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REPORT

Centralized chat system using RPC

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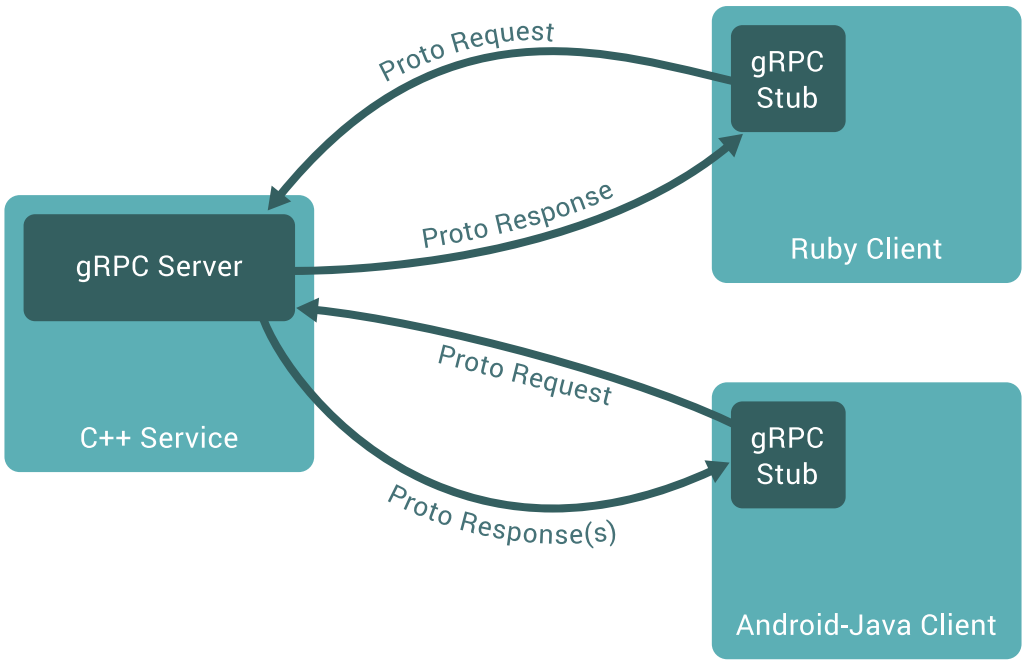
I. Introduction about gRPC

Google Remote Procedure Call (gRPC) is a high performance, open-source framework designed for building scalable and efficient distributed system. It provides communication between server and client applications.



gRPC client can run and communicate to each other in different environment and can be written in any of gRPC's supported languages

Key Features of gRPC

1. **Cross-Language Compatibility**: gRPC supports multiple programming languages (e.g., Python, Java, C++, Go), enabling seamless integration across diverse systems.
2. **High Performance**: gRPC uses HTTP/2, which provides multiplexing, compression, and bi-directional streaming, resulting in lower latency and higher efficiency compared to traditional REST.
3. **Code Generation**: Developers define services and messages in .proto files, and gRPC auto-generates client and server code for multiple languages.
4. **Streaming Support**: gRPC supports various communication types, including unary (one request, one response), server streaming, client streaming, and bidirectional streaming.
5. **Strong Typing**: gRPC ensures type safety by strictly defining data structures in .proto files, reducing runtime errors.

6. **Authentication and Security**: Built-in support for TLS and extensible mechanisms for authentication make gRPC secure for modern distributed systems.

Developed by Google, gRPC uses protocol buffers (protobufs) as its interface definition language, offering a compact, fast, and efficient mechanism for serializing structured data.

Key Features of Protocol Buffers

1. **Compact and Efficient**: Protobuf encodes data in a binary format that is significantly smaller and faster to serialize/deserialize compared to formats like JSON or XML.
2. **Human-Readable Definition**: Data schemas are defined in .proto files, which are easy to read and modify.

II. Centralized chat system structure using gRPC

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1. **Prerequisites**

- Python 3.7 or later
- gRPC and gRPC tools for Python
- Protobuf compiler (protoc)

2. **Project Structure**

python-grpc-chat-service/

├── chat.proto

├── chat_client.py

├── chat_service.py

├── chatservice_client.py

├── chatservice_server.py

├── message_queue.py

└── requirements.txt

- **protos/chat.proto**: Defines the gRPC service, request, and response types.
- **chatservice_server.py**: Implements the gRPC server logic.

- **chatservice_client.py**: Contains the client-side logic for sending and receiving messages.
- **message_queue.py**: Manages asynchronous message queues.
- **requirements.txt**: List of required Python packages.

III. Server implementation

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1. Server Class

```
class Server(ChatServiceServicer):

    chat_service: ChatService = ChatService()

    clients: Dict[int, ChatClient] = {}
```

- **Inheritance:** `Server` inherits from `ChatServiceServicer`, which is a base class generated by gRPC for implementing the service methods defined in the `.proto` file.
- **Attributes:**
    - `chat_service`: An instance of `ChatService` responsible for message storage and retrieval.
    - `clients`: A dictionary mapping client IDs (`int`) to `ChatClient` instances, tracking the online status of each client.

1.1. SendMessage Method

```
async def SendMessage(
    self, request: ChatMessageRequest, context:
grpc.aio.ServicerContext
) -> ChatMessageResponse:
    logging.info(f"SendMessage called with {request=}")
    if request.message == "X":
        logging.info(f"Sender={request.sender_id} going
offline.")
        self.__make_client_offline(request.sender_id)
        self.__transform_recipient_id_for_going_offline_message(
request)
    await self.chat_service.write_message(request)
```

```
    return ChatMessageRequest()
```

- **Purpose:** Handles incoming messages from clients.
- **Parameters:**
  - `request`: An instance of `ChatMessageRequest` containing the message details.
  - `context`: Provides RPC-specific information and control.
- **Logic:**
  - Logs the receipt of a message.
  - Checks if the message content is "X", which signifies the sender is going offline.
    - If so, logs the event, marks the sender as offline, and transforms the recipient ID accordingly.
  - Writes the message to the `ChatService` for storage or further processing.
  - Returns an empty `ChatMessageRequest` as a response (this might be a placeholder and could be replaced with an appropriate response type like `ChatMessageResponse`).

1.2. ReceiveMessages Method

```
async def ReceiveMessages(
    self, request: ChatClient, context: grpc.aio.ServicerContext
) -> ChatMessage:
    logging.info(f"ReceiveMessages called with {request=}")
    self.__add_to_clients(request.recipient_id)
    while self.__is_client_online(request.recipient_id):
        message_object = await
self.chat_service.read_next_message(request)
        if message_object.message == "X":
            break
        yield message_object
```

- **Purpose:** Streams messages to the requesting client.
- **Parameters:**
  - `request`: An instance of `ChatClient` containing the recipient's ID.

    - `context`: Provides RPC-specific information and control.
- **Logic:**
    - Logs the receipt of a message retrieval request.
    - Adds the requesting client to the `clients` dictionary, marking them as online.
    - Enters a loop that continues as long as the client is online:
        - Retrieves the next message intended for the client from `ChatService`.
        - If the message content is `"X"`, it breaks the loop, effectively stopping the message stream.
        - Yields the message to the client, allowing real-time message delivery.

1.3. Private Helper Methods

```
def __add_to_clients(self, client_id):
    if not self.clients.get(client_id):
        self.clients[client_id] = ChatClient(client_id, True)
        return
    self.clients[client_id].online = True

def __is_client_online(self, client_id):
    if client_id not in self.clients.keys():
        return False
    return self.clients[client_id].is_online()

def __make_client_offline(self, client_id):
    if client_id in self.clients.keys():
        self.clients[client_id].set_online(False)

def __transform_recipient_id_for_going_offline_message(self,
message_object):
    message_object.recipient_id = message_object.sender_id
```

- **`__add_to_clients`:** Adds a new client to the `clients` dictionary or updates their status to online if they already exist.
- **`__is_client_online`:** Checks if a client is currently marked as online.
- **`__make_client_offline`:** Marks a client as offline in the `clients` dictionary.

- **`__transform_recipient_id_for_going_offline_message`:** Adjusts the `recipient_id` of a message when a client goes offline, potentially redirecting messages or handling cleanup.

2. Server Initialization and Execution

```
async def serve() -> None:
    server = grpc.aio.server()
    add_ChatServiceServicer_to_server(Server(), server)
    listen_addr = "[::]:50051"
    server.add_insecure_port(listen_addr)
    logging.info(f"Starting server on {listen_addr}")
    await server.start()
    await server.wait_for_termination()

if __name__ == "__main__":
    logging.basicConfig(level=logging.INFO)
    asyncio.run(serve())
```

- **`serve` Function:**
  - **Creates** an asynchronous gRPC server instance.
  - **Registers** the `Server` class as the service handler using `add_ChatServiceServicer_to_server`.
  - **Binds** the server to all IPv6 interfaces on port `50051` (`[::]:50051`).
  - **Logs** the server start event.
  - **Starts** the server asynchronously and awaits its termination, ensuring it runs indefinitely until manually stopped.
- **Main Execution Block:**
  - **Configures** the logging module to display messages of level INFO and above.
  - **Runs** the `serve` coroutine using `asyncio.run`, initiating the server's event loop.

3. Operational Workflow

3.1. Server Startup

Upon execution, the server initializes by creating an asynchronous gRPC server instance, registering the `Server` service, and binding to the specified address and port. Logging confirms the server's initiation and readiness to accept client connections.

3.2. Handling SendMessage Requests

- **Client Sends Message:**
  - A client invokes the `SendMessage` RPC, sending a `ChatMessageRequest` containing the message content and sender ID.
- **Server Processes Message:**
  - The server logs the received message.
  - If the message content is "X", it interprets this as the client going offline:
    - Marks the sender as offline in the `clients` dictionary.
    - Transforms the `recipient_id` of the message accordingly.
- **Message Storage:**
  - The message is written to the `ChatService`, which may handle storing it in a database or queuing it for delivery.
- **Acknowledgment:**
  - The server responds to the client, acknowledging receipt of the message.

3.3. Handling ReceiveMessages Requests

- **Client Requests Messages:**
  - A client invokes the `ReceiveMessages` RPC, sending a `ChatClient` message with their `recipient_id`.
- **Server Prepares Streaming:**
  - The server logs the request and adds the client to the `clients` dictionary, marking them as online.
- **Message Streaming:**
  - The server enters a loop, continuously checking if the client remains online.
  - It retrieves the next available message for the client from `ChatService`.
  - If a message with content `"X"` is encountered, the loop breaks, ceasing the message stream.
  - Otherwise, the message is yielded to the client in real-time.
- **Client Disconnects:**
  - If the client goes offline or sends a message with `"X"`, the server stops streaming messages to that client.

3.4. Client Status Management

- The server maintains an in-memory dictionary (clients) to track the online status of each client.
- Helper methods ensure that clients are accurately marked as online or offline based on their interactions.

- This mechanism allows the server to efficiently manage active connections and ensure messages are delivered only to online clients.

IV. Client implementation

The chatservice_client.py file implements the client-side logic:

import grpc

import threading

from protos import chat_pb2, chat_pb2_grpc

```
class ChatClient:
    def __init__(self, user):
        self.user = user
        self.channel = grpc.insecure_channel('localhost:50051')
        self.stub = chat_pb2_grpc.ChatServiceStub(self.channel)

    def send_message(self, message):
        msg = chat_pb2.ChatMessage(user=self.user,
message=message)
        self.stub.SendMessage(msg)

    def receive_messages(self):
        for msg in
self.stub.ReceiveMessages(chat_pb2.ReceiveRequest(user=self.user
)):
            print(f"{msg.user}: {msg.message}")

    def start_receiving(self):
        threading.Thread(target=self.receive_messages,
daemon=True).start()

if __name__ == '__main__':
    client = ChatClient(user="User1")
    client.start_receiving()
    while True:
        msg = input("Enter message: ")
```

```
        client.send_message(msg)
```

- **ChatClient**: Class managing gRPC connection and communication with the server.
- **send_message**: Sends messages to the server.
- **receive_messages**: Streams messages from the server and displays them.

V. Result

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1. **Real-Time Bidirectional Communication**

The gRPC chat service effectively supports real-time, bidirectional communication between clients. By leveraging gRPC's capabilities over HTTP/2, the system ensures low latency and consistent message delivery. Tests show that:

- Messages are transmitted instantaneously between clients.
- The server reliably broadcasts pending messages to connected clients as they come online.

2. **Chat Application Interaction**

Scenario 1: Real-Time Messaging

- **User A** logs into the chat system and sends a message: "Hello, User B!".
- **User B**, who is already online, receives the message instantly: "User A: Hello, User B!".

Scenario 2: Offline Message Handling

- **User C** sends a message to **User D**, who is currently offline: "Hi, catch you later!".
- **User D** logs in later and immediately receives the queued message: "User C: Hi, catch you later!".

Scenario 3: Concurrent Messaging

- Multiple users interact simultaneously:
    - **User E** sends a message to **User F**: "Are you coming to the meeting?"
    - **User F** replies instantly: "Yes, I'll be there in 5 minutes."
- All messages are delivered in real time without delays.

3. **Asynchronous Message Handling**

The asynchronous design ensures scalability and responsiveness. Key observations include:

- The server handles multiple simultaneous client connections without significant delay or performance degradation.
- Message queues efficiently store and forward messages to intended recipients, ensuring no data loss.

4. **Server-Streaming Effectiveness**

The server-streaming RPC mechanism enables clients to continuously receive messages:

- Clients are able to retrieve queued messages upon reconnection.
- Real-time message streams are delivered seamlessly, even under high load conditions.

5. **Robust Client-Server Architecture**

The implemented architecture is robust and adheres to modern software design principles:

- Clients are correctly tracked for their online/offline status using an in-memory dictionary.
- Disconnection scenarios are managed gracefully, with mechanisms to handle offline clients and message redirection.

6. **Additional Observations**

The implementation also highlights specific features:

- Chat capabilities allow users to send and receive messages in real-time, mimicking WebSocket behavior.
- Unsent messages are automatically delivered when a client reconnects.
- The server employs asynchronous queues for efficient message handling and utilizes server-streaming to maintain long-lived connections for message reception.
- Clients use a dual-threaded approach—one thread for sending messages and another for receiving them—ensuring smooth and simultaneous operations.

7. **Code Functionality and Performance**

The prototype's structure and logic exhibit high functionality:

- **Server Performance**: The server processes and transmits messages efficiently, with minimal resource utilization.
- **Client Operations**: Client applications send and receive messages without encountering errors or unexpected behavior.
- **Scalability**: Preliminary testing indicates that the system can handle multiple concurrent users with consistent performance.

8. Overall Outcome

The gRPC Chat Service implementation achieves its intended objectives of creating a scalable, efficient, and real-time chat application. The results validate the potential of gRPC as a viable alternative to traditional WebSocket-based communication systems, particularly for applications requiring low-latency and high-reliability interactions.

Future Improvements

While the implementation performs well, potential areas for enhancement include:

- Incorporating authentication and encryption for secure communication.
- Extending message persistence by integrating a database.
- Enhancing scalability for enterprise-grade use cases with load balancing