Abstract

Range based techniques exploiting the relationship between Received Signal Strength (RSS) and distance provide a cost effective and fast solution to the non-cooperative localization problem. We look into a more robust method which uses the Differential RSS (DRSS) [4] approach to localize. In an environment with spatially correlated shadowing we analyze the objective function used for DRSS and propose an alternative – Weighted DRSS – which while preserving the robustness and speed of the former is devoid of certain drawbacks that were noticed. Simulation results show WDRSS performing better than DRSS in terms of Average Miss Distance (AMD) as well as able to meet the FCC E-911 mandate [6] with slightly fewer anchor nodes than required for the original DRSS approach.

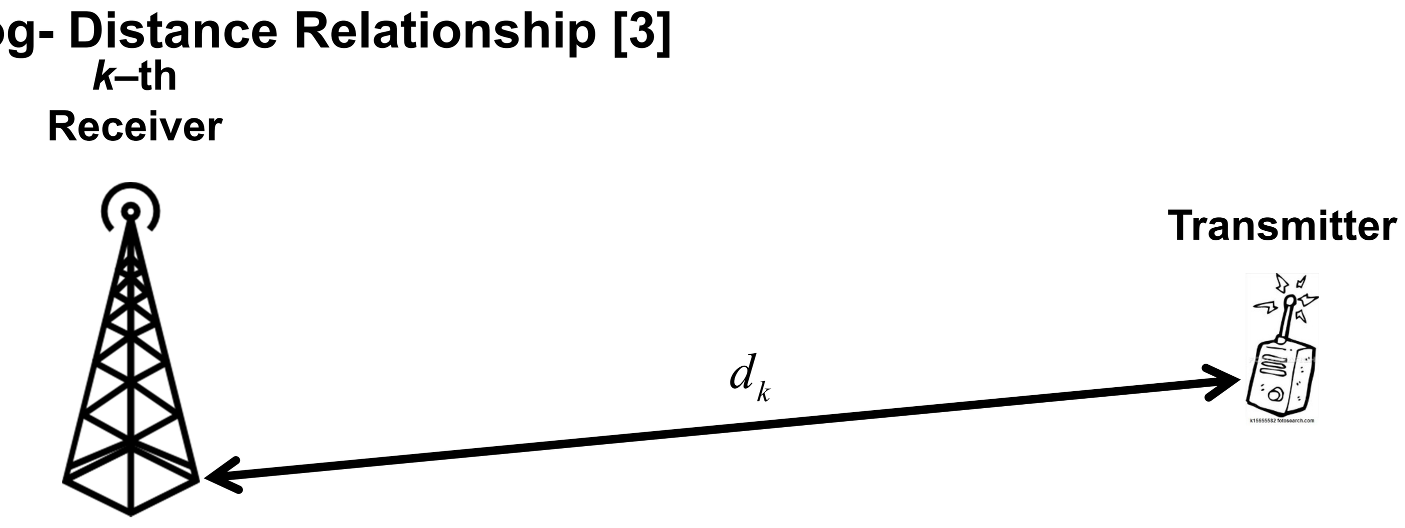
Review of Localization Methods

	Time of Arrival (TOA)	Angle of Arrival (AOA)	Received Signal Strength (RSS)	Channel Impulse Response (CIR)
Susceptibility to Multipath and NLOS	YES	YES	NO (provided the model is accurate)	NO (provided the database is extensive)
Robustness to Noise	YES	YES	NO	YES
Low Cost	YES	NO	YES	NO (cost of maintaining the database is high)
Synchronization Required	YES	NO	NO	NO
Database	NO	NO	NO	YES

■ Desired ■ Undesired

Path Loss Model

A. Log- Distance Relationship [3]

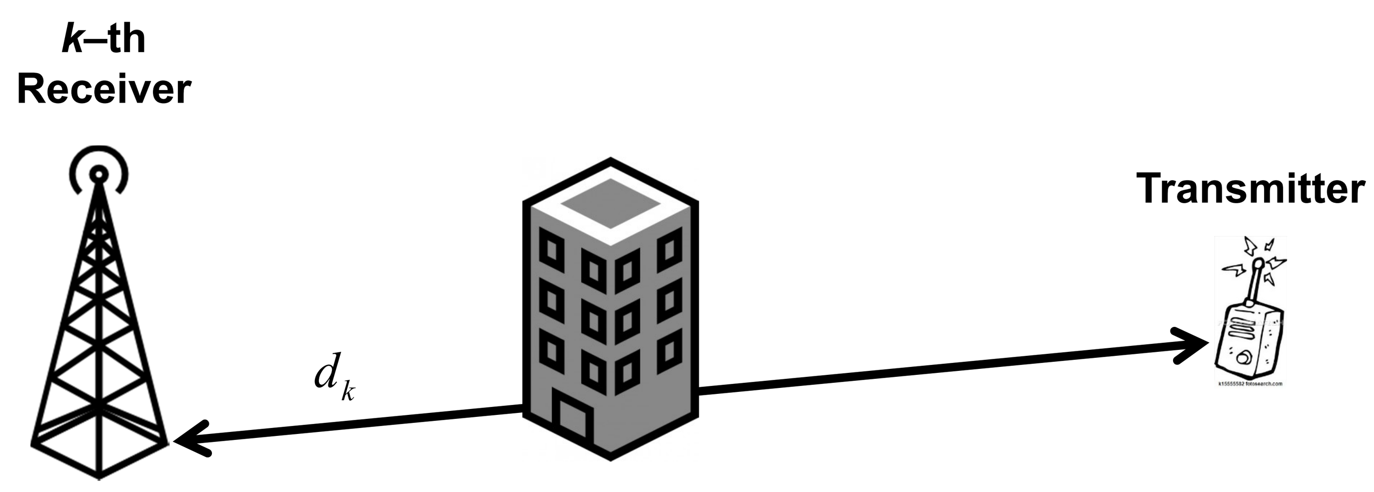


$$P(d_k) = P(d_0) - 10\alpha \log_{10}\left(d_k / d_0 \right)$$

$P(d_0)$: Power measured at a known distance d_0

α : Path Loss Exponent

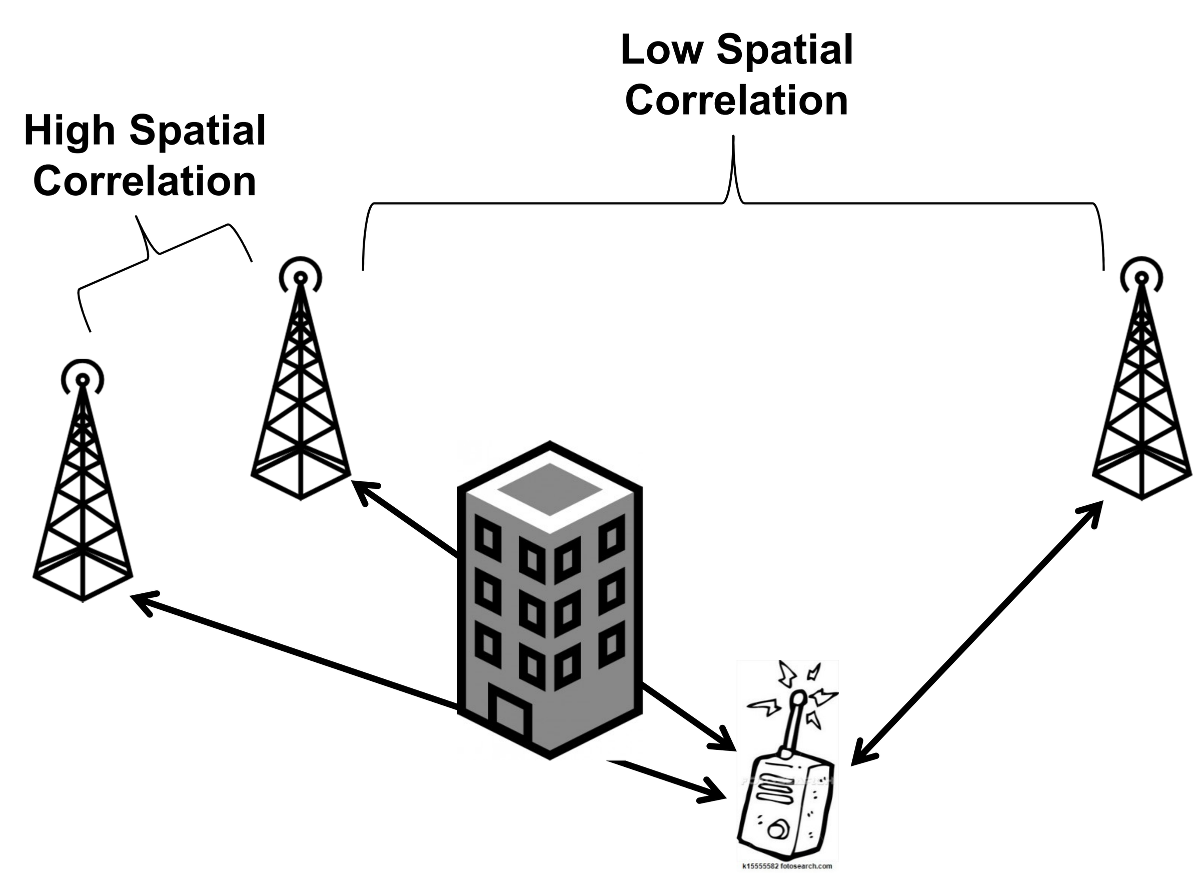
B. Shadowing Model



$$L(d_k) = P(d_0) - 10\alpha \log_{10}\left(d_k / d_0 \right) + x_k$$

$$X_k \sim N\left(0, \sigma_s^2\right)$$

C. Spatially Correlated Shadowing [4]



$$R(i,j) = \sigma_s^2 \exp\left(-\frac{d_{ij}}{d_c} \ln 2 \right)$$

Analysis of Objective Functions

A. DRSS Objective Function

The DRSS objective function ($\boldsymbol{\theta} = [x, y]$: unknown Transmitter location) is given by:

$$\hat{\boldsymbol{\theta}} = \arg\min_{\boldsymbol{\theta}} \sum_{i=1}^{N-1} \sum_{j=1}^{N} \left(L(d_i, d_j) - 10\alpha \log_{10}\left(d_j / d_i \right) \right)^2$$

where, $L(d_i, d_j) = L(d_i) - L(d_j)$

$$= 10\alpha \log_{10}\left(d_j / d_i \right) + \Delta x_{ij}$$

$$\Delta X_{ij} \sim N\left(0, 2(1-\rho_{ij})\sigma_s^2\right)$$

B. Illustrative Example

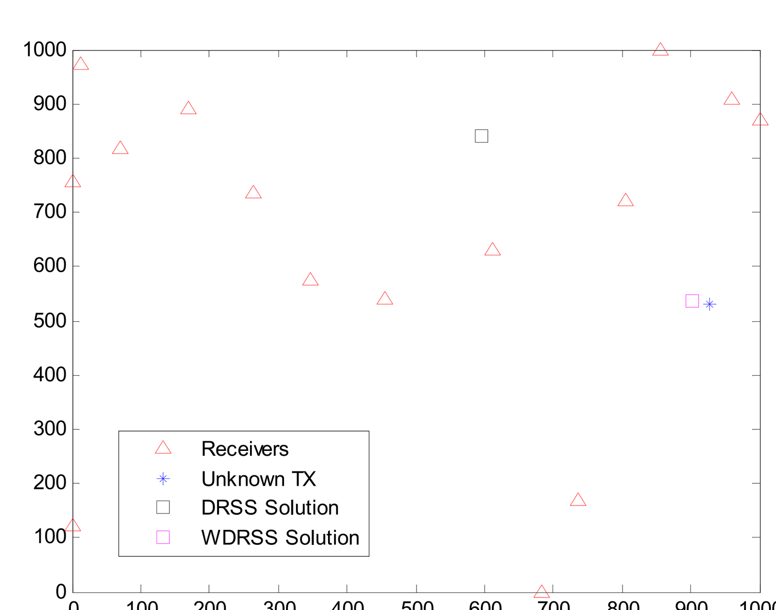


Fig 1a. Simulation Environment with Solutions.

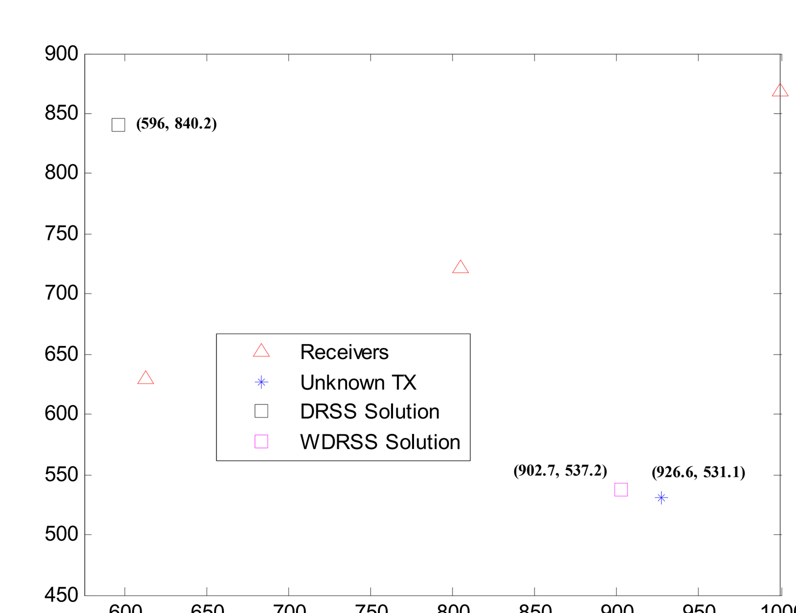
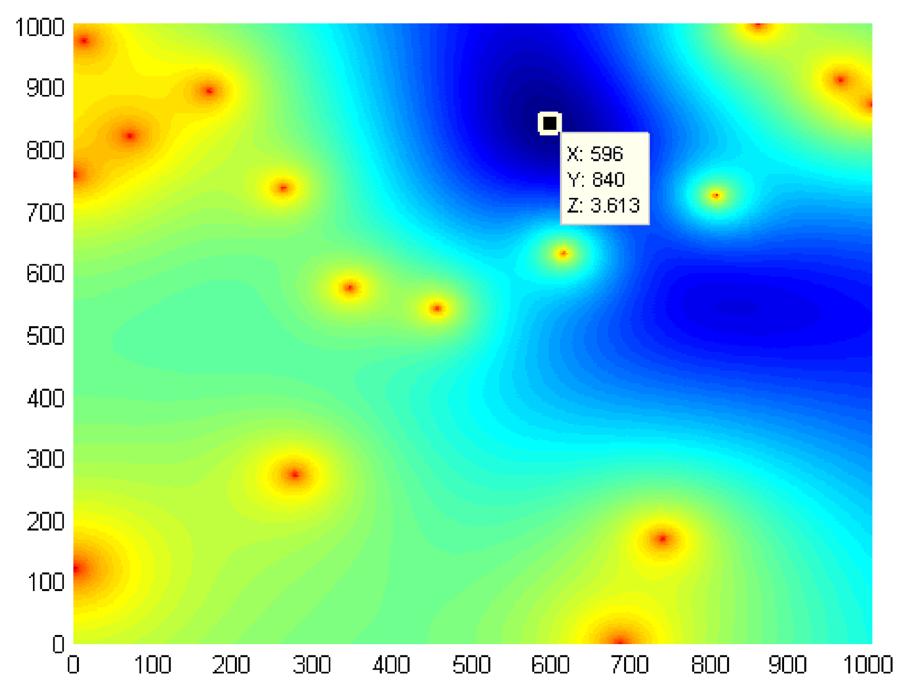


Fig 1b. Solutions (Zoomed).



Minimum of the DRSS cost function is NOT at the true location (926.6,531.1) of the unknown Transmitter.

Fig 2. Cost Function For DRSS.

C. Proposed Cost Function: Weighted DRSS

The proposed WDRSS cost function is given by:

$$\hat{\boldsymbol{\theta}} = \arg\min_{\boldsymbol{\theta}} \sum_{i=1}^{N-1}\sum_{j=1}^{N} w_{ij}\left(L(d_i, d_j) - 10\alpha \log_{10}\left(d_j \big/ d_i \right) \right)^2$$

where, $$w_{ij} = \exp\left(-\beta \frac{(d_{ij} - d_{\min})}{(d_{\max} - d_{\min})} \right)$$

β is a tunable parameter which controls the weight assigned to a pair of sensors located as far apart as physically possible.

Minimum of the WDRSS cost function is very close to (926.6,531.1), the true location of the unknown Transmitter.

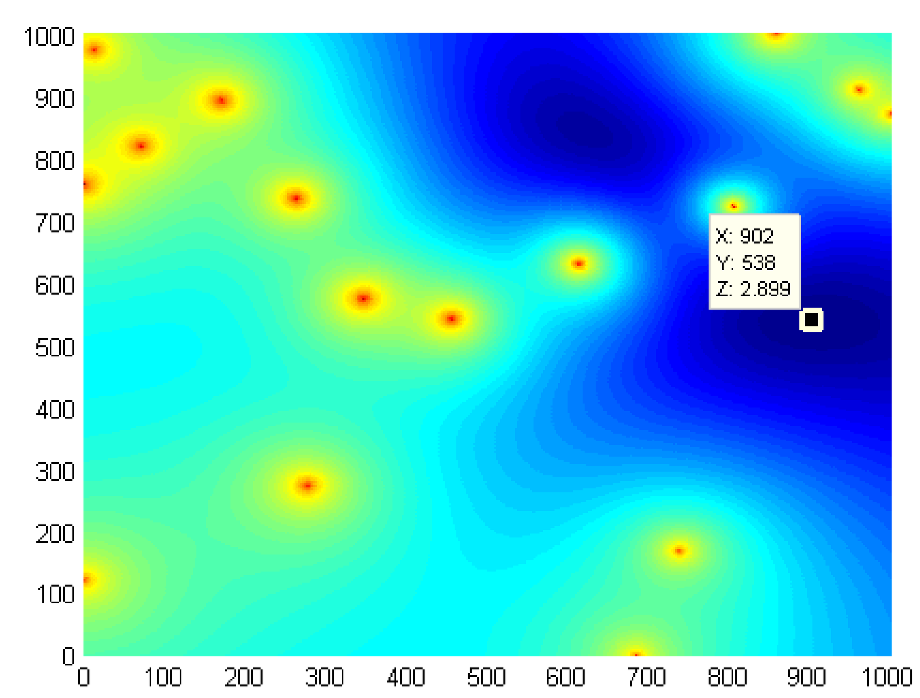


Fig 3. Cost Function For WDRSS.

Results & Discussions

A. Average Miss Distance (AMD)

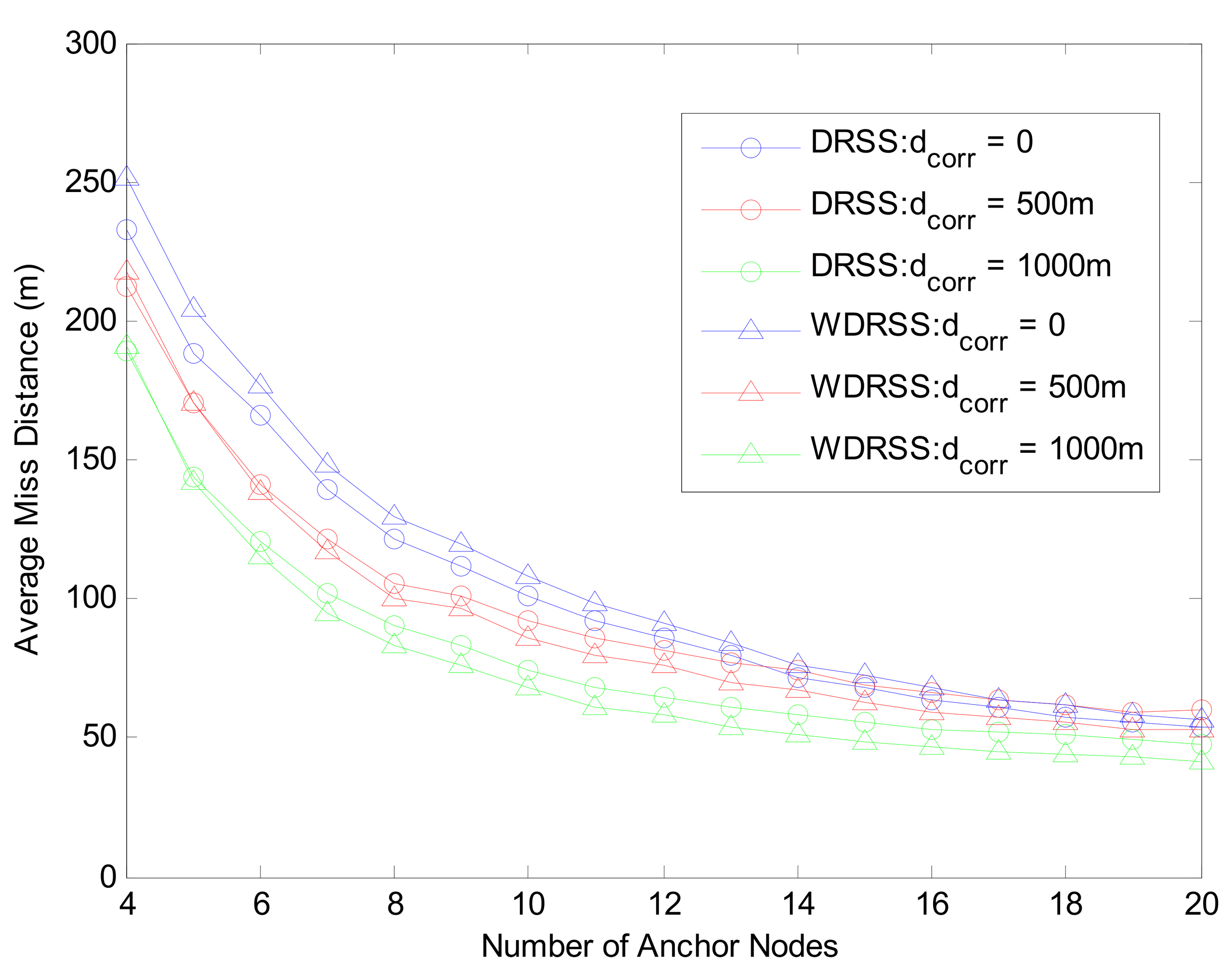


Fig 4. Comparison of Average Miss Distance (AMD).

Discussion: With the increase of dcorr (spatial correlation increases) the performance of WDRSS improves in comparison to DRSS.

B. FCC E-911 Stipulation [6]

1. **If GPS information is available**, the method should be accurate within 150 *m* 95% of the time and within 50 *m* 67% of the time.
2. **If GPS information is not available**, the accuracy should be within 300 *m* 95% of the time and within 100 *m* 67% of the time.

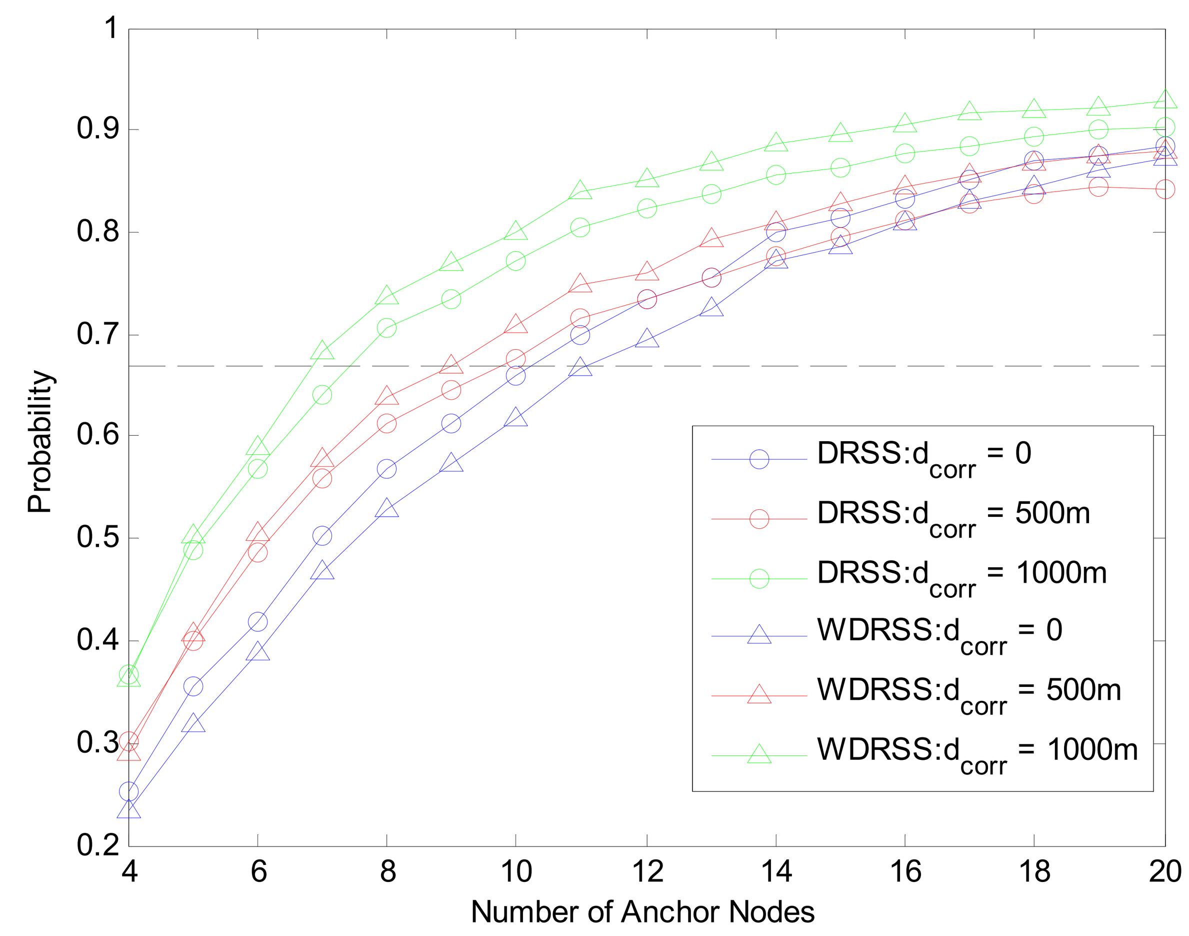


Fig 5. Comparison between WDRSS and DRSS with respect to *P*(*MD* ≤ *100 m*).

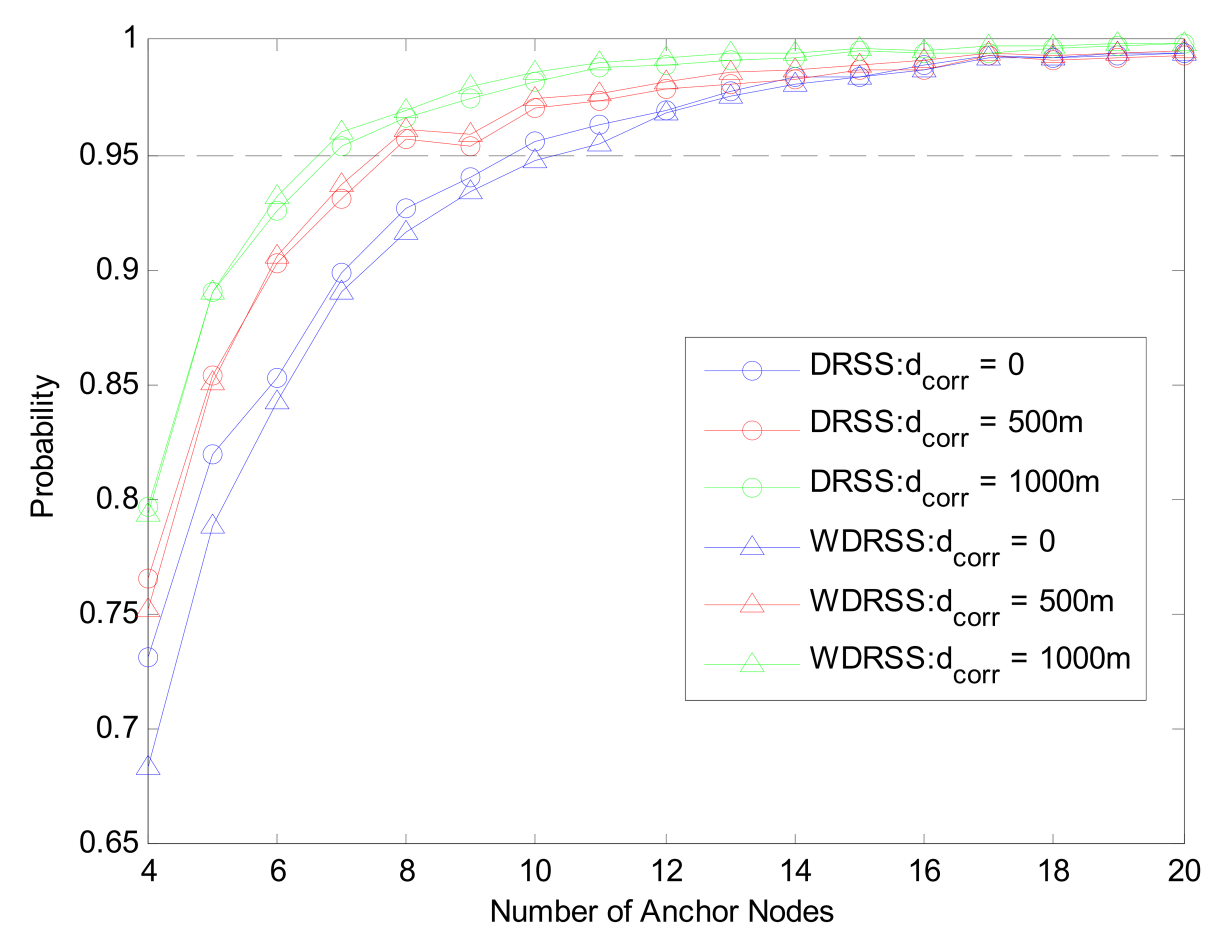


Fig 6. Comparison between WDRSS and DRSS with respect to *P*(*MD* ≤ *300 m*).

Discussion: WDRSS does better than DRSS in terms of cumulative probability as the spatial correlation increases. WDRSS achieves the stipulated FCC E-911 metrics with one sensor less than DRSS.

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