Quality Attributes Analysis

Overview

This document documents three key quality attributes implemented in this project: **Performance**, **Scalability**, and **Reliability**. Justification for each attribute is provided through design decisions and proofs of implementation is also added. cument

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1. Performance

Target Metrics

- API response time: < 100ms
- Event processing time: < 50ms per service
- End-to-end click processing: < 300ms

Design Decisions for Performance

1.1 Asynchronous Event Processing

Implementation: Used pub-sub pattern with event bus

- Click Ingestion publishes events without waiting for processing
- Each subscriber processes independently
- No blocking operations

Code Evidence (`src/services/click-ingestion.js`):

```
// Publish to event bus - non-blocking
eventBus.publish('click-events', clickEvent);

// Immediately return response
res.json({ success: true, message: 'Click received' });
```

1.2 In-Memory Event Bus

Implementation: Used Node.js EventEmitter for fast message passing

- No network latency
- No disk I/O
- Direct function calls between services

Code Evidence (`src/config/event-bus.js`):

```
publish(topic, data) {
  this.emit(topic, data);  // Immediate in-memory event
}
```

1.3 Minimal Processing Per Service

Implementation: Each service performs only the specified job

- Fraud Detection: Simple scoring algorithm
- Billing: Basic calculations
- Analytics: Counter updates

Performance Test Results

From demo run with 20 clicks:

- Average API response: ~50ms
- Total processing time: ~300ms per click
- System handled 20 clicks in 10 seconds = 2 clicks/second

Conclusion: Performance targets met for academic demonstration.

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2. Scalability

Target Metrics

- Support 10,000 clicks/second (design goal)
- Horizontal scaling of services
- No single point of failure

Design Decisions for Scalability

2.1 Pub-Sub Architecture

Implementation: Loose coupling between services

- Services don't call each other directly
- Can run multiple instances of any service
- Load distributed automatically

Code Evidence (`src/app.js`):

```
// Each service subscribes independently
fraudDetection.start();  // Can run multiple instances
billing.start();         // Can run multiple instances
analytics.start();       // Can run multiple instances
```

2.2 Stateless Services

Implementation: Services don't store state between requests

- Fraud Detection: Stateless scoring
- Billing: Budget stored separately (would be in DB)
- Analytics: Aggregates can be distributed

2.3 Topic-Based Routing

Implementation: Multiple services can subscribe to same topic

- All fraud detection instances get click-events
- All billing instances get validated-clicks
- Load balanced automatically

Code Evidence (`src/config/event-bus.js`):

```
subscribe(topic, callback) {
  this.on(topic, callback);  // Multiple subscribers allowed
}
```

Scalability Analysis

Current Implementation:

- 1 publisher, 3 subscribers
- In-memory event bus (single machine)

Production Scaling Path:

1. Replace EventEmitter with Apache Kafka
2. Run multiple instances of each service
3. Kafka partitions distribute load
4. Can scale to 10,000+ clicks/second

Horizontal Scaling Example:

```
Click Ingestion: 3 instances (load balanced)
Fraud Detection: 5 instances (Kafka consumer group)
Billing: 3 instances (Kafka consumer group)
Analytics: 2 instances (Kafka consumer group)
```

Conclusion: Architecture designed for horizontal scalability.

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3. Reliability

Target Metrics

- 99.9% uptime
- No data loss
- Graceful error handling

Design Decisions for Reliability

3.1 Budget Validation

Implementation: Check advertiser budget before charging

- Prevents overspending
- Rejects clicks when budget exhausted
- Maintains financial integrity

Code Evidence (`src/services/billing-service.js`):

```
// Check if advertiser has enough budget
if (budget.remaining < cost) {
  logger.log('BillingService', `BUDGET EXCEEDED for ${advertiserId}`);
  return; // Don't process this click
}
```

3.2 Fraud Detection

Implementation: Validate clicks before billing

- Check user agent
- Analyze IP address
- Calculate fraud score
- Block suspicious clicks

Code Evidence (`src/services/fraud-detection.js`):

```
if (fraudScore >= 0.7) {
  // This is fraud!
  eventBus.publish('fraud-alerts', {...});
  // Don't publish to validated-clicks
}
```

3.3 Error Handling

Implementation: Try-catch blocks and validation

- Input validation in API
- Error logging

- Graceful degradation

Code Evidence (`src/services/click-ingestion.js`):

```
try {
  // Validate required fields
  if (!clickData.ad_id || !clickData.campaign_id) {
    return res.status(400).json({ error: 'Missing required fields' });
  }
  // Process click
} catch (err) {
  logger.error('ClickIngestion', err.message);
  res.status(500).json({ error: 'Internal error' });
}
```

3.4 Service Independence

Implementation: Services operate independently

- If fraud detection fails, billing can still work
- If analytics fails, billing continues
- No cascading failures

Reliability Test Scenarios

Scenario 1: Budget Exhaustion

- Initial budget: $100
- After spending $100, next click rejected
- Result: System prevents overspending

Scenario 2: Fraud Detection

- Bot user agent detected
- Fraud score > 0.7
- Result: Click blocked before billing

Scenario 3: Invalid Input

- Missing required fields
- Result: 400 error returned, system continues

Conclusion: System handles error conditions reliably.

Summary

Quality Attribute	Target	Implementation	Status
Performance	<100ms API response	Async pub-sub, in-memory events	Met

Quality Attribute	Target	Implementation	Status
Scalability	10K clicks/sec	Horizontal scaling design	Designed
Reliability	99.9% uptime	Error handling, validation	Implemented

Key Takeaways

1. **Performance**: Achieved through asynchronous processing and minimal per-service work
2. **Scalability**: Enabled by pub-sub architecture and stateless services
3. **Reliability**: Ensured through validation, error handling, and service independence

Future Improvements

1. **Performance**: Add caching layer (Redis) for frequently accessed data
2. **Scalability**: Implement with Apache Kafka for production-level throughput
3. **Reliability**: Add database persistence and message replay capabilities

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