The Repeater Grid Approach for Urban Coverage

Why a Grid Approach?

Ad-hoc repeater placement - putting nodes wherever a willing host can be found - produces uneven coverage with clusters of overlapping repeaters in some areas and dead zones in others. A systematic grid approach starts from coverage requirements and works backward to site requirements, ensuring uniform coverage and efficient use of channel capacity.

Target Repeater Density by Area Type

The figures below are planning heuristics, not guarantees: actual spacing and density depend heavily on antenna height and local building/terrain density, so treat them as rough starting points and confirm with a real coverage survey.

Area Type	Target Repeater Spacing	Approx. Density	Rationale
Urban core (high-rise, dense)	1.0 - 2.0 km	1 per 1 - 3 km²	Heavy building obstruction limits each repeater to a small footprint
Suburban (low-rise, residential)	3.0 - 5.0 km	1 per 7 - 20 km²	Moderate obstruction; rooftop repeaters can reach 3 - 8 km reliably
Exurban / light industrial	5.0 - 8.0 km	1 per 20 - 50 km²	Low building density; tall structures (grain elevators, water towers) excellent
Rural (farmland, grassland)	8.0 - 15.0 km	1 per 50 - 175 km²	Near line-of-sight; hilltop or tower sites dominate

Area Type	Target Repeater Spacing	Approx. Density	Rationale
Wilderness / remote	15.0 - 30.0 km+	1 per 175 - 700 km²	Solar-powered mountain-top repeaters; realistic in open/semi-open terrain only

These spacings are heuristics that assume repeaters are elevated (10 - 30 m AGL for urban, 30+ m for rural) and achieve 10 dB of link margin at the target spacing (cross-reference your own link-budget margin calculations). For low ground-mounted installations, spacing scales roughly with the √h radio-horizon relationship rather than linearly; as a rough rule of thumb, reduce spacing by 30 - 40% (or recompute from the horizon scaling for your specific heights).

Step 1 - Identify Anchor Sites

Anchor sites are high, prominent structures that provide disproportionately large coverage footprints. Finding and securing anchor sites is the most important work in urban coverage planning. Common anchor site types:

- **Water towers:** Heights vary widely (some standpipes are under 20 m, some elevated tanks exceed 50 m; a common range is roughly 25 - 50 m AGL — consult AWWA tank standards if you need precise figures). Often publicly owned, with existing antenna mounts. Utility companies are sometimes receptive to emergency communications partnerships. Ideal anchor nodes.
- **Tall commercial buildings (10+ storeys):** Roof access is harder to obtain but a single mid-rise rooftop repeater in a dense urban core can match 5 - 10 lower installations. Target telecommunications companies, building management firms, or property owners sympathetic to community projects.
- **Hilltops and ridgelines:** In cities built on rolling terrain (Pittsburgh, San Francisco, Seattle), hilltops within or adjacent to urban areas are the highest-value sites. Even a 5 - 10 m height advantage over surrounding terrain dramatically extends range.
- **Radio / TV transmission towers:** Licensed broadcasters and tower companies sometimes offer shared mounting space. The collocation fee may be justified by the coverage gained.
- **Church steeples and clock towers:** Often the tallest structures in older residential neighborhoods. Many faith communities are receptive to community emergency communications projects.

Map all potential anchor sites in a GIS tool. Run viewshed analyses from each. Rank by coverage area. Secure the top 3 - 5 sites before planning secondary fill repeaters.

Step 2 - Fill Planning

Once anchor sites are installed and their actual coverage verified (wardriving survey or community signal reports), overlay the confirmed coverage zones on your planning map. Grid cells with no coverage, or with RSSI below −120 dBm, are fill targets.

Fill repeaters do not need to be as elevated as anchor sites - they only need to bridge a specific gap. A 5 m residential rooftop install may be sufficient to cover a neighborhood dead zone if it is positioned on the line of sight between two anchor sites. Prioritise fill sites that:

1. Cover the largest dead zone area with the smallest number of new nodes
2. Can hear at least two anchor-tier repeaters (for redundancy)
3. Are accessible for maintenance

Step 3 - Documenting Coverage Gaps

Maintain a living coverage map updated after every wardriving run or community signal report. A shared GIS layer (e.g., a Google MyMaps or an QGIS project shared via cloud storage) accessible to all network administrators is the best tool for this. For each coverage gap, record:

- Geographic boundary of the gap (polygon on the map)
- Estimated area (km²) and population affected
- Identified candidate fill site(s), if any
- Status: *open / candidate identified / site secured / fill node deployed*
- Last confirmed date of the gap (wardriving date or community report date)

A structured gap log prevents the common failure mode of deploying fill nodes in areas that are already well-covered while neglecting persistent dead zones that lack a vocal advocate.

Worked Example: Planning a Mid-Sized City Grid

Target: A city of 80,000 people covering approximately 120 km², mostly suburban with a 2 km² dense downtown core.

1. **Downtown core (2 km²):** Target 1 - 2 km spacing → need 1 - 2 anchor repeaters. Identified a 12-storey bank building and a water tower 1.3 km apart. Both anchor sites secured. Downtown coverage achieved with 2 nodes (2 nodes / 2 km² = 1 per 1 km², within the 1 - 3 km² urban-core target).
2. **Suburban ring (118 km²):** Target 4 km spacing. Hexagonal packing at 4 km site spacing (each site covering a hex of roughly 2 km radius, ≈ 2.6 × 2² ≈ 10 km² per site) gives 118 / 10 ≈ **11 - 12 sites**, not 7 - 8 — a triangular/hex grid covers less area per site than a naive square estimate. Identified 9 water towers and 3 church steeples evenly distributed across the suburban ring. All 12 sites secured. Average spacing: ~3.9 km (12 nodes / 118 km² = 1 per ~9.8 km², within the 7 - 20 km² suburban target).
3. **Total anchor infrastructure: 14 nodes** for 120 km². Report density per zone rather than as a blended average: downtown 1 per 1 km² and suburban 1 per ~9.8 km², both meeting their zone targets. (A single blended "1 per ~8.6 km²" figure would conceal that each zone is independently compliant.)
4. **Post-wardriving fill:** Survey revealed 3 dead zones in valley neighborhoods. 3 fill repeaters added on rooftops in those valleys. Total: 17 nodes for complete city coverage.

Compare this to an ad-hoc approach: a typical volunteer-driven deployment in a city this size might have 40 - 80 ground-level nodes with significant overlap in connected areas and persistent dead zones in underserved neighborhoods. The grid approach delivers better coverage with far fewer nodes and less channel congestion.

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