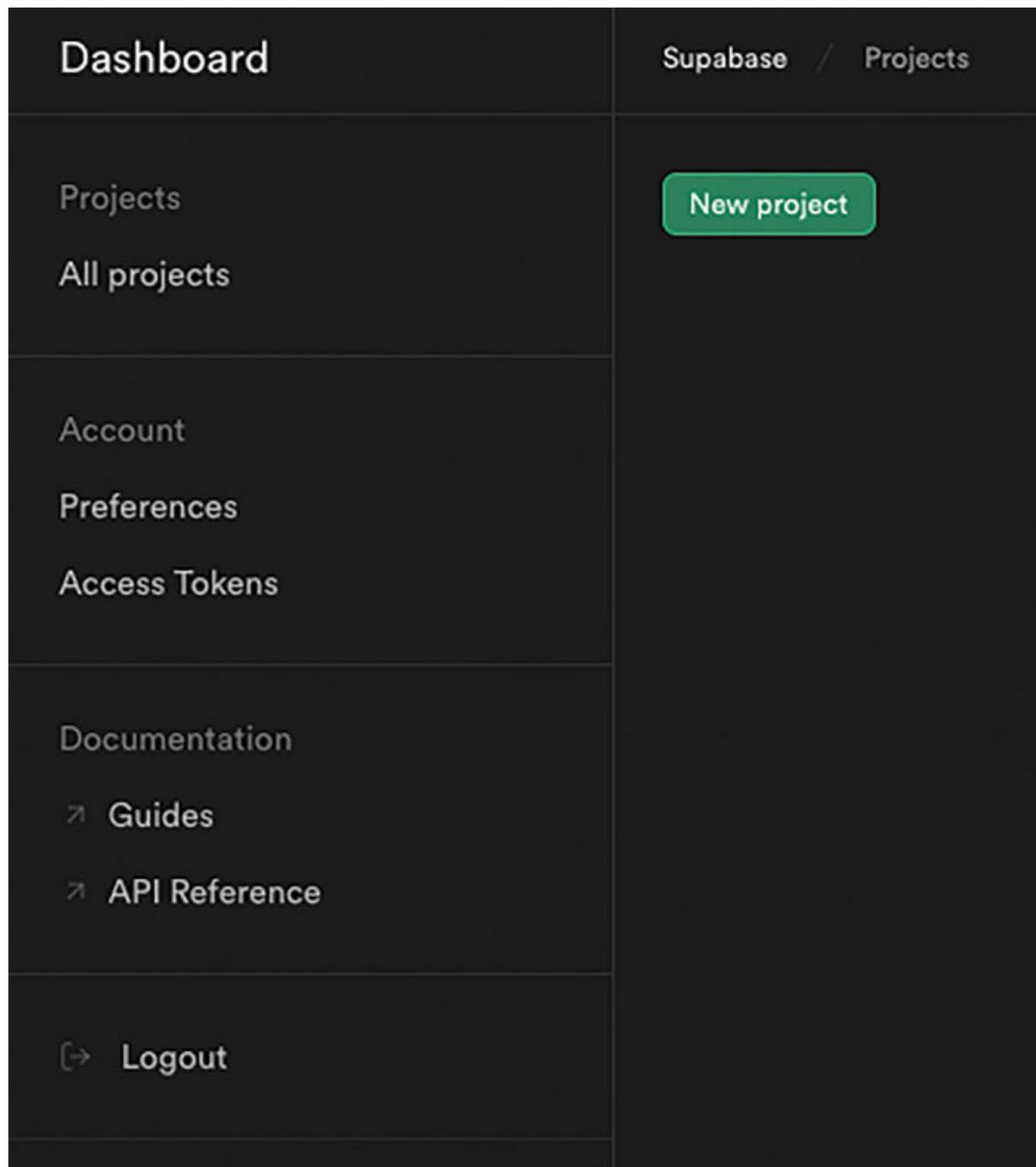
*Figure 12.8: ToDo items with checkbox and delete button*

We haven't added any functionality to the Delete button as well as the checkbox as of now as we will be covering that in the upcoming sections.

## [Setting up the database using Supabase](#)

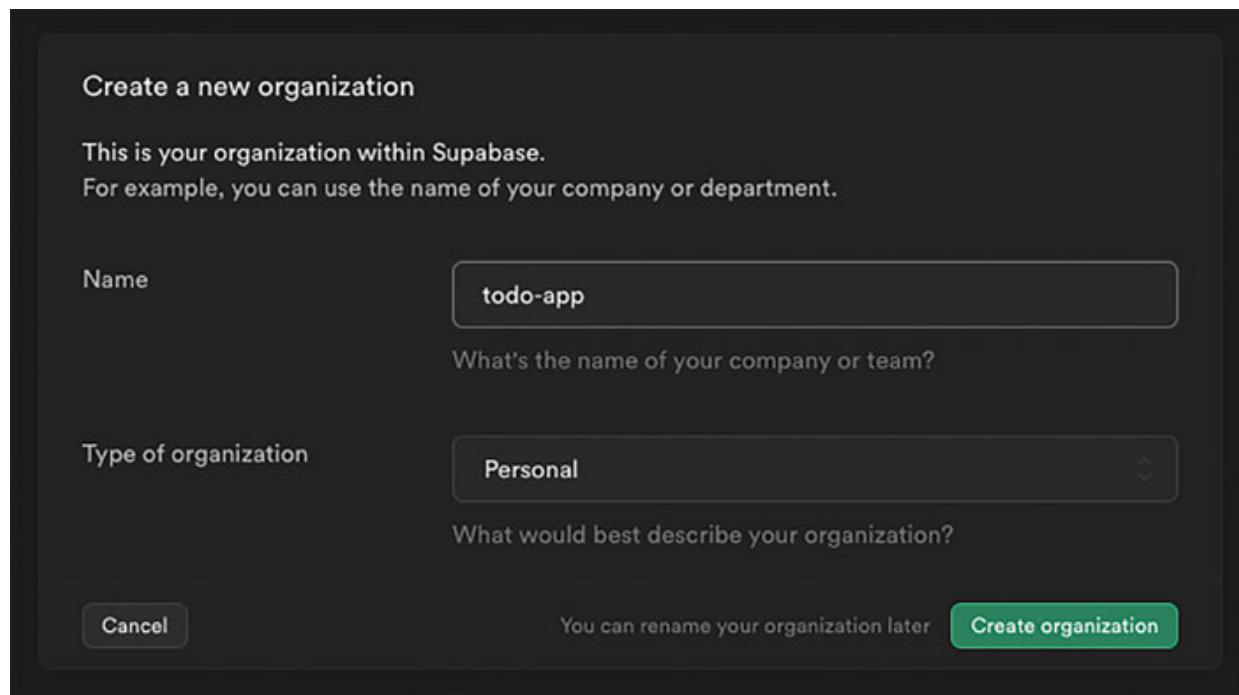
Our app now renders the UI from the static array **items** that have content `[“Go to the gym”, “Buy groceries”, “Pickup mail”]`. In a real-world application, such data would be stored in a database. We would make an API call to fetch these data from a server and then render it on the front-end. That's exactly what we are going to do now!

For that, go to Supabase.com and log in with your GitHub credentials. You will see the following dashboard:



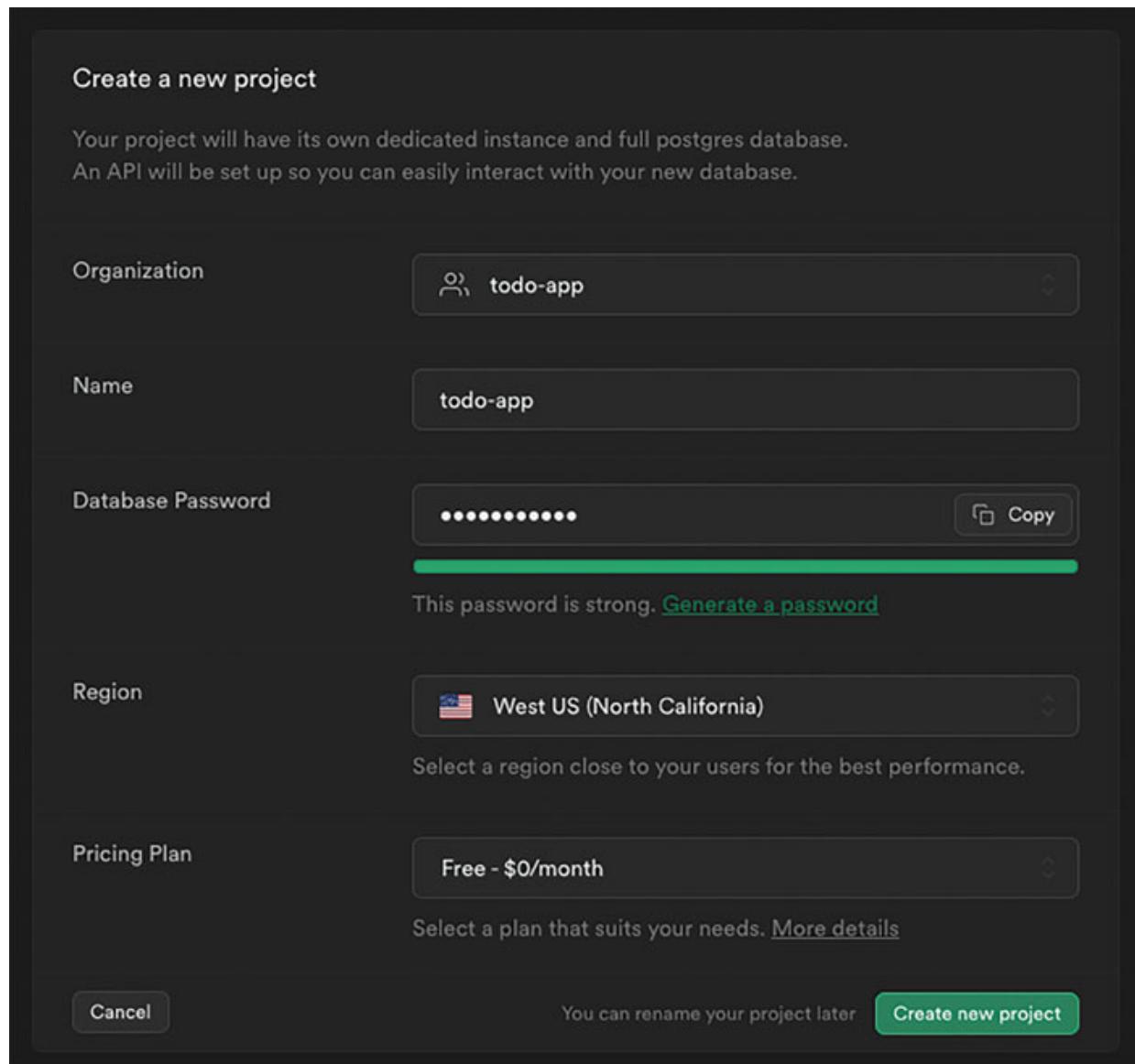
*Figure 12.9: Supabase dashboard*

Click the **New project** button and fill in the **Name** and **Type of organization**, as shown in [Figure 12.10](#):



*Figure 12.10: Supabase dashboard*

Then, fill in the following details to create a new project:



*Figure 12.11: Create a new project screen*

Go to the **Table Editor** tab, name the table as **items**, create the following four columns, and click **Save**:

| Name         | Type      | Default Value | Primary                             |
|--------------|-----------|---------------|-------------------------------------|
| id           | uuid      | NULL          | <input checked="" type="checkbox"/> |
| created_at   | timestamp | now()         | <input type="checkbox"/>            |
| name         | text      | NULL          | <input type="checkbox"/>            |
| is_completed | bool      | false         | <input type="checkbox"/>            |

Add column      Import data via spreadsheet      Cancel      Save

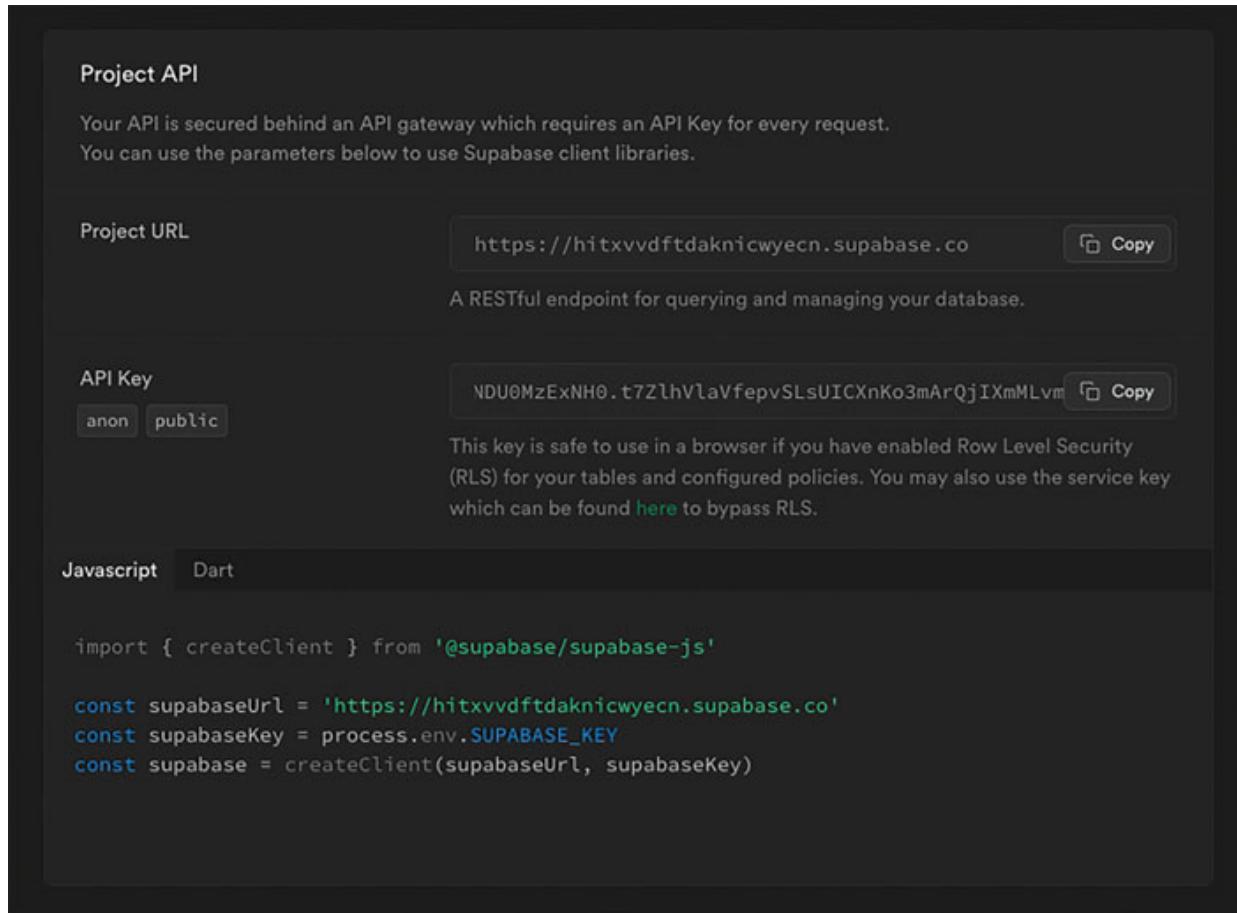
**Figure 12.12:** Database schema

Now, use the ‘**Insert**’ button to add the same ToDo items that were used in our Next.js. You can use <https://www.uuidgenerator.net/version1>, for now, to create UUIDs and add them to a row in the table. After adding these items, our table will look like this:

| id                                   | created_at                    | name          | is_completed |
|--------------------------------------|-------------------------------|---------------|--------------|
| 34287c84-1ee9-11ee-be56-0242ac120002 | 2023-07-10 06:15:53.096656+00 | Go to the gym | FALSE        |
| 4880dd84-1ee9-11ee-be56-0242ac120002 | 2023-07-10 06:16:41.043858+00 | Buy groceries | TRUE         |
| 5edfa150-1ee9-11ee-be56-0242ac120002 | 2023-07-10 06:17:12.446817+00 | Pickup mail   | FALSE        |

**Figure 12.13:** Database entries

We are making progress! The next part is to fetch this data through an API call from our Next.js app and render it in our UI. Luckily, Supbase provides an easy way to do that, as shown in [Figure 12.14](#):



**Figure 12.14:** Supabase dashboard

Open up our Next.js app and install `@supabase/supabase-js` package. Create a new **utils** folder in the root level and create a file `SupabaseClient.js` that initializes the app with the Supabase server:

```
import { createClient } from "@supabase/supabase-js";
const supabase = createClient(
 supabaseUrl,
 supabaseKey
);
export default supabase;
```

Replace the **supabaseUrl** and **supabaseKey** with the API keys from your Supabase account.

Update **crud/page.js** to:

```
"use client";
```

```

import styles from "./page.module.css";
import TodoItem from "@/components/TodoItem";
import List from "@mui/material/List";
import supabase from "@/utils/SupabaseClient";
export default async function Crud() {
let { data: items, error } = await
supabase.from("items").select("*");
return (
<div className={styles.main}>
<h2>To-Do items</h2>
<List>
{items.map((item) => (
<TodoItem item={item} />
))}
</List>
</div>
);
}

```

### **components/TodoItem.jsx:**

```

//TodoItem component which renders a single ToDo item
“use client”;

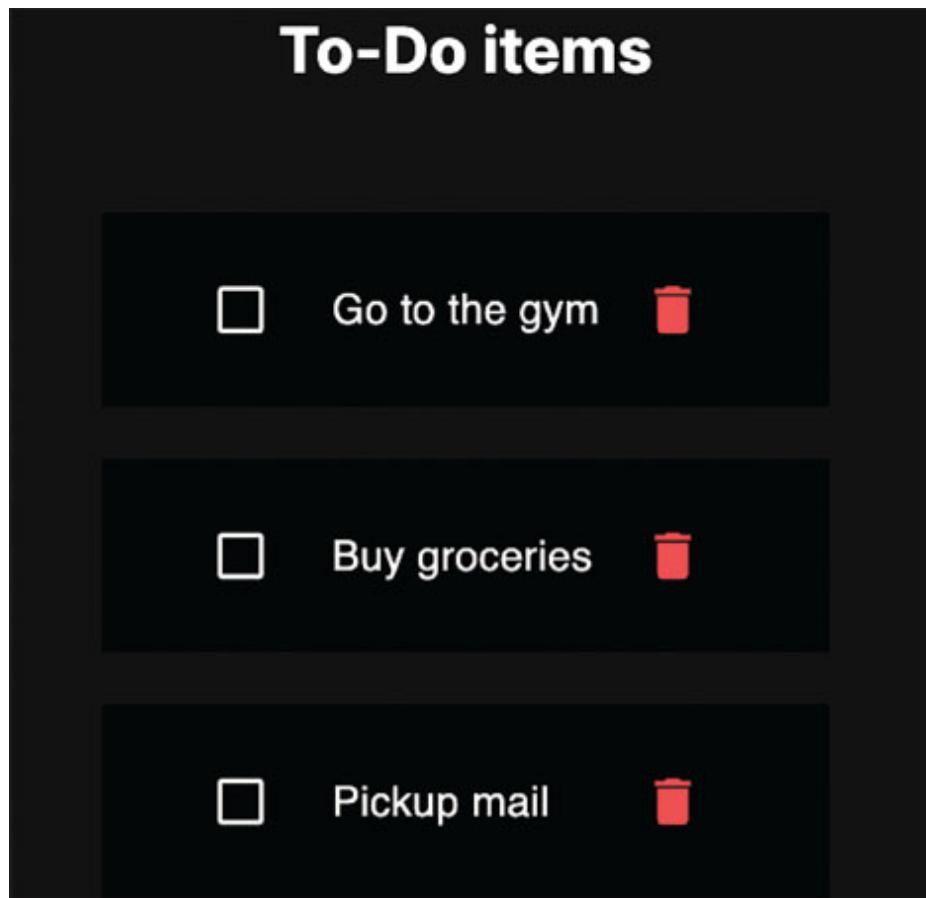
import React from “react”;
import styles from "./TodoItem.module.css";
import ListItem from "@mui/material/ListItem";
import ListItemButton from "@mui/material/ListItemButton";
import ListItemIcon from "@mui/material/ListItemIcon";
import Checkbox from "@mui/material/Checkbox";
importListItemText from "@mui/material/ListItemText";
import DeleteIcon from "@mui/icons-material/Delete";

const TodoItem = ({ item }) => {
const [checked, setChecked] = React.useState([0]);
const handleToggle = (value) => () => {
const currentIndex = checked.indexOf(value);
const newChecked = [...checked];
if (currentIndex === -1) {

```

```
newChecked.push(value);
} else {
newChecked.splice(currentIndex, 1);
}
setChecked(newChecked);
};
return (
<ListItem className={styles.item} key={item.id}>
<ListItemButton onClick={handleToggle(item.id)}>
<ListItemIcon>
<Checkbox
checked={checked.indexOf(item.id) !== -1}
tabIndex={-1}
className={styles.checkbox}
/>
</ListItemIcon>
<ListItemText primary={item.name} />
</ListItemButton>
<ListItemIcon>
<DeleteIcon className={styles.delete} />
</ListItemIcon>
</ListItem>
);
};
};

export default ToDoItem;
```



*Figure 12.15: Todo items rendered from server data*

In this step, we made an API call to fetch data from our Supabase server, which is now used to render the Todo items.

## [Adding new To-do items \(Create\)](#)

In the previous sections, we managed to implement the Read functionality and also connected our Next.js app to our Supabase backend. In this section, we will try to add a new ToDo item and update the Supabase backend table.

As the first step, we will add an input field and an Add button that appends a ToDo item to the list:

### **crud/page.js**

```
"use client";

import styles from "./page.module.css";
import TodoItem from "@/components/TodoItem";
```

```
import List from "@mui/material/List";
import supabase from "@/utils/SupabaseClient";
export default async function Crud() {
let { data: items, error } = await
supabase.from("items").select("*");
return (
<div className={styles.main}>
<h2>To-Do items</h2>
<div className={styles.container}>
<input className={styles.input} />
<button className={styles.button}>Add to list!</button>
</div>
<List>
{items.map((item) => (
<TodoItem item={item} key={item.key} />
))}
</List>
</div>
);
}
```

## crud/page.module.css

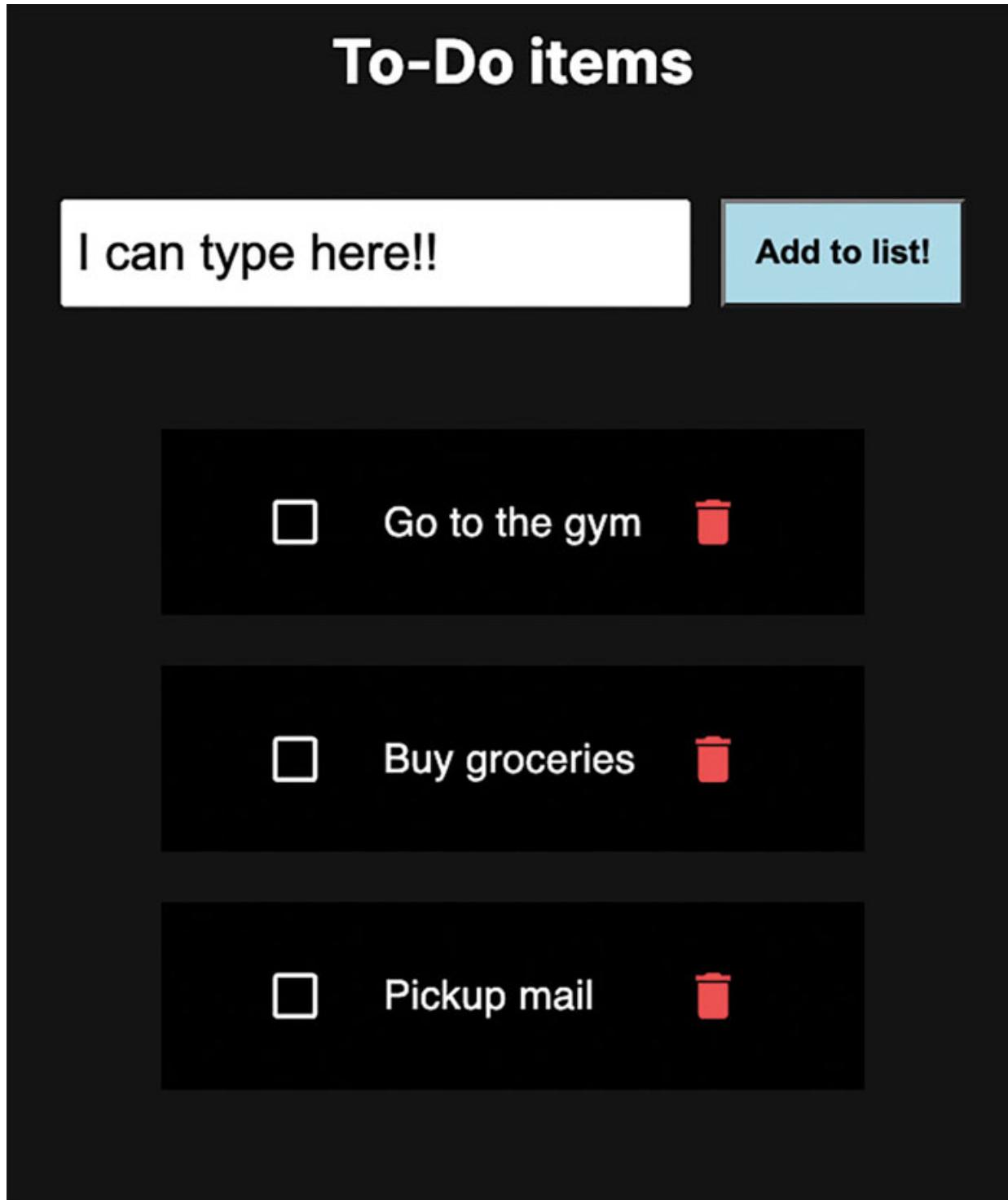
```
.main {
display: flex;
flex-direction: column;
gap: 40px;
align-items: center;
padding: 6rem;
min-height: 100vh;
}
.go-button {
background: green;
padding: 10px;
}
.input {
width: 250px;
```

```
font-size: 20px;
padding: 5px;
}

.button {
padding: 12px;
font-weight: 600;
background-color: lightblue;
}

.container {
display: flex;
gap: 12px;
}
```

The rendered UI will look like this:



*Figure 12.16: Todo items rendered from server data*

Now, let us create the logic that adds whatever we type in the input field to the ToDo list when the user clicks the **Add to list!** button. Let's refactor the code a bit and add a new function to handle adding new items to our list:

## crud/page.js

```
"use client";

import React, { useState, useEffect } from "react";
import { v4 as uuidv4 } from "uuid";
import styles from "./page.module.css";
import TodoItem from "@/components/ToDoItem";
import List from "@mui/material/List";
import supabase from "@/utils/SupabaseClient";

export default function Crud() {
 const [newItem, setNewItem] = useState(null);
 const [items, setItems] = useState([]);

 const fetchData = async () => {
 const { data, error } = await
 supabase.from("items").select("*");
 setItems(data);
 };

 useEffect(() => {
 fetchData();
 }, []);

 const addItem = async () => {
 const { data, error } = await supabase
 .from("items")
 .insert([{ is_completed: false, name: newItem, id: uuidv4() }])
 .single();
 if (!error) {
 fetchData();
 }
 };

 return (
 <div className={styles.main}>
 <h2>To-Do items</h2>
 <div className={styles.container}>
 <input
 className={styles.input}
 onChange={(e) => setNewItem(e.target.value)}
 />

```

```
<button className={styles.button} onClick={addItem}>
 Add to list!
</button>
</div>
<List>
 {items.map((item, index) => (
 <TodoItem item={item} key={index} />
)))
</List>
</div>
);
}
```

Notice that we have installed a library called `uuidv4` to generate a UUID. When you enter ‘Play football’ in the input field and click the ‘Add to list!’ button, it will send an API call to the database to add this new item and refresh the page so that we can see the new item in our UI!

# To-Do items

Add to list!

Go to the gym 

Buy groceries 

Pickup mail 

Play football 

*Figure 12.17: New Todo item added*

## Editing To-Do items (Update)

For this part, we will implement whether a task is complete or not based on whether it is checked or not in the UI. If the user ticks or unticks a ToDo item, we will update that in the Supabase table. To achieve this, we will refactor the two files as follows:

### **crud/page.js**

```
"use client";

import React, { useState, useEffect } from "react";
import { v4 as uuidv4 } from "uuid";
import styles from "./page.module.css";
import TodoItem from "@/components/TodoItem";
import List from "@mui/material/List";
import supabase from "@/utils/SupabaseClient";

export default function Crud() {
 const [newItem, setNewItem] = useState(null);
 const [items, setItems] = useState([]);

 const fetchData = async () => {
 const { data, error } = await
 supabase.from("items").select("*");
 setItems(data);
 };

 useEffect(() => {
 fetchData();
 }, []);

 const handleToggle = async (item) => {
 const { data, error } = await supabase
 .from("items")
 .update({ is_completed: !item.is_completed })
 .eq("id", item.id);
 if (!error) {
 fetchData();
 }
 };
}
```

```

const addItem = async () => {
 const { data, error } = await supabase
 .from("items")
 .insert([{ is_completed: false, name: newItem, id: uuidv4() }])
 .single();
 if (!error) {
 fetchData();
 }
};

return (
 <div className={styles.main}>
 <h2>To-Do items</h2>
 <div className={styles.container}>
 <input
 className={styles.input}
 onChange={(e) => setNewItem(e.target.value)}
 />
 <button className={styles.button} onClick={addItem}>
 Add to list!
 </button>
 </div>
 <List>
 {items.map((item) => (
 <TodoItem item={item} key={item.id} onToggle={handleToggle} />
)));
 </List>
 </div>
);
}

```

## **components/TodoItem.jsx**

```

“use client”;

import React from “react”;
import styles from “./TodoItem.module.css”;
import ListItem from “@mui/material/ListItem”;
import ListItemButton from “@mui/material/ListItemButton”;
import ListItemIcon from “@mui/material/ListItemIcon”;

```

```

import Checkbox from "@mui/material/Checkbox";
import ListItemText from "@mui/material/ListItemText";
import DeleteIcon from "@mui/icons-material/Delete";
const ToDoItem = ({ item, onToggle }) => {
 const handleToggle = () => {
 onToggle(item);
 };
 return (
 <ListItem className={styles.item}>
 <ListItemIcon>
 <Checkbox
 checked={item.is_completed}
 tabIndex={-1}
 className={styles.checkbox}
 />
 </ListItemIcon>
 <ListItemText primary={item.name} />
 </ListItemIcon>
 <ListItemIcon>
 <DeleteIcon className={styles.delete} />
 </ListItemIcon>
 </ListItem>
);
};

export default ToDoItem;

```

## **Deleting To-Do items (Delete)**

We have finally reached the final functionality, that is, deleting items when we press the delete button.

### **crud/page.js**

```

"use client";

import React, { useState, useEffect } from "react";
import { v4 as uuidv4 } from "uuid";

```

```
import styles from "./page.module.css";
import TodoItem from "@/components/ToDoItem";
import List from "@mui/material/List";
import supabase from "@/utils/SupabaseClient";
export default function Crud() {
 const [newItem, setNewItem] = useState(null);
 const [items, setItems] = useState([]);
 const fetchData = async () => {
 const { data, error } = await supabase.from("items").select("*");
 setItems(data);
 };
 useEffect(() => {
 fetchData();
 }, []);
 const handleToggle = async (item) => {
 const { data, error } = await supabase
 .from("items")
 .update({ is_completed: !item.is_completed })
 .eq("id", item.id);
 if (!error) {
 fetchData();
 }
 };
 const handleDelete = async (id) => {
 const { data, error } = await supabase.from("items").delete().eq("id", id);
 if (!error) {
 fetchData();
 }
 };
 const addItem = async () => {
 const { data, error } = await supabase
 .from("items")
 .insert([{ is_completed: false, name: newItem, id: uuidv4() }])
 .single();
 };
}
```

```

if (!error) {
 fetchData();
}
};

return (
 <div className={styles.main}>
 <h2>To-Do items</h2>
 <div className={styles.container}>
 <input
 className={styles.input}
 onChange={(e) => setNewItem(e.target.value)}
 />
 <button className={styles.button} onClick={addItem}>
 Add to list!
 </button>
 </div>
 <List>
 {items.map((item) => (
 <TodoItem
 item={item}
 key={item.id}
 onToggle={handleToggle}
 onDelete={handleDelete}
 />
))}
 </List>
 </div>
);
}

```

## components/TodoItem.jsx

```

“use client”;

import React from “react”;
import styles from “./TodoItem.module.css”;
import ListItem from “@mui/material/ListItem”;
import ListItemButton from “@mui/material/ListItemButton”;
import ListItemIcon from “@mui/material/ListItemIcon”;

```

```

import Checkbox from "@mui/material/Checkbox";
import ListItemText from "@mui/material/ListItemText";
import DeleteIcon from "@mui/icons-material/Delete";
const ToDoItem = ({ item, onToggle, onDelete }) => {
 const handleToggle = () => {
 onToggle(item);
 };
 const handleDelete = () => {
 onDelete(item.id);
 };
 return (
 <ListItem className={styles.item}>
 <ListItemIcon onClick={handleToggle}>
 <Checkbox
 checked={item.is_completed}
 tabIndex={-1}
 className={styles.checkbox}
 />
 </ListItemIcon>
 <ListItemText primary={item.name} />
 </ListItemIcon>
 <ListItemIcon onClick={handleDelete}>
 <DeleteIcon className={styles.delete} />
 </ListItemIcon>
);
};

export default ToDoItem;

```

On clicking the delete button, it will run a Supabase query to delete that specific item from the Supabase table and will refresh the UI.

## Deploying the application

Nice! We have finally added all the necessary features to our application. However, our application is just running locally on our computer, and it

would be awesome if we could share our web app with others hosted on a website. That's exactly what we are going to do in this section!

First, we will upload our repo to our remote GitHub account:

```
git remote add origin [your github repo's address]
git branch -M main
git push -u origin main
```

After this, go to [vercel.com](https://vercel.com) and log in with your GitHub account. Import the todo-app repo from the list and click 'Deploy'. That's it! You have successfully deployed your Next.js app to a website!

## Conclusion

In this chapter, we built a comprehensive CRUD (Create, Read, Update, Delete) application using Next.js 13 and Supabase. The application we designed allows users to manage a to-do list by creating new tasks, marking them as completed, and deleting them. Throughout this process, we demonstrated how to efficiently utilize the robust features of Next.js, such as its React-based framework for rendering components. We also illustrated how Supabase, with its powerful and easy-to-use client-side library, simplifies the handling of data operations in the backend. The combination of Next.js and Supabase empowers us to quickly and efficiently build scalable, serverless applications with enhanced user experiences. This project showcased just a slice of their potential, encouraging further exploration and mastery of these technologies to meet diverse web development needs.

In the next chapter, we will discuss the different ways of deploying a Next.js app by using cloud providers and hosting services.

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## CHAPTER 13

# Exploring Deployment Architecture in Next.js Applications

Deploying a Next.js application effectively is a critical aspect of the development lifecycle, ensuring that your web application reaches its intended audience securely and efficiently. In this chapter, we will dive into the realm of Deployment Architecture, exploring the myriad options available for deploying a Next.js application and providing best practices to optimize the deployment process.

To begin, we will unravel the deployment process in Next.js, understanding the necessary steps involved in taking your application from development to a live environment. This foundational knowledge will set the stage for exploring the various deployment options and considerations.

We will embark on a journey through different hosting platforms, such as Vercel, AWS, and Heroku, among others. You will discover the strengths and features offered by each platform and learn how to deploy your Next.js application seamlessly to these cloud providers. We will guide you through the necessary configurations and steps required to ensure a smooth deployment process.

As you prepare your application for production, we will delve into the crucial task of setting up environment variables specifically tailored for deployment. You will understand the significance of environment variables in managing sensitive information and learn how to configure them effectively for your Next.js application's deployment.

Optimizing the deployment process is essential for a fast and efficient release. We will explore strategies to optimize the deployment process, focusing on techniques that improve performance and reduce downtime. By implementing these best practices, you can ensure a seamless user experience and minimize disruptions during the deployment phase.

In the era of continuous integration and continuous deployment (CI/CD), we will guide you through the process of setting up pipelines specifically designed for Next.js applications. You will learn how to leverage CI/CD tools and frameworks to automate the deployment process, enabling faster and more efficient deployments while maintaining code quality and stability.

Monitoring and debugging deployed applications are crucial for maintaining their health and addressing issues promptly. We will delve into monitoring techniques and tools, empowering you to proactively monitor your deployed Next.js application's performance and address any potential bottlenecks or errors effectively.

Throughout this chapter, we will cover topics including understanding the deployment process in Next.js, deploying Next.js applications to different hosting platforms, setting up environment variables for deployment, configuring Next.js applications for production, optimizing the deployment process for efficiency, setting up CI/CD pipelines for Next.js applications, and monitoring and debugging deployed applications.

By the end of this chapter, you will have a comprehensive understanding of the deployment options available for Next.js applications, enabling you to make informed decisions about the best deployment strategy for your specific use case. So, let's embark on this journey into Deployment Architecture and ensure your Next.js application reaches its full potential in the live environment!

## Structure

In this chapter, we will cover the following topics:

- Understanding the deployment process in Next.js
- Setting up environment variables for deployment
- Configuring the Next.js application for production
- Setting up continuous integration and continuous deployment (CI/CD) pipelines for Next.js applications
- Deploying Next.js applications to different hosting platforms, including Vercel, AWS, and Heroku
- Optimizing the deployment process for faster and more efficient deployments

- Monitoring and debugging deployed applications

## Understanding the deployment process in Next.js

In the context of software development, deployment refers to the process of making a software application available and ready for use by users. It involves taking the code that has been developed and preparing it to run on servers or other computing devices, allowing users to access and interact with the application.

During the deployment process, various tasks are performed, such as compiling code, optimizing resources, configuring settings, and setting up the necessary infrastructure. The goal is to ensure that the application runs smoothly, securely, and efficiently in the intended environment.

### **Types of Deployment Environments**

A deployment environment refers to the computing infrastructure where a software application is deployed and made accessible to users. There are several types of deployment environments, each serving different purposes. Here are some common types:

- **Development Environment**

The development environment is where software developers work on coding, testing, and debugging the application. It typically runs on individual developers' machines and may include development tools, libraries, and databases. This environment is not intended for public use but serves as a sandbox for building and refining the application.

- **Testing/Staging Environment**

The testing or staging environment is a dedicated environment used to thoroughly test the application before it is released to production. It stimulates the production environment as closely as possible and allows for testing different use cases, finding and fixing bugs, and ensuring the application behaves as expected. It helps validate the application's functionality, performance, and compatibility with different systems.

- **Production Environment**

The production environment is the live environment where the application is deployed and made available to users. It is the actual

server or hosting infrastructure where the application runs and serves the intended audience. The production environment must be highly stable, secure, and optimized for performance to handle real-world usage. It often requires additional resources and configurations to ensure reliability, scalability, and high availability.

- **Deployment Platforms**

Deployment platforms are services or hosting providers that facilitate the deployment of applications. These platforms offer various features and support different deployment methods. Some popular deployment platforms include cloud providers like Amazon Web Services (AWS), Microsoft Azure, or Google Cloud Platform, as well as specialized hosting services like Netlify, Vercel, or Heroku. These platforms provide infrastructure, tools, and services to simplify the deployment process and manage the application in different environments.

It's important to note that each deployment environment serves a specific purpose in the software development lifecycle, ensuring that the application is thoroughly tested and performs well before being released to the production environment where users can access and utilize it.

Overall, deployment involves preparing and setting up the application in different environments, each serving its unique role in the development and release process.

### **Different types of deployment processes in Next.js:**

- **Static Hosting**

If your Next.js application is statically generated and doesn't require server-side rendering or API routes, you can deploy it as a set of static files. This approach is suitable for hosting platforms like Netlify, Vercel, or GitHub Pages. To deploy your application using static hosting, follow these steps:

1. Build your Next.js application by running the following command:

```
npm run build
```

2. Generate the static files by running the following command:

```
npm run export
```

3. Upload the generated static files to your chosen hosting platform, either by linking your project repository or using a file transfer method.
4. Configure your hosting platform to serve the static files and make your application accessible to users.

- **Serverless Functions**

Next.js provides an API routes feature that allows you to define serverless functions, which run on-demand and handle server-side logic. This method is useful when your application requires server-side processing, such as form submissions or fetching data from external APIs. You can deploy your Next.js application with serverless functions on platforms like Vercel, AWS Lambda, or Azure Functions. Here's a general outline of the deployment process:

1. Write your serverless functions by creating API route files in the `pages/api` directory of your Next.js project.
2. Build your Next.js application by running the following command:  
`npm run build`
3. Deploy your application to the chosen hosting platform, ensuring that the platform recognizes the API routes and deploys them alongside the application code.
4. Configure any necessary environment variables or deployment settings specific to the hosting platform.

- **Custom Server**

If your Next.js application requires advanced server-side capabilities or integration with specific infrastructure, you can deploy it using a custom server. This approach gives you more control over the server environment and is useful when you need to implement complex routing or interact with external databases or services. The deployment process for a custom server typically involves the following steps:

1. Create a custom server file, such as `server.js`, in your Next.js project.
2. Implement the necessary server logic, including routing and any additional server-side functionality.

3. Build your Next.js application by running the following command:

```
npm run build
```

4. Start the custom server by running the following command:

```
node server.js
```

5. Deploy your custom server to your chosen hosting environment, ensuring that the server script is executed correctly.

It's important to note that the deployment processes may vary based on the specific hosting platform or infrastructure you choose. Therefore, it's recommended to consult the documentation or guides provided by the platform or hosting service you plan to use for deploying your Next.js application.

## **Setting up environment variables for deployment**

Environment variables play a crucial role in the deployment of applications. They are configuration values that are external to the application code and can vary depending on the deployment environment. Environment variables provide a flexible way to store sensitive information, configuration settings, API keys, database credentials, or any other dynamic values required by the application.

Setting up environment variables for deployment involves defining and managing these variables in different environments, such as local development, testing, and production. Let's explore how to set up environment variables for deployment in each of these environments:

### **1. Local Environment**

In the local development environment, you typically set up environment variables to configure your development environment and test the application on your local machine. Here's how you can set up environment variables for local deployment:

- a. Create a `.**env**` file in the root directory of your Next.js project. This file will store your environment variables.
- b. Define your environment variables in the `.**env**` file using the format `KEY=VALUE`. For example:

```
API_KEY=12345
DATABASE_URL=mongodb://localhost:27017/mydatabase
```

- c. In your Next.js application code, access the environment variables using a package like `dotenv` or the built-in `process.env` object. For example, to access the `API\_KEY` variable:

```
const apiKey = process.env.API_KEY;
```
- d. Ensure that the `.env` file is added to your `gitignore` file so that it is not committed to version control, as it may contain sensitive information.

## 2. Test Environment

The test environment is where you deploy your application to conduct comprehensive testing before deploying it to production. The process of setting up environment variables for the test environment is similar to the local environment:

- a. Create a separate `env.test` file to store the environment variables specific to the test environment.
- b. Define the environment variables required for testing in the `env.test` file.
- c. In your test scripts or test framework configuration, load the environment variables from the `env.test` file to ensure the tests use the correct configuration.

## 3. Production Environment

The production environment is the final deployment environment where your application is made available to users. It's crucial to set up environment variables securely and efficiently. Here's a recommended approach:

- a. On the production server or hosting platform, define the environment variables using the mechanisms provided by the hosting service. This might include using a management console, dashboard, or command-line interface specific to the hosting platform.
- b. Avoid storing production environment variables directly in the codebase or configuration files. Instead, securely set the

environment variables on the production server or configure them through the hosting platform's deployment settings.

- c. On the production server, ensure that the environment variables are correctly loaded and accessible by your Next.js application during runtime.

By following these steps, you can set up environment variables for deployment in different environments. Remember to handle sensitive information securely and avoid exposing environment variables in public repositories or insecure channels.

**You can pass environment variables in the script when running your Next.js application locally on both Windows and Linux environments:**

- **Windows Environment**

In Windows, you can set environment variables inline before executing the script using the `set` command. Here's an example:

```
set API_KEY=12345 && npm run dev
```

In the preceding example, `API\_KEY` is set to `12345` before running the `npm run dev` script. You can replace `API\_KEY` and its value with your specific environment variable.

- **Linux Environment**

In Linux, you can set environment variables inline before executing the script using the `export` command. Here's an example:

```
export API_KEY=12345 && npm run dev
```

Similar to the Windows example, `API\_KEY` is set to `12345` before running the `npm run dev` script. Again, you can replace `API\_KEY` and its value with your specific environment variable.

Alternatively, you can store the environment variables in a separate file and load them before running the script.

- **Separate file method in Windows Environment**

In Windows, you can create a separate file, for example, `env.bat`, and use the `set` command to define your environment variables. Here's an example:

```
@echo off
set API_KEY=12345
```

```
set DATABASE_URL=mongodb://localhost:27017/mydatabase
```

Save the file, and then run the script by executing it before running the `npm run dev` script:

```
call env.bat && npm run dev
```

- **Separate file method in Linux Environment**

In Linux, you can create a separate file, for example, `env.sh`, and use the `export` command to define your environment variables. Here's an example:

```
#!/bin/bash
export API_KEY=12345
export DATABASE_URL=mongodb://localhost:27017/mydatabase
```

Save the file, and then run the script by executing it before running the `npm run dev` script:

```
source env.sh && npm run dev
```

By using either the inline method or the separate file method, you can pass environment variables to the script when running your Next.js application locally in both Windows and Linux environments.

**A step-by-step guide to setting up a GitHub workflow action configuration file for testing, building, and implementing CI/CD for your Next.js application:**

### **Step 1: Create a GitHub Workflow File:**

- In your Next.js project's repository on GitHub, navigate to the `/.github/workflows` directory.
- Create a new YAML file (for example, `ci-cd.yml`) in the `/.github/workflows` directory to define your workflow.

### **Step 2: Define Workflow Triggers:**

- Specify the events that trigger your workflow. For example, you can trigger the workflow on push events to the `main` branch or on pull requests:

```
name: CI/CD Workflow
on:
 push:
 branches:
```

```

 - main
pull_request:
 branches:

Step 3: Define Workflow Jobs:

• Define jobs within your workflow. For example, you can have separate
jobs for testing, building, and deployment:

jobs:
 test:
 name: Test
 runs-on: ubuntu-latest
 steps:
 - name: Checkout code
 uses: actions/checkout@v2
 - name: Install dependencies
 run: npm ci
 - name: Run tests
 run: npm run test
 build:
 name: Build
 runs-on: ubuntu-latest
 steps:
 - name: Checkout code
 uses: actions/checkout@v2
 - name: Install dependencies
 run: npm ci
 - name: Build Next.js app
 run: npm run build
 deploy:
 name: Deploy
 needs: [build]
 runs-on: ubuntu-latest
 steps:
 - name: Checkout code
 uses: actions/checkout@v2
 - name: Install dependencies

```

```
 run: npm ci
- name: Deploy to AWS/Heroku/Vercel
 run: |
 # Add deployment commands here
```

#### **Step 4: Configure Testing:**

- Add appropriate testing commands and configurations within the `test` job.

#### **Step 5: Configure Building:**

- Add commands and configurations to build your Next.js application within the `build` job.

#### **Step 6: Configure Deployment:**

- Add the necessary deployment commands or scripts within the `deploy` job. Depending on your deployment target (AWS, Heroku, Vercel), you'll need to use the appropriate commands and configurations.

#### **Step 7: Commit and Push Workflow File:**

- Commit and push the workflow file (`ci-cd.yml`) to your repository.

#### **Step 8: GitHub Actions Execution:**

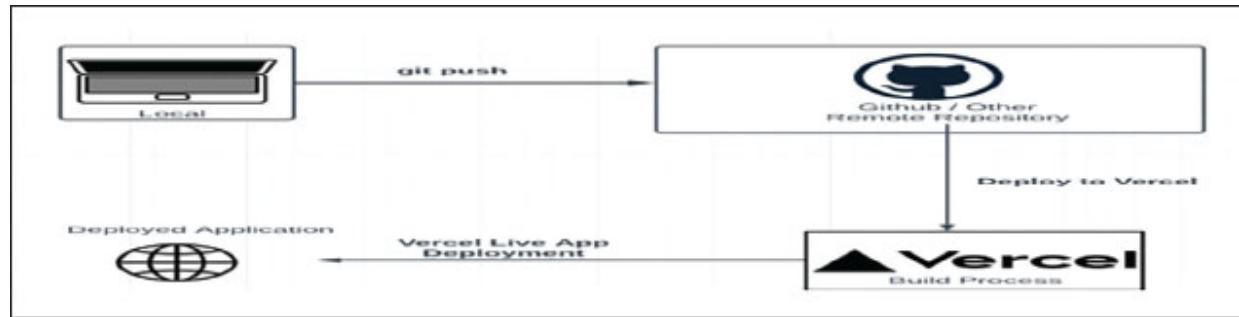
- GitHub Actions will automatically execute the defined workflow whenever the specified events are triggered (for example, on push or pull requests to the `main` branch).
- The workflow will run the defined jobs sequentially (for example, testing, building, and deployment) based on the dependencies specified using `needs` in the `deploy` job.

That's it! You have set up a GitHub workflow action configuration file to test, build, and implement CI/CD for your Next.js application. Customize the workflow file based on your specific requirements and deployment targets.

## **Deploying Next.js applications to different hosting platforms**

Deploying Next.js applications to different hosting platforms involves a few specific steps for each platform. This overview includes the deployment process for Vercel, Heroku, and AWS, along with code examples to help in navigating through the process.

## 1. Deploying Next.js Applications to Vercel



**Figure 13.1:** Vercel Deployment process

To deploy a Next.js application using Vercel, perform the following steps:

### Step 1: Install the Vercel CLI globally

Make sure you have Node.js and npm installed. Then, open your terminal and run the following command:

```
npm install -g vercel
```

### Step 2: Build the Next.js application

Navigate to your Next.js project directory in the terminal and run the following command to build your application:

```
npm run build
```

### Step 3: Create a `vercel.json` file

Create a `vercel.json` file in the root directory of your project and add the desired configurations. Here's an example of a basic `vercel.json` file:

```
{
 "version": 2,
 "builds": [
 {
 "src": "next.config.js",
 "use": "@vercel/next"
```

```

 },
],
 "routes": [
 { "src": "/api/(.*)", "dest": "api/$1" },
 { "src": "/blog", "dest": "/blog/index.html" },
 { "src": "/blog/(.*)", "dest": "/blog/$1.html" },
 { "src": "/(.*)", "dest": "/$1" }
],
 "env": {
 "API_URL": "https://api.example.com",
 "API_KEY": "@env-api-key"
 },
 "rewrites": [
 { "source": "/user/:id", "destination": "/profile?id=:id" }
],
 "redirects": [
 { "source": "/about", "destination": "/company/about",
 "statusCode": 301
 }
]
}

```

Let's break down the different sections of the `vercel.json` configuration:

- **`version`**: Specifies the version of the configuration file. Use `2` for the latest version.
- **`builds`**: Defines the build settings for your Next.js application. In this example, we use the `@vercel/next` builder, which is the default builder for Next.js projects.
- **`routes`**: Configures routing rules for your application. Each route has a `src` and `dest` property. In this example, we define routes for API endpoints, blog pages, and a catch-all route.
- **`env`**: Allows you to define environment variables for your application. You can specify custom values or use the `@env-variable` syntax to load the value from the Vercel project's environment variables.
- **`rewrites`**: Specifies URL rewrites for your application. In this example, we rewrite `/user/:id` to `/profile?id=:id`.

- `redirects`: Configures URL redirects. In this example, requests to `/about` will be redirected to `/company/about` with a `301` status code.

## Step 4: Log in to your Vercel account via the CLI

Run the following command and follow the authentication prompts:

```
vercel login
```

## Step 5: Deploy the application

In the terminal, navigate to your project directory and run the following command:

```
Vercel
```

Vercel will guide you through the deployment process, and once completed, it will provide you with a deployment URL.

## 2. Deploying Next.js Applications to Heroku

To deploy a Next.js application using Heroku, follow these steps:

### Step 1: Sign up for a Heroku account

If you don't already have a Heroku account, go to the Heroku website (<https://www.heroku.com/>) and sign up for a free account.

### Step 2: Install the Heroku CLI

Download and install the Heroku CLI (Command Line Interface) appropriate for your operating system. You can find the installation instructions on the Heroku Dev Center website: <https://devcenter.heroku.com/articles/heroku-cli#download-and-install>

### Step 3: Prepare your application for deployment

Ensure that your Next.js project is ready for deployment. Make sure you have a `package.json` file in the root directory and that the necessary dependencies are listed.

### Step 4: Create a `Procfile`

In the root directory of your Next.js project, create a file named `Procfile` (without any file extensions). Open the `Procfile` and add the following line:

```
web: npm start
```

This line tells Heroku how to start your application.

## **Step 5: Initialize Git and commit your project**

In the terminal, navigate to your project directory and run the following commands to initialize Git and commit your project:

```
git init
git add .
git commit -m "Initial commit"
```

## **Step 6: Log in to Heroku via the CLI**

Run the following command and follow the prompts to log in to your Heroku account via the CLI:

```
heroku login
```

## **Step 7: Create a new Heroku app**

Run the following command to create a new app on Heroku:

```
heroku create
```

This command will generate a unique name for your app.

## **Step 8: Deploy your application to Heroku**

To deploy your application, run the following command:

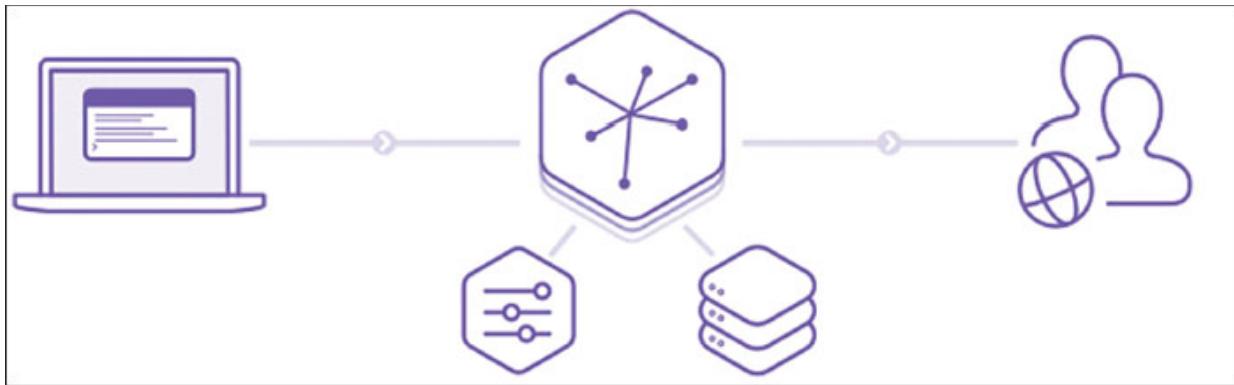
```
git push heroku master
```

## **Step 9: Open the deployed application**

Once the deployment process is complete, Heroku will provide you with a deployment URL. You can open your deployed application by running the following command:

```
heroku open
```

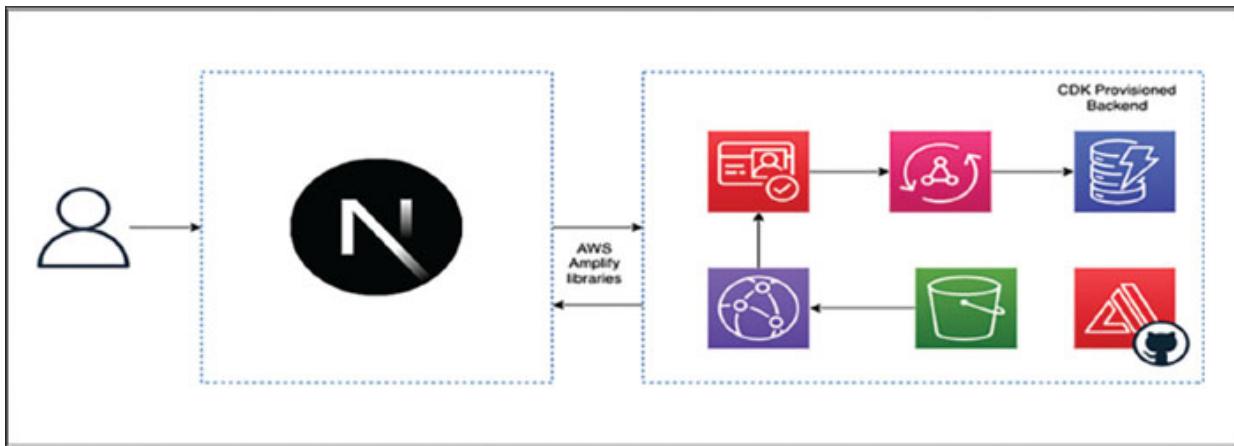
By following these steps, you can successfully deploy your Next.js application to Heroku. Remember to consult the official Heroku documentation for any additional steps or configurations specific to your application: <https://devcenter.heroku.com/categories/nodejs-support>



**Figure 13.2:** Heroku Deployment process

### 3. Deploying Next.js Applications to AWS

To deploy a Next.js application using AWS Amplify, follow these detailed steps, along with code examples:



**Figure 13.3:** AWS Deployment Process

#### Step 1: Set up an AWS Amplify Project

- a. Sign in to the AWS Management Console and navigate to the AWS Amplify service.
- b. Click “**Get Started**” or “**Create App**” to create a new Amplify app.
- c. Choose your preferred Git provider (for example, GitHub, GitLab, Bitbucket) and connect your repository.
- d. Select the branch you want to deploy from and specify the build settings. For Next.js applications, set the following values:
  - i. **Framework:** Other

- ii. **Build command:** `npm run build`
  - iii. **Start command:** `npm run start`
- e. Configure the domain settings if you want to use a custom domain. Otherwise, Amplify will provide a default domain for your app.
  - f. Review the settings and click “Next” to create the Amplify app.

## Step 2: Set up Build and Deployment Configuration

- a. In the Amplify console, click your app to access the app details.
- b. Under “**App Settings**,” click “**Build settings**” to configure the build and deployment settings.
- c. Check the “**Edit**” button for the branch you want to configure (usually “master” or “main”).
- d. Ensure the following settings are correctly configured:
  - i. **Build command:** `npm run build`
  - ii. **Start command:** `npm run start`
- a. Click “Save and Deploy” to save the configuration.

## Step 3: Deploy the Next.js Application

- a. After saving the configuration, click “**Deploy**” to start the deployment process.
- b. Amplify will automatically clone your repository, build your Next.js application, and deploy it using AWS resources.
- c. The deployment progress will be shown in the Amplify console. Wait for the deployment to complete successfully.

## Step 4: Access Your Deployed Next.js Application

- a. Once the deployment is completed, Amplify will provide you with a URL to access your deployed Next.js application.
- b. Open a web browser and visit the provided URL to see your deployed application in action.

## Step 5: Continuous Deployment (Optional)

To enable continuous deployment, which automatically deploys updates to your application whenever you push changes to your repository:

- a. In the Amplify console, go to your app's settings.
- b. Under **Branches**, click the branch you want to enable continuous deployment for.
- c. Toggle the **Manual Deploy** switch to **Auto Deploy**.
- d. Click **Save** to enable continuous deployment.

### **Now let's look at a code example for a simple Next.js application:**

1. In your Next.js project, ensure you have the following scripts in your `package.json` file:

```
{
 "scripts": {
 "build": "next build",
 "start": "next start"
 }
}
```

2. Commit and push your Next.js project to the connected Git repository (for example, GitHub).
3. Follow the preceding steps to set up an AWS Amplify app and connect it to your repository.
4. After the deployment is completed, Amplify will automatically build and deploy your Next.js application using the specified scripts.
5. Access your deployed Next.js application using the provided URL.

That's it! You have successfully deployed your Next.js application using AWS Amplify. Amplify simplifies the deployment process, allowing you to focus on developing your application.

## **Optimizing the deployment process for faster and more efficient deployments**

Optimizing the deployment process for faster and more efficient deployments involves implementing various strategies and best practices. Here is a step-by-step guide to help you optimize your deployment process:

## **Step 1: Optimize Build Process**

- **Minify and Bundle Assets:** Minify your JavaScript, CSS, and HTML files to reduce their file size and improve load times. Use tools like UglifyJS or Terser to minify JavaScript, and CSS minifiers for CSS files.
- **Code Splitting:** Implement code splitting techniques to split your application code into smaller chunks. This allows for the lazy loading of components and reduces the initial load time of your application.
- **Enable Compression:** Enable compression on your server to reduce the size of transferred files. Gzip and Brotli are commonly used compression algorithms.
- **Optimize Images:** Compress and optimize images to reduce their file size. Tools like ImageOptim, TinyPNG, or Squoosh can help with image optimization.
- **Use Server-Side Rendering (SSR):** Implement server-side rendering to pre-render pages on the server and reduce the initial load time for users.

## **Step 2: Implement Caching**

- **Use Content Delivery Networks (CDNs):** Utilize CDNs to cache static assets and serve them from edge servers closer to the user, reducing latency and improving performance.
- **Implement Browser Caching:** Set appropriate caching headers for static assets to enable browser caching. This allows the browser to store assets locally and avoid unnecessary network requests.
- **Use Cache-Control Headers:** Set Cache-Control headers to specify caching directives for static assets. Use tools like AWS CloudFront or Vercel to configure caching settings.

## **Step 3: Automation and Continuous Integration/Deployment (CI/CD):**

- **Set up CI/CD Pipelines:** Use CI/CD tools like Jenkins, CircleCI, or GitHub Actions to automate the build, testing, and deployment process. Configure pipelines to trigger deployments on code changes or specific events.

- **Parallelize Build and Deployment Steps:** Split your deployment process into parallel steps to speed up the overall deployment. For example, you can run tests, build assets, and deploy to different environments simultaneously.
- **Use Rolling Deployments:** Implement rolling deployments to update your application gradually instead of all at once. This reduces downtime and ensures a smoother transition for users.
- **Canary Deployments:** Implement canary deployments to test new features or updates on a small subset of users before rolling them out to the entire user base. This helps catch issues early and mitigate risks.

#### **Step 4: Monitoring and Performance Optimization**

- **Monitor Performance Metrics:** Use tools like Google Analytics, New Relic, or AWS CloudWatch to monitor performance metrics such as response time, page load time, and resource usage. Identify bottlenecks and areas for improvement.
- **Continuous Performance Optimization:** Continuously analyze and optimize your application's performance by identifying and resolving performance issues, optimizing database queries, and improving code efficiency.
- **Implement A/B Testing:** Conduct A/B testing to experiment with different versions of your application and measure their impact on performance. This helps identify changes that positively impact user experience.
- **Performance Budgeting:** Set performance budgets to define limits for metrics such as file size, number of requests, or load time. Ensure your application stays within these limits to maintain optimal performance.

By following these steps, you can optimize the deployment process for your Next.js application, resulting in faster and more efficient deployments. Regularly monitor and fine-tune your deployment process to adapt to changing requirements and leverage the latest technologies and best practices.

### **Configuring the Next.js application for production**

Configuring a Next.js application for production involves optimizing the application's performance, security, and scalability to ensure it runs smoothly and efficiently in a production environment. Here are the key aspects to consider when configuring a Next.js application for production:

- **Environment-specific Configuration**

Use environment variables to store configuration values that differ between development, staging, and production environments. These variables can include API keys, database connection strings, feature flags, or any other sensitive information. By separating configuration from code, you can easily manage and update settings specific to each environment without modifying the application's source code.

- **Performance Optimization**

To improve performance, implement the following techniques:

- **Code Minification:** Enable code minification to reduce the size of JavaScript and CSS files. This can be achieved using tools like Webpack or the Next.js built-in optimization features. Minification eliminates unnecessary characters, whitespace, and comments, resulting in faster loading times for users.
- **Server-side Rendering (SSR):** Utilize Next.js's server-side rendering capabilities to generate HTML on the server before sending it to the client. SSR improves initial page load times and enables search engines to index your site more effectively.
- **Client-side Optimization:** Leverage code splitting and lazy loading to ensure that only the necessary code is loaded initially. This improves performance by reducing the initial payload size and deferring the loading of non-critical resources until they are required.
- **Image Optimization:** Use Next.js's built-in Image component, which automatically optimizes images by compressing and resizing them. This reduces the image file size without sacrificing visual quality and improves overall page load times.
- **Caching:** Implement caching mechanisms to reduce server load and improve response times. You can leverage Next.js's built-in support for server-side caching or use caching solutions like

Varnish or Redis to cache frequently accessed data or rendered pages.

- **Security Measures**

Take the following security measures to protect your Next.js application:

- **Secure Communication:** Enforce HTTPS for all communication between clients and servers. Use SSL certificates to encrypt data in transit and prevent unauthorized access or tampering.
- **Input Validation:** Validate and sanitize user input to prevent common security vulnerabilities like cross-site scripting (XSS) and SQL injection attacks. Utilize libraries like Yup or Joi for input validation and avoid directly executing user-supplied data in queries or commands.
- **Authentication and Authorization:** Implement robust authentication and authorization mechanisms to control access to sensitive areas or data. Use libraries like Passport.js or NextAuth.js to handle user authentication and authorization flows securely.
- **Access Control:** Ensure that only authorized users can perform privileged actions by implementing proper access control mechanisms. Apply the principle of least privilege, granting users only the permissions necessary for their roles or responsibilities.
- **Error Handling:** Implement proper error handling and error logging to prevent sensitive information from being exposed to users. Display user-friendly error messages while logging detailed errors for debugging purposes.

- **Scalability and Deployment**

Prepare your Next.js application for scalability and efficient deployment:

- **Load Balancing:** Set up load balancing to distribute incoming traffic across multiple servers. Load balancers like AWS Elastic Load Balancer (ELB) or Nginx can help distribute the workload and ensure high availability.

- **Horizontal Scaling:** Design your application to be horizontally scalable, allowing you to add or remove instances dynamically based on demand. Utilize containerization technologies like Docker or orchestration platforms like Kubernetes to facilitate easy scaling.
- **Automated Deployment:** Implement continuous integration and continuous deployment (CI/CD) pipelines to automate the deployment process. Tools like Jenkins, Travis CI, or AWS CodePipeline can help you automate builds, tests, and deployments, ensuring a smooth and efficient release cycle.
- **Performance Monitoring:** Utilize monitoring tools like New Relic, Datadog, or AWS CloudWatch to monitor the performance of your Next.js application in production. Monitor metrics like response times, server load, and resource utilization to identify performance bottlenecks or scaling needs.

By following these configuration practices, you can optimize the performance, security, and scalability of your Next.js application, ensuring its smooth operation in a production environment.

## [\*\*Setting up \(CI/CD\) pipelines for Next.js applications\*\*](#)

Setting up continuous integration and continuous deployment (CI/CD) pipelines for Next.js applications involve automating the process of building, testing, and deploying your application whenever changes are made. This ensures that your codebase is continuously integrated, tested, and deployed to various environments. Here's a step-by-step guide for setting up CI/CD pipelines for Next.js applications, including GitHub workflows for running tests and building:

### **1. Version Control System**

Start by using a version control system (VCS) like Git to manage your Next.js application's source code. Create a Git repository to store and track changes to your project.

### **2. Choose a CI/CD Service**

Select a CI/CD service that integrates with your Git repository. Popular options include GitHub Actions, GitLab CI/CD, and Travis CI. In this guide, we'll focus on GitHub Actions.

### 3. Configure GitHub Actions

Enable GitHub Actions in your repository by navigating to the “Actions” tab and following the setup instructions. This will allow you to define workflows that automatically trigger certain actions based on events like pushes, pull requests, or scheduled intervals.

### 4. Create a Workflow File

Inside your repository, create a `.**github/workflows**` directory if it doesn't exist. In that directory, create a YAML file (for example, `main.yml`) to define your workflow. This file will contain the necessary steps for running tests and building your Next.js application.

### 5. Define Test Workflow

In the workflow file, define a job for running tests. This typically includes steps like checking out the repository, setting up the Node.js environment, installing dependencies, and executing tests. Here's an example:

```
```yaml
name: Test
on:
  push:
    branches:
      - main
jobs:
  test:
    runs-on: ubuntu-latest
    steps:
      - name: Checkout repository
        uses: actions/checkout@v2
      - name: Set up Node.js
        uses: actions/setup-node@v2
        with:
          node-version: '14'
```

```
- name: Install dependencies  
run: npm ci  
  
- name: Run tests  
run: npm test  
```
```

## 6. Define Build Workflow

Next, define a job for building your Next.js application. This job depends on the successful completion of the test job. Here's an example:

```
```yaml  
name: Build  
  
on:  
  push:  
    branches:  
      - main  
  
jobs:  
  test:  
    runs-on: ubuntu-latest  
    steps:  
      - name: Checkout repository  
        uses: actions/checkout@v2  
  
      - name: Set up Node.js  
        uses: actions/setup-node@v2  
        with:  
          node-version: '14'  
  
      - name: Install dependencies  
        run: npm ci  
      - name: Build Next.js app  
        run: npm run build  
```
```

## 7. Commit and Push

Commit the workflow file(s) to your repository and push the changes. This will trigger the defined workflows in your CI/CD pipeline.

## 8. Test and Build

GitHub Actions will now automatically execute the defined workflows whenever there are new commits or pull requests targeting the `main` branch. The “Test” workflow will run tests, and if successful, the “Build” workflow will build your Next.js application.

By following these steps, you can set up CI/CD pipelines for your Next.js application using GitHub Actions. These pipelines will automatically run tests and build your application whenever changes are made, helping you catch issues early and ensure the readiness of your code for deployment.

## Monitoring and debugging deployed applications

Monitoring and debugging deployed applications in Next.js involve using various tools and techniques to identify and resolve issues that may arise in a production environment. Next.js, a popular framework for building React applications, offers built-in features and integrates well with deployment platforms like Vercel and AWS. Let’s dive into the details of monitoring and debugging in Next.js with Vercel and AWS:

- **Monitoring Deployed Applications**

Monitoring allows you to track the health, performance, and availability of your deployed Next.js applications. It helps you identify and address issues promptly. Here are some monitoring techniques for Next.js:

- **Logging:** Implement robust logging in your Next.js application to capture relevant events, errors, and debugging information. You can use libraries like Winston or Pino to handle logging. Log messages can be stored in various locations, such as local files, remote servers, or third-party logging services like Loggly or Papertrail.
- **Error Tracking:** Integrate error tracking services like Sentry or Rollbar into your Next.js application. These services collect and analyze errors occurring in your application and provide detailed information about the source, stack trace, and context of the errors. They often include features like real-time alerts and issue grouping for efficient debugging.

- **Performance Monitoring:** Utilize tools like New Relic or Datadog to monitor the performance of your Next.js application. These tools can capture metrics related to response times, server load, database queries, and other performance-related aspects. They provide insights into potential bottlenecks or areas for optimization.
  - **Application Metrics:** Instrument your Next.js application to capture custom metrics specific to your application's behavior. You can use libraries like Prometheus or StatsD to collect and store metrics related to business-specific processes or user interactions. These metrics can help you identify patterns, track trends, and make data-driven decisions for improvements.
- **Debugging Deployed Applications:**  
Debugging deployed Next.js applications involves investigating and resolving issues that impact the functionality or performance of the application. Here are some debugging techniques for Next.js:
    - **Remote Debugging:** Use remote debugging tools like Chrome DevTools or VS Code's remote debugging capabilities to attach to your running Next.js application in the production environment. This allows you to inspect variables, step through code, and capture runtime information for troubleshooting.
    - **Error Analysis:** Analyze error logs, stack traces, and error messages to identify the root causes of issues. Leverage logging and error-tracking services to gather relevant information. Pay attention to specific error patterns, user reports, or any anomalous behavior to pinpoint the source of the problem.
    - **Load Testing:** Perform load testing using tools like Apache JMeter or Artillery to simulate high-traffic scenarios. By subjecting your Next.js application to increased load, you can uncover performance issues, scalability limitations, or resource bottlenecks that may impact its stability or responsiveness.
    - **A/B Testing and Feature Flags:** Employ A/B testing techniques and feature flags to gradually roll out new features or changes. This allows you to isolate and analyze the impact of specific changes on the deployed Next.js application. By selectively

enabling or disabling features, you can identify if a particular feature is causing issues or performance degradation.

- **Code Monitoring:** Utilize code monitoring services like Epsagon or TrackJS to track and trace issues within your Next.js application's codebase. These services can provide insights into code execution and performance hotspots, and help identify potential areas of improvement.

- **Next.js with Vercel**

Vercel is a popular deployment platform for Next.js applications. It simplifies the deployment process and provides additional monitoring and debugging features:

- **Deployment Hooks:** Vercel allows you to set up deployment hooks, which are HTTP endpoints triggered after a successful deployment. You can use these hooks to trigger custom monitoring scripts or notify external services about the deployment status.
- **Environment Variables:** Vercel allows you to manage environment variables for your Next.js application, including those related to monitoring and debugging. This enables you to configure different settings for different environments and integrate with third-party services seamlessly.
- **Analytics:** Vercel provides built-in analytics to monitor the performance and usage of your Next.js application. It tracks metrics like request count, response time, and bandwidth usage, allowing you to assess the application's behavior and make informed decisions.

- **Next.js with AWS**

AWS offers a range of services that can enhance monitoring and debugging capabilities for Next.js applications:

- **AWS CloudWatch:** CloudWatch allows you to collect and monitor logs, set up alarms, and visualize performance metrics. You can integrate Next.js application logs with CloudWatch Logs and configure custom metrics for tracking specific application behaviors.

- **AWS X-Ray:** X-Ray helps trace requests through your Next.js application and identify performance bottlenecks or errors. It provides a visual representation of the request flow, including latency data, to help you pinpoint problematic components.
- **AWS Lambda Layers:** If you’re using Next.js with serverless deployments using AWS Lambda, you can leverage Lambda Layers to include additional debugging and monitoring libraries in your function environment. This enables you to capture logs, metrics, and errors specific to your serverless functions.
- **AWS CloudFormation:** CloudFormation allows you to define your Next.js infrastructure as code. You can use CloudFormation templates to configure monitoring resources, such as alarms, logging destinations, or custom metrics, as part of your infrastructure provisioning process.

In summary, monitoring and debugging deployed Next.js applications involve implementing logging, error tracking, performance monitoring, and debugging techniques. Deployment platforms like Vercel and cloud providers like AWS offer additional features and services to enhance monitoring and debugging capabilities. By leveraging these tools effectively, you can ensure the stability, performance, and reliability of your Next.js applications in production environments.

## Conclusion

This final chapter of the book has provided a thorough exploration of deployment architecture in Next.js applications. As the culmination of our journey, we have delved into the intricacies of deploying a Next.js application effectively, ensuring it reaches its intended audience securely and efficiently.

We began by unraveling the deployment process in Next.js, understanding the necessary steps involved in taking an application from development to a live environment. This foundational knowledge set the stage for exploring the various deployment options and considerations.

Throughout this chapter, we embarked on a journey through different hosting platforms such as Vercel, AWS, and Heroku, among others. We discovered the strengths and features offered by each platform and learned

how to deploy our Next.js applications seamlessly to these cloud providers. We were guided through the necessary configurations and steps required to ensure a smooth deployment process.

Moreover, we emphasized the significance of environment variables specifically tailored for deployment, understanding their role in managing sensitive information and how to configure them effectively for our Next.js applications.

Furthermore, we explored strategies to optimize the deployment process, focusing on techniques that improve performance and reduce downtime. By implementing these best practices, we can ensure a seamless user experience and minimize disruptions during the deployment phase.

In the era of continuous integration and continuous deployment (CI/CD), we also discussed setting up pipelines specifically designed for Next.js applications. Leveraging CI/CD tools and frameworks, we can automate the deployment process, enabling faster and more efficient deployments while maintaining code quality and stability.

Finally, we delved into monitoring and debugging techniques and tools, empowering us to proactively monitor our deployed Next.js applications' performance and address any potential bottlenecks or errors effectively.

In summary, this final chapter equipped us with a comprehensive understanding of the deployment options available for Next.js applications. By incorporating the knowledge and best practices shared, we can make informed decisions about the best deployment strategy for our specific use cases. Let us embrace this knowledge and ensure our Next.js applications reach their full potential in the live environment.

## **Multiple choice questions**

1. What is the focus of this chapter?
  - A. Database management in Next.js applications
  - B. Performance optimization in Next.js applications
  - C. Deployment architecture in Next.js applications
  - D. User interface design in Next.js applications
2. Which hosting platforms are mentioned in this chapter?

- A. Firebase and MongoDB Atlas
  - B. Netlify and Azure
  - C. Vercel, AWS, and Heroku
  - D. GitHub Pages and DigitalOcean
3. What is the significance of environment variables in deployment?
- A. They enhance the visual appearance of the application
  - B. They improve the performance of the application
  - C. They manage sensitive information for the application
  - D. They automate the deployment process
4. What is one of the topics covered in this chapter?
- A. Implementing advanced data structures in Next.js applications
  - B. Designing user-friendly forms in Next.js applications
  - C. Setting up CI/CD pipelines for Next.js applications
  - D. Exploring machine learning algorithms in Next.js applications
5. Why is monitoring and debugging important for deployed applications?
- A. To increase the application's security.
  - B. To optimize the deployment process.
  - C. To ensure code quality and stability.
  - D. To enhance the application's user interface.

## Answers

- 1. C
- 2. C
- 3. C
- 4. C
- 5. C

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