

The background of the slide features a stylized, low-poly illustration of clouds in various shades of blue and grey, set against a clear blue sky. The clouds are scattered across the frame, with some appearing larger and more detailed than others.

RushCart: Cloud-Based Shopping Lists under Pressure 2023/2024

Large Scale Distributed Systems (SDLE) –
M.EIC004

Pedro Balazeiro

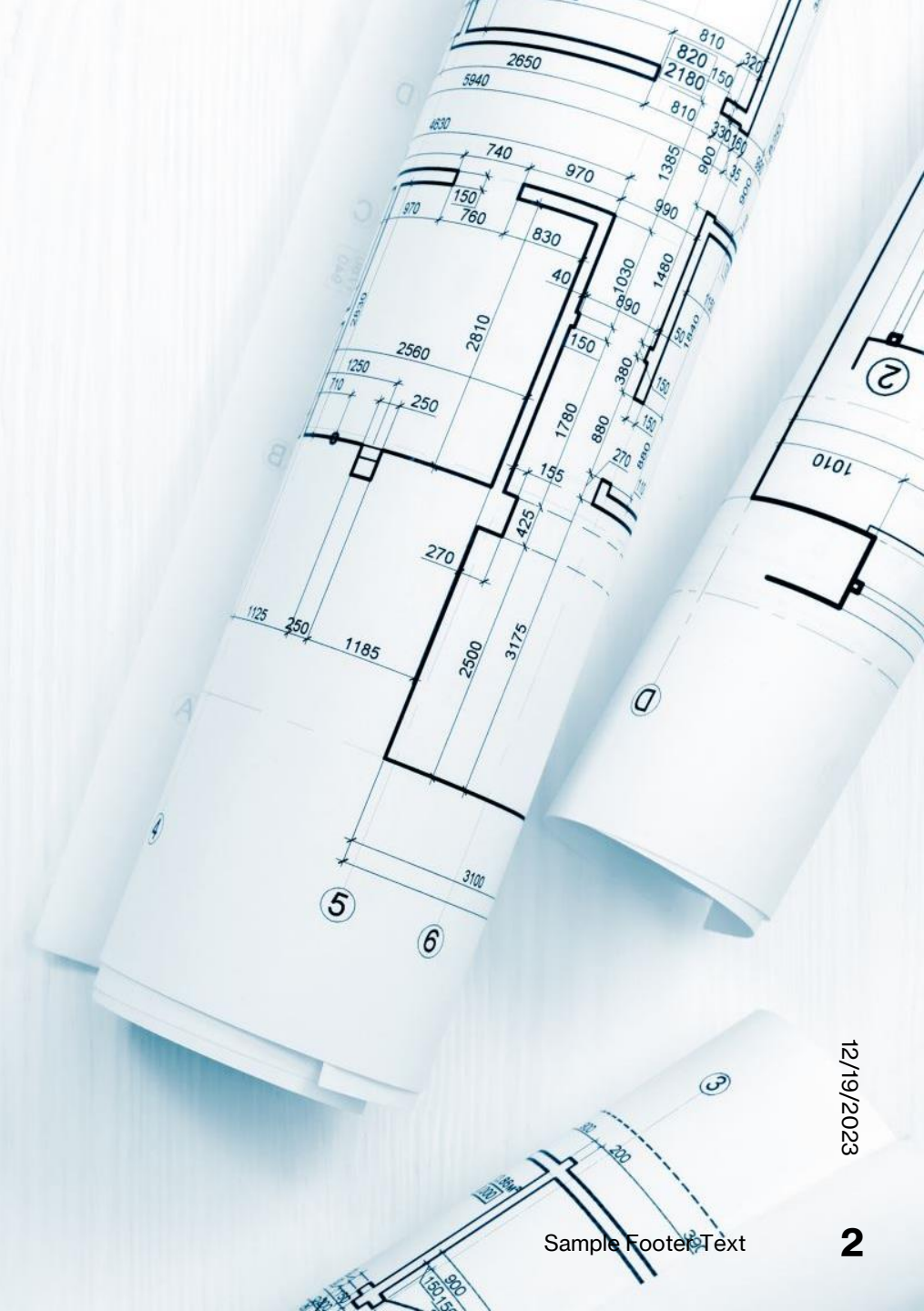
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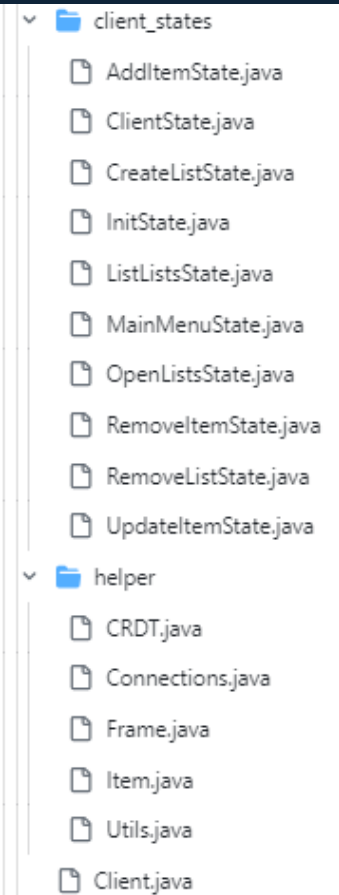
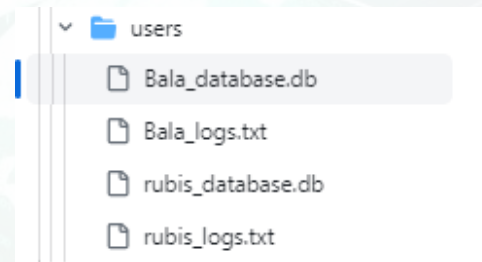
Requirements

- Creation of a local-first shopping list application
- Unique ID lists shared among users
- Managing Lists: Creating, Reading, Updating, and Deleting Entries
- CRDT based lists
- Architecting for Massive Scale: Serving Millions of Users
- Data sharding

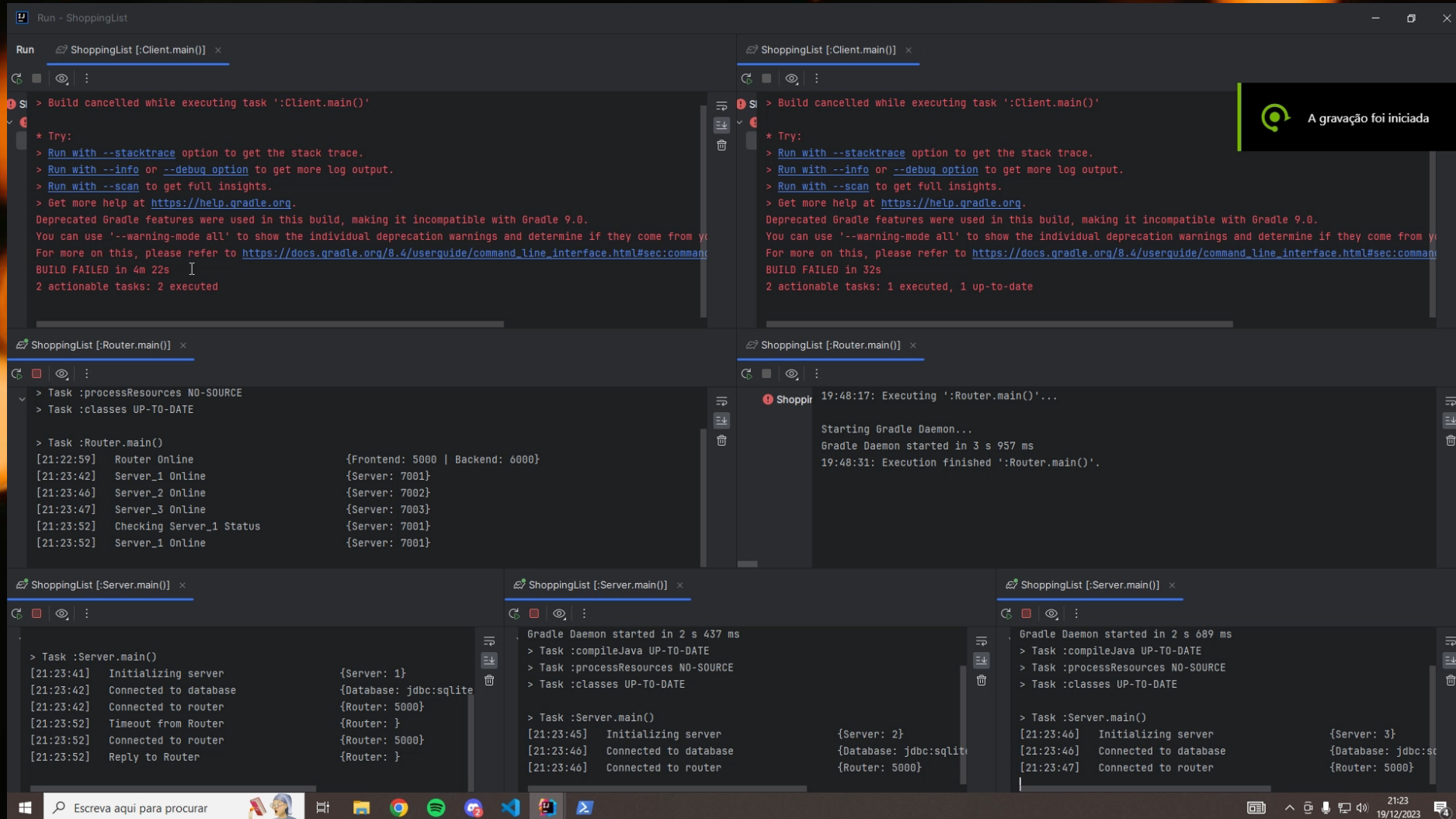


Architectural componentes - client

- State based program
- Sqlite database for each user
- Local first approach
- CLI
- The synchronization with the cloud occurs at regular intervals (every 5 seconds).
- CRDT – LWW



Video Demo – sync with cloud



The screenshot displays an IDE interface with a video recording overlay in the top right corner that reads "A gravação foi iniciada". Below this, there are several terminal windows showing the execution of a Gradle project named "ShoppingList".

Top Left Terminal (Run - ShoppingList):

```
Run ShoppingList [:Client.main()] x
> Build cancelled while executing task ':Client.main()'
* Try:
  > Run with --stacktrace option to get the stack trace.
  > Run with --info or --debug option to get more log output.
  > Run with --scan to get full insights.
  > Get more help at https://help.gradle.org.
Deprecated Gradle features were used in this build, making it incompatible with Gradle 9.0.
You can use '--warning-mode all' to show the individual deprecation warnings and determine if they come from your
For more on this, please refer to https://docs.gradle.org/8.4/userguide/command_line_interface.html#sec:command
BUILD FAILED in 4m 22s
2 actionable tasks: 2 executed
```

Top Right Terminal (ShoppingList [:Client.main()]):

```
ShoppingList [:Client.main()] x
> Build cancelled while executing task ':Client.main()'
* Try:
  > Run with --stacktrace option to get the stack trace.
  > Run with --info or --debug option to get more log output.
  > Run with --scan to get full insights.
  > Get more help at https://help.gradle.org.
Deprecated Gradle features were used in this build, making it incompatible with Gradle 9.0.
You can use '--warning-mode all' to show the individual deprecation warnings and determine if they come from your
For more on this, please refer to https://docs.gradle.org/8.4/userguide/command_line_interface.html#sec:command
BUILD FAILED in 32s
2 actionable tasks: 1 executed, 1 up-to-date
```

Middle Left Terminal (ShoppingList [:Router.main()]):

```
ShoppingList [:Router.main()] x
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Router.main()
[21:22:59] Router Online {Frontend: 5000 | Backend: 6000}
[21:23:42] Server_1 Online {Server: 7001}
[21:23:46] Server_2 Online {Server: 7002}
[21:23:47] Server_3 Online {Server: 7003}
[21:23:52] Checking Server_1 Status {Server: 7001}
[21:23:52] Server_1 Online {Server: 7001}
```

Middle Right Terminal (ShoppingList [:Router.main()]):

```
ShoppingList [:Router.main()] x
19:48:17: Executing ':Router.main()'...
Starting Gradle Daemon...
Gradle Daemon started in 3 s 957 ms
19:48:31: Execution finished ':Router.main()'.
```

Bottom Left Terminal (ShoppingList [:Server.main()]):

```
ShoppingList [:Server.main()] x
> Task :Server.main()
[21:23:41] Initializing server {Server: 1}
[21:23:42] Connected to database {Database: jdbc:sqlite}
[21:23:42] Connected to router {Router: 5000}
[21:23:52] Timeout from Router {Router: }
[21:23:52] Connected to router {Router: 5000}
[21:23:52] Reply to Router {Router: }
```

Bottom Middle Terminal (ShoppingList [:Server.main()]):

```
ShoppingList [:Server.main()] x
Gradle Daemon started in 2 s 437 ms
> Task :compileJava UP-TO-DATE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Server.main()
[21:23:45] Initializing server {Server: 2}
[21:23:46] Connected to database {Database: jdbc:sqlite}
[21:23:46] Connected to router {Router: 5000}
```

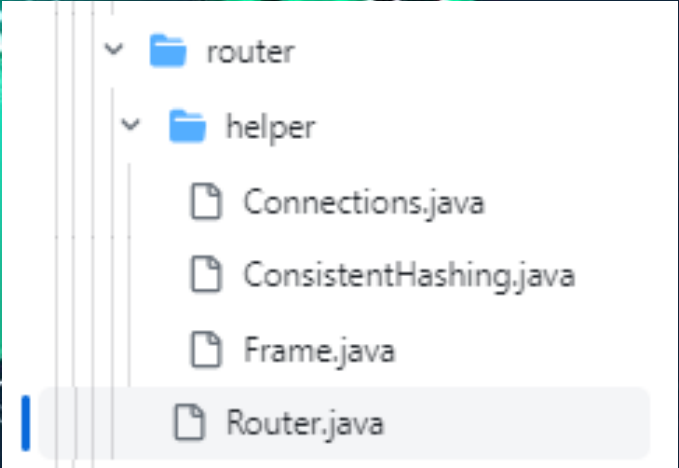
Bottom Right Terminal (ShoppingList [:Server.main()]):

```
ShoppingList [:Server.main()] x
Gradle Daemon started in 2 s 689 ms
> Task :compileJava UP-TO-DATE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Server.main()
[21:23:46] Initializing server {Server: 3}
[21:23:46] Connected to database {Database: jdbc:sqlite}
[21:23:47] Connected to router {Router: 5000}
```

The Windows taskbar at the bottom shows the date and time as 21:23 on 19/12/2023.

Architectural componentes – router

- Developed utilizing ZMQ
- A mediator connecting users' devices to server systems
- Number of routers 2
- Sharding is done using the hash ring
- Router sends heart beats to servers to check if they are online



```
router
├── helper
│   ├── Connections.java
│   ├── ConsistentHashing.java
│   ├── Frame.java
│   └── Router.java
```

Video Demo- Sharding

```
Run - ShoppingList
Run ShoppingList [:Client.main()] x
[0] Exit
> 0
Deprecated Gradle features were used in this build, making it incompatible with Gradle 9.0.
You can use '--warning-mode all' to show the individual deprecation warnings and determine if they come from your project or the Gradle plug-in.
For more on this, please refer to https://docs.gradle.org/8.4/userguide/command_line_interface.html#sec:command_line_warnings
BUILD SUCCESSFUL in 30s
2 actionable tasks: 1 executed, 1 up-to-date
21:28:11: Execution finished ':Client.main()'.

ShoppingList [:Router.main()] x
> Task :compileJava UP-TO-DATE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Router.main()
[21:28:20] Router Online {Frontend: 5000 | Backend: 6000}
[21:28:24] Server_1 Online {Server: 7001}
[21:28:25] Server_2 Online {Server: 7002}
[21:28:27] Server_3 Online {Server: 7003}

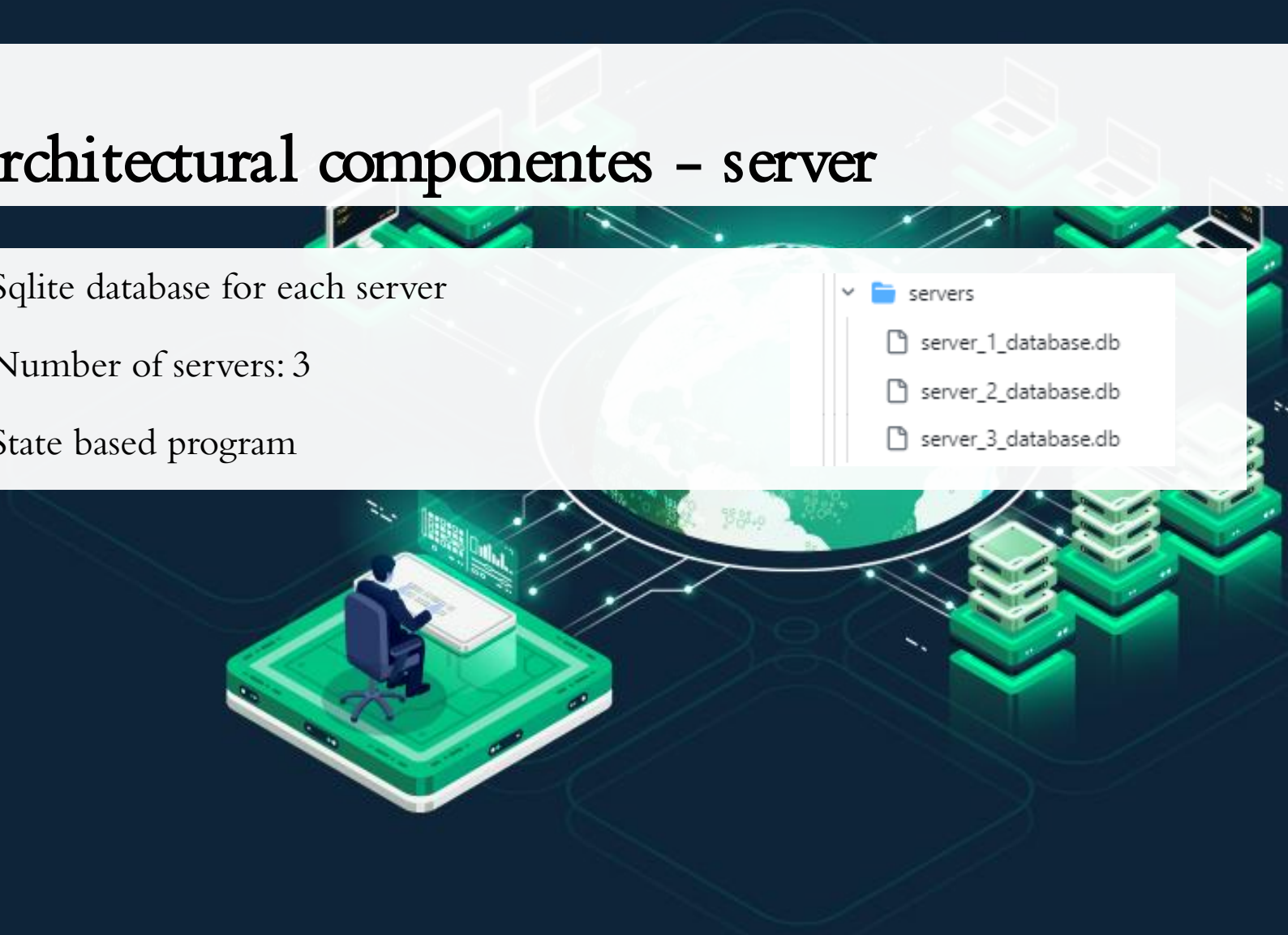
ShoppingList [:Server.main()] x
> Task :compileJava UP-TO-DATE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Server.main()
[21:28:24] Initializing server {Server: 1}
[21:28:24] Connected to database {Database: jdbc:sqlite:}
[21:28:24] Connected to router {Router: 5000}

ShoppingList [:Server.main()] x
> Task :compileJava UP-TO-DATE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Server.main()
[21:28:25] Initializing server {Server: 2}
[21:28:25] Connected to database {Database: jdbc:sqlite:}
[21:28:25] Connected to router {Router: 5000}

ShoppingList [:Server.main()] x
> Task :compileJava UP-TO-DATE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Server.main()
[21:28:26] Initializing server {Server: 3}
[21:28:27] Connected to database {Database: jdbc:sqlite:}
[21:28:27] Connected to router {Router: 5000}
```

Architectural componentes – server

- Sqlite database for each server
- Number of servers: 3
- State based program



```
▼ servers
  server_1_database.db
  server_2_database.db
  server_3_database.db
```

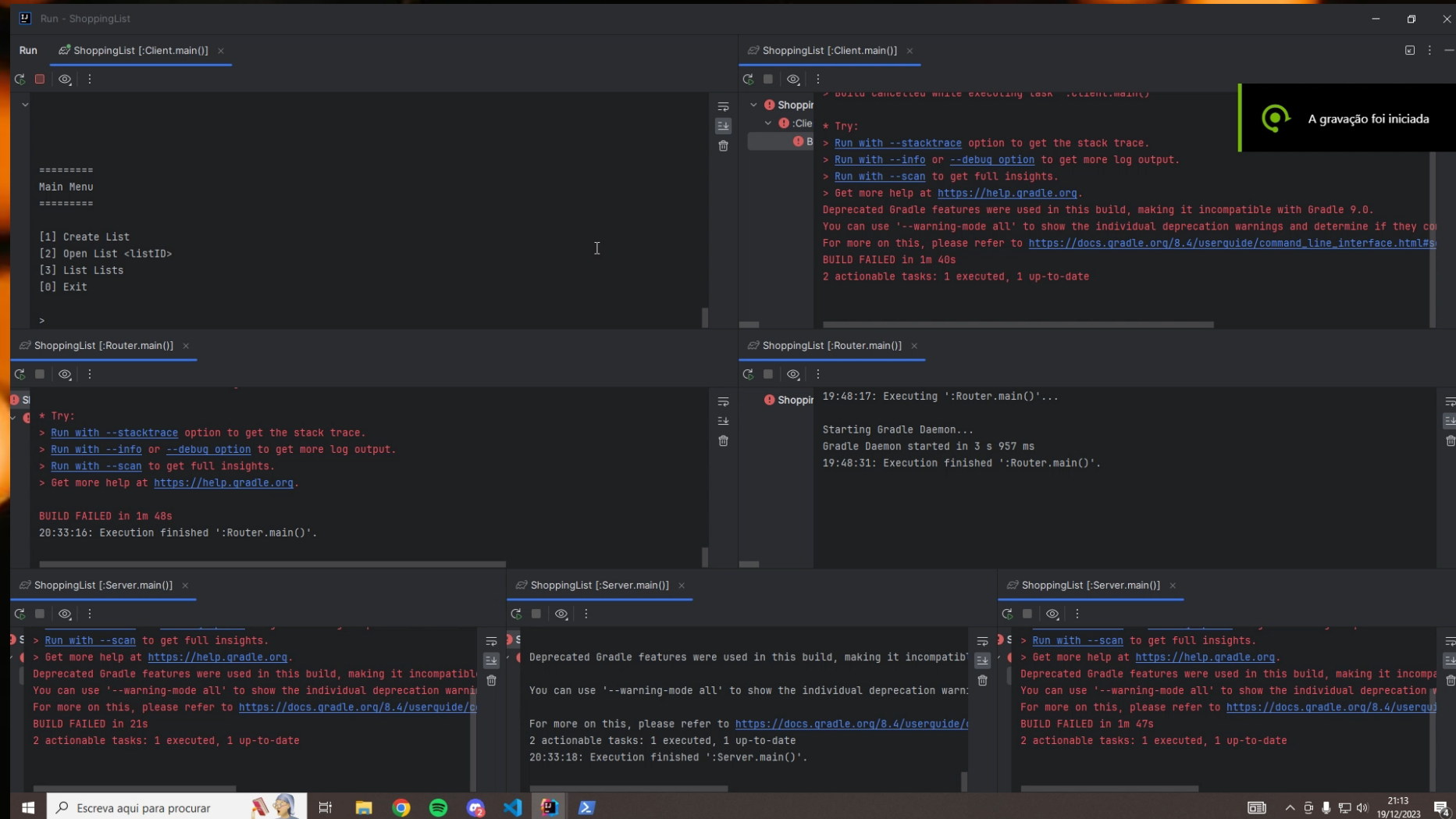
```
▼ server
  ▼ helper
    CRDT.java
    Connections.java
    Frame.java
    Item.java
  ▼ server_states
    ConnectRouterState.java
    InitState.java
    OnlineState.java
    ServerState.java
    Server.java
```


Local first implementation



- Offline Capability
- Data Consistency when network connectivity is restored
- Conflict Resolution
- Offline Editing (CRUD operations)

Video Demo – Local first



The screenshot displays an IDE interface with a video recording overlay in the top right corner that reads "A gravação foi iniciada". Below this, there are several Gradle console windows. The top-left window shows the output of the `ShoppingList [:Client.main()]` task, displaying a menu and a list of tasks. The top-right window shows the output of the `ShoppingList [:Client.main()]` task, displaying a Gradle error message: "BUILD FAILED in 1m 40s". The bottom-left window shows the output of the `ShoppingList [:Router.main()]` task, displaying a Gradle error message: "BUILD FAILED in 1m 48s". The bottom-right window shows the output of the `ShoppingList [:Server.main()]` task, displaying a Gradle error message: "BUILD FAILED in 1m 47s". The bottom-most window shows the output of the `ShoppingList [:Server.main()]` task, displaying a Gradle error message: "BUILD FAILED in 1m 47s". The IDE's taskbar at the bottom shows various application icons and the system clock indicating 21:13 on 19/12/2023.

```
Run - ShoppingList
Run ShoppingList [:Client.main()] x
=====
Main Menu
=====

[1] Create List
[2] Open List <listID>
[3] List Lists
[0] Exit
>

ShoppingList [:Client.main()] x
BUILD FAILED in 1m 40s
2 actionable tasks: 1 executed, 1 up-to-date

* Try:
> Run with --stacktrace option to get the stack trace.
> Run with --info or --debug option to get more log output.
> Run with --scan to get full insights.
> Get more help at https://help.gradle.org.

Deprecated Gradle features were used in this build, making it incompatible with Gradle 9.0.
You can use '--warning-mode all' to show the individual deprecation warnings and determine if they can be safely ignored.
For more on this, please refer to https://docs.gradle.org/8.4/userguide/command_line_interface.html#sec:command_line_warnings
BUILD FAILED in 1m 40s
2 actionable tasks: 1 executed, 1 up-to-date

ShoppingList [:Router.main()] x
19:48:17: Executing ':Router.main()'...

Starting Gradle Daemon...
Gradle Daemon started in 3 s 957 ms
19:48:31: Execution finished ':Router.main()'.

ShoppingList [:Server.main()] x
> Run with --scan to get full insights.
> Get more help at https://help.gradle.org.

Deprecated Gradle features were used in this build, making it incompatible with Gradle 9.0.
You can use '--warning-mode all' to show the individual deprecation warnings and determine if they can be safely ignored.
For more on this, please refer to https://docs.gradle.org/8.4/userguide/command_line_interface.html#sec:command_line_warnings
BUILD FAILED in 1m 47s
2 actionable tasks: 1 executed, 1 up-to-date

ShoppingList [:Server.main()] x
Deprecated Gradle features were used in this build, making it incompatible with Gradle 9.0.
You can use '--warning-mode all' to show the individual deprecation warnings and determine if they can be safely ignored.
For more on this, please refer to https://docs.gradle.org/8.4/userguide/command_line_interface.html#sec:command_line_warnings
BUILD FAILED in 1m 47s
2 actionable tasks: 1 executed, 1 up-to-date

ShoppingList [:Server.main()] x
> Run with --scan to get full insights.
> Get more help at https://help.gradle.org.

Deprecated Gradle features were used in this build, making it incompatible with Gradle 9.0.
You can use '--warning-mode all' to show the individual deprecation warnings and determine if they can be safely ignored.
For more on this, please refer to https://docs.gradle.org/8.4/userguide/command_line_interface.html#sec:command_line_warnings
BUILD FAILED in 1m 47s
2 actionable tasks: 1 executed, 1 up-to-date
```

CRDT

- Simple version
- Uses timestamp for merge
- Add, remove, update and merge operations

```
public class CRDT {  
    private Map<String, Item> items = new HashMap<>();  
    public CRDT(String itemList) {  
        JSONArray jsonArray = new Gson().fromJson(itemList, JSONArray.class);  
        for (JsonElement item : jsonArray) {  
            Item newItem = new Gson().fromJson(item, Item.class);  
            items.put(newItem.name, newItem);  
        }  
    }  
  
    public void addOrUpdateItem(Item newItem) {  
        items.put(newItem.name, newItem);  
    }  
  
    // Removing an Item is equivalent to setting its quantity to 0  
    public void removeItem(Item removedItem) {  
        Item newItem = new Item(removedItem.name, 0, removedItem.timestamp);  
        items.put(newItem.name, newItem);  
    }  
  
    // Method to merge two lists based on timestamps  
    public void merge(String otherItemList) {  
        JSONArray otherJSONArray = new Gson().fromJson(otherItemList, JSONArray.class);  
        for (JsonElement otherItem : otherJSONArray) {  
            Item item = new Gson().fromJson(otherItem, Item.class);  
            items.merge(item.name, item, (existingItem, newItem) ->  
                (existingItem.timestamp >= newItem.timestamp) ? existingItem : newItem  
            );  
        }  
    }  
  
    // Method to get the current state as a JSON string  
    public String getItemList() {  
        return new Gson().toJson(items.values());  
    }  
  
    public Collection<Item> getItems() {  
        return items.values();  
    }  
  
    public Item getItem(String name) {  
        return items.get(name);  
    }  
}
```


Video Demo- Conflict resolution

The screenshot displays four console windows from an IDE, all titled 'ShoppingList'. The top-left window shows the client's initial state with a list of items (banana: 6, pera: 3, bolo rei: 1) and a menu. The top-right window shows the client's main method execution starting the Gradle Daemon. The bottom-left window shows the router's main method execution, logging requests and responses between the client and server. The bottom-right window shows the server's main method execution, logging the initialization of the server, database connection, and the processing of requests. A notification on the right side of the IDE states 'A gravação foi iniciada' (Recording has started).

```
Run - ShoppingList
Run ShoppingList [:Client.main()] x
=====
List a285866b-a3e3-4fbd-bed9-ff0408bb4eb7
=====
- banana: 6
- pera: 3
- bolo rei: 1

[1] Add Item
[2] Remove Item
[3] Update Item
[0] Back
>

ShoppingList [:Router.main()] x
[21:31:51] Response from Server_7002 to rubis_af30 {SERVER_OK?PUSH_LIST?a285866b-a3e3-4fbd-bed9-ff0408bb4eb7:
[21:31:56] Reply to rubis_19cc {CLIENT_OK?ROUTER_STATUS??}
[21:31:56] Request from rubis_19cc to Server_7001 {CLIENT_OK?PULL_LIST?a285866b-a3e3-4fbd-bed9-ff0408bb4eb7?}
[21:31:56] Response from Server_7001 to rubis_19cc {SERVER_OK?PULL_LIST?a285866b-a3e3-4fbd-bed9-ff0408bb4eb7:
[21:31:56] Reply to rubis_307e {CLIENT_OK?ROUTER_STATUS??}
[21:31:56] Request from rubis_307e to Server_7001 {CLIENT_OK?PUSH_LIST?a285866b-a3e3-4fbd-bed9-ff0408bb4eb7?}
[21:31:56] Response from Server_7001 to rubis_307e {SERVER_OK?PUSH_LIST?a285866b-a3e3-4fbd-bed9-ff0408bb4eb7:
[21:31:56] Request from rubis_307e to Server_7002 {CLIENT_OK?PUSH_LIST?a285866b-a3e3-4fbd-bed9-ff0408bb4eb7?}
[21:31:56] Response from Server_7002 to rubis_307e {SERVER_OK?PUSH_LIST?a285866b-a3e3-4fbd-bed9-ff0408bb4eb7:

ShoppingList [:Server.main()] x
[21:31:51] Request from Client {CLIENT_OK?PULL_LIST?a
[21:31:51] List Pulled {List: a285866b-a3e3-4
[21:31:51] Request from Client {CLIENT_OK?PUSH_LIST?a
[21:31:51] List Updated {List: a285866b-a3e3-4
[21:31:56] Request from Client {CLIENT_OK?PULL_LIST?a
[21:31:56] List Pulled {List: a285866b-a3e3-4
[21:31:56] Request from Client {CLIENT_OK?PUSH_LIST?a
[21:31:56] List Updated {List: a285866b-a3e3-4

ShoppingList [:Server.main()] x
> Task :Server.main()
[21:31:47] Initializing server {Server: 2}
[21:31:48] Connected to database {Database: jdbc:sqlite
[21:31:48] Connected to router {Router: 5000}
[21:31:51] Request from Client {CLIENT_OK?PUSH_LIST?
[21:31:51] List Updated {List: a285866b-a3e3-4
[21:31:56] Request from Client {CLIENT_OK?PUSH_LIST?
[21:31:56] List Updated {List: a285866b-a3e3-4

ShoppingList [:Server.main()] x
Gradle Daemon started in 2 s 723 ms
> Task :compileJava UP-TO-DATE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :Server.main()
[21:31:50] Initializing server {Server: 3}
[21:31:50] Connected to database {Database: jdbc:sc
[21:31:50] Connected to router {Router: 5000}
```

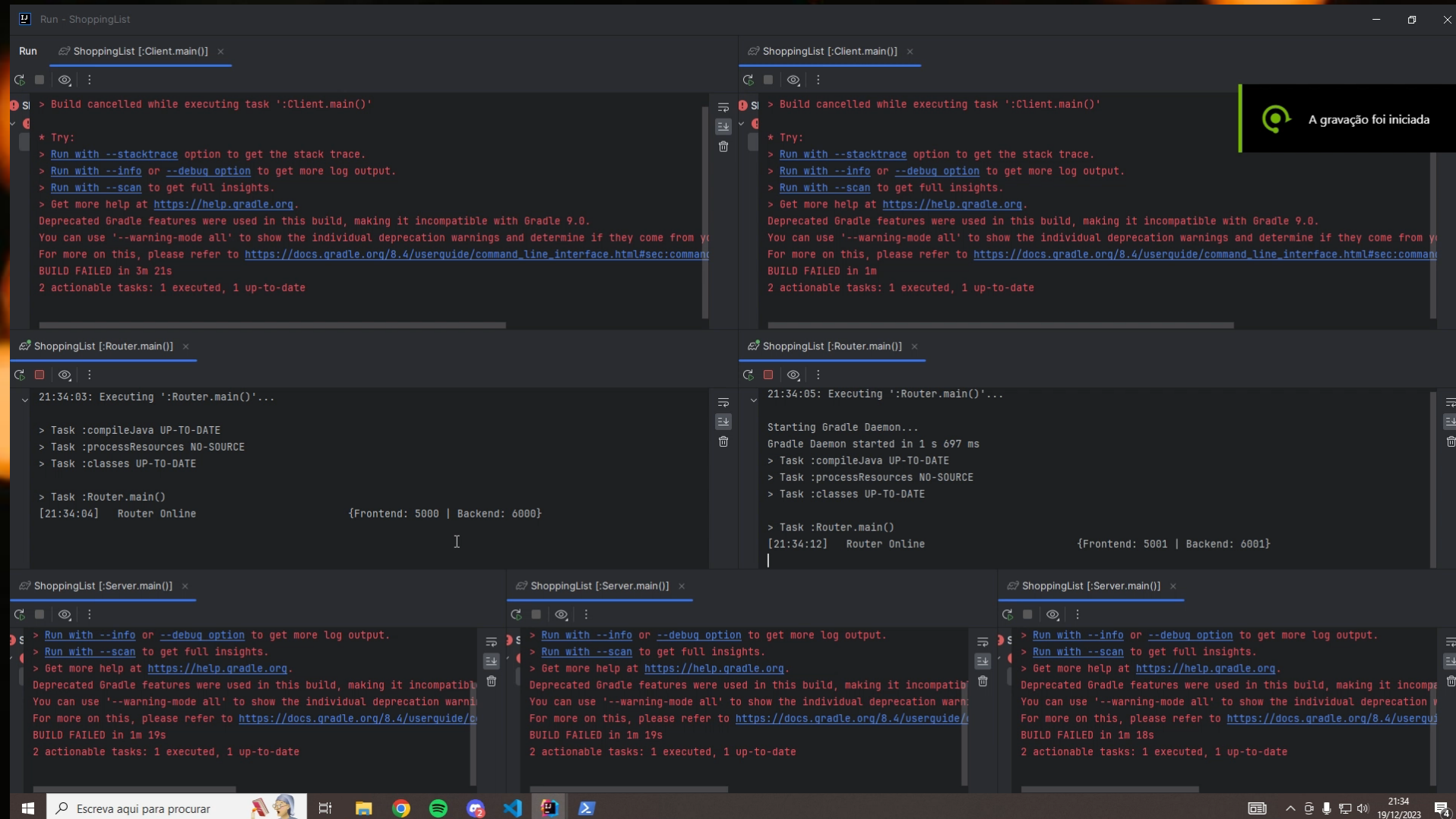

Consistent hashing

- Number of virtual nodes per server: 3
- Used sha256

```
public class ConsistentHashing {  
    private final int numberOfReplicas; // Number of virtual nodes per server  
    private final SortedMap<String, Integer> hashRing = new TreeMap<>(); // Hash ring  
    private final MessageDigest hashFunction;
```

```
class ConsistentHashing  
    func ConsistentHashing  
    func addServer  
    func removeServer  
    func hash  
    func bytesToHex  
    func getServer
```

Video Demo – reconnection router



The screenshot displays an IDE interface with a video recording overlay in the top right corner that reads "A gravação foi iniciada". Below the overlay, there are six terminal windows arranged in a 2x3 grid, all showing the output of a Gradle build for a project named "ShoppingList".

The top row of terminals shows the output of the `Client.main()` task, which has been cancelled. The output includes a warning about deprecated Gradle features and a "BUILD FAILED" message.

The middle row of terminals shows the output of the `Router.main()` task. The left terminal shows the task execution starting at 21:34:03, and the right terminal shows the task execution starting at 21:34:05. Both show the task execution progress and the final output: "Router Online" with frontend and backend ports.

The bottom row of terminals shows the output of the `Server.main()` task, which has also been cancelled. The output includes a warning about deprecated Gradle features and a "BUILD FAILED" message.

The IDE's status bar at the bottom shows the time as 21:34 on 19/12/2023.

Conclusions and future work

- Upgrade CRDT
- Communication between servers
- Improvement of hash ring
- Hinted Handoff

