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Data-Driven Estimation of 5G Link Reliability from Multi-City Radio Signal Measurements

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Reliable evaluation of 5G network performance requires real-world measurements; however, such datasets often lack packet success information needed to assess service reliability directly. Here, a data-driven framework that addresses this limitation **by inferring reliability from standard radio-layer indicators using a probabilistic logistic model calibrated to the empirical SINR distribution and mapped to RSRP** is presented.
The method is applied to 5G field trial data collected across 4 representative cities and evaluated for different link requirements in the 3GPP service classes URLLC, eMBB, and mMTC. Results show that cities with strong SINR and well-aligned power-quality characteristics exhibit steep reliability transitions and compact coverage, whereas interference-limited areas display gradual reliability decay and inflated ranges.
Analysis across macro-microcell regimes shows that the proposed framework, by integrating multi-city empirical data with logistic reliability inference and service-class coverage mapping, provides an interpretable, measurement-based approach for estimating 5G link reliability and coverage without packet-level data.

Key Contributions

- ✓ 5G Data-Driven Reliability Framework inferred from field-measured signal quality (SINR) and strength (RSRP)
- ✓ Validated across four cities with diverse propagation environments and interference conditions
- ✓ Coverage radius estimation for 3GPP URLLC, eMBB, and mMTC service classes
- ✓ Practical tool for reliability-based 5G deployment optimization

Methodology

A. SINR-Based Reliability Proxy

The probability of successful packet delivery probability modeled as:

$$R\_proxy(SINR) = 1 / (1 + \exp[-\beta(SINR - SINR_{50})])$$

where $SINR_{50}$ is the median SINR and $\beta = 4.394 / (SINR_{90} - SINR_{10})$ defines the transition slope.

B. Mapping Reliability to RSRP

A second logistic model maps reliability to RSRP:

$$R(RSRP) = 1 / (1 + \exp[-\alpha(RSRP - RSRP_{50})])$$

parameters α and $RSRP_{50}$ are optimized via MSE minimization.

C. Coverage Radius Estimation

For reliability target p:

$$RSRP^*(p) = RSRP_{50} + (1/\alpha) \cdot \ln(p/(1-p))$$

$$d(p) = 10^{((EIRP - RSRP^*(p) - PL_0) / 10n)}$$

Measured Signal Statistics

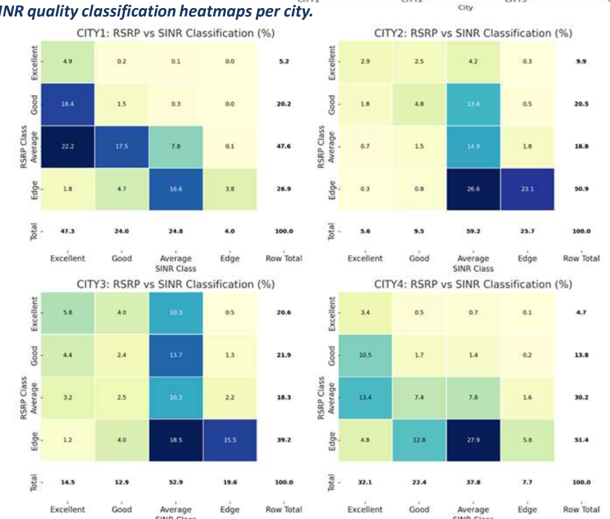
	$RSRP_{50}$ (dBm)	RSRP IQR (dB)	$SINR_{50}$ (dB)	SINR IQR (dB)
CITY1	−95.54	10.53	19.23	13.82
CITY2	−100.61	23.60	4.93	10.50
CITY3	−94.14	24.54	7.83	12.35
CITY4	−100.22	13.12	13.72	14.03

	RSRP (dBm)	SINR (dB)
Excellent	>= -80	>= 20
Good	-80 to -90	13 to 20
Average	-90 to -100	0 to 13
Edge	<= -100	<= 0

RSRP and SINR distributions (violin plots) across 4 cities:

- CITY1 & CITY4: optimized coverage and low interference, shown by a strong, consistent RSRP–SINR correlation.
- CITY2: Indicates high interference or network load, exhibiting broad signal dispersion.
- CITY3: Reflects uneven propagation conditions, maintaining moderate signal consistency that skews toward mid-level SINR ranges.

RSRP–SINR quality classification heatmaps per city.



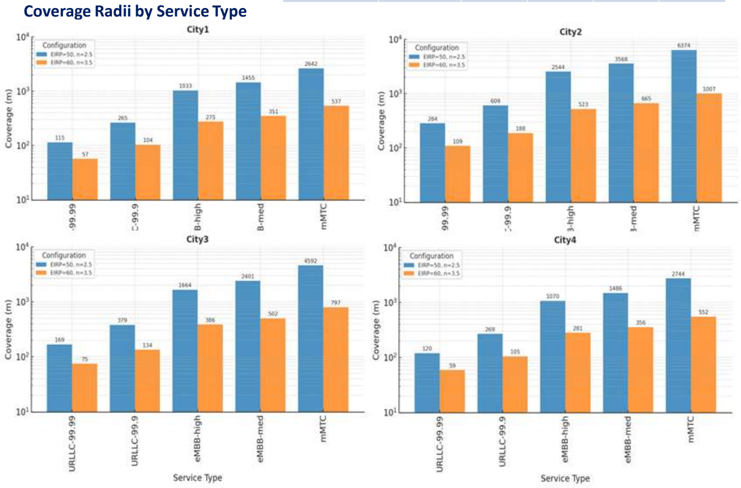
Results

Fitting the RSRP-based reliability model, equivalent signal thresholds were estimated for the 3GPP service classes

Table III: Reliability Targets & RSRP Thresholds (dBm)

Service	Target (p)	CITY1	CITY2	CITY3	CITY4
URLLC-99.99	0.9999	−71.82	−81.68	−76.01	−72.32
URLLC-99.9	0.999	−80.93	−89.95	−84.82	−81.10
eMBB-high	0.97	−95.69	−105.48	−100.87	−96.07
eMBB-med	0.95	−99.41	−109.15	−104.85	−99.64
mMTC	0.90	−105.89	−115.45	−111.89	−106.30

Coverage Radii by Service Type



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Conclusions

- Framework infers 5G reliability from SINR/RSRP without packet success logs.
- Cities with high SINR medians achieve target reliability at stronger RSRP → efficient, stable operation.
- Weak SINR environments produce shallower reliability slopes and larger but less robust coverage.
- URLLC limited to sub-100 m; eMBB/mMTC extend to multi-km ranges.
- Practical tool for reliability-based 5G coverage evaluation and deployment optimization.

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