Performance Comparison of MR-FDPF and Ray Launching in an Indoor Office Scenario

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Introduction

Radio-wave propagation modelling plays a fundamental role in the wireless network planning and optimization (P&O). A satisfactory network P&O tool relies on accurate and fast radio propagation models. There are many propagation models in the literature where those can be categorized into Empirical Models and Deterministic Models. The comparison between different propagation models is the prerequisite to the choice of which is better fit for network P&O tools. The performance of two deterministic propagation models which are based on different mechanisms are compared in an indoor office scenario in terms of speed and accuracy.

Model Description

Multi-Resolution Frequency Domain ParFlow (MR-FDPF)

MR-FDPF is a FDTD-like method which is derived from the time domain ParFlow method and makes it work in the frequency domain by a Fourier Transform of the local scattering matrix. The Maxwell's wave equation is approximated by an equation on the 2D grid in ParFlow method. This equation is then solved to get inward flows of each pixels. Finally the electric field is computed directly from the inward flows.

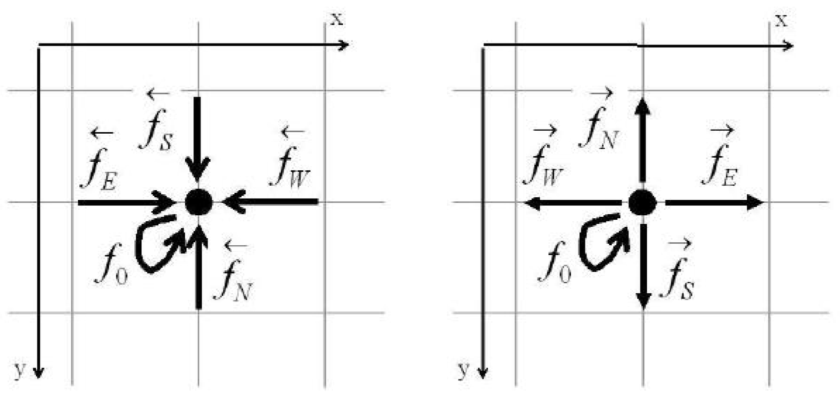
$$\delta_t^2 \Psi(r,t) - (\frac{c_0}{n_r})^2 \cdot \nabla^2 \Psi(r,t) = -\frac{1}{\epsilon} \cdot \delta_t i(r,t) \quad (1)$$

$$\overrightarrow{F}(r,t) = \Sigma(r) \cdot \overleftarrow{F}(r,t-dt) + \overrightarrow{S}(r,t) \quad (2)$$

$$\overrightarrow{F}_e(r) = \Sigma_e(r) \cdot \overleftarrow{F}_e(r) + \overrightarrow{S}_e(r) \quad (3)$$

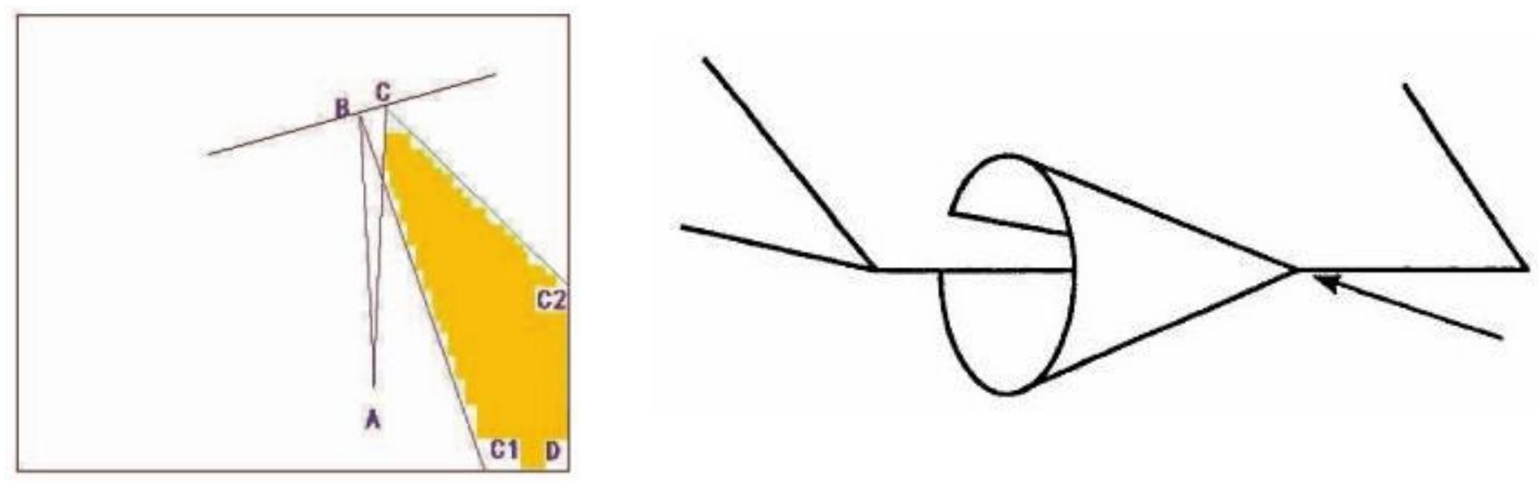
$$\overleftarrow{F_e} = \sum_{k=0}^{\infty} (\Sigma_e)^k \cdot \overleftarrow{S_e} = \overleftarrow{S_e} + \Sigma_e \cdot \overleftarrow{S_e} + (\Sigma_e)^2 \cdot \overleftarrow{S_e} + \cdots \quad (4)$$

$$\Psi(r,v_0) = \frac{(1+k_r)}{n_r^2} \cdot [\overleftarrow{f_E}(r) + \overleftarrow{f_W}(r) + \overleftarrow{f_S}(r) + \overleftarrow{f_N}(r)] \quad (5)$$



Intelligent Ray Launching Algorithm (IRLA)

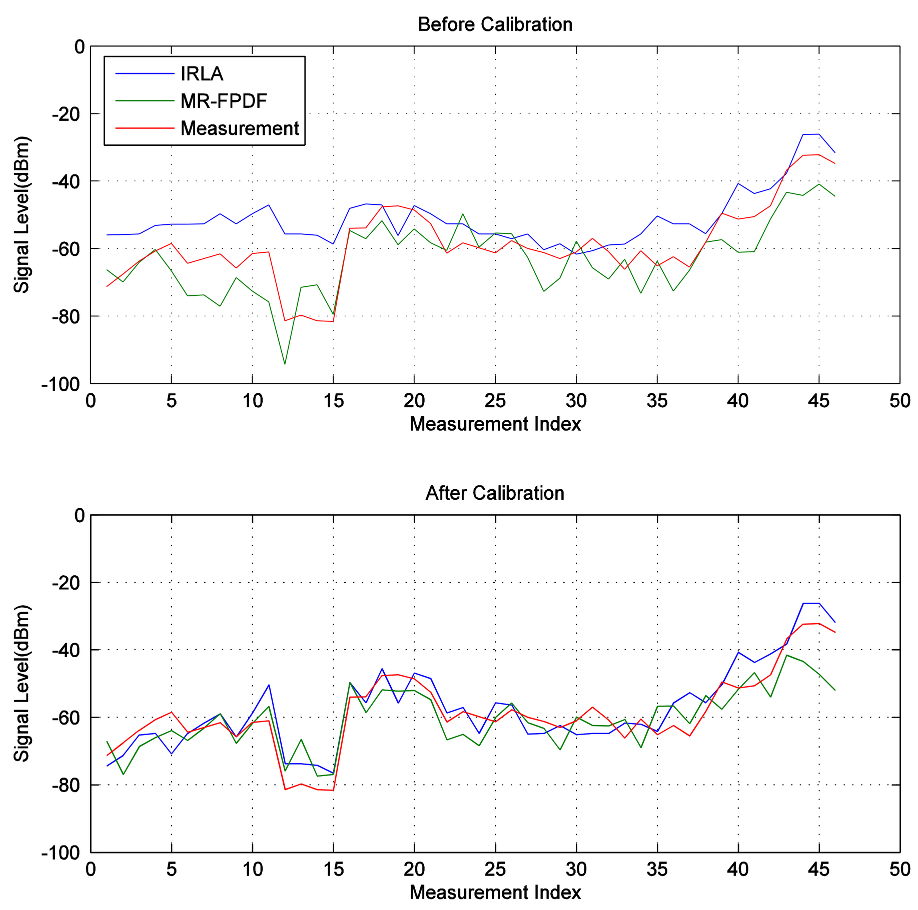
The IRLA model is extended from the Geometry Optics (GO) theory. Rays are launched from the emitter and secondary rays that are caused by reflections or diffractions will be tracked when they hit the obstacles. Rays are sampled with a pre-defined angle aiming to cover the whole environment. The GO theory itself does not take into account the shadowing effect, which however has significant impact on the radio wave propagations. Thus, the Geometrical Theory of Diffraction (GTD) is introduced to model the shadowing effect.

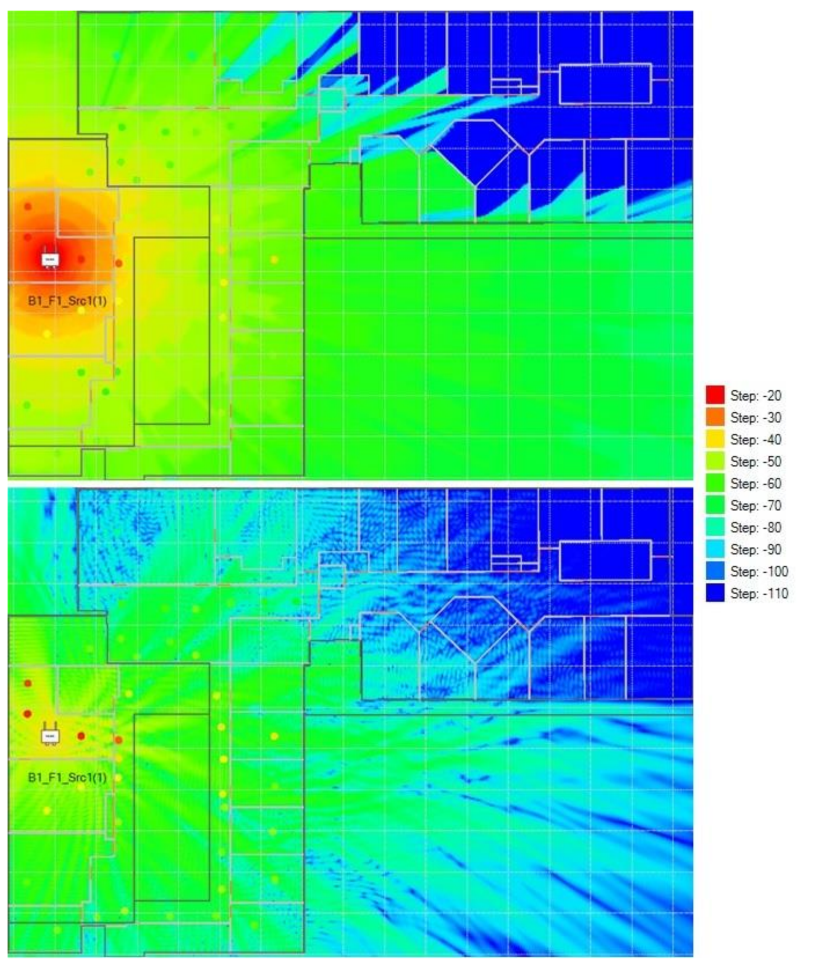


Comparison Result

The MR-FDPF model and the IRLA model use the Genetic Algorithm (GA) and Simulate Annealing (SA) algorithm respectively to process the calibration. The fitness function is both defined as the root mean square errors between the prediction and measurement.

The figure on the right shows the calibration result for both models before and after the calibration. The RMSE is reduced from 10.46dB to 5.38dB for the MR-FDPF model, and from 7.83dB to 6.3dB for the IRLA model.



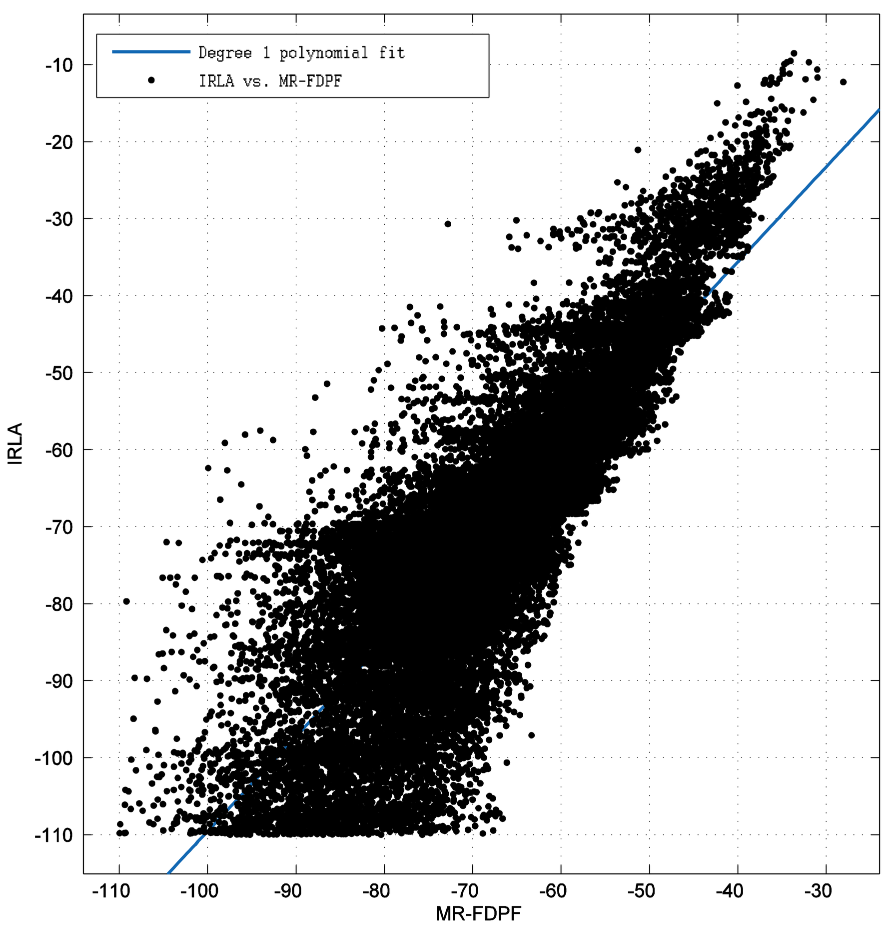


The best signal level prediction result with resolution set at 0.1m is shown on the left figure. The top plot is from the IRLA model and the bottom one is from the MR-FDPF model. The measurement points are also in this figure.

	0.1 m	0.2 m	0.3 m	0.5 m
Time (IRLA)	9m44s	43s	8s	3s
Time (MR-FDPF)	38s	8s	4s	2s
Memory (IRLA)	1.02 GB	205 MB	94 MB	42 MB
Memory (MR-FDPF)	1.9 GB	448 MB	201 MB	82 MB
RMSE (IRLA)	5.1 dB	5.4 dB	5.9 dB	6.9 dB
RMSE (MR-FDPF)	6.5 dB	6.8 dB	8.6 dB	11.5 dB

The above table lists the time and memory consumption of these two models at different resolutions. The simulation is performed on a laptop with Intel i7-3610QM CPU and 8GB RAM. In overall, the MR-FDPF model consumes less time but more memory than the IRLA model. The difference is significant especially when the resolution is set to 0.1m. It also should be noted that the IRLA performs 3D simulations but MR-FDPF only calculates in 2D.

The figure on the right shows the best linear fitting for these two sets of predictions. The X-axis represents the prediction from the MR-FDPF model and the Y axis represents the prediction from the IRLA model. The fitting polynomial with the least RMSE is given as $f(x) = 1.232x + 13.71$. The function indicates that the IRLA tends to give an more optimistic prediction than MR-FDPF when the signal level is above −59dBm while these values appear closer to the signal source.



Conclusion

These two models are accurate and similar to each other at small resolutions. However at big resolution e.g. 5cm, the IRLA model still maintains accurate results, which is not the case for the MR-FDPF model. While in terms of the resource consumption, the MR-FDPF model uses less time but more memory especially at small resolutions. Both models are suitable for coverage predictions in indoor environments. Based on the comparison, it is recommended to use the MR-FDPF model for small or complex scenarios while for large scenarios, e.g. outdoors or very large buildings, the IRLA model is more suitable.

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