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Build a GraphQL API with Subscriptions using Python, Asyncio and Ariadne

In my previous GraphQL article, we learnt about creating a GraphQL API that implements queries and mutations. GraphQL, however, has a third type of operation called *subscriptions*.

Nowadays, most applications have a real-time component. For example, social media applications notify you in real time of new messages, or ride hailing apps stream the driver's location in real time. GraphQL subscriptions allow a server to send real time updates to subscribed clients each time new data is available, usually via WebSocket.

In this tutorial, we will build a project in which the server pushes messages sent by other users to subscribed clients.

Requirements

The only requirement to follow this tutorial is to have Python 3.6 or higher installed. If you don't have it installed, get it here.

Create a Python virtual environment

We will install a few Python packages for our project. A virtual environment will come in handy as it will give us an isolated Python environment that will not affect other Python projects. Let's go ahead and create one now.

Create a directory called *chat_api* for our project and navigate to it.

```
mkdir chat_api
cd chat_api
```

Create the virtual environment:

```
python3 -m venv chat_api_env`
```

If you are using a Mac OS or Unix computer, activate the virtual environment as follows:

```
source chat_api_env/bin/activate
```

To activate the virtual environment on Windows, use the following command:

```
chat_api_env\Scripts\activate.bat
```

To build this project we will need the following Python packages:

- ariadne: Adds GraphQL support to python
- uvicorn: An ASGI server

Let's go ahead and install these packages in our new virtual environment:

```
pip install ariadne "uvicorn[standard]"
```

We install uvicorn with the "standard" option since that brings optional extras like WebSocket support.

What we will build

We will build a GraphQL API that allows users to message each other. The goal is to implement the following:

- A mutation to create a new user. A user will have a `user_id` and a `username` .
- A mutation to create a new message. A message will have a `sender` and a `recipient` .
- A query to retrieve the `user_id` of a user given its username.
- A query to list all the messages addressed to a user.
- A subscription that sends new messages to subscribed clients when they are created.

Asynchronous servers in Python

ASGI is an emerging standard for building asynchronous services in Python that support HTTP/2 and WebSocket. Web frameworks like Flask and Pyramid are examples of WSGI based frameworks and do not support ASGI. Django was for a long time a WSGI based framework but it has introduced ASGI support in version 3.1.

ASGI has two components:

- Protocol Server: Handles low level details of sockets, translating them to connections and relaying them to the application
- Application: A callable that is responsible for handling incoming requests. There are several ASGI frameworks that simplify building applications.

As an application developer, you might find that you will be mostly working at the application and framework levels.

Examples of ASGI servers include Uvicorn, Daphne and Hypercorn. Examples of ASGI frameworks include Starlette, Django channels, FastAPI and Quart.

Ariadne provides a GraphQL class that implements an ASGI application so we will not need an ASGI framework. We will use the `uvicorn` server to run our application.

Async in Python using asyncio

The asyncio library adds async support to Python. To declare a function as asynchronous, we add the keyword `async` before the function definition as follows:

```
async def hello_world():
    return "Hello world"
```

We can call asynchronous functions in 3 ways:

- `asyncio.run`
- `asyncio.create_task`
- Using the `await` keyword

Using `await`, we would call our asynchronous function as follows:

```
greeting = await hello_world()
```

We will use the third approach throughout the article. It is important to note that we can only use `await` inside an asynchronous function. This article provides an in-depth introduction to `asyncio` in Python.

Writing the GraphQL schema

Create a file called *schema.graphql*. We will use it to define our GraphQL schema.

Custom types

Our schema will include five custom types, described below.

The `User` type represents a user of the application and has two fields:

- `username`: A string.
- `userId`: A string.

The `Message` type represents a message and has three fields:

- `content`: String representing message content.
- `senderId`: user id of the sender.
- `recipientId`: user id of the recipient.

`createUserResult` is the return type for the `createUser` mutation we will create later. It has three fields:

- `user`: An object of type User.
- `success`: Boolean flag indicating whether an operation was successful.

- `errors` : A list of errors if any that occurred during processing.

`createMessageResult` is the return type for the `createMessage` mutation we will create later. It has three fields:

- `message` : An object of type `Message` .
- `success` : Boolean flag indicating whether an operation was successful.
- `errors` : A list of errors if any that occurred during processing.

`messagesResult` is the return type for the `messages` query and it has three fields:

- `messages` : A list whose elements are of type `Message` .
- `success` : Boolean flag indicating whether an operation was successful.
- `errors` : A list of errors if any that occurred during processing.

Let's add these types to the new *schema.graphql* file:

```
type User {
    username: String
    userId: String
}

type Message {
    content: String
    senderId: String
    recipientId: String
}

type createUserResult {
    user: User
    success: Boolean!
    errors: [String]
}

type createMessageResult {
    message: Message
    success: Boolean!
    errors: [String]
}

type messagesResult {
    messages: [Message]
    success: Boolean!
    errors: [String]
}
```

Queries

Our schema will define the following queries:

1. `hello` : Returns the String `Hello World` . We will use this query to test that our GraphQL APi is running. We will then remove it.
2. `messages` : Accepts a `userId` and returns the messages for that user.
3. `userId` : Returns the user id of the user with the given username.

Add these queries at the bottom of *schema.graphql*:

```
type Query {
    hello: String!
    messages(userId: String!): messagesResult
    userId(username: String!): String
}
```

Mutations

Our API will have two mutations:

1. `createUser` : Accepts a `username` and creates a user.
2. `createMessage` : Accepts the user ID of the sender, the user ID of the recipient and the content of the message as a string, and creates a message that will be delivered to the recipient.

Add the mutation definitions at the bottom of *schema.graphql*:

```
type Mutation {
    createUser(username: String!): createUserResult
    createMessage(senderId: String, recipientId: String, content: Strin
}
```

Subscriptions

In the GraphQL schema, subscriptions are defined similarly to queries. We will have one subscription, called `messages` . It will take a `userId` argument and the API will return messages for that user, as soon as they are created.

Let's define the subscription at the end of the *schema.graphql* file:

```
type Subscription {
    messages(userId: String): Message
}
```

To complete the schema and tie everything together, add the code below to the top of the *schema.graphql* file:

```
schema {
  query: Query
  mutation: Mutation
  subscription: Subscription
}
```

Setting up the project

Create a file called *app.py* and add the code below:

```
from ariadne import QueryType, make_executable_schema, load_schema_from
from ariadne.asgi import GraphQL

type_defs = load_schema_from_path("schema.graphql")

query = QueryType()


@query.field("hello")
def resolve_hello(*_):
    return "Hello world!"


schema = make_executable_schema(type_defs, query)
app = GraphQL(schema, debug=True)
```

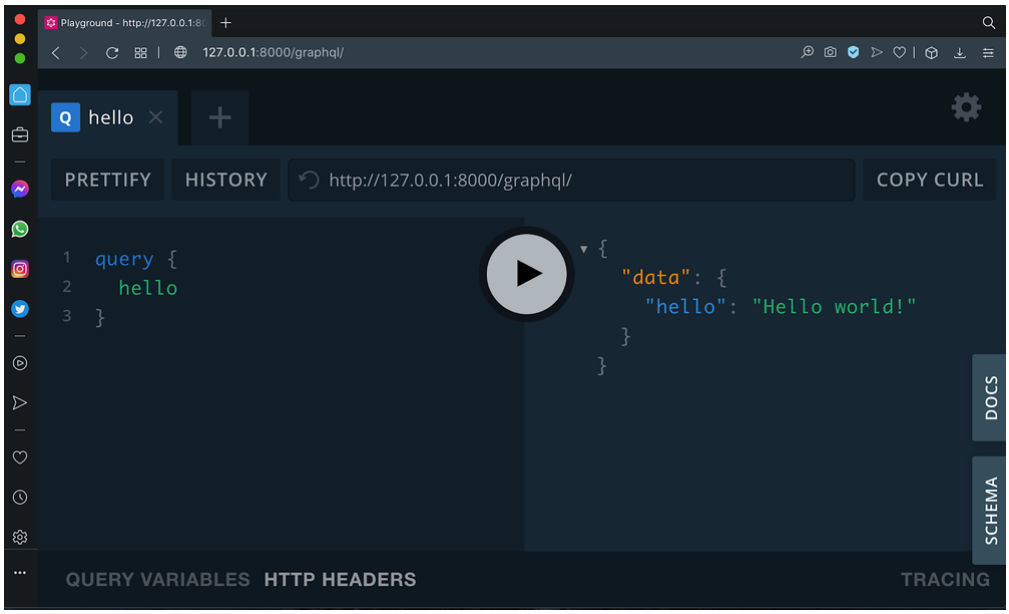
We read the schema defined in the *schema.graphql* file and added a simple query called `hello` that we will use to test that our server is running. Our server is now ready to accept requests.

Start the server by running:

```
uvicorn app:app --reload
```

Open the GraphQL PlayGround by visiting *http://localhost:8000*. Paste the `hello` query below and hit the "Play" button:

```
query {
  hello
}
```



Congratulations, your GraphQL server is running!

Once you confirm that the server is running fine, you can delete the `resolve_hello` function from *app.py* and delete the `hello` query in the type Query `section of schema.graphql`.

Storing users and messages

Since this article discusses GraphQL operations with an emphasis on subscriptions, we will skip the database component entirely and store our data in memory. We will use two variables for this:

- `users` : A python dictionary where the keys are usernames and the values are the user details.
- `messages` : A python list which will store all messages

Create a file called *store.py*. Initialize users `to an empty dict and` messages` to an empty list.

```
users = dict()
messages = []
```

Defining the mutations

Let's add resolvers for the mutations defined in the schema. These will live inside a file called *mutations.py.* Go ahead and create it.

First add the `createUser` resolver to *mutations.py*.

```python
from ariadne import ObjectType, convert_kwargs_to_snake_case

from store import users, messages

mutation = ObjectType("Mutation")


@mutation.field("createUser")
@convert_kwargs_to_snake_case
async def resolve_create_user(obj, info, username):
    try:
        if not users.get(username):
            user = {
                "user_id": len(users) + 1,
                "username": username
            }
            users[username] = user
            return {
                "success": True,
                "user": user
            }
        return {
            "success": False,
            "errors": ["Username is taken"]
        }

    except Exception as error:
        return {
            "success": False,
            "errors": [str(error)]
        }
```

We import `ObjectType` and `convert_kwargs_to_snake_case` from the Ariadne package. `ObjectType` is used to define the mutation resolver, and `convert_kwargs_to_snake_case` recursively converts arguments case from `camelCase` to `snake_case`.

We also import `users` and `messages` from *store.py*, since these are the variables we will use as storage for our users and messages.

Inside `resolve_create_user`, we check if a user with the given username exists. If the username exists, we return an error message warning that the username is taken. If the username is new, we create a dictionary to store `user_id` and `username` and add it to

`users` with the user's username as the key. We calculate the `user_id` by taking the length of the `users` dictionary and adding one to it.

Next, we add the resolver for creating a new message after the `resolve_create_user` function in *mutations.py*:

```
@mutation.field("createMessage")
@convert_kwargs_to_snake_case
async def resolve_create_message(obj, info, content, sender_id, recipie
    try:
        message = {
            "content": content,
            "sender_id": sender_id,
            "recipient_id": recipient_id
        }
        messages.append(message)
        return {
            "success": True,
            "message": message
        }
    except Exception as error:
        return {
            "success": False,
            "errors": [str(error)]
        }
```

In `resolve_create_message`, we create a dictionary that stores the attributes of the message. We append it to the `messages` list and return the created message. If successful, we set `success` to `True` and return `success` and the created message object. If there was an error, we set `success` to `False` and return `success` and the error message.

We now have our two resolvers, so we can point Ariadne to them. Make the following changes to *app.py*:

At the top of the file, import the mutations:

```
from mutations import mutation
```

Then add `mutation` to the list of arguments passed to `make_executable_schema`:

```
schema = make_executable_schema(type_defs, query, mutation)
```

Defining the queries

Now we are ready to implement the two queries of our API. Let's start with the `messages` query. Create a new file, *queries.py* and update it as follows:

```
from ariadne import ObjectType, convert_kwargs_to_snake_case

from store import messages, users

query = ObjectType("Query")


@query.field("messages")
@convert_kwargs_to_snake_case
async def resolve_messages(obj, info, user_id):
    def filter_by_userid(message):
        return message["sender_id"] == user_id or \
               message["recipient_id"] == user_id

    user_messages = filter(filter_by_userid, messages)
    return {
        "success": True,
        "messages": user_messages
    }
```

The `resolve_messages` function accepts a `user_id` argument and returns a list of `messages` for that user. We use the Python standard library function `filter`, which accepts a function and an iterable and returns the elements from the iterable for which the function returns `True`. The implementation filters `messages` for messages where the `sender_id` or `recipient_id` match the `user_id` passed as an argument.

Let's implement the `userId` query by adding the following code at the end of *queries.py*:

```
@query.field("userId")
@convert_kwargs_to_snake_case
async def resolve_user_id(obj, info, username):
    user = users.get(username)
    if user:
        return user["user_id"]
```

The `resolve_user_id` function accepts a `username`, checks whether a user with that username exists, and in that case returns their user_id. If no user is found, then `None` is returned.

We are now ready to register the two queries with Ariadne. Replace all the code in *app.py* with the updated version below:

```
from ariadne import make_executable_schema, load_schema_from_path, \
    snake_case_fallback_resolvers
from ariadne.asgi import GraphQL
from mutations import mutation
from queries import query

type_defs = load_schema_from_path("schema.graphql")

schema = make_executable_schema(type_defs, query, mutation,
                                snake_case_fallback_resolvers)
app = GraphQL(schema, debug=True)
```

Real time message notifications

One defining feature of chat applications is receiving notifications of new messages in real time. We want to implement similar functionality in our GraphQL API. In a conventional HTTP request/response cycle our clients would need to poll the API at regular intervals to see if there are any new messages.

The problem we want to solve is informing our clients in real time as soon as new messages are available. For this we will use the subscriptions feature of GraphQL.

At a high level, each active subscription will have a *queue*, on which new messages are published. This will enable the client subscription to watch the queue for new messages.

Introduction to message queues

Python provides implementations of a FIFO queue in queue.Queue and asyncio.Queue. We will use `asyncio.Queue` since it is specifically designed to be used in async/await code.

We initialize an asyncio queue as follows:

```
import asyncio
queue = asyncio.Queue(maxsize=0)
```

`maxsize` is an optional argument that defines the maximum number of items allowed in the queue. If `maxsize` is zero, less than one or not provided, the queue size is infinite.

The following example shows how to add items to a queue:

```
message = "Hello"
await queue.put(message)
```

The `asyncio.Queue.put` method adds an item into the queue. If the queue is full, the call blocks until a free slot is available to add the item.

To retrieve items from the queue the `asyncio.Queue.get` method is used:

```
item = await queue.get()
queue.task_done()
```

The `asyncio.Queue.get` method returns the first item from the queue. If the queue is empty, it blocks until an item is available. For each `get()` used to fetch an item, a subsequent call to `task_done()` is used to tell the queue that the processing on the item is complete.

Adding new messages to a queue

Now that we know how to work with a queue we can add queuing support to our API. Whenever a client subscribes to the messages of a user, a queue for the subscription will be created. Replace the contents of *store.py*, with the following updated version:

```
users = dict()
messages = []
queues = []
```

The new `queues` list will hold the queues that are allocated by the active subscriptions.

Next, we will import the list of queues into our mutations file. Add the following import to *mutations.py:*

```
from store import users, messages, queues
```

Finally, let's rewrite the `resolve_create_message` function to pass new messages to all the subscription queues:

```
@mutation.field("createMessage")
@convert_kwargs_to_snake_case
async def resolve_create_message(obj, info, content, sender_id, recipie
    try:
        message = {
            "content": content,
            "sender_id": sender_id,
            "recipient_id": recipient_id
        }
        messages.append(message)
        for queue in queues:
            await queue.put(message)
        return {
            "success": True,
            "message": message
        }
    except Exception as error:
        return {
            "success": False,
            "errors": [str(error)]
        }
```

Take note of the line `await queue.put(message)` . This is where we add the newly created message to each of the queues that will be watched by active subscriptions.

Subscribing to new messages

New messages are now being added to subscription queues, but we do not have any queues yet. All that is remaining is implementing our GraphQL subscription to create a queue and add it to the `queues` list, read messages from it and push the appropriate ones to the GraphQL client.

In Ariadne, we need to declare two functions for every subscription defined in the schema.

- Subscription source: An asynchronous generator that generates the data we will send to the client. This is where we will read new messages from the queue.
- Subscription resolver: This tells the server how to send the data received from the subscription source to the client. The return value of the subscription resolver needs to match the structure defined in the GraphQL schema.

Subscription source

Create a new file, *subscriptions.py* and define our subscription source in it as follows:

```
import asyncio
from ariadne import convert_kwargs_to_snake_case, SubscriptionType

from store import queues

subscription = SubscriptionType()


@subscription.source("messages")
@convert_kwargs_to_snake_case
async def messages_source(obj, info, user_id):
    queue = asyncio.Queue()
    queues.append(queue)
    try:
        while True:
            print('listen')
            message = await queue.get()
            queue.task_done()
            if message["recipient_id"] == user_id:
                yield message
    except asyncio.CancelledError:
        queues.remove(queue)
        raise
```

Several things are happening here. First, we import Ariadne utilities to set up our resolver, then we import the queue list, and finally we initialize a subscription type.

Inside the `messages_source` function, we create a new queue and add it to the list. From this point on, the `createMessage` mutation will add new messages to this queue.

Inside the while-loop, we check for new messages being posted to the queue. When a message is retrieved, we check if the `recipient_id` matches the `user_id` provided by the client of the subscription. This makes sure that we only act on messages that were sent to this user and not to others.

If the `recipient_id` matches the provided `user_id`, we yield the message, which will tell Ariadne that it needs to notify the client. If the `recipient_id` does not match the `user_id`, it means that the message belongs to a different user, so we do nothing and go back to wait for the next message.

When the subscription is removed by the client, this function is going to be cancelled. We catch the `CancelledError` exception and at that point we remove the queue from the list.

Subscription resolver

All that is remaining to complete our API is to implement a subscription resolver. In our resolver, we will define how the message yielded from the subscription source will be sent to the client.

Add the following code at the end of *subscriptions.py*:

```
@subscription.field("messages")
@convert_kwargs_to_snake_case
async def messages_resolver(message, info, user_id):
    return message
```

The `messages_resolver` function receives three arguments:

- `message`: This the value yielded by the subscription source `messages_source`.
- `info`: Context information passed to subscription resolvers.
- `user_id`: The user_id passed in the subscription call made by the client.

The return value of `messages_resolver` needs to adhere to the expected return type defined in the GraphQL schema. We return `message` as it is without further processing since the return value of our subscription source is a dictionary with the expected structure.

Finally, let's bind our subscription so that they are available on the GraphQL API.

Add this import near the top of the app.py file:

```
from subscriptions import subscription
```

Then replace the code that creates the `schema` variable with the following updated version:

```
schema = make_executable_schema(type_defs, query, mutation, subscriptio
                                snake_case_fallback_resolvers)
```

All the hard work is done! Now comes the easy part; seeing the API in action. Open the GraphQL Playground by visiting http://localhost:8000.

Let's begin by creating two users, `user_one` and `user_two`. Paste the following mutation and hit play.

```
mutation {
  createUser(username:"user_one") {
    success
    user {
      userId
      username
    }
  }
}
```

Once the first user is created, change the username in the mutation from `user_one` to `user_two` and hit play again to create the second user.

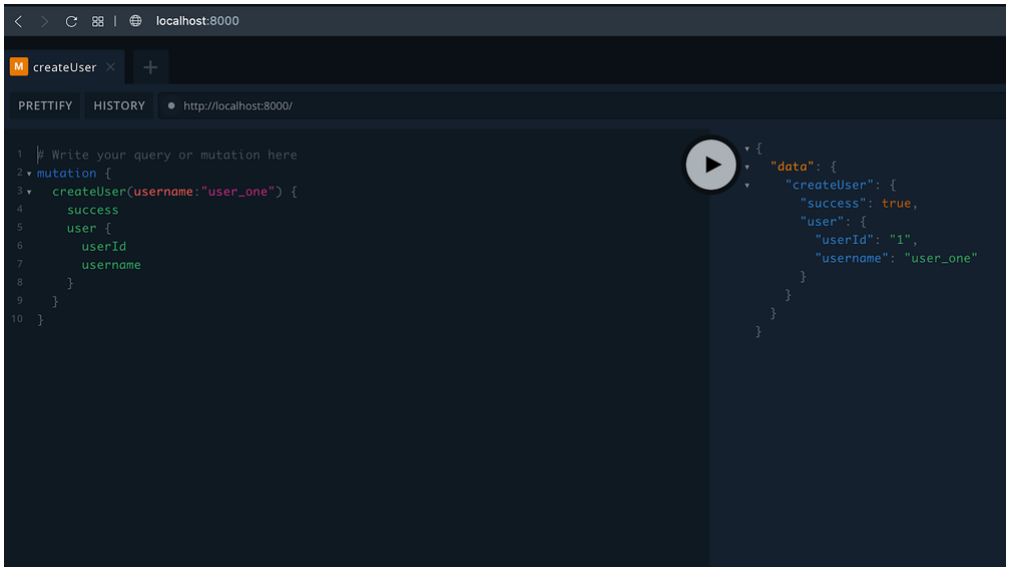
Now we have two users who can message each other. Our `createMessage` mutation expects us to provide `senderId` and `recipientId`. If you looked at the responses from the

`createUser` mutations you already know what IDs were assigned to them, but let's assume we only know the usernames, so we will use the `userId` query to retrieve the IDs.

Paste the query below in the GraphQL Playground and hit play to query for the user ID of `user_one`:

```
query {
  userId(username:"user_one")
}
```

Take note of the `userId` returned and repeat the same for `user_two`. If you are following the tutorial instructions, you should have `userId == "1"` for `user_one` and `userId == "2"` for `user_two`.



Next, we are going to test sending and receiving messages. Open a second GraphQL Playground window and position it side by side with the first.

In the first window, we will execute the `messages` subscription to subscribe to incoming messages for `user_two`. In the second window, we will execute the `createMessage` mutation to send a message from `user_one` to `user_two`.

In the first window, paste the following subscription in the GraphQL editor and hit play:

```
subscription {
  messages(userId: "2") {
    content
    senderId
    recipientId
  }
}
```

If your `user_two` had a different id, then replace "2" above with the correct `userId`.

A WebSocket connection is now created and our client (GraphQL Playground) is listening for notifications and ready to receive new messages as they are sent to `user_two`.

On the second Playground window, paste the following mutation to send a message and hit the play button:

```
mutation {
  createMessage(
    senderId: "1",
    recipientId: "2",
    content:"Hello there"
  ) {
    success
    message {
      content
      recipientId
      senderId
    }
  }
}
```

Remember to replace `senderId` with the appropriate user id for `user_one` and `recipientId` with the appropriate user id for `user_two` if they are different.

When we execute the `createMessage` mutation, the same message is pushed to the client as a response in the window running the subscription. Feel free to send as many messages as you want to `user_two` and watch them show up on the subscription window in real time.

Conclusion

Congratulations for completing this tutorial. We learnt about ASGI, how to add subscriptions to a GraphQL server built with Ariadne, and using `asyncio.Queue`.

To learn more about ASGI, you can get started with this gentle yet detailed introduction to ASGI, written by the author of Uvicorn and Starlette. Using coroutines (async/await) is just one way to add async capabilities to an application. To understand more about sync v async python and the various ways you can add async capabilities to an application, read this article that compares both in depth.

This was just a simple API to demonstrate how we can use subscriptions to add real time functionality to a GraphQL API. The API could be improved by adding a database, user authentication, allowing users to attach files in messages, allowing users to delete messages and adding user profiles.

If you are wondering how you can incorporate a database to an async API, here are two options:

- aiosqlite: A friendly, async interface to sqlite databases.
- gino: A lightweight asynchronous ORM built on top of SQLAlchemy core for Python asyncio. Note that gino only supports PostgreSQL at this time.

I can't wait to see what you build!

Alex is a developer and technical writer. He enjoys building web APIs and backend systems. You can reach him at:

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