

Network Architecture Design for MetroRail Transit Authority (MTA)

Introduction

The rapid advancement of intelligent transportation systems has revolutionized the way railway networks operate, emphasizing the need for secure, efficient, and scalable network architectures. As the network architect for MetroRail Transit Authority (MTA), the task at hand is to design a state-of-the-art network infrastructure that supports an intelligent railway system spanning five major metropolitan cities in Bangladesh: Dhaka, Chittagong, Sylhet, Rajshahi, and Khulna.

Each city serves a unique role within the network, from Dhaka as the central operations hub managing over 10 railway stations, to Rajshahi acting as the disaster recovery and data redundancy center. The proposed system will integrate cutting-edge technologies such as IPv4 addressing for scalability, VLAN segmentation for traffic isolation, and SD-WAN for optimized interconnectivity between hubs. Additionally, robust security measures, including Zero Trust authentication and firewall policies, will ensure protection against cyber threats while maintaining operational reliability.

1. IPv4 Addressing Plan

The IPv4 addressing scheme is designed to ensure scalability, efficiency, and security across all hubs and stations. Each regional hub and its associated railway stations are assigned unique subnets.

Subnet Breakdown

- **Dhaka (Main Branch):**
 - Central Operations Hub: 192.168.0.0/24
 - Railway Stations (10 stations): 192.168.1.0/24 to 192.168.10.0/24
 - IoT Sensors, Surveillance Cameras, Ticketing Systems, and Passenger Wi-Fi: Subnets divided further into /26 blocks.
- **Chittagong (South Maintenance Hub):**
 - Hub Network: 192.168.20.0/24
 - Railway Stations (5 stations): 192.168.21.0/24 to 192.168.25.0/24
- **Sylhet (South-West Control Center):**

- Hub Network: 192.168.30.0/24
- Railway Stations (4 stations): 192.168.31.0/24 to 192.168.34.0/24
- **Rajshahi (Disaster Recovery & Data Redundancy Center):**
 - Hub Network: 192.168.40.0/24
 - Backup Data Storage: 192.168.41.0/24
- **Khulna (East Expansion & Future Scaling):**
 - Hub Network: 192.168.50.0/24
 - Reserved for Future Stations: 192.168.51.0/24 to 192.168.55.0/24

Scalability, Efficiency, and Security

The hierarchical subnet structure ensures that each hub and station operates independently while maintaining connectivity. This design allows for easy addition of new stations and hubs without disrupting existing networks. VLAN segmentation further enhances security by isolating sensitive operational traffic from passenger services.

2. Network Diagram Description

The network architecture consists of:

- **Central Hub (Dhaka):** Acts as the primary control center with connections to all regional hubs via SD-WAN.
- **Regional Hubs:** Chittagong, Sylhet, Rajshahi, and Khulna serve specific roles such as maintenance, control, disaster recovery, and future expansion.
- **SD-WAN Links:** Secure and optimized interconnectivity between hubs with QoS policies.
- **Firewalls:** Deployed at each hub to enforce access control and Zero Trust policies.
- **Redundancy Links:** Backup links ensure continuous operation during failures.

3. SD-WAN Configuration Plan

Traffic Prioritization Policies

- Train Control Data: Highest priority (Priority 1).
- Real-Time Tracking and Scheduling: Priority 2.
- Passenger Wi-Fi: Lowest priority (Priority 3).

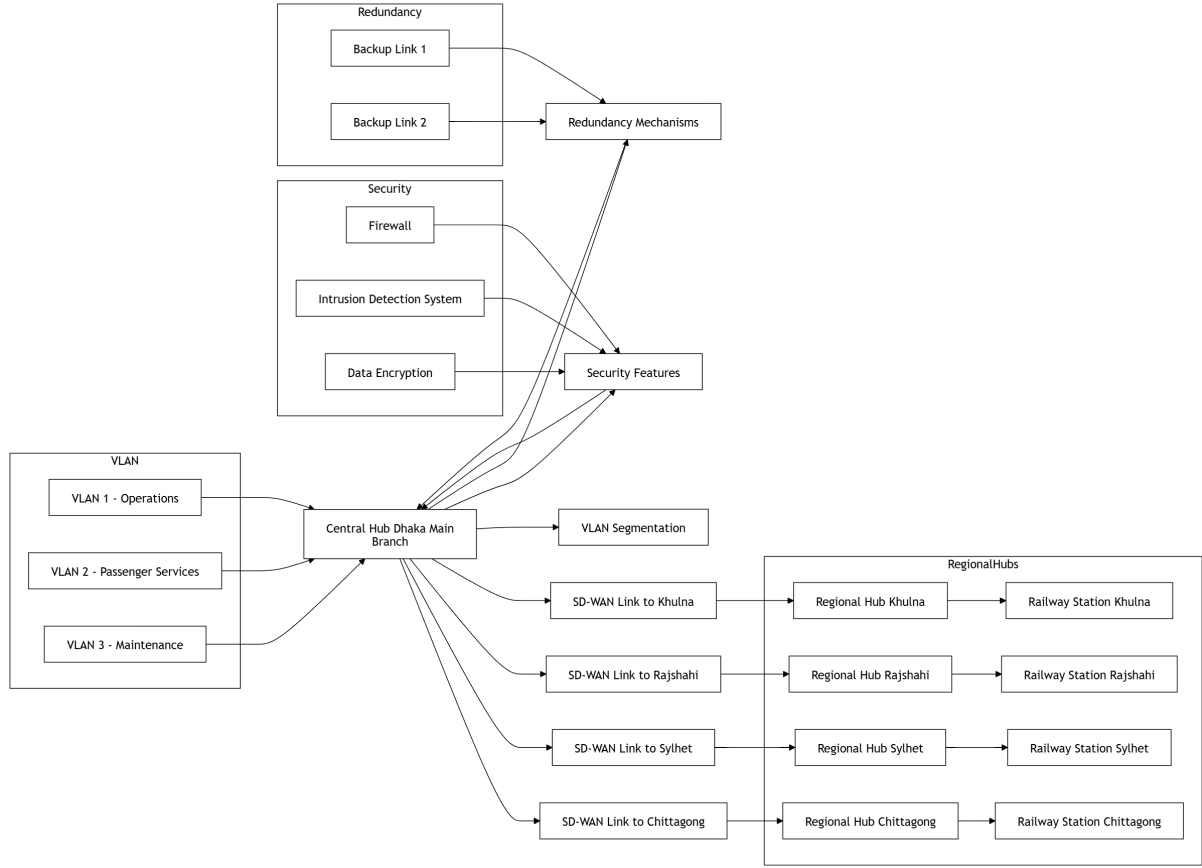


Figure 1: High-Level Network Architecture

Failover Mechanism

- Automatic failover is implemented using dual SD-WAN links.
- If the primary link fails, traffic is rerouted through a backup link with minimal disruption.
- Rajshahi serves as the disaster recovery site, ensuring data integrity and system availability.

4. Security and Firewall Configuration

Firewall Policies

- Restrict external access to core railway operations.
- Whitelist specific traffic types (e.g., control data from Dhaka to Chittagong).
- Block unauthorized access to sensitive databases and systems.

Zero Trust Authentication

- All inter-region communication requires mutual authentication.
- Use certificates and multi-factor authentication (MFA) for secure access.

5. Justifications and Scalability Considerations

Scalability

The hierarchical subnet design allows for seamless addition of new stations and hubs. Reserved subnets in Khulna ensure future expansion.

Challenges

- **Cybersecurity:** Continuous monitoring and updates are required to mitigate evolving threats.
- **Bandwidth Management:** QoS policies ensure efficient use of available bandwidth.
- **Redundancy:** Backup links and disaster recovery mechanisms ensure high availability.

Conclusion

The proposed network architecture meets the requirements for security, scalability, reliability, and efficiency. It leverages IPv6 adoption, VLAN segmentation, and SD-WAN to provide a robust foundation for MetroRail's intelligent railway system.