Birla Institute of Technology & Science, Pilani
Work Integrated Learning Programmes Division
Second Semester 2023-2024

Comprehensive Examination
(EC-3 Regular)

Course No.   : SE ZG651
Course Title   : Software Architecture
Nature of Exam   : Open Book
Weightage   : 40%
Duration   : 2 ½ Hours
Date of Exam   : 18/05/2024 (FN)

No. of Pages   = 3
No. of Questions = 3

Note to Students:
1.   Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
2.   All parts of a question should be answered consecutively. Each answer should start from a fresh page.
3.   Assumptions made if any, should be stated clearly at the beginning of your answer.

Q.1   The government wants to implement a gas subsidy scheme for consumers whose income
      is below Rs. 3 lakh per year. The way it works is as follows:
      Those wanting to avail gas subsidy need to fill in an application form and provide
      documents such as Aadhaar card and their bank account details (account number and
      IFSC) to the gas company (e.g. Bharat Petroleum/Indane/HP) along with income proof.
      These details are entered by the gas company staff into the Central Gas Subsidy system.
      The system validates the Aadhaar and Bank account by interfacing with respective systems
      such as Aadhaar System & Bank System.

      When gas is booked and delivered, the consumer pays the full amount to the delivery boy.
      This transaction is later entered by the gas company staff into their Gas distribution system.
      These transactions need to be sent to the Central Gas Subsidy system. For each transaction,
      the Subsidy system checks if the customer is eligible for subsidy. If eligible, the Subsidy
      system should transfer the subsidy amount to the consumer's account. The subsidy
      payment should transfer the amount to the eligible customer's account within 3 days of the
      Gas Delivery.

      Here are some important requirements:
      i)   It is possible that some sub-systems involved in the overall system, may be down. This
            should not come in the way to paying the subsidy. The System should not miss out on
            paying the subsidy.
      ii)   The subsidy should reach the correct person's account. We should be able to check the
            accuracy of money transfer at the end of each day.
      iii) Only authorized systems such as the Subsidy system should be able to access the Aadhaar
            system and Income tax systems. Other systems trying to access Aadhaar system should be
            denied access.

Questions
a.   Explain with diagram how you will implement broker pattern for the above scenario. What
      advantage or disadvantage you will get if you implement Pipe and Filter Pattern over broker
      pattern.   [2+2+1=5]

Broker Pattern Implementation

Explanation:
The broker pattern is useful for systems with distributed components. It acts as an intermediary,

enabling communication between consumers and service providers, such as the Gas Subsidy System, Aadhaar System, and Bank System in this case. The broker manages requests, forwards them to the appropriate service, and returns the response to the client.

Diagram:

- **Components**: Broker, Gas Company, Aadhaar System, Bank System, Central Gas Subsidy System.
- **Flow**:
    1. Consumers interact with gas companies to submit their details.
    2. The broker system routes these requests to Aadhaar and Bank systems for validation.
    3. The broker manages gas delivery and payment details to ensure timely subsidy transfer.

(Insert labeled diagram here)

Advantages of Pipe and Filter Pattern Over Broker Pattern:

- **Flexibility**: Easy to replace or add filters without major changes.
- **Reusability**: Filters can be reused across different workflows.

Disadvantages:

- **Performance Overhead**: Multiple data transformations can slow the system.
- **Error Propagation**: Issues in one filter can propagate downstream.

b.   Explain with diagram, how you will implement Service Oriented Architecture to implement the above-mentioned scenario? What is the advantage or disadvantage of using it?   [2+2+1 =5]

Explanation:
SOA uses loosely coupled services to enable interoperability. Each key operation (e.g., Aadhaar validation, bank transfer, subsidy calculation) is encapsulated in a service.

Diagram:

- **Services**:
    1. Aadhaar Validation Service
    2. Bank Account Validation Service
    3. Gas Booking Service
    4. Subsidy Transfer Service
- **Flow**:
    1. Consumers submit data via the gas company.
    2. SOA handles service calls for validation and data processing.
    3. The subsidy amount is transferred post-validation.

(Insert labeled diagram here)

Advantages:

- Scalability: Services can scale independently.
- Interoperability: Allows integration with different systems.

Disadvantages:

- Complexity: Managing service communication adds overhead.
- Dependency: Failure of one service may affect others.

c. Identify the security issues in the above SOA mechanism and suggest the security tactics that can be implemented to overcome those issues. (you should provide end-to-end solution with implementation details)   [1+3=4]

Security Issues and Tactics in SOA

Security Issues:
1. Unauthorized access to Aadhaar and Income Tax systems.
2. Data breaches during inter-system communication.

Security Tactics:
1. **Authentication and Authorization**: Use OAuth2 or JWT to ensure only authorized systems access sensitive services.
2. **Encryption**: Use TLS for secure communication between services.
3. **Monitoring and Auditing**: Employ logging and monitoring to detect unauthorized access attempts.

Implementatio_Details:
(Provide detailed steps to apply each tactic to the SOA implementation.)

Q.2 Now-a-days Webster is a popular web service platform, but after its establishment, Webster's internal development team got a problem. They were adding a lot of software engineers, but despite the growing headcount, the pace of development was staying about the same. The issue was that each developer was setting up new and unique 'compute', 'storage' and 'database' resources for each project. The IT group realized that if they could standardize those resources and simplify the process of deploying new IT infrastructure, they might be able to speed things up.

A few years later, after analysing the problems identified by the internal development team, the CEO of Webster made a 'Vision Statement' where it was emphasized that infrastructure would be totally standardized, completely automated, and relied extensively on web-services for things like storage. The CEO also gave huge importance to selling virtual servers as a service to the customer.

a. Describe the architecture of a virtual server equipped with different web-services with a schematic diagram.   [5 marks]

Virtual Server Architecture

Architecture Description:
(Describe the architecture of a virtual server with web services for compute, storage, and database.)

Diagram:
(Draw and label the virtual server architecture schematic.)

b. What kind of follow-up are required for the measurement of performance of the virtual server before its deployment? Justify your answer in context to the case study.   [4 marks]

Performance Measurement Follow-Up

1. **Load Testing**: Simulate high transaction volumes to identify bottlenecks.
2. **Latency Analysis**: Measure response times for critical operations.
3. **Resource Utilization Monitoring**: Track CPU, memory, and storage usage to ensure optimal configuration.

Justification:
These activities ensure the server is robust and meets performance expectations under realistic workloads.

c. What primitive steps are required to use machine learning techniques/algorithms correctly and effectively to develop "completely automated" web-service platform mentioned by the CEO of Webster? Justify your answer in the context to the case study.   [4 marks]

Machine Learning Steps for Automation

1. **Data Collection**: Gather datasets from current system logs and usage patterns.
2. **Feature Engineering**: Extract relevant features like transaction trends, resource usage, etc.
3. **Model Selection**: Choose supervised learning models for prediction and optimization tasks.
4. **Training and Validation**: Train the model using historical data and validate accuracy with unseen data.
5. **Deployment and Monitoring**: Implement the trained model in production and monitor for performance adjustments.

Justification:
(Explain how each step aligns with the CEO's vision for an automated platform.)

Q.3   Hermes Corporation has decided to launch 'Project Phoenix' to Upgrade the E-commerce Platform of the Company: Futureproof Catalyst Plc. After an initial meeting with the key stakeholders two schools have emerged.

The company is considering a major software architecture upgrade for the e-commerce platform. The current architecture is monolithic, leading to scalability issues and hindering the addition of new features. Two upgrade options are being considered:

Microservices Architecture:
        This option involves deconstructing the monolithic application into smaller, independent services. Benefits include improved scalability, faster development cycles, and easier maintenance. However, the upfront development cost is high due to the need for new infrastructure and development effort.
Containerized Monolith:
        This option involves containerizing the existing monolithic application. Benefits include some improvement in scalability and deployment flexibility at a lower upfront cost compared to 'Microservices Architecture'. However, the inherent limitations of the monolithic architecture remain, potentially hindering future growth.

The estimated development cost for 'Microservices Architecture' is Rs 8 Crore and for 'Containerized Monolith' is Rs 4 Crore.

The expected annual maintenance cost for 'Microservices Architecture' is Rs 80 Lakh and for 'Containerized Monolith' is Rs 1.60 Crore.

The platform expects to handle a 30% increase in transaction volume in the next year. This has no impact on the cost of setting up or maintaining the new application. The e-commerce platform's mobile app is experiencing slow loading times, particularly on product listing pages with high-resolution images. This is leading to customer frustration and cart abandonment. This may lead to increase in the number of issues with more volume The development team is considering two approaches to improve performance:

Image Optimization: This option involves implementing techniques like image resizing, compression, and lazy loading to reduce image file size and improve loading speed. The estimated cost of development and implementation is Rs 1,60,00,000, and it's expected to reduce the average page load time by 30%. This will give a 1% reduction in cart abandonment rate.

Mobile-Specific App Architecture: This option involves developing a separate, lightweight mobile app that focuses on essential functionalities like product browsing and purchasing. The estimated cost of development for this new app is Rs 80,00,000. However, it's expected to deliver a 50% reduction in average page load time compared to the current app. This will give a 0.5% reduction in cart abandonment rate,

The e-commerce platform currently has 10,00,000 active mobile app users. The average order value is Rs 8000. The platform estimates that reduction in cart abandonment rate could lead to an additional annual revenue. Assume a 10% gross margin in revenue.

   a. Considering a 5-year lifespan for the upgraded architecture, calculate the total cost of ownership (TCO) for each of options: 'Microservices Architecture' and 'Containerized Monolith'. [3]

Total Cost of Ownership (TCO)

Calculations:

   1. **Microservices Architecture**:
        o Development cost: Rs 8 Crore.
        o Maintenance cost over 5 years: 80 Lakh × 5 = Rs 4 Crore.
        o **TCO = Rs 12 Crore**.
   2. **Containerized Monolith**:
        o Development cost: Rs 4 Crore.
        o Maintenance cost over 5 years: 1.6 Crore × 5 = Rs 8 Crore.
        o **TCO = Rs 12 Crore**.

   b. The platform estimates that 'Microservices Architecture' will enable a 20% reduction in development time (complete development cycle) for new features as compared to 'Containerized Monolith'. The platform plans to release 4 new features per year using 'Containerized Monolith'. Each new feature is estimated to generate an additional Rs 2 Crore in annual revenue. Calculate the potential additional revenue generated by the faster development cycles of 'Microservices Architecture' over the 5-year lifespan. [4]

Revenue from Faster Development

Assumptions: Microservices reduce development time by 20%, enabling faster release of features.

Calculations:

- Number of new features over 5 years with **Containerized Monolith**: $4 \times 5 = 20$.
- Additional revenue per feature: Rs 2 Crore.
- Total revenue with Containerized Monolith: $20 \times 2 = $ Rs 40 Crore.
- Time saved using Microservices = 20% of total time.
- Additional features enabled: $20\% \times 20 = 4$ (total features = 24).
- Revenue with Microservices: $24 \times 2 = $ Rs 48 Crore.
- **Additional revenue due to Microservices = Rs 48 Crore - Rs 40 Crore = Rs 8 Crore**.

c. Based on your answers to a and b, calculate the Return on Investment (ROI) for both plans. Recommend the most cost-effective option for the e-commerce platform, considering both financial and development speed benefits. [3]

ROI for E-commerce Platform

Formula: ROI = (Total Revenue - Total Cost) / Total Cost.

1. **Microservices Architecture**:
   - Total cost: Rs 12 Crore.
   - Total revenue (from Q3b): Rs 48 Crore.
   - ROI = (48 - 12) / 12 = **300%**.
2. **Containerized Monolith**:
   - Total cost: Rs 12 Crore.
   - Total revenue (from Q3b): Rs 40 Crore.
   - ROI = (40 - 12) / 12 = **233%**.

Recommendation: Microservices Architecture offers higher ROI and faster development benefits, making it the preferred choice.

d. Considering a five-year timeframe, calculate the potential return on investment (ROI) for each option in the mobile platform. For 'Image Optimization' and 'Mobile-Specific App Architecture', factor in the estimated cost savings from reduced cart abandonment due to faster loading times and performance improvement. Based on your calculations, recommend the most cost-effective option for the mobile e-commerce platform. [3]

ROI for Mobile Platform

1. **Image Optimization**:
   - Cost: Rs 1.6 Crore.
   - Reduction in cart abandonment rate: 1%.
   - Increased annual revenue: $1\% \times 10$ Lakh users $\times$ Rs 8000 $\times$ 10% margin = Rs 80 Lakh/year.
   - Revenue over 5 years = 80 Lakh $\times$ 5 = Rs 4 Crore.
   - ROI = (4 - 1.6) / 1.6 = **150%**.
2. **Mobile-Specific App Architecture**:
   - Cost: Rs 80 Lakh.
   - Reduction in cart abandonment rate: 0.5%.
   - Increased annual revenue: $0.5\% \times 10$ Lakh users $\times$ Rs 8000 $\times$ 10% margin = Rs 40 Lakh/year.

- o Revenue over 5 years = 40 Lakh $\times$ 5 = Rs 2 Crore.
- o ROI = (2 - 0.8) / 0.8 = **150%**.

Recommendation: Both options yield the same ROI of 150%. The choice should be based on budget constraints and long-term performance goals.

$$******$$