Repeater Density and Coverage Calculations

How many repeaters do you need, and where should they go? This page provides practical calculation methods for MeshCore network coverage planning.

Link Budget Basics

The maximum range between two MeshCore nodes depends on the link budget:

```
Link Budget = TX Power + TX Antenna Gain + RX Antenna Gain - Feedline Loss - Path Loss

Example (typical repeater setup):
TX Power: +22 dBm (158 mW - legal limit for USA ISM)
TX Antenna: +5 dBi (fiberglass omni)
RX Antenna: +5 dBi (fiberglass omni)
Feedline Loss: -1 dB each end = -2 dB total
Path Loss at 5 km free space: ~108 dB at 915 MHz
Receiver Sensitivity (SX1262, SF9): -125 dBm

Available fade margin:
(22 + 5 + 5 - 2) - 108 - (-125) = 47 dB fade margin

Real-world adjustment (buildings, terrain): -10 to -20 dB
Net fade margin: 27-37 dB - solid link
```

Terrain Effects on Range

Free-space calculations assume line of sight. Real-world path loss modifiers:

Environment	Typical Range (equal-height nodes)	Range (one node elevated 30m)
Flat open terrain	3-8 km	10-20 km

Environment	Typical Range (equal-height nodes)	Range (one node elevated 30m)
Suburban (low buildings)	1-3 km	5-10 km
Dense urban (high-rise)	0.3-1 km	2-5 km
Forest/jungle	0.5-2 km	2-5 km
Mountainous (valley-to-peak)	Variable	20-50 km (ridge-to-ridge)

Coverage Area Calculation

For a given expected range R, a single omnidirectional repeater covers approximately:

```
Coverage area = pi * R^2

At R = 3 km: ~28 km^2 (~11 sq miles)
At R = 5 km: ~78 km^2 (~30 sq miles)
At R = 10 km: ~314 km^2 (~121 sq miles)
```

These are theoretical maximums. Actual coverage is typically 50-70% of the theoretical circle due to terrain, buildings, and RF absorption.

Repeater Density Guidelines

For a network where most clients are within 1 hop of a repeater:

- **Urban dense (Manhattan, downtown Chicago):** 1 repeater per 0.5-1 km^2 (500m radius)
- **Suburban:** 1 repeater per 3-8 km^2 (1-1.5 km radius)
- **Rural flat terrain:** 1 repeater per 20-50 km^2 (2.5-4 km radius)
- **Rural with elevation advantages:** 1 repeater per 50-200 km^2 (4-8 km radius)

These are starting points. After initial deployment, use the actual RSSI/SNR data from your node database to identify coverage holes and place additional repeaters strategically.

Path Hop Analysis

In MeshCore, messages travel via discovered paths. The path length (hop count) determines:

- **Latency:** ~100-500ms per hop in normal conditions

- **Reliability:** Each hop adds failure probability; a 5-hop path with 95% per-hop reliability = 77% end-to-end delivery probability

Target: most clients should reach the room server within 3 hops. 5+ hops indicates a coverage gap that a new repeater could address.

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