Designing GraphQL APIs for Modular Table Queries Using NestJS

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***Abstract*—Modern applications often require seamless interaction with various database tables through APIs. GraphQL, coupled with NestJS, provides a powerful approach for defining APIs within a modular architecture, enabling efficient and scalable data retrieval. This paper explores the design of GraphQL APIs tailored for querying database tables while adhering to modular principles. Key metrics include functional query architecture, reusability, and efficient data management.**

I. Introduction

As applications grow in complexity, efficient data retrieval and management become critical for performance and scalability. Traditional REST APIs, while widely used, often struggle with over-fetching and under-fetching data. GraphQL addresses these challenges by enabling clients to request only the data they need. This results in reduced bandwidth usage and improved performance.

NestJS, a progressive Node.js framework, complements GraphQL by offering a robust and modular architecture for server-side development. By combining these technologies, developers can create APIs that are not only efficient but also maintainable and scalable. This paper outlines the process of designing modular GraphQL APIs for interacting with database tables, highlighting key architectural principles and implementation steps.

II. GraphQL Query Definitions

GraphQL organizes data interactions through types, queries, and resolvers. It provides a flexible, efficient way to define interactions with the backend data, offering fine-grained control over what data is fetched. For each database table, GraphQL defines tailored queries to handle common use cases. This modularity simplifies development and enhances scalability, as it allows developers to define only the necessary queries and mutations that meet the needs of the frontend.

A. Core Queries for Database Tables

The following are standard query patterns that can be implemented for each table:

1) **Fetch All Records:** Returns all rows from the table. This query is useful for displaying large datasets where the frontend needs to render a list of all available records. This can be optimized with pagination or filtering to reduce the data load.
2) **Fetch by ID:** Retrieves a single record based on its unique identifier. This is commonly used for detail pages or record-specific operations, where the frontend needs the full information of a specific item.
3) **Custom Queries:** These queries allow developers to combine and transform data across multiple tables. They can be tailored to the specific business logic requirements, such as aggregating data or applying complex filters.

B. Example: User Table Queries

The following GraphQL schema demonstrates basic queries for a ‘User‘ table. These queries allow fetching a list of all users or a specific user by their unique identifier (ID).

```
type Query {
    users: [User]         # Fetch all users
    user(id: ID!): User   # Fetch a single
    user by ID
}

type User {
    id: ID!
    firstName: String
    lastName: String
    email: String
    phone: String
}
```

Listing 1: GraphQL Schema for User Table

In the above schema, the ‘users‘ query returns a list of all users, while the ‘user‘ query returns a single user based on the provided ‘id‘. The ‘User‘ type defines the shape of the data returned by the queries.

III. Implementation in NestJS

NestJS leverages decorators, dependency injection, and a modular architecture to streamline the creation of GraphQL APIs. The process involves defining modules, resolvers, and services to handle the GraphQL queries and their corresponding business logic. This structured approach ensures that the application remains maintainable, scalable, and testable.

Step 1: Create Modules

Each database table is represented as a module in NestJS. This modularity ensures that the architecture remains organized and manageable. A module in NestJS encapsulates all

the necessary components for a specific functionality, such as resolvers, services, and other dependencies.

For instance, to define a ‘User‘ module, we would import the necessary components and define the module as follows:

```
@Module({
    imports: [GraphQLModule], # Import GraphQL
        module for API functionality
    providers: [UserResolver, UserService], #
        Add resolver and service providers
})
export class UserModule {}
```

Listing 2: User Module Definition

In this example, the ‘UserModule‘ imports the ‘GraphQLModule‘ and provides the ‘UserResolver‘ and ‘UserService‘. The ‘UserResolver‘ is responsible for handling the GraphQL queries, and the ‘UserService‘ interacts with the database to fetch data.

Step 2: Define Resolvers

Resolvers in GraphQL map the queries and mutations to their corresponding business logic. In NestJS, resolvers are defined as classes decorated with the ‘@Resolver()‘ decorator. These resolvers receive queries as methods and return data to the client.

Here’s an example of a ‘UserResolver‘ that handles the ‘users‘ and ‘user‘ queries:

```
@Resolver(of => User)
export class UserResolver {
    constructor(private userService:
        UserService) {}

    @Query(returns => [User])
    async users() {
        return this.userService.findAll(); #
            Fetch all users using UserService
    }

    @Query(returns => User)
    async user(@Args('id') id: string) {
        return this.userService.findById(id); #
            Fetch a single user by ID
    }
}
```

Listing 3: User Resolver

In this example: - The ‘@Query()‘ decorator defines GraphQL query resolvers. - The ‘users()‘ method calls the ‘findAll()‘ method of the ‘UserService‘ to retrieve all user records. - The ‘user()‘ method takes an ‘id‘ argument and calls the ‘findById()‘ method of the ‘UserService‘ to fetch the specific user by ID.

Step 3: Implement Services

The service layer in NestJS is responsible for handling database operations and ensuring business logic is separate from the API logic. This separation of concerns allows the GraphQL resolvers to remain focused on data retrieval, while the services handle actual data manipulation and querying.

Here’s an example of the ‘UserService‘ which performs the actual database operations:

```
@Injectable()
export class UserService {
    constructor(@InjectRepository(User)
        private userRepository:
        Repository<User>) {}

    // Fetch all users from the database
    async findAll(): Promise<User[]> {
        return await this.userRepository.find();
    }

    // Fetch a single user by their ID
    async findById(id: string): Promise<User> {
        return await
            this.userRepository.findOne(id);
    }
}
```

Listing 4: User Service

In this example: - The ‘UserService‘ class is marked with ‘@Injectable()‘, making it available for dependency injection in other parts of the application. - The ‘userRepository‘ is injected into the service using NestJS’s ‘@InjectRepository()‘ decorator. This repository handles interactions with the database. - The ‘findAll()‘ method returns all users from the database, and ‘findById()‘ fetches a user based on their unique ‘id‘.

Step 4: Additional Custom Queries

In addition to basic queries, developers can create custom queries that join data from multiple tables, apply filters, or return aggregated results. For example, a query to fetch users along with their related posts might look like this:

```
@Query(returns => [User])
async usersWithPosts() {
    return
        this.userService.findUsersWithPosts();
        # Custom logic to fetch users with
        related posts
}
```

Listing 5: Custom Query for User with Posts

The ‘findUsersWithPosts()‘ method in the ‘UserService‘ would implement the custom logic, potentially using SQL joins or additional data transformations to fetch and return users along with their related posts.

Step 5: Testing and Validation

It is essential to ensure the accuracy and performance of GraphQL queries. Testing can be performed at both the resolver and service layers. Unit tests can validate that the resolvers correctly map the queries to the service methods, and integration tests can ensure that the entire GraphQL endpoint works as expected.

To write tests for a resolver, NestJS provides utilities such as ‘@nestjs/testing‘ to create isolated tests for individual components. For example, testing the ‘UserResolver‘ might

involve checking that the correct service methods are called and that the data returned matches expectations.

```
import { Test, TestingModule } from
    '@nestjs/testing';
import { UserResolver } from
    './user.resolver';
import { UserService } from './user.service';

describe('UserResolver', () => {
   let resolver: UserResolver;
   let service: UserService;

   beforeEach(async () => {
      const module: TestingModule = await
          Test.createTestingModule({
         providers: [UserResolver,
             UserService],
      }).compile();

      resolver =
          module.get<UserResolver>(UserResolver);
      service =
          module.get<UserService>(UserService);
   });

   it('should return all users', async () => {
      const result = [{ id: '1', firstName:
          'John', lastName: 'Doe' }];
      jest.spyOn(service,
          'findAll').mockResolvedValue(result);

      expect(await
          resolver.users()).toBe(result);
   });

   it('should return a user by ID', async ()
       => {
      const result = { id: '1', firstName:
          'John', lastName: 'Doe' };
      jest.spyOn(service,
          'findById').mockResolvedValue(result);

      expect(await
          resolver.user('1')).toBe(result);
   });
});
```

Listing 6: User Service Unit Tests

IV. Advantages of Modular GraphQL APIs

The combination of GraphQL and NestJS offers a powerful and flexible approach for building scalable, maintainable, and efficient backend systems. Below are the key advantages:

- **Efficiency:** One of the major benefits of using GraphQL is its ability to allow clients to fetch only the data they need. Unlike REST, where multiple endpoints might be required to gather related data, GraphQL enables a client to request exactly what it needs in a single query. This reduces over-fetching and under-fetching of data, improving bandwidth usage and response times. Moreover, the structure of the query ensures that only the relevant data is transmitted over the network, making interactions more efficient. This is particularly beneficial for mobile devices or applications with limited bandwidth.
- **Modularity:** NestJS supports the creation of modular applications by organizing code into discrete modules. Each module is responsible for a specific domain, which in the case of GraphQL APIs corresponds to each database table or entity. This modularity allows developers to encapsulate business logic, data retrieval, and API interactions within individual modules. It fosters a clean, organized codebase where changes to one module are less likely to affect others. Additionally, this separation of concerns improves collaboration within teams, as different modules can be worked on independently without stepping on each other's toes. For example, modifying the schema of a 'User' table would only affect the 'UserModule' without introducing breaking changes to other parts of the application.
- **Scalability:** The modular nature of NestJS and GraphQL makes it easier to scale applications as the number of tables or the complexity of queries grows. Each table, represented by a distinct module, can be independently modified or extended with new fields, queries, or mutations without disrupting the overall architecture. For instance, if a new table is introduced to the system, it can be integrated as a new module with minimal changes to existing functionality. Similarly, additional queries and mutations can be added to existing tables, providing an efficient way to handle growing data needs. As the application grows in size and complexity, the architecture remains easy to extend and maintain, ensuring long-term scalability.
- **Maintainability:** Modular GraphQL APIs also enhance the maintainability of an application. Since each table is encapsulated in its own module, the logic related to querying or mutating that table is contained within a specific area of the codebase. This clear separation makes it easier to debug, test, and update individual modules without affecting other parts of the system. In addition, this structure supports code reuse, as modules can be imported into other parts of the application when necessary. When updating the schema or modifying the queries for a specific table, the changes are isolated to the relevant module, thus reducing the risk of introducing bugs into unrelated parts of the system. Furthermore, this modular approach allows for better version control, as individual modules can be tracked and updated independently.
- **Improved Collaboration:** Modular GraphQL APIs also foster better collaboration among teams. With each team focusing on a specific module (representing a table or a set of related functionalities), the overall workflow becomes more streamlined. The responsibilities are clearly defined, and there is no need for one team to manage or have in-depth knowledge of the other parts of the application. As a result, development cycles are faster, and teams can work in parallel without much coordination overhead. This is especially advantageous in large teams

where different developers may be working on different parts of the API simultaneously.

- **Reusability:** One of the strongest aspects of modularity is the potential for reusing code. Each module can be reused in different parts of the application or even in different projects with minimal changes. For instance, a 'ProductModule' designed for one application can be reused in another project that requires similar database queries and mutations. This significantly reduces development time and improves code consistency across multiple applications.
- **Seamless Integration with TypeORM:** NestJS integrates seamlessly with TypeORM, allowing developers to interact with the database via object-relational mapping (ORM). This makes it easier to perform CRUD operations and define database relations while keeping the codebase clean and well-structured. With GraphQL, data is automatically fetched in a structured format, and developers can define complex queries that span multiple related tables, further enhancing the flexibility and power of the application.
- **Consistent Query Language:** Using GraphQL provides a unified query language for the entire API. Regardless of the number of tables or data sources, developers and clients can interact with the API using a consistent query language. This reduces the cognitive load required for understanding different data retrieval patterns, as developers can rely on the same syntax for every query, mutation, or subscription. This consistency ensures that the API is intuitive to use, and it reduces the learning curve for new developers joining the team.
- **Security and Data Authorization:** By modularizing the GraphQL APIs, security measures and data authorization policies can be applied at the module level. This means that sensitive data from certain tables can be restricted based on user roles or permissions. For example, only authorized users should have access to personal user data, while others may only be allowed to access less sensitive information. By implementing role-based access control (RBAC) or attribute-based access control (ABAC) for each module, sensitive data can be kept secure without compromising the overall system's integrity.

V. Conclusion

This paper has outlined a robust approach to designing GraphQL APIs using NestJS. By leveraging modular architecture principles, developers can create scalable, efficient, and maintainable APIs for complex applications. Future work can explore advanced topics like real-time updates with subscriptions and performance optimization techniques for GraphQL queries.

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