MATLAB CODE EXPLANATION

Three Simulation Configurations

Case 1: Fixed gNodeB Environment Testing

- gNodeBs remain stationary throughout simulation
- Focus on comparing performance across different environments (Urban, Suburban, Rural)
- UEs move randomly within the coverage area
- Purpose: Baseline performance analysis with stable infrastructure

Case 2: Mobile gNodeB Scalability Testing

- Both gNodeBs and UEs are mobile
- Tests network adaptability with moving infrastructure
- Advanced mobility patterns for gNodeBs
- Purpose: Dynamic network performance under infrastructure mobility

Case 3: Fixed UEs with Varying gNodeB Count

- **Key Innovation**: UEs remain completely stationary, gNodeBs are mobile
- Tests multiple gNodeB configurations (varying count from min to max)
- Analyzes coverage optimization for fixed user distributions
- Purpose: Infrastructure scalability and coverage optimization

Initial Configuration & Validation

User Input Handling

- Configuration selection (1, 2, or 3)
- UE count validation (50-1000 range with specific limits per case)
- gNodeB configuration based on selected case
- Input validation with comprehensive error checking

Environment Setup

- **Three environments**: Urban (500m²), Suburban (800m²), Rural (1200m²)
- Each environment has unique characteristics:
    - **Interference levels**: Urban (high), Suburban (medium), Rural (low)
    - **Path loss exponents**: Different signal propagation characteristics
    - **Base latency values**: Environment-specific delay characteristics

Network Topology Generation

gNodeB Placement Strategy

- **Grid-based layout**: Automatic grid calculation based on gNodeB count
- **Scaling approach**:
  - ≤4 gNBs: 2×2 grid (Small network)
  - ≤9 gNBs: 3×3 grid (Medium network)
  - ≤25 gNBs: 5×5 grid (Large network)
  - 25 gNBs: Dynamic grid sizing
- **Spacing calculation**: Even distribution across environment area

UE Initial Positioning

- UEs initially positioned near gNodeBs for realistic coverage
- Random offset from gNodeB positions (±20m)
- Boundary checking to ensure UEs stay within environment limits

Mobility Models

Case 1 (Fixed gNodeB)

- gNodeBs: Completely stationary
- UEs: Random movement (±15m per time step)

Case 2 (Mobile gNodeB)

- gNodeBs: Standard mobility (±5m per time step)
- UEs: Random movement (±15m per time step)
- Mobility scaling based on network density

Case 3 (Fixed UE, Mobile gNodeB)

- **UEs: Completely stationary** (key feature)
- **gNodeBs: Enhanced mobility** for coverage optimization
- Purpose: Analyze mobile infrastructure serving fixed user locations

Signal Quality Calculations

RSSI (Received Signal Strength Indicator)

RSSI = -30 - distance × 0.8 - 10×log10(1 + interference_factor)

RSRP (Reference Signal Received Power)

RSRP = RSSI - 5 dB

SINR (Signal-to-Interference-plus-Noise Ratio)

SINR = 10×log10(signal_power / (interference_power + noise_power))

Range: -10 dB to +30 dB

RSRQ (Reference Signal Received Quality)

RSRQ = RSRP - RSSI

Range: -20 dB to -3 dB

Handover Management

Association Logic

- UEs connect to nearest gNodeB (minimum distance)
- Handover triggered when UE moves closer to different gNodeB
- **Handover tracking**: Count, timing, and affected UEs recorded

Handover Metrics

- Total handovers per simulation
- Handovers per UE
- Handover rate (percentage of UEs experiencing handovers)
- Maximum handovers for any single UE

Resource Allocation Simulation

Application-Based Requirements

- **9 Application types**: Emergency, Video Call, Voice Call, Streaming, Gaming, etc.
- **Bandwidth requirements**: Different for each application (0.1-5 Mbps)
- **Priority handling**: Emergency applications get priority

Throughput Calculation

Base Throughput = max(2.0, 15 - 0.4 × distance)

Interference Penalty = 1 / (1 + interference_factor)

SINR Bonus = max(0.5, min(2.0, 1 + SINR/30))

Final Throughput = Base × Interference_Penalty × SINR_Bonus

Load Balancing

- **gNodeB capacity**: 200 Mbps maximum per gNodeB
- **Congestion factor**: Performance degrades with more UEs per gNodeB
- **Resource allocation efficiency**: Varies by application priority