Here's a comprehensive solution for designing an Amazon Transportation System with a focus on scalability, reliability, and other considerations.

1. Problem Statement: Designing an Amazon Transportation System

Scenario: The goal is to create a transportation system that efficiently manages the lifecycle of packages from labeling to delivery. The system should also optimize routes and handle increased loads during peak seasons while ensuring reliability and fault tolerance.

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2. System Requirements

1. **Labeling:** Generate unique labels for each package that include tracking information.
2. **Packaging:** Manage various types of packages and ensure they are properly packaged for transport.
3. **Delivery Management:** Optimize delivery routes based on real-time data and maintain delivery status.
4. **Scalability:** Design the system to handle increased loads, especially during peak periods (like Diwali).
5. **Reliability and Fault Tolerance:** Implement redundancy and monitoring systems to ensure high availability.

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3. Key Classes

- `Package`**:** Represents a package, encapsulating details like ID, weight, and type. (Concrete class)
- `Label`**:** Responsible for generating labels for packages. (Concrete class)
- `Delivery`**:** Manages package delivery processes and tracks delivery status. (Concrete class)
- `MonitoringSystem`**:** Monitors the status of packages and delivery processes. (Concrete class)

Class Functions:

- `Package` **Class Functions:**
  - Constructor to initialize package details.
- `Label` **Class Functions:**
  - Method to generate a label for a package.
- `Delivery` **Class Functions:**
  - Method to add a package for delivery.
  - Method to update the status of a package.
  - Method to retrieve the status of a package.
- `MonitoringSystem` **Class Functions:**
  - Method to log package tracking information.
  - Method to generate alerts based on status changes.

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4. Data Structures Used

- **HashMap (C++ equivalent: `unordered_map`):**

  - **Purpose:** Maps package IDs to their status.
  - **Complexity:** Average O(1) for insertions and lookups.

- **Queue:**

  - **Purpose:** Manages the order of packages for delivery.
  - **Complexity:** O(1) for enqueue and dequeue operations.

- **Vector:**

  - **Purpose:** Used for storing lists of packages or deliveries.
  - **Complexity:** O(1) for accessing elements, O(n) for resizing.

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5. High-Level Design

1. **Package Class:** Contains attributes for package ID, weight, and type.
2. **Label Class:** Generates unique labels for each package upon creation.
3. **Delivery Class:** Adds packages to a delivery queue and updates their status based on real-time tracking.
4. **MonitoringSystem Class:** Monitors package status and generates alerts if a package is delayed or encounters an issue.

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6. Clarifying Questions for the Interviewer

- **How do you expect the system to scale during peak periods?**

  - Discuss the potential for horizontal scaling (adding more servers) versus vertical scaling (upgrading existing servers) to handle increased load.

- **What measures are in place for redundancy and fault tolerance?**

  - Explain how data replication can help maintain availability in case of a component failure.

- **How will monitoring and alerts be handled?**

  - Describe the importance of real-time monitoring systems that can notify administrators of issues before they affect operations.

- **What strategies will be used for route optimization?**

  - Discuss potential algorithms (like Dijkstra's) for finding the shortest path and the importance of real-time data.

Responsible Code Sections:

- **Scalability:** Handled in the `Delivery` class where load distribution can be optimized.
- **Reliability:** Addressed by the `MonitoringSystem` class for alerts and redundancy.

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7. Open-Ended Questions from Interviewer

1. **How do you ensure data integrity in package tracking?**
   - Implement checks and balances when updating package status, ensuring that only authorized functions can change critical information.
2. **What happens if a package is lost during transit?**
   - Develop procedures for reporting lost packages, possibly integrating insurance options within the system.
3. **How would you extend this system to include international shipping?**
   - Discuss implementing features to handle customs, international regulations, and varied shipping rates.

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8. C++ Code Implementation

```cpp
#include <iostream>
#include <string>
#include <unordered_map>
#include <queue>

// Package class to represent packages
class Package {
public:
    std::string id;
    double weight;
    std::string type; // "Standard", "Express"

    Package(std::string id, double weight, std::string type)
        : id(id), weight(weight), type(type) {}
};

// Label class to generate labels for packages
class Label {
public:
    std::string generateLabel(Package& pkg) {
        return "Label_" + pkg.id + "_" + pkg.type;
    }
};

// Delivery class to handle package delivery status
class Delivery {
private:
    std::unordered_map<std::string, std::string> packageStatus;
    std::queue<Package> deliveryQueue;

public:
    void addPackage(Package& pkg) {
        deliveryQueue.push(pkg);
        packageStatus[pkg.id] = "In Transit"; // Initially, package is in transit
    }

    void updateStatus(Package& pkg, std::string status) {
        packageStatus[pkg.id] = status; // Update the status of the package
    }

    std::string getStatus(Package& pkg) {
        return packageStatus[pkg.id]; // Get current status of the package
    }

    void processDeliveries() {
        while (!deliveryQueue.empty()) {
            Package pkg = deliveryQueue.front();
            deliveryQueue.pop();
            std::cout << "Delivering package: " << pkg.id << std::endl;
            updateStatus(pkg, "Delivered");
        }
    }
};

// MonitoringSystem class for tracking packages
class MonitoringSystem {
private:
    std::unordered_map<std::string, std::string> trackingInfo;

public:
    void trackPackage(Package& pkg, std::string location) {
        trackingInfo[pkg.id] = location; // Track the current location of the
package
    }

    std::string getTrackingInfo(Package& pkg) {
        return trackingInfo[pkg.id]; // Get the current location of the package
    }

    void alert(std::string message) {
        std::cout << "Alert: " << message << std::endl; // Generate an alert
    }
};

int main() {
    // Create instances
    Package pkg1("P001", 2.5, "Express");
    Package pkg2("P002", 1.0, "Standard");

    Label label;
    std::cout << "Package 1 Label: " << label.generateLabel(pkg1) << std::endl;

    Delivery delivery;
    delivery.addPackage(pkg1);
    std::cout << "Package 1 Status: " << delivery.getStatus(pkg1) << std::endl;

    delivery.processDeliveries();
    std::cout << "Package 1 Status after delivery: " << delivery.getStatus(pkg1)
```

```
<< std::endl;

    MonitoringSystem tracker;
    tracker.trackPackage(pkg1, "City_B");
    std::cout << "Package 1 Location: " << tracker.getTrackingInfo(pkg1) <<
std::endl;

    return 0;
}
```

Code Explanation

1. `Package Class:` Contains details about each package, such as ID, weight, and type.
2. `Label Class:` Generates labels for each package, ensuring unique identifiers.
3. `Delivery Class:` Manages the delivery process by maintaining a queue of packages, updating their statuses, and processing deliveries.
4. `MonitoringSystem Class:` Keeps track of the current location of each package and can issue alerts when necessary.

This design is modular and scalable, making it suitable for handling transportation services at Amazon efficiently.