Assignment 3 Documentation

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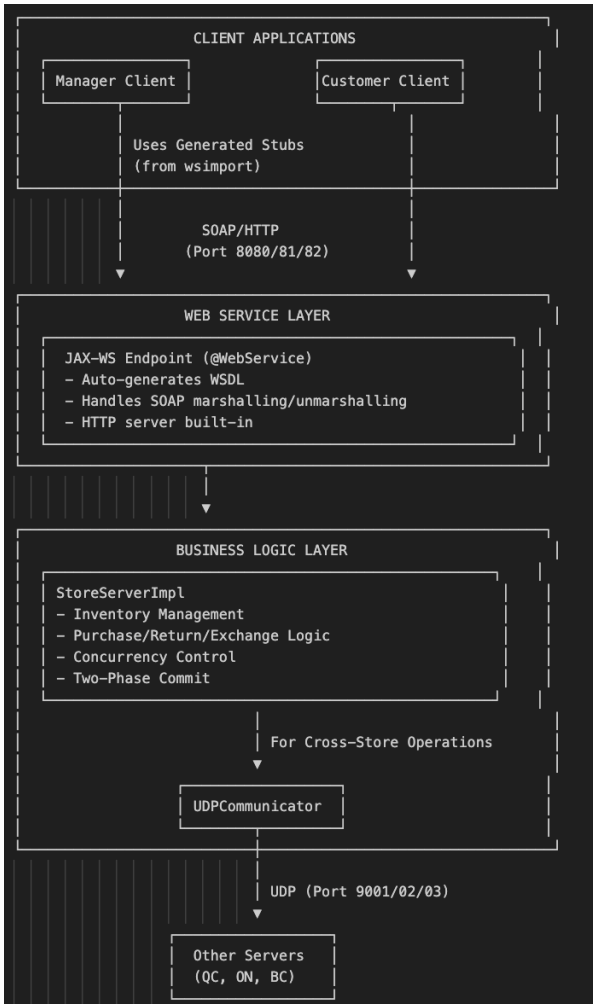
Summary:

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 JAX-WS Web Services (SOAP/HTTP) 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**: Java interface defining service methods with JAX-WS annotations

- **StoreServerImpl**: Main server implementation with @WebService annotation

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

- **ManagerClient/CustomerClient**: User interface applications using generated web service stubs

- **DSMSLogger**: Comprehensive logging system

- **Generated Client Stubs**: wsimport-generated classes for web service consumption

- **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

Communication Protocols

Web Services Communication (Client ↔ Server):

Protocol Stack:

- Application Layer: JAX-WS (Java API for XML Web Services)

- Message Format: SOAP (Simple Object Access Protocol) - XML-based

- Transport: HTTP/HTTPS

- Service Description: WSDL (Web Services Description Language)

Ports:

- QC Server (8080 HTTP), ON Server (8081 HTTP), BC Server: (8082 HTTP)

Endpoints:

- QC: http://localhost:8080/QCServer, ON: http://localhost:8081/ONServer, BC: http://localhost:8082/BCServer

WSDL URLs (for client stub generation):

- QC: http://localhost:8080/QCServer?wsdl, ON: http://localhost:8081/ONServer?wsdl, BC: http://localhost:8082/BCServer?wsdl

Methods:

- Manager: addItem, removeItem, listItemAvailability

- Customer: purchaseItem, findItem, returnItem, exchangeItem

- Helper: addToWaitlist, getStorePrefix

UDP Communication (Server ↔ Server):

- Ports: 9001 (QC), 9002 (ON), 9003 (BC)

- Protocol: UDP with marshalled Java objects

- Operations: Cross-store purchases, inventory searches

Technical Implementation:

Data Structures

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 through JAX-WS web service 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 web service endpoint validation.

Actual Results: ALL TESTS PASSED (6/6)

Analysis: Perfect security implementation with role-based access control working correctly through JAX-WS. The annotated service implementation properly validates manager credentials before executing operations via SOAP requests.

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 web services implementation.

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 through web service calls.

Actual Results: ALL TESTS PASSED (8/8)

Analysis: Excellent business logic implementation with proper UDP cross-store communication. JAX-WS web services seamlessly handle client-server communication via SOAP/HTTP while UDP manages inter-server coordination.

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

Test Case 3: Customer Return Operations

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. Web services implementation 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 web services validation.

Actual Results: ALL TESTS PASSED (5/5)

Analysis: Comprehensive business logic validation. 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. JAX-WS's built-in thread-safe HTTP server properly handles concurrent SOAP 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:

Additional Challenge in Assignment 3: Web Services Migration

Problem: Migrating from CORBA to JAX-WS While Maintaining Functionality

Complexity:

- Converting CORBA-specific code to web service annotations

- Understanding JAX-WS marshalling/unmarshalling mechanisms

- Generating and integrating client stubs from WSDL

- Ensuring SOAP XML serialization works correctly for all data types

- Fixing cross-store search bug (foundItems serialization in UDPResponse)

- Coordinating HTTP ports (8080/8081/8082) with UDP ports (9001/9002/9003)

- Adapting build process for wsimport stub generation

- Testing web service endpoints and WSDL accessibility

Solution - JAX-WS Implementation:

Server-Side:

1. Removed all CORBA imports and dependencies (org.omg.*)

2. Added JAX-WS annotations to interface and implementation:

```
@WebService
```

@WebMethod

@WebParam

3. Changed server startup from ORB.init() to Endpoint.publish()

4. Maintained all business logic unchanged

Client-Side:

1. Removed CORBA naming service lookups

2. Implemented wsimport-based stub generation in build process

3. Updated clients to use generated service stubs:

```
StoreServerService service = new StoreServerService(wsdlURL);
StoreServer server = service.getStoreServerImplPort();
```

4. Maintained same method signatures for seamless transition

Achievements:

- Seamless migration with zero functional regressions
- Improved firewall compatibility (HTTP vs IIOP)
- Platform-independent service descriptions (WSDL)
- Industry-standard protocols (SOAP/HTTP)
- Better debugging capabilities (readable XML messages)
- Fixed cross-store search serialization bug from Assignment 2