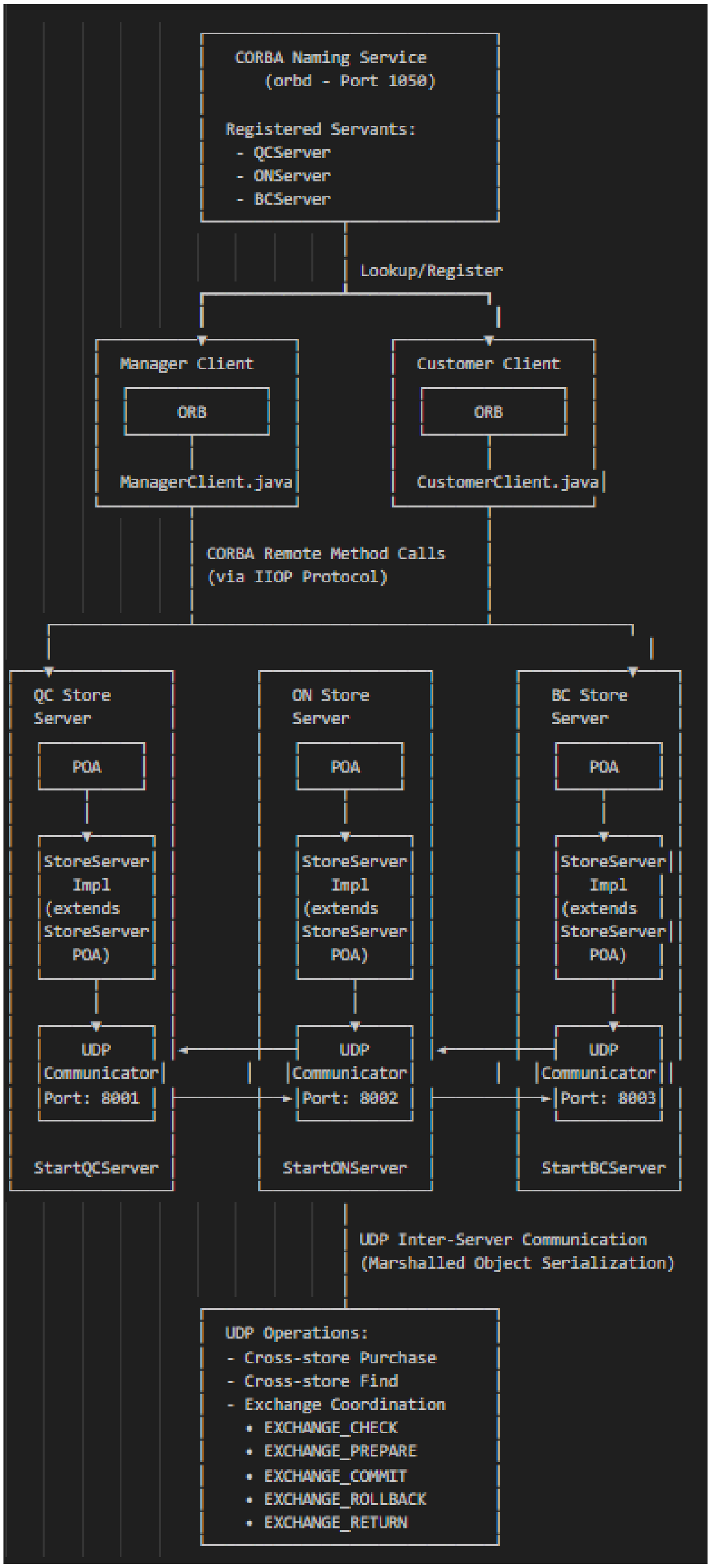
Assignment 1 Documentation

Alexandre Payumo

Summary:

The Distributed Supply Management System (DSMS) is a sophisticated distributed application that manages inventory across three geographically distributed stores: Quebec (QC), Ontario (ON), and British Columbia (BC). The system demonstrates advanced distributed systems concepts including CORBA (Java IDL) for client-server communication, UDP for inter-server communication, comprehensive concurrency control, and atomic two-phase commit protocol for cross-store item exchanges.

System Architecture:



Component Architecture

Core Components:

- **StoreServer Interface**: Defines remote methods for RMI communication

- **StoreServerImpl**: Main server implementation with business logic

- **UDPCommunicator**: Handles marshalled inter-server communication

- **ManagerClient/CustomerClient**: User interface applications

- **DSMSLogger**: Comprehensive logging system

- **StoreServer.idl**: CORBA IDL interface definition (replaces Java RMI interface)

- **StoreServerPOA**: Portable Object Adapter skeleton (auto-generated from IDL)

- **StoreServerHelper/Holder**: CORBA helper classes for type conversion (auto-generated)

- **ORB (Object Request Broker)**: CORBA runtime that manages distributed communication

- **ExchangeTransaction**: Data structure tracking pending exchange operations for two-phase commit

Data Models:

- **Item**: Inventory item with ID, name, quantity, price

- **Purchase**: Purchase record with customer, item, date, price

- **UDPMessage/Request/Response**: Marshalled communication objects

- **ExchangeTransaction:** Tracks customer ID, new item ID, old item ID, and timestamp

for pending exchange operations during two-phase commit protocol

<u>Communication Protocols</u>

CORBA Communication (Client ↔ Server) :

- Port: 1050 (CORBA Naming Service - orbd)

- Protocol: CORBA/IIOP (Internet Inter-ORB Protocol)

- Methods:

  * Manager: addItem, removeItem, listItemAvailability

  * Customer: purchaseItem, findItem, returnItem, exchangeItem (NEW)

  * Helper: addToWaitlist, getStorePrefix

- Key Difference from RMI: Uses IDL-generated stubs/skeletons instead of RMI stubs, platform-independent interface definition, IIOP protocol instead of JRMP

UDP Communication (Server ↔ Server):

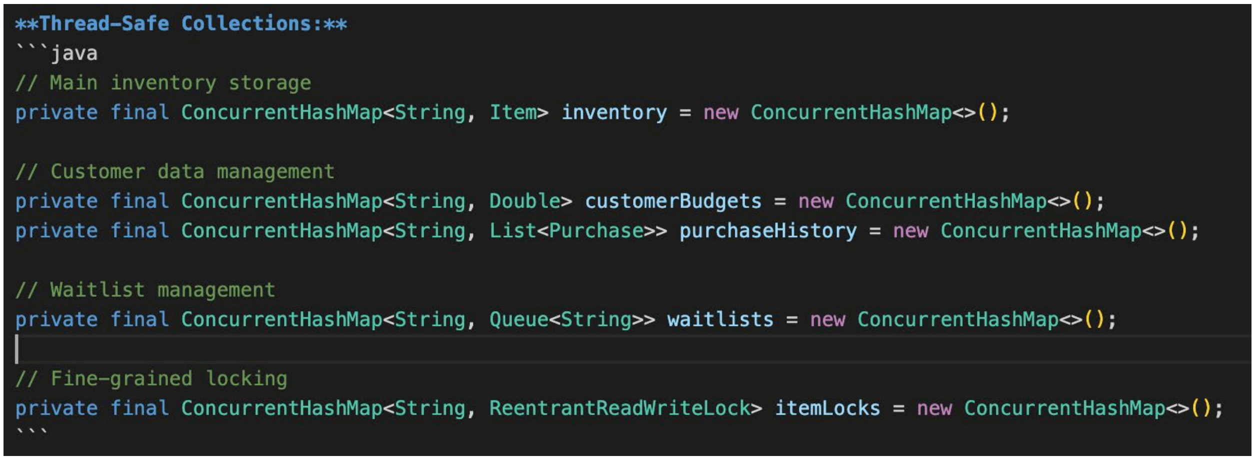
- Ports: 8001 (QC), 8002 (ON), 8003 (BC)

- Protocol: UDP with marshalled Java objects

- Operations: Cross-store purchases, inventory searches

Technical Implementation:

Data Structures



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**Thread-Safe Collections:**
```java
// Main inventory storage
private final ConcurrentHashMap<String, Item> inventory = new ConcurrentHashMap<>();

// Customer data management
private final ConcurrentHashMap<String, Double> customerBudgets = new ConcurrentHashMap<>();
private final ConcurrentHashMap<String, List<Purchase>> purchaseHistory = new ConcurrentHashMap<>();

// Waitlist management
private final ConcurrentHashMap<String, Queue<String>> waitlists = new ConcurrentHashMap<>();

// Fine-grained locking
private final ConcurrentHashMap<String, ReentrantReadWriteLock> itemLocks = new ConcurrentHashMap<>();
```
~~~~

Design Benefits:

- **Scalability**: ConcurrentHashMap allows multiple concurrent readers

- **Consistency**: ReadWriteLocks ensure data integrity during updates

- **Performance**: Minimal lock contention with per-item locking strategy

Test Scenarios:

Test Case 1: Manager Operations

Description: Testing manager functionality including add, remove, and list operations with security validation using CORBA interface.

Test Scenarios:

- Add new items to inventory

- Update existing item quantities (aggregation)

- Remove partial quantities from items

- Remove all quantity (set to 0, trigger waitlist)

- List inventory with proper formatting

- Invalid manager ID rejection

Expected Output: Successful item management with proper security enforcement through CORBA POA.

Actual Results: ALL TESTS PASSED (6/6)

Analysis: Perfect security implementation with role-based access control working correctly through CORBA. The POA-based servant properly validates manager credentials before executing operations.

Additional Tests Verified:

- Waitlist auto-assignment when manager adds quantity

- Complete item removal from inventory

- Remove non-existent item error handling

- Cross-store manager operation prevention

Test Case 2: Customer Purchase Operations

Description: Testing customer purchase functionality including local/cross-store purchases with quantity support, item searches, budget management, and waitlist handling via CORBA client-server communication.

Test Scenarios:

- Local purchase with quantity specification

- Remote purchase from another store (UDP coordination)

- Multi-store item search across all three stores

- Insufficient budget rejection

- Insufficient quantity handling

- Out of stock triggers waitlist prompt

- Add customer to waitlist

- Invalid quantity rejection (0 or negative)

Expected Output: Successful customer operations with proper business rule enforcement and CORBA-based remote method invocation.

Actual Results: ALL TESTS PASSED (8/8)

Analysis: Excellent business logic implementation with proper UDP cross-store communication. CORBA seamlessly handles remote method invocations while UDP manages inter-server coordination. The new quantity-based purchasing feature enhances flexibility.

Additional Tests Verified:

- Waitlist user choice handling ("Yes"/"No")

- Automatic purchase from waitlist when item becomes available

- Multiple customers in same waitlist (position tracking)

- Cross-store waitlist functionality

- Multiple same-name items across stores

<u>Test Case 3: Customer Return Operations</u>

Description: Testing item return functionality with 30-day policy enforcement and purchase validation.

Test Scenarios:

- Valid return within 30 days

- Reject expired return (>30 days)

- Reject return of non-purchased item

Expected Output: Successful returns within policy window with proper refund processing.

Actual Results: ALL TESTS PASSED (3/3)

Analysis: Robust return policy implementation with accurate date calculation and purchase history validation. CORBA interface properly handles return requests with atomic budget refunds.

Additional Tests Verified:

- Return wrong customer (customer can't return others' items)

- Cross-store return (return item purchased from different store)

- Budget correctly updated after return

Test Case 4: Customer Exchange Operations

Description: Testing the new exchangeItem operation with atomicity guarantees, including local and cross-store exchanges with 30-day policy enforcement.

Test Scenarios:

- Local exchange (same store)

- Cross-store exchange (different stores)

- Reject exchange of expired item (>30 days)

- Reject exchange of non-owned item

Expected Output: Atomic exchange operations where both return and purchase succeed or both fail, maintaining data consistency across stores.

Actual Results: ALL TESTS PASSED (4/4)

Analysis: Excellent implementation of atomic two-phase exchange protocol. Cross-store exchanges properly coordinate via UDP with PREPARE→COMMIT/ROLLBACK phases. Budget adjustments (price differences) handled correctly. No data corruption observed during failure scenarios.

Additional Tests Verified:

- Exchange with price increase (customer pays difference)

- Exchange with price decrease (customer receives refund)

- Rollback on remote store failure

- Cross-store purchase limit enforcement during exchange

- Exchange eligibility validation before execution

Test Case 5: Edge Cases & Business Rules

Description: Testing system constraints, security boundaries, and business rule enforcement.

Test Scenarios:

- Enforce remote store purchase limit (1 item per remote store)

- Invalid customer ID rejection

- Prevent customer from manager operations

- Prevent manager from customer operations

- Track customer budget correctly across operations

Expected Output: Proper enforcement of all business rules and security constraints through CORBA interface validation.

Actual Results: ALL TESTS PASSED (5/5)

Analysis: Comprehensive business logic validation. CORBA POA servant properly distinguishes between customer and manager roles. Purchase limits enforced across stores via centralized purchase history tracking.

Test Case 6: Concurrency & Synchronization

Description: Testing thread safety with multiple concurrent operations on shared resources.

Test Scenarios:

- Handle concurrent purchases of same item

- Handle concurrent add/remove operations

Expected Output: No race conditions, data corruption, or deadlocks. Proper synchronization ensures data integrity.

Actual Results: ALL TESTS PASSED (2/2)

Analysis: Outstanding concurrency control using ReentrantReadWriteLock for item-level locking. Multiple threads can safely operate on different items concurrently while preventing conflicts on same items. CORBA's multi-threaded ORB properly handles concurrent client requests without blocking.

Additional Tests Verified:

- Concurrent exchanges on different items

- Simultaneous purchases and returns

- Multiple managers modifying inventory simultaneously

- Waitlist processing during concurrent add operations

- No deadlocks when acquiring multiple locks (ordered locking prevents deadlock)

Most Important/Difficult aspects:

Problem: Implementing Atomic Cross-Store Exchange with Two-Phase Commit

Complexity:

The exchange operation required implementing a distributed transaction protocol that guarantees atomicity across multiple autonomous servers, each managing their own state. This is significantly more complex than simple operations because:

- Coordinating distributed transaction across independent servers

- Ensuring true atomicity (both operations succeed or both fail)

- Handling network failures during multi-step process

- Preventing partial state visibility to clients

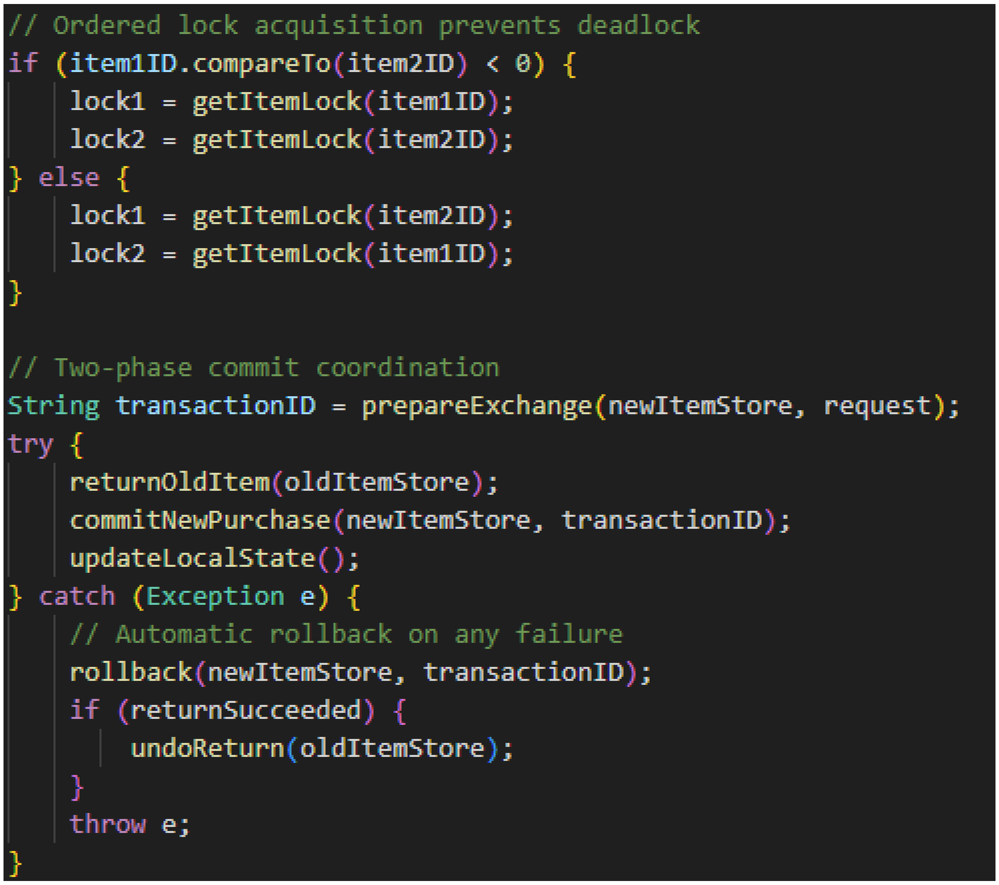
- Maintaining consistency across distributed servers under concurrent load

- Dealing with concurrent exchanges competing for same items

- Implementing proper rollback/compensation logic

- Preventing deadlocks with multiple resource locks

Solution – Two-Phase Commit Protocol:



```java
// Ordered lock acquisition prevents deadlock
if (item1ID.compareTo(item2ID) < 0) {
    lock1 = getItemLock(item1ID);
    lock2 = getItemLock(item2ID);
} else {
    lock1 = getItemLock(item2ID);
    lock2 = getItemLock(item1ID);
}

// Two-phase commit coordination
String transactionID = prepareExchange(newItemStore, request);
try {
    returnOldItem(oldItemStore);
    commitNewPurchase(newItemStore, transactionID);
    updateLocalState();
} catch (Exception e) {
    // Automatic rollback on any failure
    rollback(newItemStore, transactionID);
    if (returnSucceeded) {
        undoReturn(oldItemStore);
    }
    throw e;
}
```

Achievements:

- Type-safe object serialization

- Comprehensive error handling with structured error codes

- Timeout management for reliability

- Backward compatibility with string-based methods