Class Management System

Prepared By:

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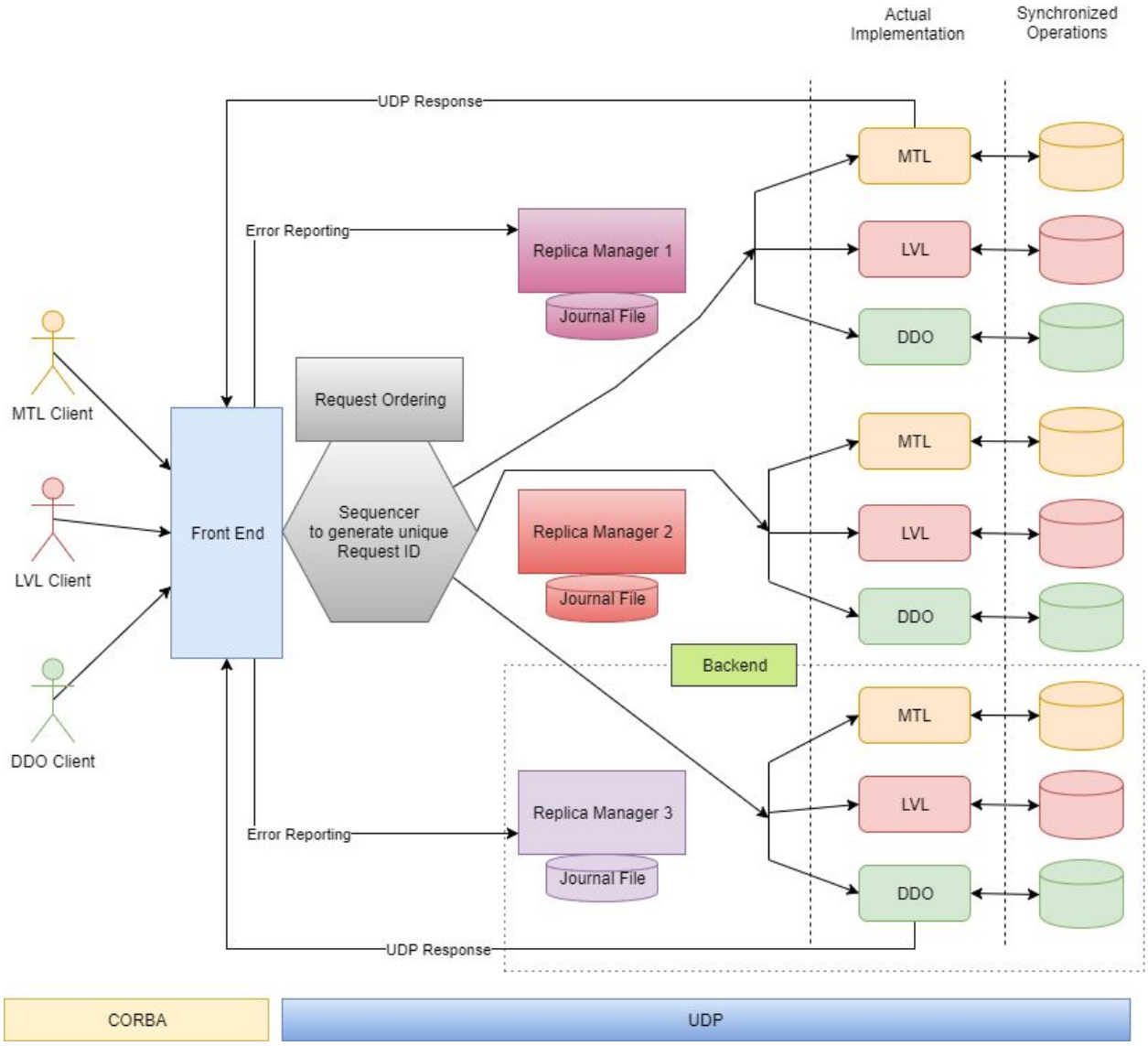
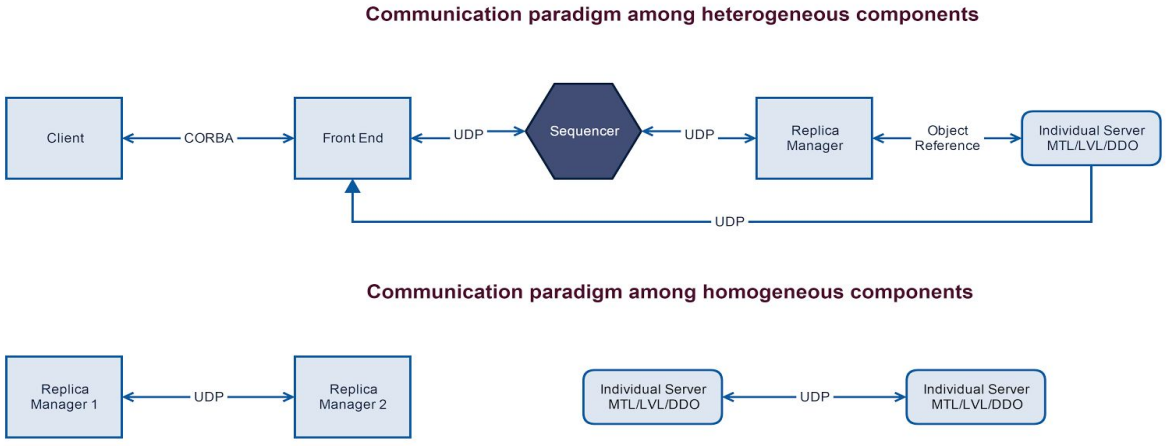
Objective:

Design and develop a distributed system which provides an infrastructure for Class Management System shared across three data centers. Expose CORBA APIs to the user which abstract the underlying distributed nature of the platform and provide network transparency. Implement multi threading with proper synchronization to handle concurrent requests safely. Implement multiple replicas for each server to detect and recover from failures.

Overall Design Architecture:



Communication among components:



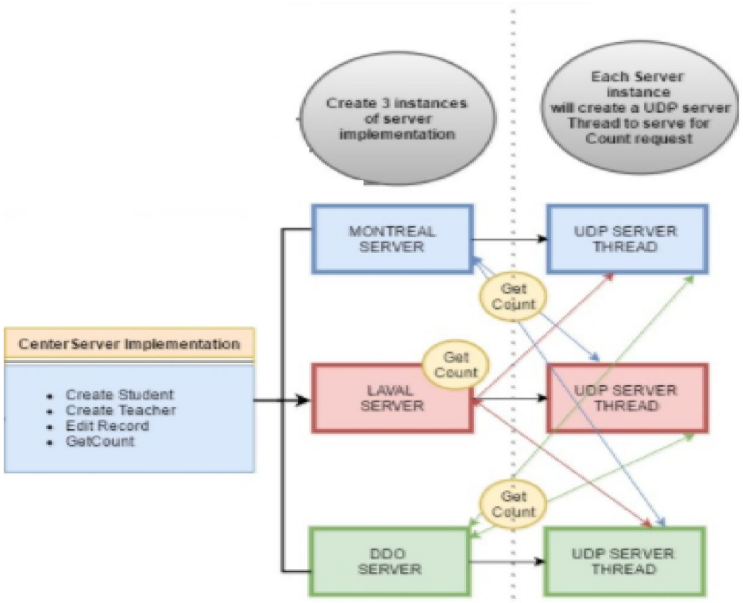
Overall Workflow:

- Front End will register CORBA remote reference with Naming Service
- Client will send request to Front End (FE) using CORBA remote invocation
- With the help of Sequencer FE will generate unique request id and multicast it to all three replicas
- Sequencer is responsible to maintain Request Ordering
- Replicas will buffer each request and make sure to execute in same order received
- Server implementations will process the request and send the result back to FE
- Replica will also buffer some last processed results along with Request Id to avoid any duplicate request processing
- On receiving response from all replicas, FE will do following:
    - In case of any inconsistency in result, FE will report Error to respective replica manager with request ID.
    - If FE doesn't receive response from replica for a reasonable time then it reports crash to Replica Manager
    - FE will respond back client with most appropriate answer
- Replica Manager will declare a replica as corrupted and initializes new replica instance
    - if it receives consecutive three Error reports from FE or unresponsive for the same replica.

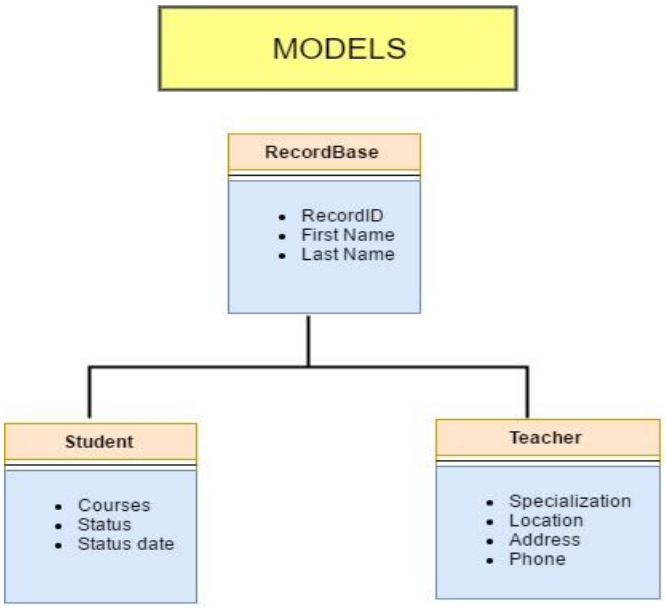
Replica failure recovery:

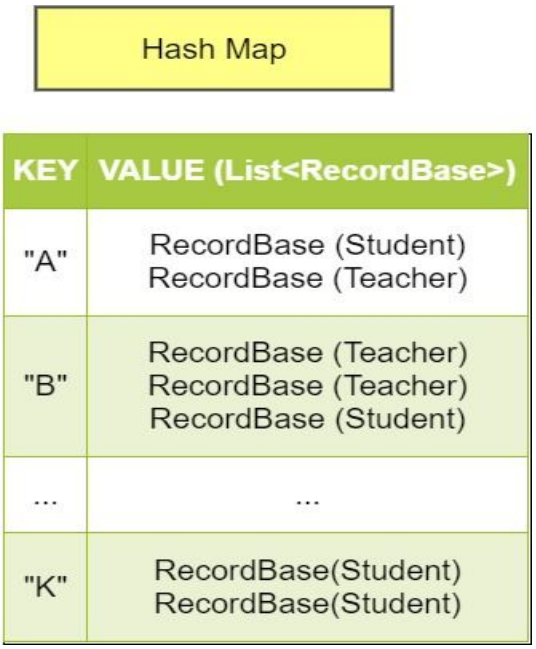
1. Replica Manager(RM) will keep all new requests in the buffer for that replica and stop forwarding to the replica.
2. RM will parse through the journal file to generate the hashmap
3. Ask replica to complete all pending requests buffered at RM
4. On catching up all pending requests, new replica will start operating smoothly

Server Architecture: (For Eg Montreal Server)



Data Modelling:





RecordBase:

- This is the base model which holds the common properties like firstname, lastname and recordID.

Student:

- This extends the base class RecordBase and has its own properties like Courses, Status and StatusDate

Teacher:

- This class extends the base class RecordBase and has its own properties like Specialization, Location, Phone and Address.

HashMap:

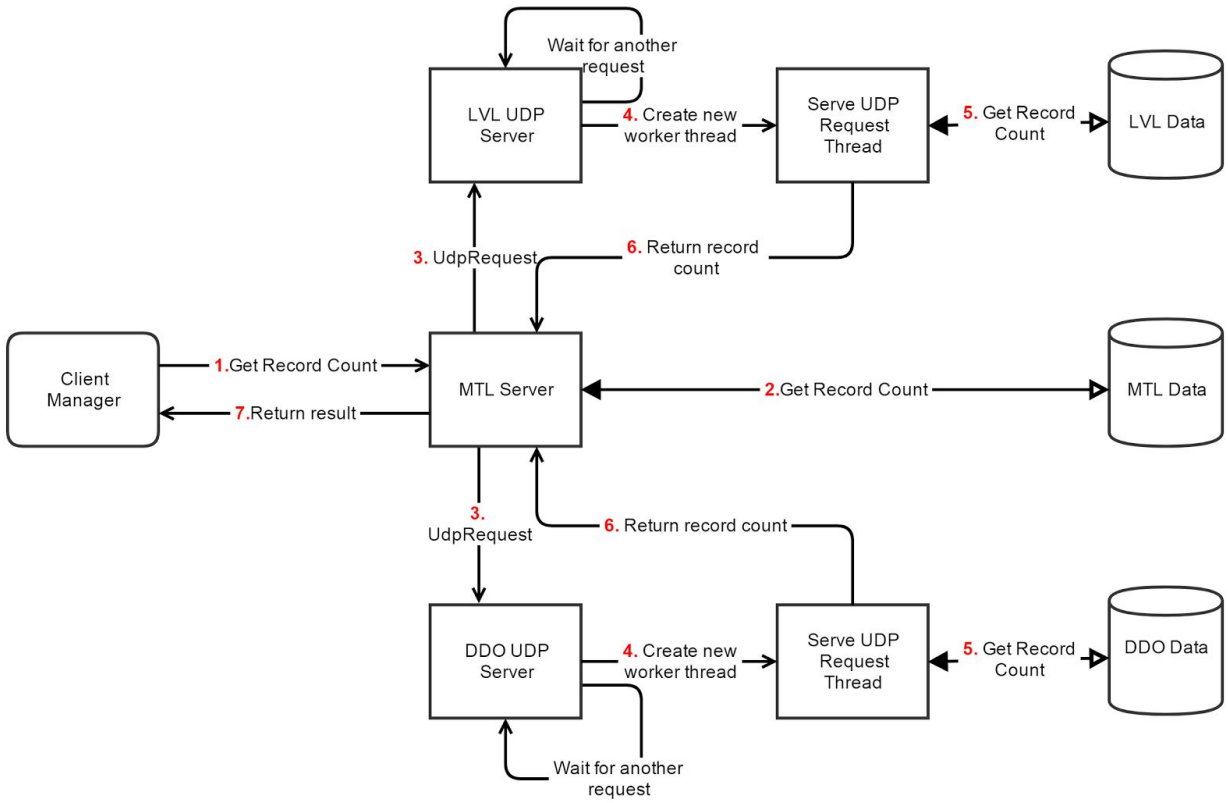
- Signature : **HashMap<String, List<RecordBase>>**
- Hashmap is used as a database for storing/retrieving/editing teacher and student records.
- Since both Teacher and Student derives from RecordBase, both the record types can be stored in the same HashMap.
- **Storing Procedure:**
    - The first letter of the last name of any record has been used as the key.
    - Since Lastname is used as the key in the hashmap. It has been validated against
        - Empty
        - Null
    - If Validation Passes
        - The record will be added to the list which corresponds to the key in the hashmap.
        - Log this event in journal file on persistent storage.
    - Else
        - Last Name validation failed exception will be thrown.
- **Editing Procedure:**
    - The record will be searched in the hashmap based on the RecordID
    - If a matching record is found
        - The input field name and value will be validated
        - If Validation is success
            - Then the record will be updated with the new value
            - Log this event in journal file on persistent storage.
        - Else
            - Validation Failed Exception will be thrown
    - Else
        - Record Not Found Exception will be thrown

- **Transfer Record:**
    - The record will be searched in the hashmap based on the RecordID

- If a matching record is found
  - An UDP request will be created for the respective server with the matching record as argument.
  - If the UDP request is success:
    - Then delete the record from the hash map.
    - Log this event in journal file on persistent storage.
  - Else
    - Record Transfer Failed Exception will be thrown.
- Else
  - Record Not Found Exception will be thrown

UDP Server Design:

On receiving get record count request each server will fork get count request threads to remaining servers. Communication among all three servers take place using UDP/IP protocol.



Execution flow:

1. The server receives the GetCount request.
2. Server access its data set to fetch the record count details
3. Generates two new UDP request threads to send get count request to remaining two locations.

4. UDP server of respective location will receive the request and generate new worker thread to serve that request
5. Worker thread will access respective data set to fetch the record count details
6. Worker thread will respond to the request with record count details
7. Sever who received get record count request will collect results and return to the Manager client

Concurrency:

- Location Server creates new thread to communicate to each UDP server
- UDP Server creates a new worker thread for each coming request and delegates the service request.

Synchronization:

- Each request to access Data set is synchronized. Hence only one thread can get the hold on it which makes it thread safe.
- Additionally, each thread is a new object hence possesses its own memory space hence no shared resources among other threads.

Logging for troubleshooting :

We have used the inbuilt logger provided by Java (java.util.logging) to perform logging in both server and client side.

Log Format:

Generally each log entry should have the following data

- Timestamp
- Class and function name which performs the action

Center Server:

Each server log (Montreal, Laval, DDO) will be saved in their respective folder

- LOGS/MTL/logger.log
- LOGS/LVL/logger.log
- LOGS/DDO/logger.log

Following events will be captured in log file

- Record Created
- Record Edited
- Exceptions
- UDP communications

Client:

Every Manager is a client. A log file will be created for each manager and actions performed by him/her will be logged. The actions logged are as follows

- Creating record

- Editing Record
- Exceptions

Implementation:

- Create a Unique logger for each Server. (java.util.logging)
- Add a file handler to save the contents to the respective log file.
- Log using various levels like (INFO, WARNING, ERROR (java.util.logging.Level)) based on the severity.

Challenges:

- Fine grained locking on shared objects
    - HashMap: Central data set
    - Counter: Unique record ID generator
- Concurrency in UDP server

Reliability:

We have implemented two features for reliability measures.

- **Journaling**
    - Motivation: As HashMap remains in memory. any server crash event will result into whole data lost. Journaling is the solution to provide backup of HashMap data.
    - Design: Any Edit/Add action performed on HashMap will be recorded in the journal file which remains on persistent storage with event identifier and required data.
    - Failure recovery: In case of any server crash event, parse through the journal file to recover whole data.
- **Serialization of Counter objects**
    - Motivation: Counter objects are being used to generate unique record id. Any inconsistency in that operation may cause duplicate record Ids and inconsistent data eventually.
    - Design: Make counter objects serialized and store it into a persistent storage on each modification.
    - Failure recovery: Read counter object from storage and deserialize it during server recovery phase.

Test Scenarios:

1. Add Student record with different inputs
2. Add Teacher record with different inputs

3. Update student record
4. Update Teacher record
5. Get record count for all servers
6. Student status date should be updated whenever status changes.
7. Exception handling for the following scenarios:
    a. Invalid last name while creating a record.
    b. Invalid Record ID during editing a record.
    c. Invalid value. (foe eg: Location, status)
    d. Trying to update Invalid field (for eg: firstname)
    e. Invalid Manager ID (Manager ID should start with MTL, LVL, DDO)

The above scenarios should also work when making multiple requests asynchronously using threads.

Learnings:

- Java
- Concurrency with multithreaded system
- Data modelling
- Fine grained locking and synchronization
- Java Reflection

References:

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  https://stackoverflow.com/questions/2836646/java-serializable-object-to-byte-array
  http://www.javapractices.com/topic/TopicAction.do?Id=57
- Random access a binary file:
  http://docs.oracle.com/javase/6/docs/api/java/io/RandomAccessFile.html
- Java coding standards:
  https://google.github.io/styleguide/javaguide.html
- Java Set implementation:
  http://tutorials.jenkov.com/java-collections/set.html
- Get record count on hashmap:
  https://stackoverflow.com/questions/5496944/java-count-the-total-number-of-items-in-a-hashmapstring-arrayliststring
- Serialize and encode the HashMap data to Base64

https://stackoverflow.com/questions/2221413/how-to-encode-a-mapstring-string-as-base64-string

- Get all values of enum:
  https://docs.oracle.com/javase/8/docs/api/java/lang/Enum.html
- Get current directory of Java application:
  https://stackoverflow.com/questions/4871051/getting-the-current-working-directory-in-java

- Java int datatype range: https://docs.oracle.com/javase/tutorial/java/nutsandbolts/datatypes.html
- Private port range: https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers
- Java reflection: https://stackoverflow.com/questions/3333974/how-to-loop-over-a-class-attributes-in-java