

# Distributed Systems CA Project

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## 1. Introduction - Smart office

Recent years have seen a rise in office workers working from home, or on a hybrid basis. Communication and collaboration need to be efficient and quick. Workers need flexibility in their work environment. This means that space and resources need to be allocated in a more automated way. When workers are in the office there is a requirement to manage shared spaces such as meeting rooms, and lockers. When an employee is working from home, they would need access to remote IT support. These requirements can be met using smart office client-server software which can automatically allocate resources and allow for remote communications.

## 2. Service Definitions

### a. Unary RPC

Unary RPC is where the client sends a single request to the server and receives a single response back.

### b. Server-side streaming RPC

Server-side streaming RPC is where the client sends a request to the server and a stream reads a sequence of responses back. The client reads the stream until there are no responses left.

### c. Client streaming RPC

Client-side streaming is where the client writes a sequence of messages to the server using a stream. The client specifies when the stream ends, and the server then sends its response.

### d. Bi-directional RPC

Bi-directional RPC is where both sides send a sequence of messages using a read-write stream. Clients and servers can stream in any order, meaning that messages can be sent at any time.

## 3. Service Implementations

### a. Unary RPC

The code I have made provides a client with the opportunity to enter information about the duration of meeting room bookings. The server will calculate total weekly duration values from the client's information and send this back to the client. This will give an insight for the overall duration of meetings in a week.



## Meeting Duration Calculator

[Total meeting duration](#)

[Change meeting duration](#)

[Calculate recurring meeting](#)

[Calculate number of meetings required](#)

Meeting 1 duration (mins)

Meeting 2 duration (mins)

Calculate!

### b. Server-side-streaming RPC

The code that I have made allows a client to enter the number of lockers that they require when they go to work in their office. The server will then respond with the up to 4 digit PIN codes for the number of lockers requested. The PIN codes will be random numbers generated in the code. This will allow the management of space in an office where there is a hybrid working environment.

```
C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\SSRPCExample\server-side-streaming-example\client>npm start
> client@1.0.0 start
> node app.js

How many office lockers would you like to access?6
Locker PIN is: 5005
Locker PIN is: 735
Locker PIN is: 960
Locker PIN is: 2626
Locker PIN is: 6033
Locker PIN is: 9867

C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\SSRPCExample\server-side-streaming-example\client>
```

### c. Client-side-streaming RPC

The code that I have made allows a client to enter a number of different expenses items. They can enter the name of the expense (e.g. petrol, food, hotel etc), they can enter the name of the person whose expense account is used, and they can also enter the amount for each item. The server will then respond with the number of expenses items and the total amount of the expenses claim. This allows for the remote management of mundane tasks such as expenses claims to be handled quickly and efficiently.

```

C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\CSRPCExample\client>npm start

> client@1.0.0 start
> node app.js

What is the expenses item name? (q to Quit):petrol
Who is the person claiming the expenses?bob
How much is being claimed in euro?450
What is the expenses item name? (q to Quit):hotel
Who is the person claiming the expenses?alice
How much is being claimed in euro?500
What is the expenses item name? (q to Quit):q
You have entered 2 expenses items.
The total cost is: 950

```

#### d. Bi-directional streaming RPC

The code that I have made is an IT helpdesk for employees working remotely. When they log on as a client, they can enter their name. The IT support employee can also log in and see the chat stream. This is an important service for office workers, especially since the increase in employees working from home.

```

C:\Users\helen>cd C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\ITSupportChatBDgRPC\client
C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\ITSupportChatBDgRPC\client>npm start
> client@1.0.0 start
> node app.js

Welcome to the IT chat support for Big Company Ltd.
Type your name and press enter.bob
bob: bob joined the IT support chatroom.
Please type your IT issue or response and press enter
carol: carol joined the IT support chatroom.
Please type your IT issue or response and press enter
>

C:\Users\helen>cd C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\ITSupportChatBDgRPC\client
C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\ITSupportChatBDgRPC\client>npm start
> client@1.0.0 start
> node app.js

Welcome to the IT chat support for Big Company Ltd.
Type your name and press enter.alice
alice: alice joined the IT support chatroom.
Please type your IT issue or response and press enter
bob: bob joined the IT support chatroom.
Please type your IT issue or response and press enter
carol: carol joined the IT support chatroom.
Please type your IT issue or response and press enter
>

Microsoft Windows [Version 10.0.19045.3803]
(c) Microsoft Corporation. All rights reserved.

C:\Users\helen>cd C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\ITSupportChatBDgRPC\client
C:\Users\helen\OneDrive\Documents\HDSDev\DistSystems\CA\ITSupportChatBDgRPC\client>npm start
> client@1.0.0 start
> node app.js

Welcome to the IT chat support for Big Company Ltd.
Type your name and press enter.carol
carol: carol joined the IT support chatroom.
Please type your IT issue or response and press enter
>

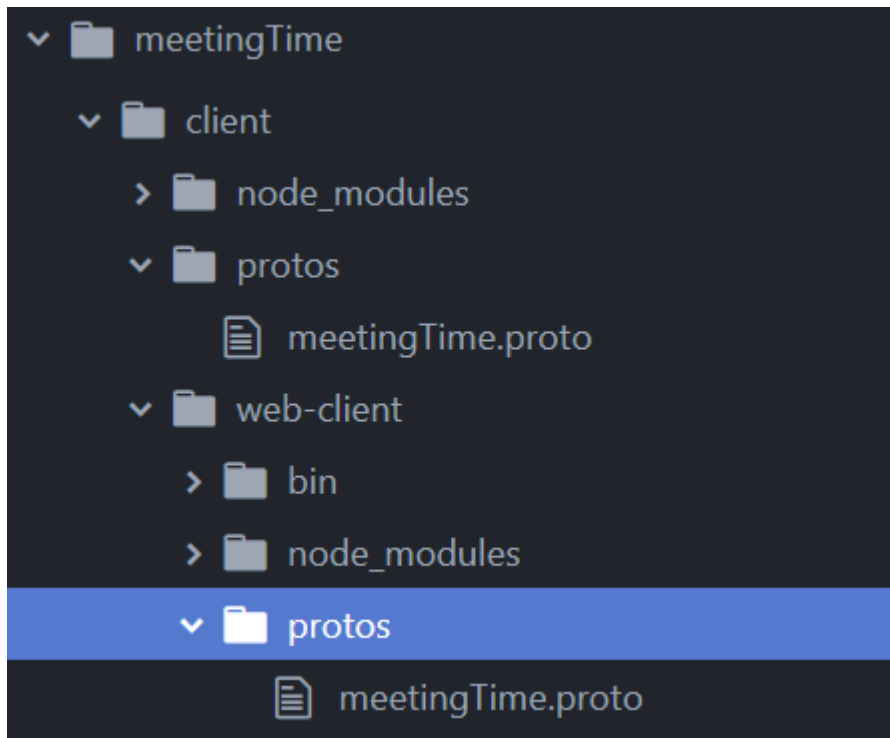
```

## 4. Naming conventions

### a. Unary RPC

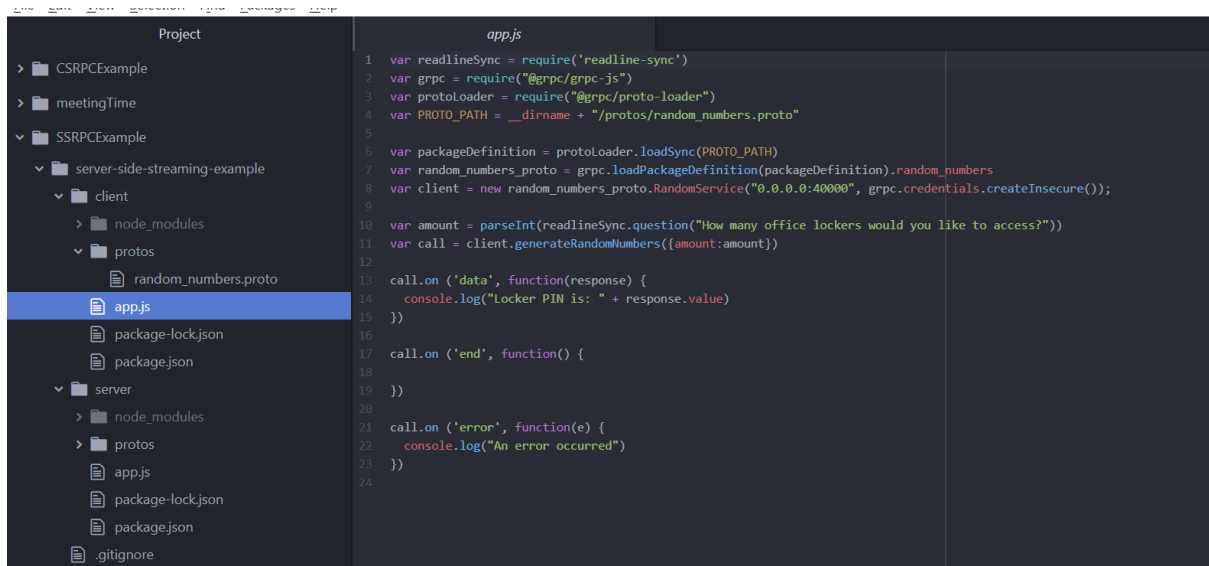
The protos were named meetingTime in client and server folders.

The input numbers were kept as num1 and num2 in all functions so that it would be easier to reuse the code.



### b. Server-side-streaming RPC

The naming for the protos was random\_numbers as this was a general random number generator. It was possible to tailor the RPC within the app.js for the client and server so that it was a specific locker app.



### c. Client-side-streaming RPC

The protos were named expenses.proto.

```

1 var readlineSync = require('readline-sync')
2 var grpc = require('@grpc/grpc-js')
3 var protoLoader = require('@grpc/proto-loader')
4 var PROTO_PATH = __dirname + "/protos/expenses.proto"
5
6 var packageDefinition = protoLoader.loadSync(PROTO_PATH)
7 var expenses_proto = grpc.loadPackageDefinition(packageDefinition).expenses
8 var client = new expenses_proto.BookStore("0.0.0.0:40000", grpc.credentials.createInsecure());
9
10 var call = client.totalCartValue(function(error, response) {
11   if(error) {
12     console.log("An error occurred")
13   } else {
14     console.log("You have entered " + response.books + " expenses items. \n The total cost is: " + response.price)
15   }
16 })
17
18 while(true) {
19   var book_name = readlineSync.question("What is the expenses item name? (q to Quit):")
20   if(book_name.toLowerCase() === "q") {
21     break
22   }
23
24   var author = readlineSync.question("Who is the person claiming the expenses?")
25   var price = readlineSync.question("How much is being claimed in euro?")
26
27   call.write({
28     price: parseFloat(price),
29     author: author,
30     name: book_name
31   })
32 }
33 call.end()
34

```

#### d. Bi-directional-streaming RPC

The protos were named ITchat.proto in client and server.

```

1 var PROTO_PATH = __dirname + '/protos/ITchat.proto';
2 var grpc = require('@grpc/grpc-js');
3 var protoLoader = require('@grpc/proto-loader');
4 var packageDefinition = protoLoader.loadSync(PROTO_PATH);
5 var ITchat_proto = grpc.loadPackageDefinition(packageDefinition).ITchat;
6
7 var clients = {
8 }
9
10 function sendMessage(call) {
11   call.on('data', function(chat_message) {
12
13     if (!(chat_message.name in clients)) {
14       clients[chat_message.name] = {
15         name: chat_message.name,
16         call: call
17       }
18     }
19
20     for (var client in clients) {
21       clients[client].call.write(
22         {
23           name: chat_message.name,
24           message: chat_message.message
25         }
26       )
27     }
28   });
29   call.on('end', function() {
30     call.end();
31   });
32
33   call.on('error', function(e) {
34     console.log(e)
35   });
36 }

```

## 5. Remote Error Handling

The client app.js files deal with errors, for example in the bi-directional streaming RPC, there is an error handling mechanism where an output telling the user “Cannot connect to IT chat server”.

```
var name = readlineSync.question ("Welcome to the IT chat support for Big Company Ltd. \n Type your name and press enter.")
var call = client.sendMessage();

call.on('data', function(resp) {
  console.log(resp.name + ": " + resp.message)
});
call.on('end', function() {

});
call.on("error", function(e) {
  console.log("Cannot connect to IT chat server")
})
```

## 6. Client GUI

There is a GUI using HTML for the unary RPC. Users can choose the function they require from hyperlinks. They can choose one of four functions, each of which has specific labels on the dialog boxes and buttons.

### Meeting Duration Calculator

[Total meeting duration](#)  
[Change meeting duration](#)  
[Calculate recurring meeting](#)  
[Calculate number of meetings required](#)

Original meeting duration (min)   
Reduce meeting time by (mins)

### Meeting Duration Calculator

[Total meeting duration](#)  
[Change meeting duration](#)  
[Calculate recurring meeting](#)  
[Calculate number of meetings required](#)

Meeting duration   
Number of meetings

## 7. Github repository

Code can be found at:

<https://github.com/laineysu/DSCA>

The code is arranged as follows:

meetingtime: This is the unary RPC. There is a web client folder within the client folder to give access to the GUI.

SSRPCEXample/server-side-streaming-example: This is the code for the server-side streaming

CSRPCExample: This is the code for the client-side streaming

ITSupportChatBDgRPC: This is the code for the bi-directional streaming gRPC example.

## Appendix: app.js and proto files for RPC's

These can be found at <https://github.com/laineysu/DSCA>

### a. Unary RPC – meeting durations

```
meetingTime.proto — web-client\protos X meetingTime
1  syntax = "proto3";
2
3  package meetingTime;
4
5  service CalcService {
6      rpc add(CalcRequest) returns (CalcResponse) {}
7      rpc subtract(CalcRequest) returns (CalcResponse) {}
8      rpc multiply(CalcRequest) returns (CalcResponse) {}
9      rpc divide(CalcRequest) returns (CalcResponse) {}
10 }
11 message CalcRequest {
12     uint32 number1 = 1;
13     uint32 number2 = 2;
14 }
15
16 message CalcResponse {
17     uint32 result = 1;
18     string message = 2;
19 }
20
```



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meetingTime.proto	index.js	app.js
<pre>1 var express = require('express'); 2 var router = express.Router(); 3 var grpc = require('@grpc/grpc-js'); 4 var protoLoader = require('@grpc/proto-loader'); 5 6 var PROTO_PATH = __dirname + '/../protos/meetingTime.proto'; 7 packageDefinition = protoLoader.loadSync(PROTO_PATH); 8 var meetingTime_proto = grpc.loadPackageDefinition(packageDefinition).meetingTime; 9 var client = new meetingTime_proto.CalcService('0.0.0.0:40000', grpc.credentials.createInsecure()); 10 11 // test route: GET / 12 router.get('/', function(req, res, next) { 13   var number1 = req.query.number1 14   var number2 = req.query.number2 15   var result 16 17   if(!isNaN(number1) &amp;&amp; !isNaN(number2)) { 18     try { 19       client.add({ number1: number1, number2: number2 }, function(error, response) { 20         try { 21           res.render('index', { title: 'Meeting Duration Calculator', error: error, result: response.result }); 22         } catch (error) { 23           console.log(error) 24           res.render('index', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 25         } 26       }); 27     } catch (error) { 28       console.log(error) 29       res.render('index', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 30     } 31   } else { 32     res.render('index', { title: 'Meeting Duration Calculator', error: null, result: result }) 33   } 34 }); 35 36 // test route: GET /subtract 37 router.get('/subtract', function(req, res, next) { 38   var number1 = req.query.number1 39   var number2 = req.query.number2 40   var result 41 42   if(!isNaN(number1) &amp;&amp; !isNaN(number2)) { 43     try { 44       client.subtract({ number1: number1, number2: number2 }, function(error, response) { 45         try { 46           res.render('subtract', { title: 'Meeting Duration Calculator', error: error, result: response.result }); 47         } catch (error) { 48           console.log(error) 49         } 50       }); 51     } catch (error) { 52       console.log(error) 53     } 54   } else { 55     res.render('subtract', { title: 'Meeting Duration Calculator', error: null, result: result }) 56   } 57 }); 58 59 // test route: GET /divide 60 router.get('/divide', function(req, res, next) { 61   var number1 = req.query.number1 62   var number2 = req.query.number2 63   var result 64 65   if(!isNaN(number1) &amp;&amp; !isNaN(number2)) { 66     try { 67       client.divide({ number1: number1, number2: number2 }, function(error, response) { 68         try { 69           res.render('divide', { title: 'Meeting Duration Calculator', error: error, result: response.result }); 70         } catch (error) { 71           console.log(error) 72           res.render('divide', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 73         } 74       }); 75     } catch (error) { 76       console.log(error) 77       res.render('divide', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 78     } 79   } else { 80     res.render('divide', { title: 'Meeting Duration Calculator', error: null, result: result }) 81   } 82 }); 83 84 // test route: GET /multiply 85 router.get('/multiply', function(req, res, next) { 86   var number1 = req.query.number1 87   var number2 = req.query.number2 88   var result 89 90   if(!isNaN(number1) &amp;&amp; !isNaN(number2)) { 91     try { 92       client.multiply({ number1: number1, number2: number2 }, function(error, response) { 93         try { 94           res.render('multiply', { title: 'Meeting Duration Calculator', error: error, result: response.result }); 95         } catch (error) { 96           console.log(error) 97         } 98       }); 99     } catch (error) { 100       console.log(error) 101     } 102   } else { 103     res.render('multiply', { title: 'Meeting Duration Calculator', error: null, result: result }) 104   } 105 });</pre>		

client(web-client/routes/index.js 113:1 (112,4628) CRLF UTF-8 JavaScript main Fetch GitHub Git (0)

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meetingTime.proto	index.js	app.js
	<pre>50   res.render('subtract', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 51   }); 52   } catch (error) { 53     console.log(error) 54     res.render('subtract', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 55   } 56   } else { 57     res.render('subtract', { title: 'Meeting Duration Calculator', error: null, result: result }) 58   } 59   }); 60 61 // test route: GET /divide 62 router.get('/divide', function(req, res, next) { 63   var number1 = req.query.number1 64   var number2 = req.query.number2 65   var result 66 67   if(!isNaN(number1) &amp;&amp; !isNaN(number2)) { 68     try { 69       client.divide({ number1: number1, number2: number2 }, function(error, response) { 70         try { 71           res.render('divide', { title: 'Meeting Duration Calculator', error: error, result: response.result }); 72         } catch (error) { 73           console.log(error) 74           res.render('divide', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 75         } 76       }); 77     } catch (error) { 78       console.log(error) 79       res.render('divide', { title: 'Meeting Duration Calculator', error: 'Meeting Duration Calculator is not available at the moment please try again later', result: null }); 80     } 81   } else { 82     res.render('divide', { title: 'Meeting Duration Calculator', error: null, result: result }) 83   } 84   }); 85 86 // test route: GET /multiply 87 router.get('/multiply', function(req, res, next) { 88   var number1 = req.query.number1 89   var number2 = req.query.number2 90   var result 91 92   if(!isNaN(number1) &amp;&amp; !isNaN(number2)) { 93     try { 94       client.multiply({ number1: number1, number2: number2 }, function(error, response) { 95         try { 96           res.render('multiply', { title: 'Meeting Duration Calculator', error: error, result: response.result }); 97         } catch (error) { 98           console.log(error) 99         } 100       }); 101     } catch (error) { 102       console.log(error) 103     } 104   } else { 105     res.render('multiply', { title: 'Meeting Duration Calculator', error: null, result: result }) 106   } 107   });</pre>	

client(web-client/routes/index.js 113:1 (112,4628) CRLF UTF-8 JavaScript main Fetch GitHub Git (0)

meetingTime.proto	index.js	app.js
-------------------	----------	--------

```
67 if(!isNaN(number1) && !isNaN(number2)) {
68   try {
69     client.divide({ number1: number1, number2: number2 }, function (error, response) {
70       try {
71         res.render('divide', { title: 'Meeting Duration Calculator', error: error, result: response.result });
72       } catch (error) {
73         console.log(error)
74         res.render('divide', { title: 'Meeting Duration Calculator', error: "Meeting Duration Calculator is not available at the moment please try again later", result: null });
75       }
76     });
77   } catch (error) {
78     console.log(error)
79     res.render('divide', { title: 'Meeting Duration Calculator', error: "Meeting Duration Calculator is not available at the moment please try again later", result: null });
80   }
81 } else {
82   res.render('divide', { title: 'Meeting Duration Calculator', error: null, result: result })
83 }
84 }
85 });
86
87 router.get('/multiply', function(req, res, next) {
88   var number1 = req.query.number1
89   var number2 = req.query.number2
90   var result
91
92   if(!isNaN(number1) && !isNaN(number2)) {
93     try {
94       client.multiply({ number1: number1, number2: number2 }, function (error, response) {
95         try {
96           res.render('multiply', { title: 'Meeting Duration Calculator', error: error, result: response.result });
97         } catch (error) {
98           console.log(error)
99           res.render('multiply', { title: 'Meeting Duration Calculator', error: "Meeting Duration Calculator is not available at the moment please try again later", result: null });
100         }
101       });
102     } catch (error) {
103       console.log(error)
104       res.render('multiply', { title: 'Meeting Duration Calculator', error: "Meeting Duration Calculator is not available at the moment please try again later", result: null });
105     }
106   } else {
107     res.render('multiply', { title: 'Meeting Duration Calculator', error: null, result: result })
108   }
109 }
110 });
111
112 module.exports = router;
113
```

client/web-client/routes/index.js 113:1 (112, 4628)

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index.ejs	meetingTime.proto	add.ejs	app.js
<pre> 1 &lt;!DOCTYPE html&gt; 2 &lt;html&gt; 3 &lt;head&gt; 4   &lt;title&gt;&lt;%= title %&gt;&lt;/title&gt; 5   &lt;link rel="stylesheet" href="/stylesheets/style.css" /&gt; 6 &lt;/head&gt; 7 &lt;body&gt; 8   &lt;h1&gt;&lt;%= title %&gt;&lt;/h1&gt; 9 10   &lt;a href="/"&gt;Total meeting duration&lt;/a&gt; 11   &lt;a href="/subtract"&gt;Change meeting duration &lt;/a&gt; 12   &lt;a href="/multiply"&gt;Calculate recurring meeting &lt;/a&gt; 13   &lt;a href="/divide"&gt;Calculate number of meetings required &lt;/a&gt; 14 15   &lt;%= error %&gt; 16 &lt;/body&gt; 17 18 &lt;form action="/" method="get"&gt; 19   &lt;input type="number" value="Meeting 1 duration (mins)&lt;/label&gt; 20   &lt;input type="number" name="number1"&gt; 21   &lt;br/&gt; 22   &lt;input type="number" value="Meeting 2 duration (mins)&lt;/label&gt; 23   &lt;input type="number" name="number2"&gt; 24   &lt;button type="submit"&gt;Calculate&lt;/button&gt; 25 &lt;/form&gt; 26 27 &lt;%= if(result != undefined) { %&gt; 28   &lt;div&gt;Total meeting time&lt;/div&gt;&lt;%= result %&gt; 29 &lt;%= } %&gt; 30 31 &lt;/body&gt; 32 &lt;/html&gt; </pre>	<pre> 1 &lt;!DOCTYPE html&gt; 2 &lt;html&gt; 3 &lt;head&gt; 4   &lt;title&gt;&lt;%= title %&gt;&lt;/title&gt; 5   &lt;link rel="stylesheet" href="/stylesheets/style.css" /&gt; 6 &lt;/head&gt; 7 &lt;body&gt; 8   &lt;h1&gt;&lt;%= title %&gt;&lt;/h1&gt; 9 10   &lt;a href="/"&gt;Total meeting duration&lt;/a&gt; 11   &lt;a href="/subtract"&gt;Change meeting duration &lt;/a&gt; 12   &lt;a href="/multiply"&gt;Calculate recurring meeting &lt;/a&gt; 13   &lt;a href="/divide"&gt;Calculate number of meetings required &lt;/a&gt; 14 15   &lt;%= error %&gt; 16 &lt;/body&gt; 17 18 &lt;form action="/" method="get"&gt; 19   &lt;input type="number" value="Meeting 1 duration (mins)&lt;/label&gt; 20   &lt;input type="number" name="number1"&gt; 21   &lt;br/&gt; 22   &lt;input type="number" value="Meeting 2 duration (mins)&lt;/label&gt; 23   &lt;input type="number" name="number2"&gt; 24   &lt;button type="submit"&gt;Calculate&lt;/button&gt; 25 &lt;/form&gt; 26 27 &lt;%= if(result != undefined) { %&gt; 28   &lt;div&gt;Total meeting time&lt;/div&gt;&lt;%= result %&gt; 29 &lt;%= } %&gt; 30 31 &lt;/body&gt; 32 &lt;/html&gt; </pre>	<pre> 1 &lt;!DOCTYPE html&gt; 2 &lt;html&gt; 3 &lt;head&gt; 4   &lt;title&gt;&lt;%= title %&gt;&lt;/title&gt; 5   &lt;link rel="stylesheet" href="/stylesheets/style.css" /&gt; 6 &lt;/head&gt; 7 &lt;body&gt; 8   &lt;h1&gt;&lt;%= title %&gt;&lt;/h1&gt; 9 10   &lt;a href="/"&gt;Total meeting duration&lt;/a&gt; 11   &lt;a href="/subtract"&gt;Change meeting duration &lt;/a&gt; 12   &lt;a href="/multiply"&gt;Calculate recurring meeting &lt;/a&gt; 13   &lt;a href="/divide"&gt;Calculate number of meetings required &lt;/a&gt; 14 15   &lt;%= error %&gt; 16 &lt;/body&gt; 17 18 &lt;form action="/" method="get"&gt; 19   &lt;input type="number" value="Meeting 1 duration (mins)&lt;/label&gt; 20   &lt;input type="number" name="number1"&gt; 21   &lt;br/&gt; 22   &lt;input type="number" value="Meeting 2 duration (mins)&lt;/label&gt; 23   &lt;input type="number" name="number2"&gt; 24   &lt;button type="submit"&gt;Calculate&lt;/button&gt; 25 &lt;/form&gt; 26 27 &lt;%= if(result != undefined) { %&gt; 28   &lt;div&gt;Total meeting time&lt;/div&gt;&lt;%= result %&gt; 29 &lt;%= } %&gt; 30 31 &lt;/body&gt; 32 &lt;/html&gt; </pre>	<pre> 1 &lt;!DOCTYPE html&gt; 2 &lt;html&gt; 3 &lt;head&gt; 4   &lt;title&gt;&lt;%= title %&gt;&lt;/title&gt; 5   &lt;link rel="stylesheet" href="/stylesheets/style.css" /&gt; 6 &lt;/head&gt; 7 &lt;body&gt; 8   &lt;h1&gt;&lt;%= title %&gt;&lt;/h1&gt; 9 10   &lt;a href="/"&gt;Total meeting duration&lt;/a&gt; 11   &lt;a href="/subtract"&gt;Change meeting duration &lt;/a&gt; 12   &lt;a href="/multiply"&gt;Calculate recurring meeting &lt;/a&gt; 13   &lt;a href="/divide"&gt;Calculate number of meetings required &lt;/a&gt; 14 15   &lt;%= error %&gt; 16 &lt;/body&gt; 17 18 &lt;form action="/" method="get"&gt; 19   &lt;input type="number" value="Meeting 1 duration (mins)&lt;/label&gt; 20   &lt;input type="number" name="number1"&gt; 21   &lt;br/&gt; 22   &lt;input type="number" value="Meeting 2 duration (mins)&lt;/label&gt; 23   &lt;input type="number" name="number2"&gt; 24   &lt;button type="submit"&gt;Calculate&lt;/button&gt; 25 &lt;/form&gt; 26 27 &lt;%= if(result != undefined) { %&gt; 28   &lt;div&gt;Total meeting time&lt;/div&gt;&lt;%= result %&gt; 29 &lt;%= } %&gt; 30 31 &lt;/body&gt; 32 &lt;/html&gt; </pre>

client/web-client/views/error.ejs 1:1

Project	app.js	multiply.ejs
<ul style="list-style-type: none"> <li>CSRPExample</li> <li>meetingTime</li> <li>client <ul style="list-style-type: none"> <li>node_modules</li> <li>protos <ul style="list-style-type: none"> <li>meetingTime.proto</li> </ul> </li> <li>web-client <ul style="list-style-type: none"> <li>bin</li> <li>node_modules</li> <li>protos <ul style="list-style-type: none"> <li>meetingTime.proto</li> </ul> </li> <li>public</li> <li>routes <ul style="list-style-type: none"> <li>index.ejs</li> </ul> </li> <li>views <ul style="list-style-type: none"> <li>add.ejs</li> <li>divide.ejs</li> <li>error.ejs</li> <li>index.ejs</li> <li><b>multiply.ejs</b></li> <li>subtract.ejs</li> </ul> </li> <li>app.js</li> <li>package-lock.json</li> <li>package.json</li> <li>app.js</li> <li>package-lock.json</li> </ul> </li> </ul> </li></ul>	<pre> 1 var createError = require('http-errors'); 2 var express = require('express'); 3 var path = require('path'); 4 var cookieParser = require('cookie-parser'); 5 var logger = require('morgan'); 6 7 var indexRouter = require('./routes/index'); 8 9 10 var app = express(); 11 12 // view engine setup 13 app.set('view engine', 'ejs'); 14 app.set('views', path.join(__dirname, 'views')); 15 16 app.use(logger('dev')); 17 app.use(express.json()); 18 app.use(express.urlencoded({ extended: false })); 19 app.use(cookieParser()); 20 app.use(express.static(path.join(__dirname, 'public'))); 21 22 app.use('/', indexRouter); 23 24 // catch 404 and forward to error handler 25 app.use(function(req, res, next) { 26   next(createError(404)); 27 }); 28 29 // error handler 30 app.use(function(err, req, res, next) { 31   // set locals, only providing error in development 32   res.locals.message = err.message; 33   res.locals.error = req.app.get('env') === 'development' ? err : {}; 34 35   // render the error page 36   res.status(err.status    500); 37   res.render('error'); 38 }); 39 40 module.exports = app; </pre>	<pre> 1 &lt;!DOCTYPE html&gt; 2 &lt;html&gt; 3 &lt;head&gt; 4   &lt;title&gt;&lt;%= title %&gt;&lt;/title&gt; 5   &lt;link rel="stylesheet" href="/stylesheets/style.css" /&gt; 6 &lt;/head&gt; 7 &lt;body&gt; 8   &lt;h1&gt;&lt;%= title %&gt;&lt;/h1&gt; 9 10   &lt;a href="/"&gt;Total meeting duration&lt;/a&gt; 11   &lt;a href="/subtract"&gt;Change meeting duration &lt;/a&gt; 12   &lt;a href="/multiply"&gt;Calculate recurring meeting &lt;/a&gt; 13   &lt;a href="/divide"&gt;Calculate number of meetings required &lt;/a&gt; 14 15   &lt;%= error %&gt; 16 &lt;/body&gt; 17 18 &lt;form action="/multiply" method="get"&gt; 19   &lt;input type="number" value="Meeting duration&lt;/label&gt; 20   &lt;input type="number" name="number1"&gt; 21   &lt;br/&gt; 22   &lt;input type="number" value="Number of meetings&lt;/label&gt; 23   &lt;input type="number" name="number2"&gt; 24   &lt;button type="submit"&gt;Calculate total meeting time&lt;/button&gt; 25 &lt;/form&gt; 26 27 &lt;%= if(!isNaN(result)) { %&gt; 28   &lt;div&gt;Total meeting time for all meetings: &lt;/div&gt;&lt;%= result %&gt; 29 &lt;%= } %&gt; 30 31 &lt;/body&gt; 32 &lt;/html&gt; </pre>

client/web-client/views/multiply.ejs 1:1

Project	subtract.ejs	app.js
<ul style="list-style-type: none"> <li>protos               <ul style="list-style-type: none"> <li>meetingTime.proto</li> </ul> </li> <li>public</li> <li>routes               <ul style="list-style-type: none"> <li>index.js</li> </ul> </li> <li>views               <ul style="list-style-type: none"> <li>add.ejs</li> <li>divide.ejs</li> <li>error.ejs</li> <li>index.ejs</li> <li>multiply.ejs</li> <li><b>subtract.ejs</b></li> </ul> </li> <li>app.js</li> <li>package-lock.json</li> <li>package.json</li> <li>server               <ul style="list-style-type: none"> <li>node_modules</li> <li>protos                   <ul style="list-style-type: none"> <li>app.js</li> <li>package-lock.json</li> <li>package.json</li> </ul> </li> </ul> </li> <li>SSRPCExample</li> <li>ITSupportChatBDgRPC</li> </ul>	<pre> 1 &lt;!DOCTYPE html&gt; 2 &lt;html&gt; 3 &lt;head&gt; 4   &lt;title&gt;&lt;%= title %&gt;&lt;/title&gt; 5   &lt;link rel="stylesheet" href="/stylesheets/style.css" /&gt; 6 &lt;/head&gt; 7 &lt;body&gt; 8   &lt;h1&gt;&lt;%= title %&gt;&lt;/h1&gt; 9 10   &lt;a href="/"&gt;Total meeting duration&lt;/a&gt; 11   &lt;a href="/subtract"&gt;Change meeting duration&lt;/a&gt; 12   &lt;a href="/multiply"&gt;Calculate recurring meeting&lt;/a&gt; 13   &lt;a href="/divide"&gt;Calculate number of meetings required&lt;/a&gt; 14 15   &lt;%= if(error) { %&gt; 16     &lt;%= error %&gt; 17   &lt;%= %&gt; 18 19   &lt;form action="/subtract" method="get"&gt; 20     &lt;label for="number1"&gt;Original meeting duration (min)&lt;/label&gt; 21     &lt;input type="number" name="number1"&gt; 22     &lt;br&gt; 23     &lt;label for="number2"&gt;Reduce meeting time by (mins)&lt;/label&gt; 24     &lt;input type="number" name="number2"&gt; 25     &lt;button type="submit"&gt;Calculate&lt;/button&gt; 26   &lt;/form&gt; 27 28   &lt;%= if(!isNaN(result)) { %&gt; 29     &lt;%= new meeting duration: %&gt;&lt;%= result %&gt; 30   &lt;%= %&gt; 31 32 &lt;/body&gt; 33 &lt;/html&gt; </pre>	<pre> 1 var grpc = require("grpc/grpc-js"); 2 var protoLoader = require("grpc/proto-loader"); 3 var PROTO_PATH = __dirname + "/protos/meetingTime.proto"; 4 var packageDefinition = protoLoader.loadSync( 5   PROTO_PATH, 6   {} 7 ); 8 var meetingTime_proto = grpc.loadPackageDefinition(packageDefinition).meetingTime; 9 10 function add(call, callback) { 11   try { 12     var number1 = parseInt(call.request.number1); 13     var number2 = parseInt(call.request.number2); 14     if(!isNaN(number1)&amp;&amp;!isNaN(number2)) { 15       var result = number1 + number2; 16       callback(null, { 17         message: undefined, 18         result: result 19       }); 20     } else { 21       callback(null, { 22         message: "Please specify two numbers" 23       }); 24     } 25   } catch(e) { 26     callback(null, { 27       message: "An error occurred during computation" 28     }); 29   } 30 } 31 32 function subtract(call, callback) { 33   try { 34     var number1 = parseInt(call.request.number1); 35     var number2 = parseInt(call.request.number2); 36     if(!isNaN(number1)&amp;&amp;!isNaN(number2)) { 37       var result = number1 - number2; 38       callback(null, { 39         message: undefined, 40         result: result 41       }); 42     } else { 43       callback(null, { 44         message: "Please specify two numbers" 45       }); 46     } 47   } catch(e) { 48     callback(null, { 49       message: "An error occurred during computation" 50     }); 51   } 52 } </pre>

client/web-client/views/subtract.ejs 1:1

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Project	subtract.ejs	app.js
<ul style="list-style-type: none"> <li>protos               <ul style="list-style-type: none"> <li>meetingTime.proto</li> </ul> </li> <li>public</li> <li>routes               <ul style="list-style-type: none"> <li>index.js</li> </ul> </li> <li>views               <ul style="list-style-type: none"> <li>add.ejs</li> <li>divide.ejs</li> <li>error.ejs</li> <li>index.ejs</li> <li>multiply.ejs</li> <li><b>subtract.ejs</b></li> </ul> </li> <li>app.js</li> <li>package-lock.json</li> <li>package.json</li> <li>server               <ul style="list-style-type: none"> <li>node_modules</li> <li>protos                   <ul style="list-style-type: none"> <li>app.js</li> <li>package-lock.json</li> <li>package.json</li> </ul> </li> </ul> </li> <li>SSRPCExample</li> <li>ITSupportChatBDgRPC</li> </ul>	<pre> 1 &lt;!DOCTYPE html&gt; 2 &lt;html&gt; 3 &lt;head&gt; 4   &lt;title&gt;&lt;%= title %&gt;&lt;/title&gt; 5   &lt;link rel="stylesheet" href="/stylesheets/style.css" /&gt; 6 &lt;/head&gt; 7 &lt;body&gt; 8   &lt;h1&gt;&lt;%= title %&gt;&lt;/h1&gt; 9 10   &lt;a href="/"&gt;Total meeting duration&lt;/a&gt; 11   &lt;a href="/subtract"&gt;Change meeting duration&lt;/a&gt; 12   &lt;a href="/multiply"&gt;Calculate recurring meeting&lt;/a&gt; 13   &lt;a href="/divide"&gt;Calculate number of meetings required&lt;/a&gt; 14 15   &lt;%= if(error) { %&gt; 16     &lt;%= error %&gt; 17   &lt;%= %&gt; 18 19   &lt;form action="/subtract" method="get"&gt; 20     &lt;label for="number1"&gt;Original meeting duration (min)&lt;/label&gt; 21     &lt;input type="number" name="number1"&gt; 22     &lt;br&gt; 23     &lt;label for="number2"&gt;Reduce meeting time by (mins)&lt;/label&gt; 24     &lt;input type="number" name="number2"&gt; 25     &lt;button type="submit"&gt;Calculate&lt;/button&gt; 26   &lt;/form&gt; 27 28   &lt;%= if(!isNaN(result)) { %&gt; 29     &lt;%= new meeting duration: %&gt;&lt;%= result %&gt; 30   &lt;%= %&gt; 31 32 &lt;/body&gt; 33 &lt;/html&gt; </pre>	<pre> 50 var number1 = parseInt(call.request.number1); 51 var number2 = parseInt(call.request.number2); 52 if(!isNaN(number1)&amp;&amp;!isNaN(number2)) { 53   var result = number1 + number2; 54   callback(null, { 55     message: undefined, 56     result: result 57   }); 58 } else { 59   callback(null, { 60     message: "Please specify two numbers" 61   }); 62 } 63 64 } catch(e) { 65   callback(null, { 66     message: "An error occurred during computation" 67   }); 68 } 69 70 function divide(call, callback) { 71   try { 72     var number1 = parseInt(call.request.number1); 73     var number2 = parseInt(call.request.number2); 74     if(number2 === "0") { 75       callback(null, { 76         message: "Cannot divide by 0" 77       }); 78     } 79   } else if(!isNaN(number1)&amp;&amp;!isNaN(number2)) { 80     var result = number1 / number2; 81     callback(null, { 82       message: undefined, 83       result: result 84     }); 85   } else { 86     callback(null, { 87       message: "Please specify two numbers" 88     }); 89   } 90 } 91 92 } catch(e) { 93   callback(null, { 94     message: "An error occurred during computation" 95   }); 96 } 97 98 } 99 100 } 101 102 var server = new grpc.Server(); </pre>

client/web-client/views/subtract.ejs 1:1

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## b. Server-side RPC

The screenshot shows a VS Code editor with a project named 'SSRPCExample' containing a 'server-side-streaming-example' folder. Inside this folder are 'client' and 'server' subfolders. The 'client' folder contains 'app.js' and 'random\_numbers.proto'. The 'server' folder contains 'app.js'. The 'random\_numbers.proto' file defines a gRPC service 'RandomService' with a unary method 'generateRandomNumbers'. The 'client/app.js' file uses 'readline-sync' to prompt the user for the number of lockers and then calls the 'generateRandomNumbers' method. The 'server/app.js' file sets up a gRPC server, loads the proto definition, and implements the 'generateRandomNumbers' method by generating random numbers and writing them to the stream.

```
File Edit View Selection Find Packages Help

Project

> CSRPCExample
> meetingTime
> SSRPCExample
  > server-side-streaming-example
    > client
      > node_modules
      > protos
        random_numbers.proto
      app.js
      package-lock.json
      package.json
    > server
      > node_modules
      > protos
        app.js
        package-lock.json
        package.json
      .gitignore
> ITSupportChatBDgRPC

random_numbers.proto
1 syntax = "proto3";
2
3 package random_numbers;
4
5 service RandomService {
6   rpc generateRandomNumbers (RandomRequest) returns (stream RandomReply) {}
7 }
8
9 message RandomRequest {
10   uint32 amount = 1;
11 }
12
13 message RandomReply {
14   uint32 value = 1;
15 }
16

app.js
1 var grpc = require("@grpc/grpc-js");
2 var protoloader = require("@grpc/proto-loader");
3 var PROTO_PATH = __dirname + "/protos/random_numbers.proto";
4 var packageDefinition = protoloader.loadSync(
5   PROTO_PATH
6 );
7 var random_numbers_proto = grpc.loadPackageDefinition(packageDefinition).random_numbers;
8
9 function generateRandomNumbers(call, callback) {
10   for (var i = 0; i < call.request.amount; i++) {
11     call.write({
12       value: Math.round(Math.random()*10000)
13     });
14   }
15   call.end();
16 }
17
18 var server = new grpc.Server();
19 server.addService(random_numbers_proto.RandomService.service, {generateRandomNumbers: generateRandomNumbers});
20 server.bindAsync("0.0.0.0:40000", grpc.ServerCredentials.createInsecure(), function() {
21   server.start();
22 });

app.js
1 var readlineSync = require('readline-sync');
2 var grpc = require("@grpc/grpc-js");
3 var protoloader = require("@grpc/proto-loader");
4 var PROTO_PATH = __dirname + "/protos/random_numbers.proto";
5
6 var packageDefinition = protoloader.loadSync(PROTO_PATH);
7 var random_numbers_proto = grpc.loadPackageDefinition(packageDefinition).random_numbers;
8 var client = new random_numbers_proto.RandomService("0.0.0.0:40000", grpc.credentials.createInsecure());
9
10 var amount = parseInt(readlineSync.question("How many office lockers would you like to access"));
11 var call = client.generateRandomNumbers({amount: amount});
12
13 call.on('data', function(response) {
14   console.log("Locker PIN is: " + response.value);
15 });
16
17 call.on('end', function() {
18 });
19
20 call.on('error', function(e) {
21   console.log("An error occurred");
22 });
23
24

server-side-streaming-example/client/app.js 1:1 CRLF UTF-8 JavaScript main Fetch GitHub Git (0)
```

## c. Client-side RPC

```
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Project
  CSRPCExample
    client
      node_modules
      protos
        expenses.proto
      app.js
      package-lock.json
      package.json
    server
      node_modules
      protos
        app.js
      package-lock.json
      package.json
      .gitignore
    meetingTime
    SSRPCExample
    ITSupportChatBDgRPC

server/app.js 31:1

app.js
1 var packageDefinition = protoLoader.loadSync(
2   PROTO_PATH
3 )
4 var expenses_proto = grpc.loadPackageDefinition(packageDefinition).expenses
5
6 function totalCartValue(call, callback) {
7   var books = 0
8   var price = 0
9
10  call.on('data', function(request) {
11    price += request.price
12    books += 1
13  })
14
15  call.on('end', function() {
16    callback(null, {
17      price: price,
18      books: books
19    })
20  })
21
22  call.on('error', function(e) {
23    console.log("An error occurred")
24  })
25
26 }
27
28 var server = new grpc.Server()
29 server.addService(expenses_proto.BookStore.service, { totalCartValue: totalCartValue })
30 server.bindSync("0.0.0.0:40000", grpc.ServerCredentials.createInsecure(), function() {
31  server.start()
32 })
33
34
35 expenses.proto
36 1 syntax = "proto3";
37 2
38 3 package expenses;
39 4
40 5 service BookStore {
41 6   rpc totalCartValue (stream Book) returns (Cart) {}
42 7 }
43 8
44 9
45 10 message Book {
46 11   string name = 1;
47 12   string author = 2;
48 13
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## d. Bi-directional RPC

The screenshot shows a code editor with the following structure:

- Project Tree (Left Sidebar):**
  - server
    - node\_modules
    - protos
      - Ichat.proto
    - app.js
    - package-lock.json
    - package.json
    - .gitignore
  - meetingTime
  - SSRPCExample
  - ITSupportChatBDgRPC
    - client
      - node\_modules
      - protos
      - Ichat.proto
      - app.js
      - package-lock.json
      - package.json
      - .gitignore

- Code Editor (Center):**
- app.js (Left Pane):**

```
1 | var PROTO_PATH = __dirname + '/protos/Ichat.proto';
2 | var grpc = require('@grpc/grpc-js');
3 | var protoloader = require('@grpc/proto-loader');
4 | var packageDefinition = protoloader.loadSync(PROTO_PATH);
5 | var Ichat_proto = grpc.loadPackageDefinition(packageDefinition).Ichat;
6 |
7 | var clients = {
8 | }
9 |
10 | function sendMessage(call) {
11 |   call.on('data', function(chat_message) {
12 |
13 |     if (!chat_message.name in clients) {
14 |       clients[chat_message.name] = {
15 |         name: chat_message.name,
16 |         call: call
17 |       }
18 |     }
19 |
20 |     for (var client in clients) {
21 |       clients[client].call.write(
22 |         {
23 |           name: chat_message.name,
24 |           message: chat_message.message
25 |         }
26 |       )
27 |     }
28 |   });
29 |   call.on('end', function() {
30 |     call.end();
31 |   });
32 | }
33 | call.on('error', function(e) {
34 |   console.log(e)
35 | });
36 | }
```
- Ichat.proto (Right Pane):**

```
1 | syntax = "proto3";
2 |
3 | package Ichat;
4 |
5 | service ChatService {
6 |   rpc sendMessage(stream ChatMessage) returns (stream ChatMessage) {}
7 | }
8 |
9 | message ChatMessage {
10 |   string name = 1;
11 |   string message = 2;
12 | }
```
- app.js (Far Right Pane):**

```
1 | var readline = require('readline');
2 | var readlineSync = require('readline-sync');
3 | var PROTO_PATH = __dirname + '/protos/Ichat.proto';
4 | var grpc = require('@grpc/grpc-js');
5 | var protoloader = require('@grpc/proto-loader');
6 |
7 | var packageDefinition = protoloader.loadSync(PROTO_PATH);
8 | var Ichat_proto = grpc.loadPackageDefinition(packageDefinition).Ichat;
9 |
10 | var client = new Ichat_proto.ChatService('localhost:4000', grpc.credentials.createInsecure());
11 |
12 | var name = readlineSync.question("Welcome to the IT chat support for Big Company Ltd. \n Name: ");
13 | var call = client.sendMessage();
14 |
15 | call.on('data', function(resp) {
16 |   console.log(resp.name + ": " + resp.message)
17 | });
18 | call.on('end', function() {
19 |
20 | });
21 | call.on("error", function(e) {
22 |   console.log("Cannot connect to IT chat server")
23 | });
24 |
25 | call.write({
26 |   message: name + " joined the IT support chatroom. \n Please type your IT issue or response\n Name: "
27 | });
28 |
29 | var rl = readline.createInterface({
30 |   input: process.stdin,
31 |   output: process.stdout
32 | });
33 |
34 | rl.on("line", function (message) {
35 |   if (message.toLowerCase() === "quit") {
36 |     call.write({
37 |       message: name + " left the IT support chatroom.",
38 |       name: name
39 |     });
40 |     call.end();
41 |     rl.close();
42 |   } else {
43 |     call.write({
44 |       message: message,
45 |       name: name
46 |     });
47 |   }
48 | })
```
- Status Bar (Bottom):** CRLF UTF-8 JavaScript main Fetch GitHub Git (0)