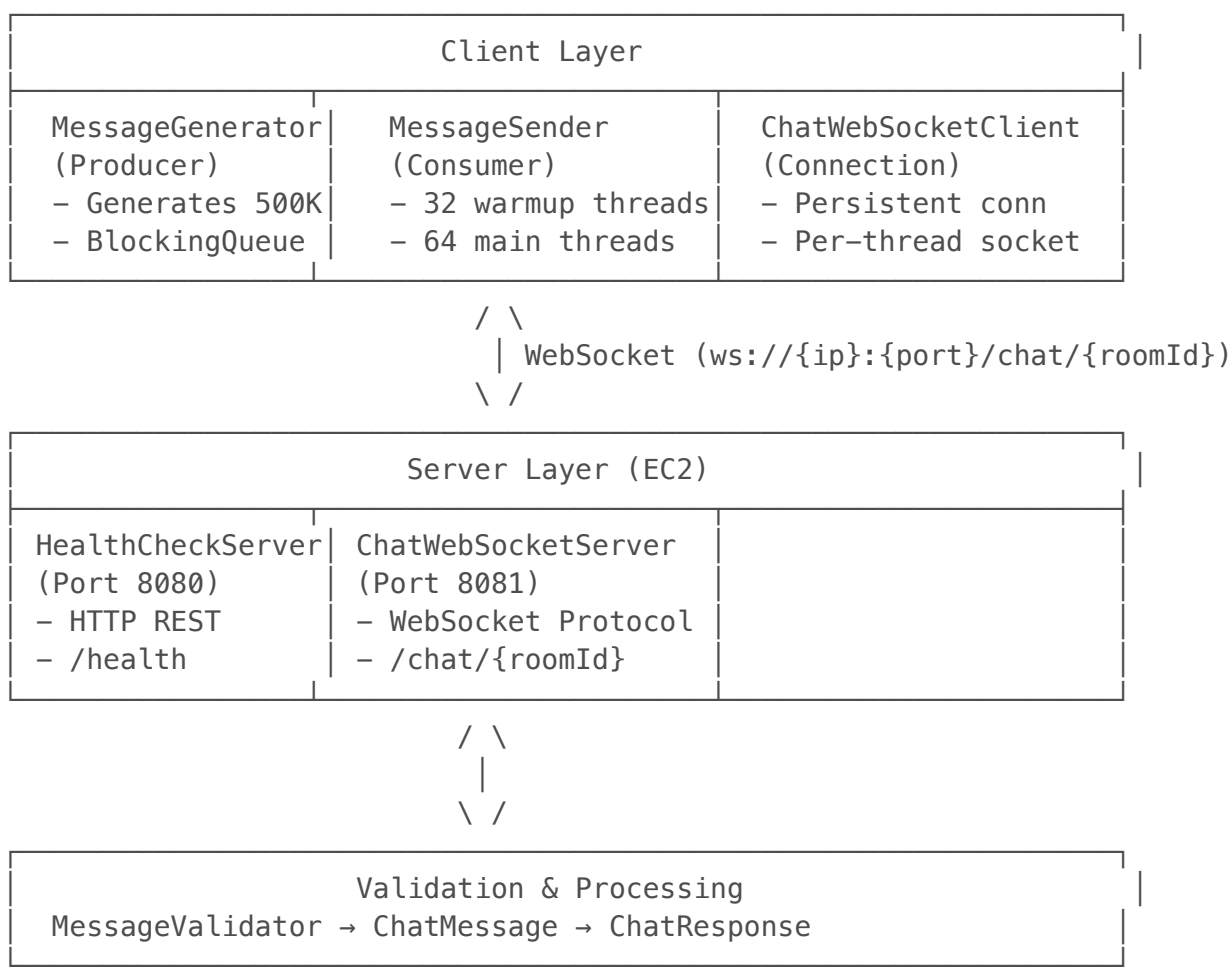
ChatFlow WebSocket Server

1. github

https://github.com/yimdx/ChatFlow

2. System Architecture

Architecture Diagram



Major Classes and Relationships

Server-Side Classes

ChatWebSocketServer (Main Server)

- Extends `WebSocketServer` from Java-WebSocket library
- Manages WebSocket lifecycle: `onOpen`, `onMessage`, `onClose`, `onError`
    - Build connection with client, recieve `ChatMessage` and return `ChatResponse`
- Validates room IDs (1-20) using regex pattern `^/chat/(\\d+)$`

HealthCheckServer (HTTP Health Endpoint)

- Uses `HttpServer` from JDK
- Serves `/health` endpoint on port 8080
- Returns JSON: `{"status":"healthy"}`

MessageValidator

- Validates `ChatMessage` fields (username, message length, etc.)
- Returns list of validation errors

Models:

- `ChatMessage`: Request model (userId, username, message, timestamp, messageType, roomId)
- `ChatResponse`: Response model (includes serverTimestamp, status)
- `ErrorResponse`: Error handling model

Client-Side Classes

MessageGenerator (Producer Thread)

- Implements `Runnable`
- Generates 500,000 random pre-defined messages
- Populates `BlockingQueue<ChatMessage>`
- Random message types: 90% TEXT, 5% JOIN, 5% LEAVE

MessageSender (Consumer Thread)

- Implements `Runnable`
- Creates ONE persistent WebSocket connection per thread
- Consumes messages from `BlockingQueue`
- Sends messages sequentially with response waiting
- Tracks success/failure counts atomically

ChatWebSocketClient (WebSocket Connection)

- Extends `WebSocketClient` from Java-WebSocket library
- Manages connection lifecycle and message serialization
- Tracks metrics: success count, failure count, latency

Part 2 Additional Classes:

- `MetricRecord`: Records per-message metrics (timestamp, latency, room)
- `CsvWriter`: Writes metrics to CSV for analysis
- `PerformanceAnalyzer`: Calculates statistics (mean, median, p95, p99, throughput per room)
- `ThroughputVisualizer`: Generates throughput-over-time analysis

Threading Model

1. **Generator Thread (1 thread)**
    - Runs independently
    - Produces all 500K messages upfront
    - Non-blocking producer to `BlockingQueue`

2. **Warmup Phase (32 threads)**
    - Fixed thread pool: `Executors.newFixedThreadPool(32)`
    - Each thread: 1,000 messages (32K total)
    - Each thread maintains ONE persistent WebSocket connection
    - Duration: ~20 seconds (with 20ms latency)
3. **Main Phase (64 threads)**
    - Thread count: `64`
    - Each thread: ~14,625 messages (468K total)
    - Duration: ~150 seconds (with 20ms latency)

Thread Lifecycle:

```
Thread Start → Create WebSocket → Connect (blocking)
     ↓
For each message:
  → Take from queue (blocking)
  → Send message
  → Wait for response (1s timeout)
  → Increment success/fail counter
     ↓
Close WebSocket → Thread Exit
```

Synchronization Mechanisms:

- `BlockingQueue<ChatMessage>`: Thread-safe message queue
- `AtomicInteger`: Lock-free counters (success, failure, reconnections)
- `ExecutorService`: Managed thread lifecycle
- `ConcurrentHashMap` for thread-safe room management

4. WebSocket Connection Management Strategy

Client-Side Strategy: **Thread-Persistent Connections**

Design Decision: Each thread maintains ONE persistent connection for its entire lifecycle.

Key Properties:

- **Connection Count:** 96 total (32 warmup + 64 main, sequential phases)
- **Connection Reuse:** No pooling or sharing between threads
- **Room Distribution:** Uniform random (each thread picks room 1-20)
- **Failure Handling:** Exponential backoff retry (up to 5 attempts)

5. Little's Law Calculations and Predictions

Little's Law Formula

```
L = λ × W

Where:
λ (lambda) = Throughput (requests/second)
L = Concurrency (number of simultaneous requests)
W = Average response time (seconds)
```

System Parameters

Measured Values from Warmup:

- Total messages: 32k
- Total runtime: ~34 seconds (warmup)
- average latency 34ms
- Threads: 32 concurrent

Performance Predictions

Ideal Throughput

```
# for warmup phase
λ = 32 concurrent threads/ 34 ms
λ ≈ 1k messages/second

# for main phase

λ = 64 concurrent threads/ 34 ms
λ ≈ 1.9k messages/second
```

Test Results

Part1

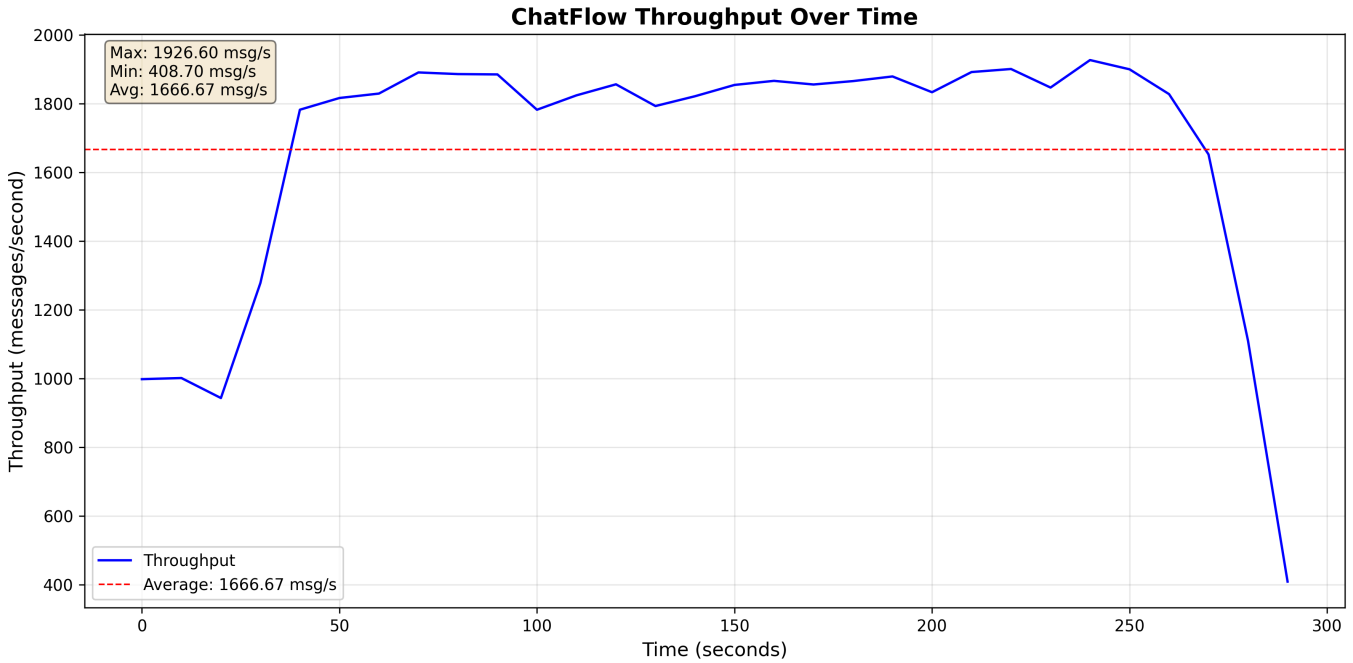
```
ection
13:33:15.837 [main] INFO  cs6650.assignment1.Main - Main Phase completed in 263507 ms
13:33:15.837 [main] INFO  cs6650.assignment1.Main -
13:33:15.837 [main] INFO  cs6650.assignment1.Main - ========================================
13:33:15.837 [main] INFO  cs6650.assignment1.Main - PERFORMANCE RESULTS
13:33:15.837 [main] INFO  cs6650.assignment1.Main - ========================================
13:33:15.837 [main] INFO  cs6650.assignment1.Main - 1. Successful messages sent: 500001
13:33:15.837 [main] INFO  cs6650.assignment1.Main - 2. Failed messages: 6
13:33:15.837 [main] INFO  cs6650.assignment1.Main - 3. Total runtime: 307915 ms (307.915 seconds)
13:33:15.837 [main] INFO  cs6650.assignment1.Main -    - Warmup phase: 34399 ms
13:33:15.837 [main] INFO  cs6650.assignment1.Main -    - Main phase: 263507 ms
13:33:15.837 [main] INFO  cs6650.assignment1.Main - 4. Overall throughput: 1623.8247568322427 messages/second
13:33:15.837 [main] INFO  cs6650.assignment1.Main -    - Warmup throughput: 930.259600569784 messages/second
13:33:15.838 [main] INFO  cs6650.assignment1.Main -    - Main phase throughput: 1776.043900162045 messages/secon
d
13:33:15.838 [main] INFO  cs6650.assignment1.Main - 5. Connection statistics:
13:33:15.838 [main] INFO  cs6650.assignment1.Main -    - Total persistent connections: 96
13:33:15.838 [main] INFO  cs6650.assignment1.Main -    - Reconnections: 0
13:33:15.838 [main] INFO  cs6650.assignment1.Main - ========================================
```

Part2

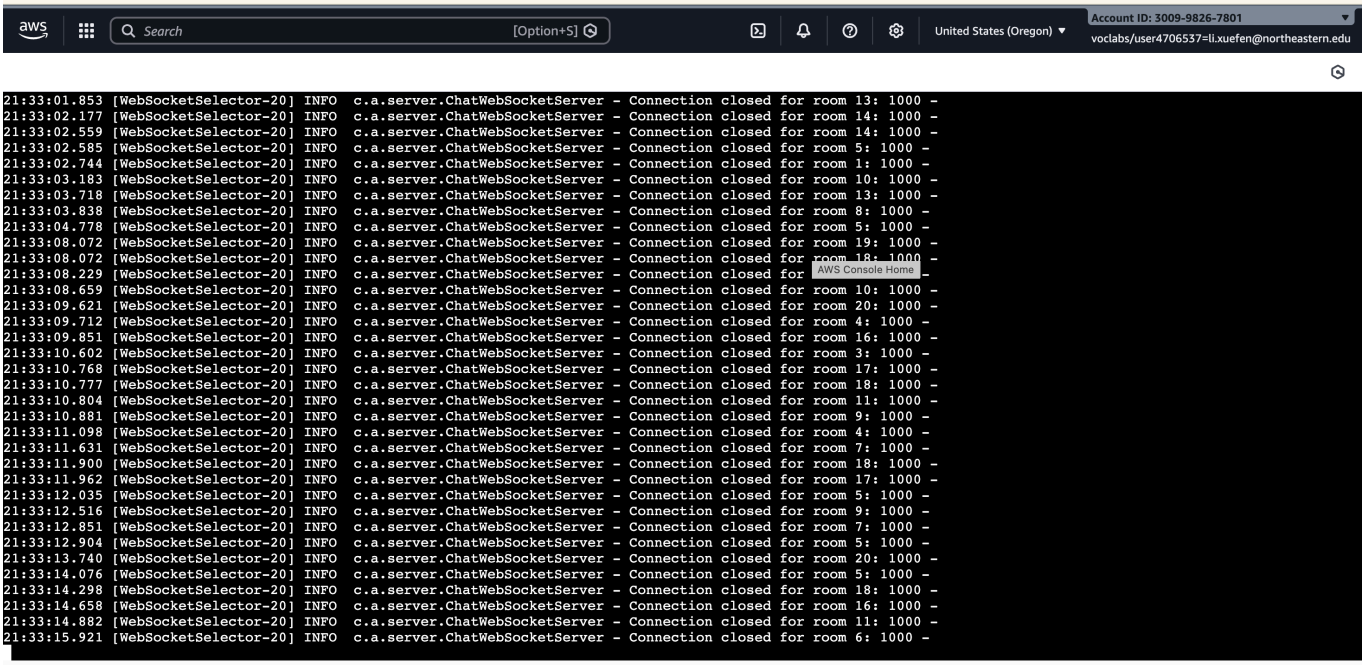
```
14:05:15.308 [main] INFO  cs6650.assignment1.Main - ========================================
14:05:15.308 [main] INFO  cs6650.assignment1.Main - BASIC PERFORMANCE RESULTS
14:05:15.308 [main] INFO  cs6650.assignment1.Main - ========================================
14:05:15.308 [main] INFO  cs6650.assignment1.Main - 1. Successful messages sent: 500000
14:05:15.308 [main] INFO  cs6650.assignment1.Main - 2. Failed messages: 0
14:05:15.308 [main] INFO  cs6650.assignment1.Main - 3. Total runtime: 303600 ms (303.6 seconds)
14:05:15.308 [main] INFO  cs6650.assignment1.Main -    - Warmup phase: 34511 ms
14:05:15.308 [main] INFO  cs6650.assignment1.Main -    - Main phase: 264991 ms
14:05:15.308 [main] INFO  cs6650.assignment1.Main - 4. Overall throughput: 1646.9038208168643 messages/sec
14:05:15.308 [main] INFO  cs6650.assignment1.Main -    - Warmup throughput: 927.2405899568254 messages/sec
14:05:15.308 [main] INFO  cs6650.assignment1.Main -    - Main phase throughput: 1766.0977165262216 message
14:05:15.308 [main] INFO  cs6650.assignment1.Main - 5. Connection statistics:
14:05:15.308 [main] INFO  cs6650.assignment1.Main -    - Total persistent connections: 96
14:05:15.308 [main] INFO  cs6650.assignment1.Main -    - Reconnections: 0
14:05:15.308 [main] INFO  cs6650.assignment1.Main - ========================================
14:05:15.308 [main] INFO  cs6650.assignment1.Main -
Performing statistical analysis...
14:05:15.311 [main] INFO  c.a.util.PerformanceAnalyzer - Analyzing metrics from: results/metrics_20260213_
14:05:15.572 [main] INFO  c.a.util.PerformanceAnalyzer - Analysis completed
```

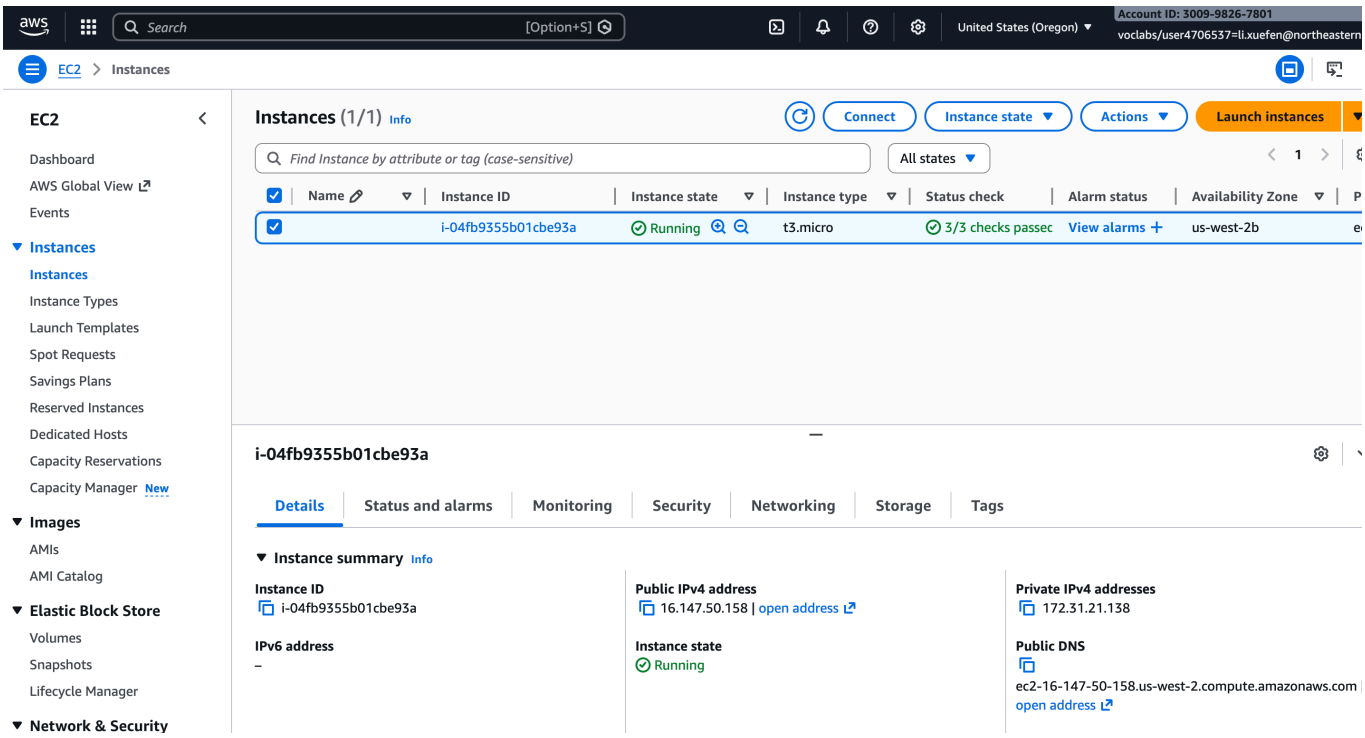
```
========================================
STATISTICAL ANALYSIS
========================================
Total Messages: 500000
Mean Response Time: 34.02 ms
Median Response Time: 32.00 ms
95th Percentile: 50.00 ms
99th Percentile: 68.00 ms
Min Response Time: 1 ms
Max Response Time: 281 ms

Message Type Distribution:
  LEAVE: 24923 (5.0%)
  JOIN: 24857 (5.0%)
  TEXT: 450220 (90.0%)

Message Count Per Room:
  Room 1: 40560 messages
  Room 2: 36560 messages
  Room 3: 7312 messages
  Room 4: 9312 messages
  Room 5: 17624 messages
  Room 6: 30248 messages
  Room 7: 7312 messages
  Room 8: 8312 messages
  Room 9: 7312 messages
  Room 10: 22936 messages
  Room 11: 38560 messages
  Room 12: 28936 messages
  Room 13: 3000 messages
  Room 14: 22936 messages
  Room 15: 73152 messages
  Room 16: 22936 messages
  Room 17: 66808 messages
  Room 18: 23936 messages
  Room 19: 22936 messages
```

```
  Room 20: 9312 messages

Throughput Per Room:
  Room 1: 136.28 messages/second
  Room 2: 138.56 messages/second
  Room 3: 29.09 messages/second
  Room 4: 33.87 messages/second
  Room 5: 59.95 messages/second
  Room 6: 104.90 messages/second
  Room 7: 29.36 messages/second
  Room 8: 30.62 messages/second
  Room 9: 30.43 messages/second
  Room 10: 79.19 messages/second
  Room 11: 128.97 messages/second
  Room 12: 100.21 messages/second
  Room 13: 87.79 messages/second
  Room 14: 76.65 messages/second
  Room 15: 278.75 messages/second
  Room 16: 77.35 messages/second
  Room 17: 226.77 messages/second
  Room 18: 80.30 messages/second
  Room 19: 77.59 messages/second
  Room 20: 32.94 messages/second
========================================
```



EC2


Search [Option+S]
United States (Oregon)
Account ID: 3009-9826-7801
voclabs/user4706537=li.xuefen@northeastern.edu
21:33:01.853 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 13: 1000 -
21:33:02.177 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 14: 1000 -
21:33:02.559 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 14: 1000 -
21:33:02.585 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 5: 1000 -
21:33:02.744 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 1: 1000 -
21:33:03.183 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 10: 1000 -
21:33:03.718 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 13: 1000 -
21:33:03.838 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 8: 1000 -
21:33:04.778 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 5: 1000 -
21:33:08.072 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 19: 1000 -
21:33:08.072 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 18: 1000 -
21:33:08.229 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for
AWS Console Home
21:33:08.659 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 10: 1000 -
21:33:09.621 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 20: 1000 -
21:33:09.712 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 4: 1000 -
21:33:09.851 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 16: 1000 -
21:33:10.602 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 3: 1000 -
21:33:10.768 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 17: 1000 -
21:33:10.777 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 18: 1000 -
21:33:10.804 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 11: 1000 -
21:33:10.881 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 9: 1000 -
21:33:11.098 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 4: 1000 -
21:33:11.631 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 7: 1000 -
21:33:11.900 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 18: 1000 -
21:33:11.962 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 17: 1000 -
21:33:12.035 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 5: 1000 -
21:33:12.516 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 9: 1000 -
21:33:12.851 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 7: 1000 -
21:33:12.904 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 5: 1000 -
21:33:13.740 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 20: 1000 -
21:33:14.076 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 5: 1000 -
21:33:14.298 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 18: 1000 -
21:33:14.658 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 16: 1000 -
21:33:14.882 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 11: 1000 -
21:33:15.921 [WebSocketSelector-20] INFO c.a.server.ChatWebSocketServer - Connection closed for room 6: 1000 -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United States (Oregon)
Account ID: 3009-9826-7801
EC2 > Instances
EC2
Dashboard
AWS Global View
Events
Instances
Instances
Instance Types
Launch Templates
Spot Requests
Savings Plans
Reserved Instances
Dedicated Hosts
Capacity Reservations
Capacity Manager New
Images
AMIs
AMI Catalog
Elastic Block Store
Volumes
Snapshots
Lifecycle Manager
Network & Security
Instances (1/1) Info
Connect
Instance state
Actions
Launch instances
Find Instance by attribute or tag (case-sensitive)
All states
Name
Instance ID
Instance state
Instance type
Status check
Alarm status
Availability Zone
i-04fb9355b01cbe93a
Running
t3.micro
3/3 checks passec
View alarms +
us-west-2b
i-04fb9355b01cbe93a
Details
Status and alarms
Monitoring
Security
Networking
Storage
Tags
Instance summary Info
Instance ID
i-04fb9355b01cbe93a
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Public IPv4 address
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Instance state
Running
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Public DNS
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open address