Large-Scale Cellular Coverage Analyses for UAV Data Relay via Channel Modeling

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Motivation

- Rural areas are of a very low priority in terms of cellular broadband coverage, because of the low population density and the high cost of infrastructure construction.
- Digital agriculture has become a powerful motivator for improving rural wireless.
- UAVs could help extend coverage via data relay.

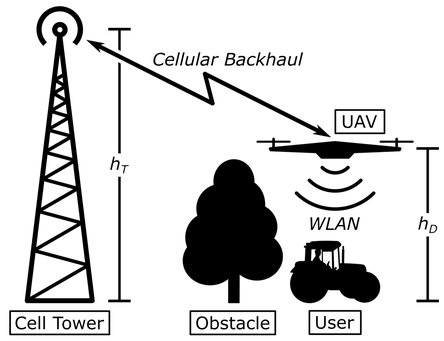
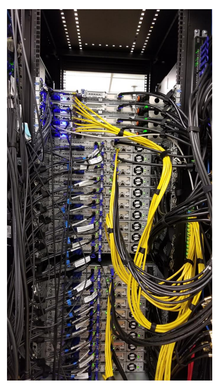


Figure 1. Illustration for a simple UAV data relay scenario.

Simulation

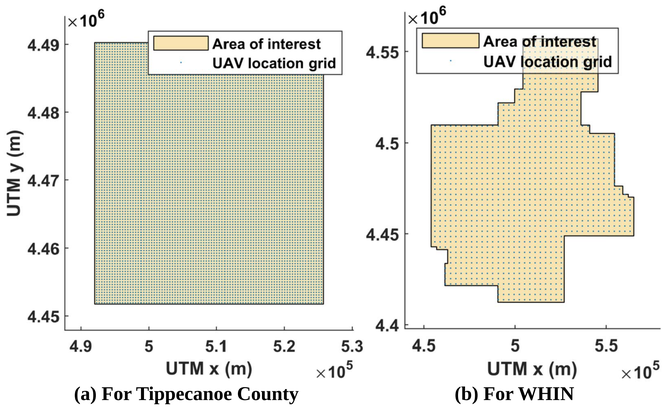
- Blockage maps to locate blocked areas
- Path loss maps to quantify channel condition

(a) Front view



(b) Back view

Figure 2. The Purdue cluster used for the simulation.



(a) For Tippecanoe County (b) For WHIN

Figure 3. UAV locations selected by the location sampler.

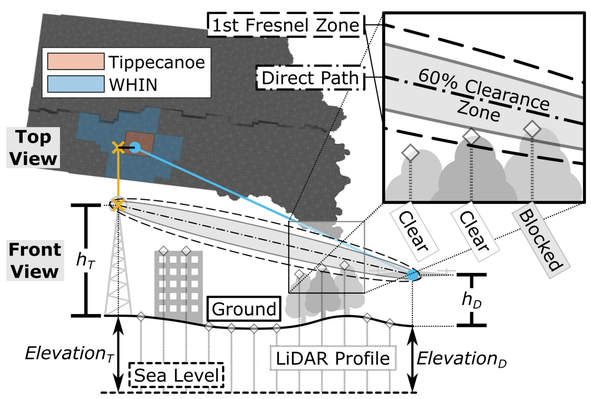


Figure 4. Determining blockage status.

A series of ***quantitative*** analyses for ***large geographic*** areas based on ***real-life*** data [a].

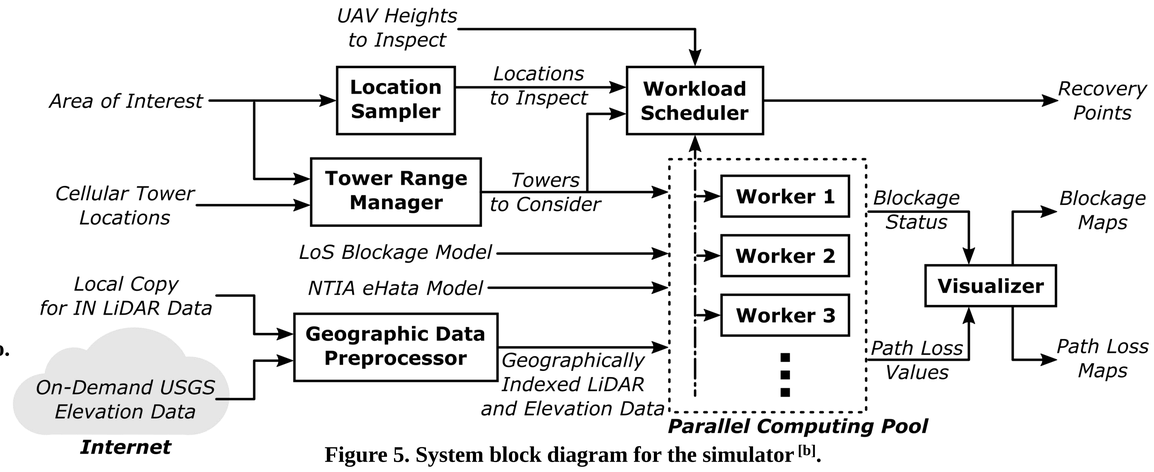
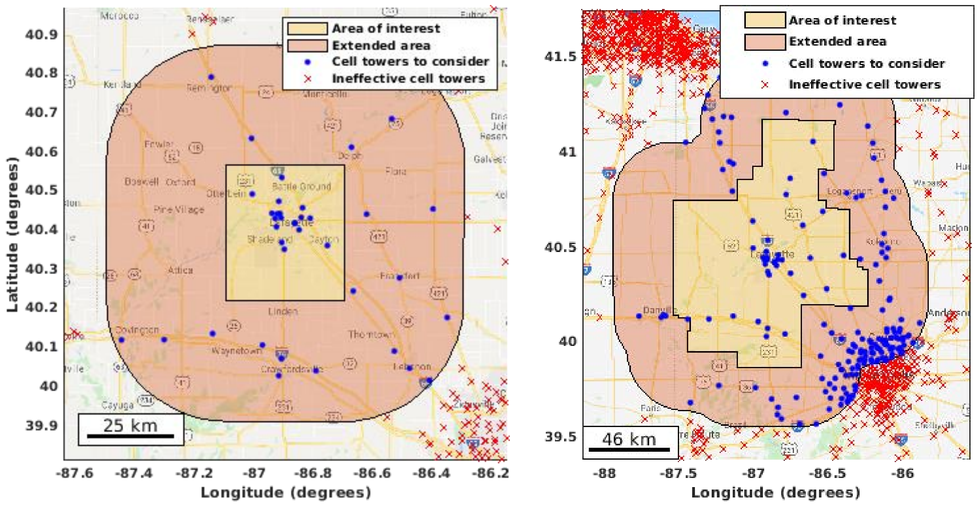


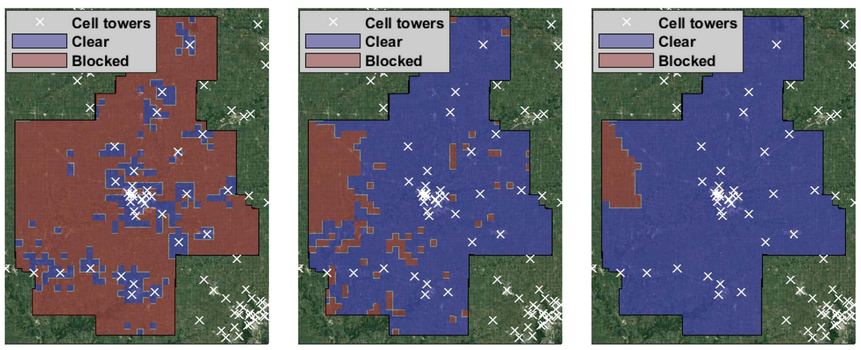
Figure 5. System block diagram for the simulator [b].



(a) For Tippecanoe County (b) For WHIN

Figure 6. Cellular towers chosen by the tower range manager.

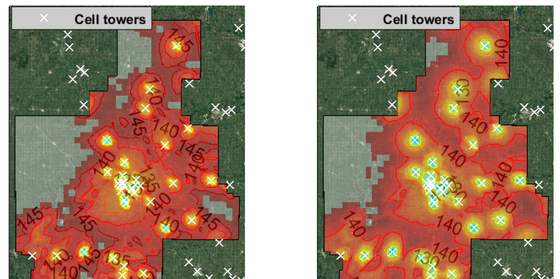
Figure 7. Blockage maps for WHIN.



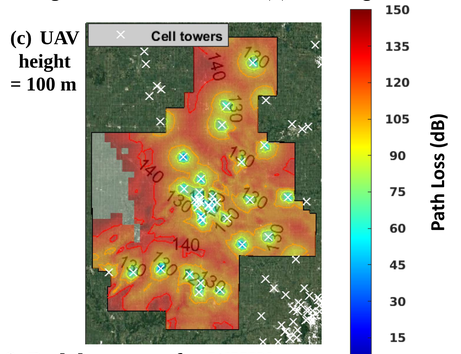
(a) UAV height = 1.5 m (b) UAV height = 10 m (c) UAV height = 100 m

Upper bounds on **system-level coverage gains**: around 45% cellular coverage ratio gain is expected for Indiana with UAVs@100 m (baseline: 1.5 m)

$$\text{Coverage Ratio Gain} = \frac{\text{Coverage Area}}{\text{Total Area}} - \frac{\text{Baseline Coverage Area}}{\text{Total Area}}$$



(a) UAV height = 1.5 m (b) UAV height = 10 m



(c) UAV height = 100 m

Figure 8. Path loss maps for WHIN.

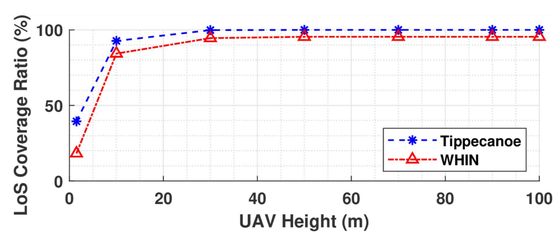


Figure 9. Clear LoS coverage ratio based on blockage maps.

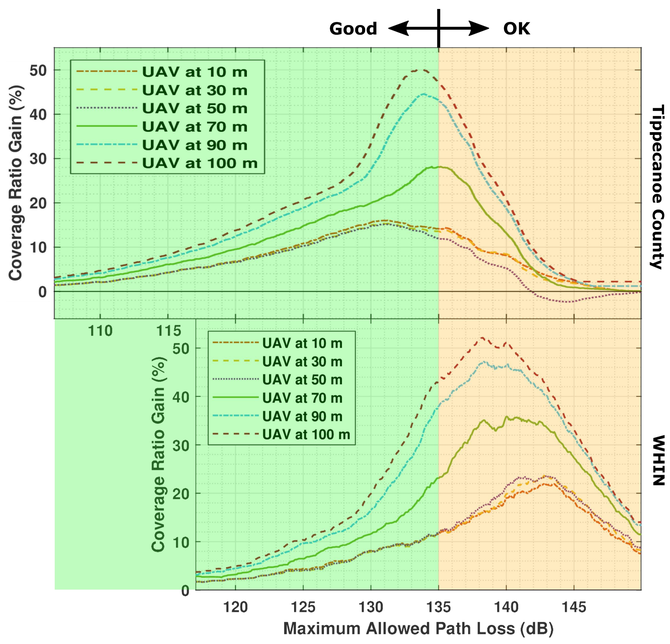


Figure 10. Coverage ratio gain relative to the h_D = 1.5 m case.

Discussion

- More improvement is expected for areas with larger elevation variation.
- Future work includes (1) simulation for larger geographic regions, e.g. the whole Indiana state; (2) higher-resolution simulations; (3) performance evaluation via measurements; (4) data relay UAV deployment and track planning.

Acknowledgements

Sponsorship for this work was provided by the Foundation for Food and Agriculture Research under award 534662 and the National Science Foundation under grant CNS-1642982.

[a] Zhang, T. Arakawa, J. V. Krogmeier, C. R. Anderson, D. J. Love and D. R. Buckmaster, "Large-Scale Cellular Coverage Analyses for UAV Data Relay via Channel Modeling," *ICC 2020 - 2020 IEEE International Conference on Communications (ICC)*, Dublin, Ireland, 2020, pp. 1-6, doi: 10.1109/ICC40277.2020.9149403.

[b] Implemented using Matlab. More about Matlab at: https://www.mathworks.com/products/matlab.html
Matlab code available at: https://github.com/YaguangZhang/CellCoverageMapperForDronesMatlabWorkspace.git