National College of Ireland

HDip in Computing

Distributed Systems

Domain: smart education

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HDip in Science in Computing

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github repo: https://github.com/Jeremywikim/GrpcSmartClassroom.git

Part 1

1. Domain Description

For my smart classroom scenario, I have four rpc services to track students attendance(simple rpc), random arrangement of presentation(server side stream rpc), bidirectional chatting prompt(bidirectional rpc) and
CCTV systems(client side stream rpc). The overall aim of the app is designed to provide convenience for
students and teachers, so that all four services I picked are very common used.

Attendance Tracking Service:
Integrating with students to get student's name sent to server's recording csv file, with essential information as student name and the clocked in time (the time is server side time), so that Tutors can easily know the exact problem of attendance. (Also, I have another service based on the attended students)

Chat Service:
It is another common usage in class, students can easily send questions to tutor and get responses during lessons.

Presentation Management Service:
Managing the order of student presentations, ensuring a smooth transition between speakers and providing the instructor with control over the session flow.

CCTV Service:
Ensuring a safe and secure learning environment is important, and the CCTV Service plays a crucial role in achieving this objective.

In my case project, attendance service is the most important one, as it not only gets the information of students' attendance but also provides presentation service basic data, in real scenario, tutors might manage random presentation during class(so the exact attended students are necessary). chat service is also playing an essential role especially in a big classroom with much more students. Lastly, CCTV service usually
runs all the day (I made it simple in my case, but certainly, it ain't simple).

2. Service definition and RPC

Attendance Tracking Service

RPC Methods:
sendUnaryRequest(unary rpc): Recording a student's attendance and return confirm.
Request: AttendanceRequest contains studentName,it comes from the entering prompt.
Response: AttendanceResponse includes message confirming successfuly clocked-in.
in detail, it is override as "Welcome, " + clientName + "! You checked at " + formattedDate in Implementations.

Presentation Service

RPC Methods:

streamServerRequest(server side stream rpc): Adding a student to the presentation queue.
Request: PresentationRequest specifies the sessionDate.
Response: PresentationList provides a list of students and the exact time of server.

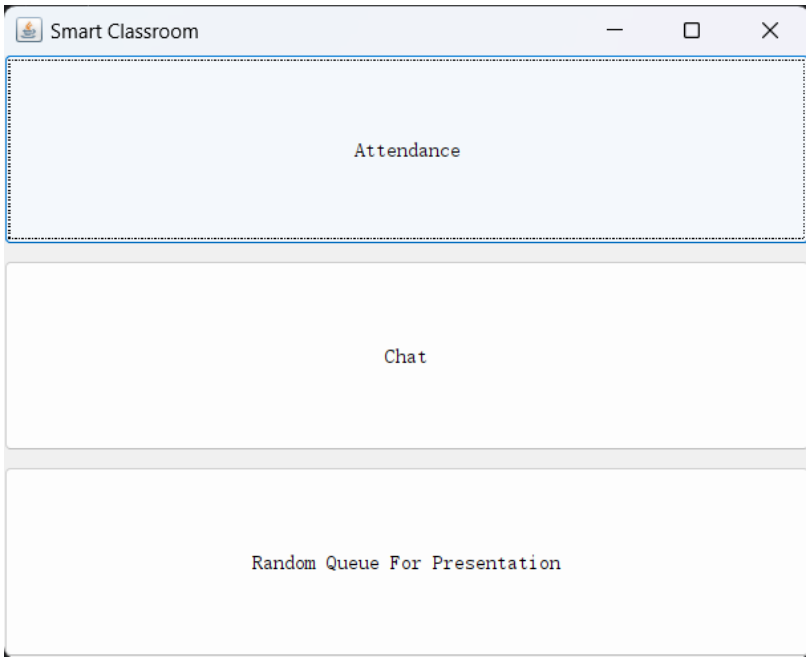
Chat Service

RPC Methods:
LiveSession (bidirectional): Sending and receiving stream messages between user and server.
Request: ClassroomMessage includes user(name), message,timestamp.
Response: MessageResponse confirms the message delivery with status.

CCTV Service

RPC Methods:
StreamVideo (client side stream rpc): Sending stream from client to server.
Request: VideoFrame includes number (simulating images) and timestamp.
Response: StreamVideoResponse confirms that video is transferred successfully.

3. Service Implementations

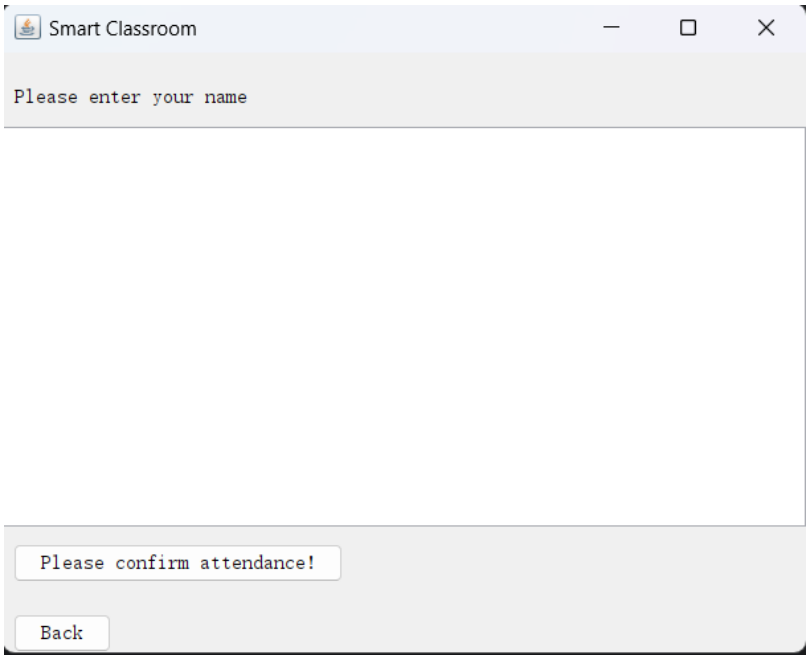


This is the first page of GUI dashboard, There are three services available on it.

3.1 Attendance service (unary rpc)

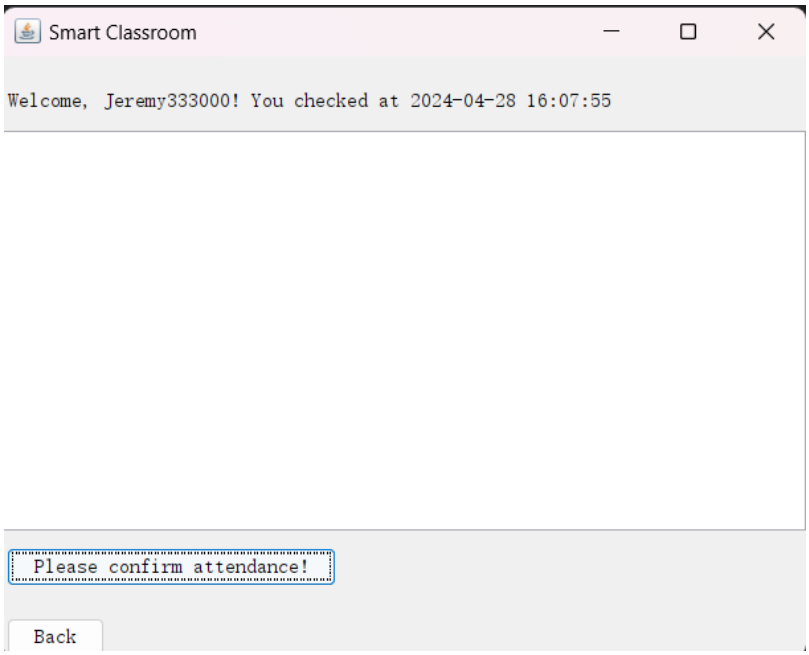
3.1.1 Demonstration

Clicking on the button, it goes to attendance panel, showing as below.



At the above part there is a text area showing "please enter your name",middle part is enter prompt that allows students enter their name, then click on the confirm button, the name will be sent to the server. and saved in a csv file,

also, confirm information will be response to the client. like image below.

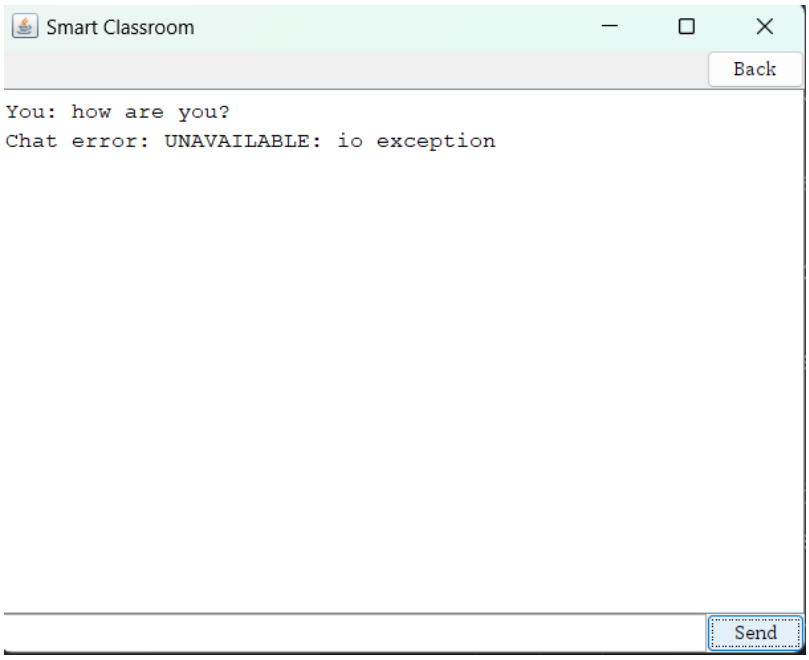


3.1.2 Error Handling and logic correction

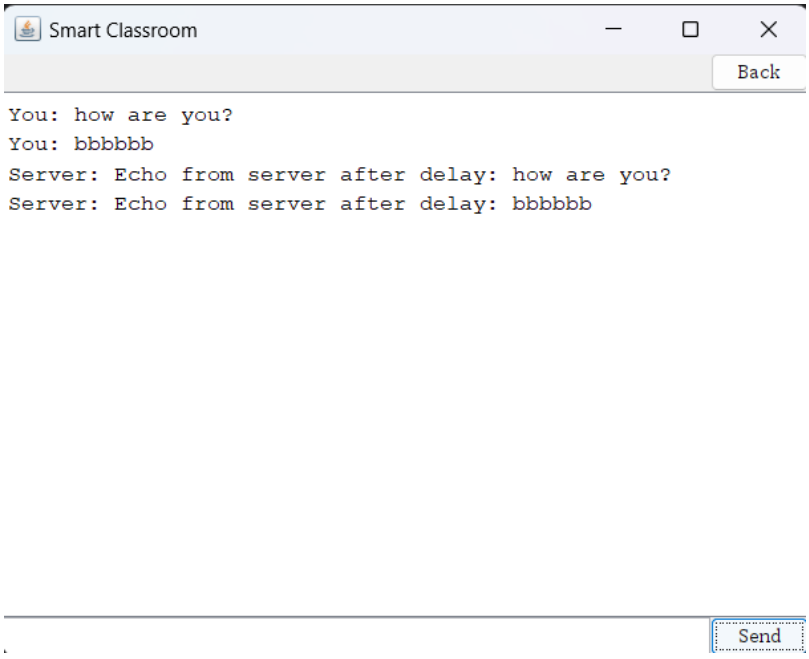
1. If the server is not available, the notification will be "UNAVAILABLE: io exception" and the system can still be running, once server is available, response can be received.
2. After a name is entered to the prompt and confirm button is clicked, the prompt is cleared so that next name can be entered directly. also, when users get back to first page and go to attendance page again, all the previous data got cleared.
3. In the server side, when a name is received, the server will always check if ".csv" file is existing. If it is, the name will be saved in the file plus the exact time. It keeps the server service stronger.

3.2 Chat service (bidirectional stream rpc)

3.2.1 Demonstration



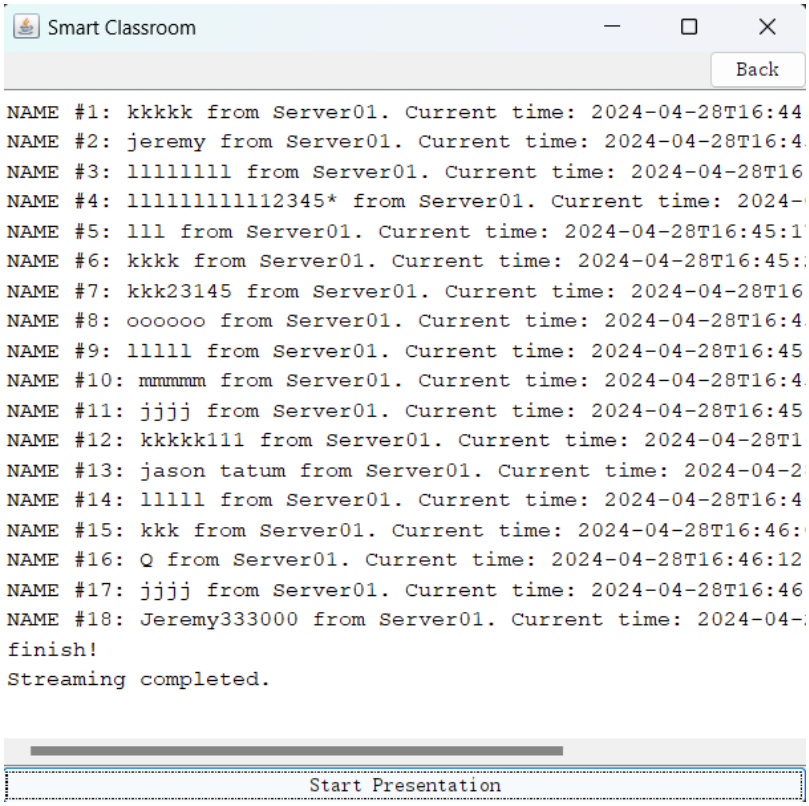
1. As shown in the image, once server is not available, error is shown.



2. It Successfully gets response from server.
3. when it gets to first page and gets back, the words is saved (referred to social app).
4. I have 5 seconds delay after receive the request as it demonstrates non-block stream
   in bidirectional rpc.

3.3 Presentation service (server side stream rpc)

3.3.1 Demonstration



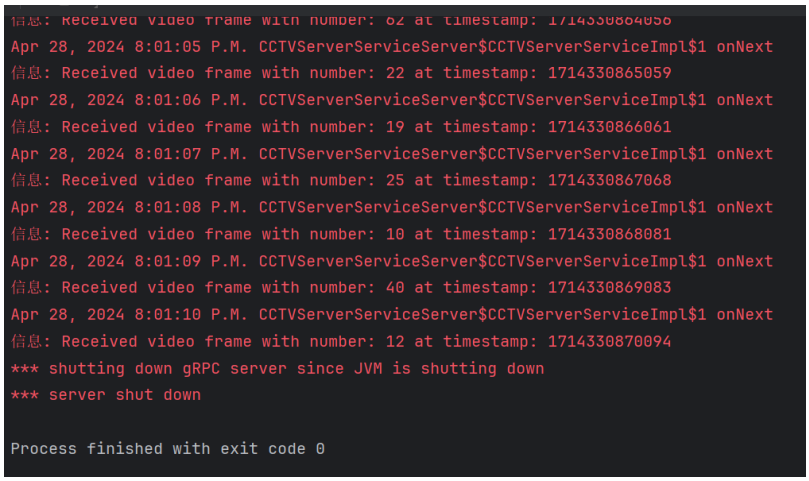
1. The student name will be printed one by one on the dash until no names in csv file available.

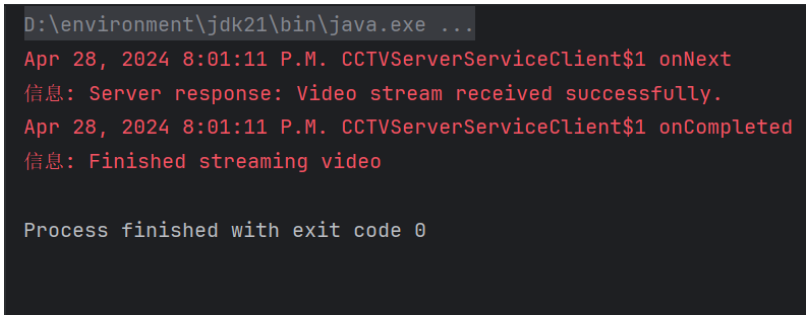
3.3.2 Error Handling and logic correction

1. Handling the header of csv file, keeping it from sent to client.
2. Determining how many names left in order to forbid INDEX OUT BOUNDARY ERROR.

3.4 CCTV service (Client side stream rpc)

3.4.1 Demonstration





1. As shown in the images, when the stream of data has been sent to the server, the server sent a response to client (Video stream received successfully.), then the onCompleted function was triggered and the client just shut down.
   Here is the stack flow:

   Client-side Stream Completion:
   In CCTVServerServiceClient, the shutdown process is initiated after the client completes
   its interaction, with calling the onCompleted()
   method on the StreamObserver that is used to send messages to the server.
   This tells server that the client has finished sending all its data.

   Waiting for Server Response:
   After telling server the completion with onCompleted(), the client still needs to ensure that
   receive responses from the server.

   Finish Latch:
   The client uses a CountDownLatch to wait for the server's final response.

The onCompleted() method from the server's response observer will decrement this latch,
which allows the client to shut down only after the server
has also signaled that it has completed the interaction.

Shutdown Call:
Once all responses are received and the interaction is fully completed
, the client then shuts down

ii. On server side:
Server-side Stream Handling: The handling of the stream can be
set to shut down the server once the streaming completes.
StreamObserver Implementation: In the server implementation, when the server's StreamObserver's onCompleted() method
is called by the client-side, the server can handle this by sending a final message back to
the client and then invoking its own shutdown procedures.

Immediate Shutdown: The server can implement a shutdown directly in the onCompleted() handling of
the StreamObserver, which will shut down the server as soon as the client tells server
that no more data will be sent. This is a forced shutdown that occurs right after the current client-server interaction ends.

Part 2 backup

```
import com.mingyan.smartClassroom.CCTVService.*;
import io.grpc.Server;
import io.grpc.ServerBuilder;
import io.grpc.stub.StreamObserver;
import java.io.IOException;
import java.util.concurrent.TimeUnit;
import java.util.logging.Logger;
```

```java
/**
 * Server to interact with the CCTV client using gRPC.
 * Connection to the client,
 * Receiving video frames, and handling request.
 */
public class CCTVServerServiceServer {

    private static final Logger logger = Logger.getLogger(CCTVServerServiceServer.c

    private Server server;

    /**
     * Starts the gRPC server.
     * throws IOException if there is an error starting the server.
     */
    private void start() throws IOException {
        int port = 20000; // Initialize and start the server on the specified port
        server = ServerBuilder.forPort(port)
                .addService(new CCTVServerServiceImpl())
                .build()
                .start();
        logger.info("CCTV Server started, listening on " + port);

        // Add a shutdown hook to ensure clean shutdown including freeing port and
        Runtime.getRuntime().addShutdownHook(new Thread(() -> {
            System.err.println("*** shutting down gRPC server since JVM is shutting
            try {
                CCTVServerServiceServer.this.stop();
            } catch (InterruptedException e) {
                e.printStackTrace(System.err);
            }
            System.err.println("*** server shut down");
        }));
    }

    /**
     * Stops the server and waits for it to shut down completely within a timeout.
     */
    private void stop() throws InterruptedException {
        if (server != null) {
            server.shutdown().awaitTermination(30, TimeUnit.SECONDS); // 30s
        }
    }

    /**
```

```
     * Blocks until the server shuts down.
     * throws InterruptedException if the thread is interrupted while waiting.
     */
    private void blockUntilShutdown() throws InterruptedException {
        if (server != null) {
            server.awaitTermination();
        }
    }

    /**
     * Implements the server-side logic for the CCTV service.
     */
    class CCTVServerServiceImpl extends CCTVServerServiceGrpc.CCTVServerServiceImpl

        /**
         * Handles incoming video frame streams from clients.
         * return a stream observer to handle the client's video frame stream.
         */
        @Override
        public StreamObserver<VideoFrame> streamVideo(StreamObserver<StreamVideoRes
            return new StreamObserver<VideoFrame>() {
                @Override
                public void onNext(VideoFrame videoFrame) {
                    // Log each received video frame
                    logger.info("Received video frame with number: " + videoFrame.g
                }

                @Override
                public void onError(Throwable t) {
                    // Log any errors encountered during the stream
                    logger.warning("StreamVideo encountered error: " + t);
                }

                @Override
                public void onCompleted() {
                    // Send a completion message back to the client
                    StreamVideoResponse response = StreamVideoResponse.newBuilder()
                            .setMessage("Video stream received successfully.")
                            .build();
                    responseObserver.onNext(response);
                    responseObserver.onCompleted();

                    // Trigger server shutdown here
                    try {
                        CCTVServerServiceServer.this.stop();
                    } catch (InterruptedException e) {
```

```
                    e.printStackTrace();
                }
            }
        };
    }
}

/**
 * Main method to run the server.
 */
public static void main(String[] args) throws IOException, InterruptedException
    final CCTVServerServiceServer server = new CCTVServerServiceServer();
    server.start();
    server.blockUntilShutdown();
}
}
```

```
import com.mingyan.smartClassroom.CCTVService.*;
import io.grpc.ManagedChannel;
import io.grpc.ManagedChannelBuilder;
import io.grpc.stub.StreamObserver;
import java.util.concurrent.CountDownLatch;
import java.util.concurrent.TimeUnit;
import java.util.logging.Logger;

/**
 * Client to interact with the CCTV service using gRPC.
 * This class is responsible for establishing a connection to the server,
 * sending video frames, and handling server responses.
 */
public class CCTVServerServiceClient {
    private static final Logger logger = Logger.getLogger(CCTVServerServiceClient.c
    private final ManagedChannel channel; // Channel for making remote calls
    private final CCTVServerServiceGrpc.CCTVServerServiceStub asyncStub; // Asynchr

    /**
     * Constructs a client for accessing the server at the given host and port.
     */
    public CCTVServerServiceClient(String host, int port) {
        this(ManagedChannelBuilder.forAddress(host, port)
                .usePlaintext() // Configure the channel to not use SSL/TLS to allo
                .build());
    }
```

```
/**
 * Constructs a client for accessing a pre-configured channel.
 */
CCTVServerServiceClient(ManagedChannel channel) {
    this.channel = channel;
    asyncStub = CCTVServerServiceGrpc.newStub(channel);
}

/**
 * Shuts down the channel gracefully.
 */
public void shutdown() throws InterruptedException {
    channel.shutdown().awaitTermination(5, TimeUnit.SECONDS);
}

/**
 * Async client-side streaming call to send video frames to the server.
 * This method prepares a latch to handle the asynchronous completion of the vi
 */
public void streamVideo() throws InterruptedException {
    final CountDownLatch finishLatch = new CountDownLatch(1);
    StreamObserver<StreamVideoResponse> responseObserver = new StreamObserver<S
        @Override
        public void onNext(StreamVideoResponse response) {
            logger.info("Server response: " + response.getMessage());
        }

        @Override
        public void onError(Throwable t) {
            logger.warning("StreamVideo failed: " + t);
            finishLatch.countDown();
        }

        @Override
        public void onCompleted() {
            logger.info("Finished streaming video");
            finishLatch.countDown();
        }
    };

    StreamObserver<VideoFrame> requestObserver = asyncStub.streamVideo(response
    try {
        // Simulate streaming video data
        for (int i = 0; i < 10; i++) {
            long timestamp = System.currentTimeMillis();
            VideoFrame videoFrame = VideoFrame.newBuilder()
```

```
                        .setNumber((int) (Math.random() * 100))
                        .setTimestamp(timestamp)
                        .build();
                requestObserver.onNext(videoFrame);
                // Sleep for demonstration purposes
                Thread.sleep(1000);
            }
        } catch (RuntimeException e) {
            requestObserver.onError(e);
            throw e;
        }
        // Mark the end of requests
        requestObserver.onCompleted();

        // Wait for the server to respond or error before finishing the client.
        finishLatch.await(1, TimeUnit.MINUTES);
    }

    /**
     * Main method to run the client.
     * It creates an instance of the client, starts video streaming, and finally sh
     */
    public static void main(String[] args) throws InterruptedException {
        CCTVServerServiceClient client = new CCTVServerServiceClient("localhost", 2
        try {
            client.streamVideo();
        } finally {
            client.shutdown();
        }
    }
}
```

```
import com.mingyan.smartClassroom.attendanceTrackingService.*;
import io.grpc.Server;
import io.grpc.ServerBuilder;
import io.grpc.stub.StreamObserver;

import java.io.*;
import java.nio.file.StandardOpenOption;
import java.time.format.DateTimeFormatter;
import java.util.ArrayList;
import java.util.HashSet;
import java.util.List;
import java.util.Set;
import java.util.concurrent.TimeUnit;
```

```
import java.time.LocalDateTime;

import java.io.IOException;
import java.nio.file.Files;
import java.nio.file.Paths;
import java.util.concurrent.atomic.AtomicBoolean;
import java.util.concurrent.atomic.AtomicInteger;
import java.util.logging.Logger;


public class AttendanceServerServiceServer extends StreamingServerServiceGrpc.Strea

    static final Logger logger = Logger.getLogger(AttendanceServerServiceServer.cla
    /**
    * override send sendUnaryRequest to have some customized features
    * formattedDate is the time when client sends name to the server,
    * the server will respond '"Welcome, " + clientName + "! You checked at " + for
    * also, the server saves the clientName, formattedDate information from each re
     */
    @Override
    public void sendUnaryRequest(AttendanceRequest request, StreamObserver<Attendan
        String clientName = request.getName();
        // Get the current time
        LocalDateTime now = LocalDateTime.now();
        // Format it to a readable form
        DateTimeFormatter formatter = DateTimeFormatter.ofPattern("yyyy-MM-dd HH:mm
        String formattedDate = now.format(formatter);
        String message = "Welcome, " + clientName + "! You checked at " + formatted
        AttendanceResponse response = AttendanceResponse.newBuilder()
                .setMessage(message)
                .build();
        responseObserver.onNext(response);
        responseObserver.onCompleted();

        // Save to CSV
        saveAttendanceRecord(clientName, formattedDate);
    }


    /**
     * Streams random client names from a CSV file back to the client every 5 secon
     * finishing when all names have been sent.
     */
    @Override
    public void streamServerRequest(StreamServerRequest request, StreamObserver<Str
        String serverName = request.getServerName();
```

```
        List<String> clientNames = new ArrayList<>();
        // Load client names from CSV, skipping the first line
        try (BufferedReader reader = new BufferedReader(new FileReader("attendance_
            String line;
            boolean firstLine = true;
            while ((line = reader.readLine()) != null) {
                if (firstLine) {
                    firstLine = false; // Skip the first line (titles)
                    continue;
                }
                clientNames.add(line.split(",")[0]); // Assuming the name is the fi
            }
        } catch (IOException e) {
            e.printStackTrace();
        }

        AtomicBoolean finished = new AtomicBoolean(false);
        AtomicInteger nameCounter = new AtomicInteger(1); // Counter for names

        Runnable streamingTask = () -> {
            try {
                while (!Thread.currentThread().isInterrupted() && !finished.get())
                    if (clientNames.isEmpty()) {
                        responseObserver.onNext(StreamServerResponse.newBuilder()
                                .setMessage("finish!")
                                .build());
                        finished.set(true);
                    } else {
                        // Pick a random name from the list
                        int index = (int) (Math.random() * clientNames.size());
                        String name = clientNames.get(index);
                        clientNames.remove(index); // Remove the name to avoid rese

                        String message = "NAME #" + nameCounter.getAndIncrement() +
                                " from " + serverName + ". Current time: " + LocalD
//                          String message = "Message #" + nameCounter.getAndIncremen
//                                  " from " + serverName + ". Current time: " + Loca

                        responseObserver.onNext(StreamServerResponse.newBuilder()
                                .setMessage(message)
                                .build());
                    }
                    Thread.sleep(5000); // Stream every 5 seconds
                }
            } catch (InterruptedException e) {
                Thread.currentThread().interrupt();
```

```
            } finally {
                responseObserver.onCompleted();
            }
        };

        Thread streamingThread = new Thread(streamingTask);
        streamingThread.start();
    }



//    @Override
//    public void streamServerRequest(StreamServerRequest request, StreamObserver<S
//        String serverName = request.getServerName();
//        Runnable streamingTask = () -> {
//            try {
//                while (!Thread.currentThread().isInterrupted()) {
//                    String message = "This is a message from the server: " + serv
//                    StreamServerResponse response = StreamServerResponse.newBuild
//                            .setMessage(message)
//                            .build();
//                    responseObserver.onNext(response);
//                    Thread.sleep(5000); // Stream every 5 seconds
//                }
//            } catch (InterruptedException e) {
//                Thread.currentThread().interrupt();
//            } finally {
//                responseObserver.onCompleted();
//            }
//        };
//
//        Thread streamingThread = new Thread(streamingTask);
//        streamingThread.start();
//    }



    /**
    * The method appends each client's name and check-in time to a CSV file.
    * It uses BufferedWriter and handles potential I/O exceptions.
    * The method is marked synchronized to prevent concurrent modifications
    *  of the file from multiple threads, which might corrupt the file.
     */
    private synchronized void saveAttendanceRecord(String clientName, String date)
        try (BufferedWriter bw = Files.newBufferedWriter(Paths.get("attendance_reco
            bw.write(clientName + "," + date);
            bw.newLine();
```

```
        } catch (IOException e) {
            System.err.println("Failed to write to CSV: " + e.getMessage());
        }
    }

    /**
    * initCSV()
    * When the server starts, it checks if the CSV file exists. If not, it creates
    * and writes a header row. This ensures that data fields are properly labeled a
     */
    private static void initCSV() throws IOException {
        if (!Files.exists(Paths.get("attendance_records.csv"))) {
            try (BufferedWriter bw = Files.newBufferedWriter(Paths.get("attendance_
                bw.write("ClientName,FormattedDate");
                bw.newLine();
            }
        }
    }


    public static void main(String[] args) throws IOException, InterruptedException
        // // Ensure the CSV file exists and has a header
        initCSV();
        AttendanceServerServiceServer server = new AttendanceServerServiceServer();
        Server grpcServer = ServerBuilder.forPort(8080)
                .addService(server)
                .build();

        grpcServer.start();
//        System.out.println("Attendance Server started, listening on port 8080\n")
        logger.info("Attendance Server started, listening on port 8080\n");

        // Graceful shutdown
        Runtime.getRuntime().addShutdownHook(new Thread(() -> {
            System.out.println("Shutting down gRPC server");
            try {
                grpcServer.shutdown().awaitTermination(30, TimeUnit.SECONDS);
            } catch (InterruptedException e) {
                e.printStackTrace(System.err);
            }
        }));

        grpcServer.awaitTermination();
    }
}
```

```java
import com.mingyan.smartClassroom.attendanceTrackingService.*;
import io.grpc.ManagedChannel;
import io.grpc.ManagedChannelBuilder;
import io.grpc.stub.StreamObserver;

import java.util.Scanner;
import java.util.concurrent.TimeUnit;

public class AttendanceServerServiceClient {

    private final ManagedChannel channel;
    private final StreamingServerServiceGrpc.StreamingServerServiceStub stub;

    /**
     * AttendanceServerServiceClient to send request to server
     */
    public AttendanceServerServiceClient(String host, int port) {
        this.channel = ManagedChannelBuilder.forAddress(host, port)
                .usePlaintext()
                .build();
        this.stub = StreamingServerServiceGrpc.newStub(channel);
    }

//    public void sendUnaryRequest(String name) {
//        AttendanceRequest request = AttendanceRequest.newBuilder()
//                .setName(name)
//                .build();
//        stub.sendUnaryRequest(request, new StreamObserver<AttendanceResponse>() {
//            @Override
//            public void onNext(AttendanceResponse response) {
//                System.out.println("Unary response from server: " + response.getM
//            }
//
//            @Override
//            public void onError(Throwable t) {
//                System.err.println("Error in unary request: " + t.getMessage());
//            }
//
//            @Override
//            public void onCompleted() {
//                System.out.println("Unary request completed");
//            }
//        });
//    }
```

```
    /**
    * sendUnaryRequest is used to send a Unary Request to server with two parameter
    * name is to container of name of student, responseObserver is container to con
    * the information of response of server
     */
    public void sendUnaryRequest(String name, StreamObserver<AttendanceResponse> re
        AttendanceRequest request = AttendanceRequest.newBuilder()
                .setName(name)
                .build();
        stub.sendUnaryRequest(request, responseObserver);  // Use the passed Stream
    }


    /**
    * streamServerRequest is to send request to server
     * and get stream response
     */

    public void streamServerRequest(StreamObserver<StreamServerResponse> responseOb
        StreamServerRequest request = StreamServerRequest.newBuilder()
                .setServerName("Server01")
                .build();
        stub.streamServerRequest(request, responseObserver);
    }




//    public void streamServerRequest() {
//        StreamObserver<StreamServerResponse> responseObserver = new StreamObserve
//            @Override
//            public void onNext(StreamServerResponse response) {
//                System.out.println("Server message: " + response.getMessage());
//            }
//
//            @Override
//            public void onError(Throwable t) {
//                System.err.println("Error in server streaming: " + t.getMessage()
//            }
//
//            @Override
//            public void onCompleted() {
//                System.out.println("Server streaming completed");
//            }
//        };
```

```
//
//        stub.streamServerRequest(StreamServerRequest.newBuilder().setServerName("
//    }


    /**
    * for the test (before I change the parameter of sendUnaryRequest ), this main
    * the same for streamServerRequest().
     */
    public static void main(String[] args) {
        AttendanceServerServiceClient client = new AttendanceServerServiceClient("l
//        client.sendUnaryRequest("Client01");
//        client.streamServerRequest();

        Scanner scanner = new Scanner(System.in);
        while (true) {
            System.out.println("Press 'Q' to quit");
            String input = scanner.nextLine();
            if (input.equalsIgnoreCase("Q")) {
                client.shutdown();
                break;
            }
        }
    }

    /**
    * shutdown is used to shut down the client, ACTUALLY, only between the test, I
    * shut down the client (just run the main function), I keep it here maybe it is
     */
    public void shutdown() {
        try {
            channel.shutdown().awaitTermination(5, TimeUnit.SECONDS);
        } catch (InterruptedException e) {
            System.err.println("Error while shutting down client: " + e.getMessage(
        }
    }
}
```

```
import com.mingyan.smartClassroom.CCTVService.*;
import io.grpc.Server;
import io.grpc.ServerBuilder;
import io.grpc.stub.StreamObserver;
import java.io.IOException;
import java.util.concurrent.TimeUnit;
import java.util.logging.Logger;
```

```java
/**
 * Server to interact with the CCTV client using gRPC.
 * Connection to the client,
 * Receiving video frames, and handling request.
 */
public class CCTVServerServiceServer {

    private static final Logger logger = Logger.getLogger(CCTVServerServiceServer.c

    private Server server;

    /**
     * Starts the gRPC server.
     * throws IOException if there is an error starting the server.
     */
    private void start() throws IOException {
        int port = 20000; // Initialize and start the server on the specified port
        server = ServerBuilder.forPort(port)
                .addService(new CCTVServerServiceImpl())
                .build()
                .start();
        logger.info("CCTV Server started, listening on " + port);

        // Add a shutdown hook to ensure clean shutdown including freeing port and
        Runtime.getRuntime().addShutdownHook(new Thread(() -> {
            System.err.println("*** shutting down gRPC server since JVM is shutting
            try {
                CCTVServerServiceServer.this.stop();
            } catch (InterruptedException e) {
                e.printStackTrace(System.err);
            }
            System.err.println("*** server shut down");
        }));
    }

    /**
     * Stops the server and waits for it to shut down completely within a timeout.
     */
    private void stop() throws InterruptedException {
        if (server != null) {
            server.shutdown().awaitTermination(30, TimeUnit.SECONDS); // 30s
        }
    }

    /**
```

```
     * Blocks until the server shuts down.
     * throws InterruptedException if the thread is interrupted while waiting.
     */
    private void blockUntilShutdown() throws InterruptedException {
        if (server != null) {
            server.awaitTermination();
        }
    }

    /**
     * Implements the server-side logic for the CCTV service.
     */
    class CCTVServerServiceImpl extends CCTVServerServiceGrpc.CCTVServerServiceImpl

        /**
         * Handles incoming video frame streams from clients.
         * return a stream observer to handle the client's video frame stream.
         */
        @Override
        public StreamObserver<VideoFrame> streamVideo(StreamObserver<StreamVideoRes
            return new StreamObserver<VideoFrame>() {
                @Override
                public void onNext(VideoFrame videoFrame) {
                    // Log each received video frame
                    logger.info("Received video frame with number: " + videoFrame.g
                }

                @Override
                public void onError(Throwable t) {
                    // Log any errors encountered during the stream
                    logger.warning("StreamVideo encountered error: " + t);
                }

                @Override
                public void onCompleted() {
                    // Send a completion message back to the client
                    StreamVideoResponse response = StreamVideoResponse.newBuilder()
                            .setMessage("Video stream received successfully.")
                            .build();
                    responseObserver.onNext(response);
                    responseObserver.onCompleted();

                    // Trigger server shutdown here
                    try {
                        CCTVServerServiceServer.this.stop();
                    } catch (InterruptedException e) {
```

```
                    e.printStackTrace();
                }
            }
        };
    }
}

/**
 * Main method to run the server.
 */
public static void main(String[] args) throws IOException, InterruptedException
    final CCTVServerServiceServer server = new CCTVServerServiceServer();
    server.start();
    server.blockUntilShutdown();
}
}
```

```
import com.mingyan.smartClassroom.CCTVService.*;
import io.grpc.ManagedChannel;
import io.grpc.ManagedChannelBuilder;
import io.grpc.stub.StreamObserver;
import java.util.concurrent.CountDownLatch;
import java.util.concurrent.TimeUnit;
import java.util.logging.Logger;

/**
 * Client to interact with the CCTV service using gRPC.
 * This class is responsible for establishing a connection to the server,
 * sending video frames, and handling server responses.
 */
public class CCTVServerServiceClient {
    private static final Logger logger = Logger.getLogger(CCTVServerServiceClient.c
    private final ManagedChannel channel; // Channel for making remote calls
    private final CCTVServerServiceGrpc.CCTVServerServiceStub asyncStub; // Asynchr

    /**
     * Constructs a client for accessing the server at the given host and port.
     */
    public CCTVServerServiceClient(String host, int port) {
        this(ManagedChannelBuilder.forAddress(host, port)
                .usePlaintext() // Configure the channel to not use SSL/TLS to allo
                .build());
    }

    /**
```

```
     * Constructs a client for accessing a pre-configured channel.
     */
    CCTVServerServiceClient(ManagedChannel channel) {
        this.channel = channel;
        asyncStub = CCTVServerServiceGrpc.newStub(channel);
    }

    /**
     * Shuts down the channel gracefully.
     */
    public void shutdown() throws InterruptedException {
        channel.shutdown().awaitTermination(5, TimeUnit.SECONDS);
    }

    /**
     * Async client-side streaming call to send video frames to the server.
     * This method prepares a latch to handle the asynchronous completion of the vi
     */
    public void streamVideo() throws InterruptedException {
        final CountDownLatch finishLatch = new CountDownLatch(1);
        StreamObserver<StreamVideoResponse> responseObserver = new StreamObserver<S
            @Override
            public void onNext(StreamVideoResponse response) {
                logger.info("Server response: " + response.getMessage());
            }

            @Override
            public void onError(Throwable t) {
                logger.warning("StreamVideo failed: " + t);
                finishLatch.countDown();
            }

            @Override
            public void onCompleted() {
                logger.info("Finished streaming video");
                finishLatch.countDown();
            }
        };

        StreamObserver<VideoFrame> requestObserver = asyncStub.streamVideo(response
        try {
            // Simulate streaming video data
            for (int i = 0; i < 10; i++) {
                long timestamp = System.currentTimeMillis();
                VideoFrame videoFrame = VideoFrame.newBuilder()
                        .setNumber((int) (Math.random() * 100))
```

```
                        .setTimestamp(timestamp)
                        .build();
                requestObserver.onNext(videoFrame);
                // Sleep for demonstration purposes
                Thread.sleep(1000);
            }
        } catch (RuntimeException e) {
            requestObserver.onError(e);
            throw e;
        }
        // Mark the end of requests
        requestObserver.onCompleted();

        // Wait for the server to respond or error before finishing the client.
        finishLatch.await(1, TimeUnit.MINUTES);
    }

    /**
     * Main method to run the client.
     * It creates an instance of the client, starts video streaming, and finally sh
     */
    public static void main(String[] args) throws InterruptedException {
        CCTVServerServiceClient client = new CCTVServerServiceClient("localhost", 2
        try {
            client.streamVideo();
        } finally {
            client.shutdown();
        }
    }
}
```