Poster: Cell Tower Extension through Drones

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ABSTRACT

Internet connectivity on mobile devices is an essential commodity in today's world. While outdoors, most people connect through cellphone towers on 3G or 4G. However, cellphone tower coverage is not uniform and is affected by electromagnetic shadows cast by large structures, multipath, and absorption by various surfaces. Users with high data needs suffer in such locations due to insufficient network bandwidth. A similar insufficiency can also be felt by flash crowds in locations with otherwise moderate signal strength due to division of the available bandwidth.

We explore the possibility of using drones as a solution to this problem. The drones can hover with direct line of sight with a cellphone tower and extend cellular coverage into the weaker regions. Our idea is to use the knowledge of large structures in the area to compute the expected SNR space around the client's current location. We use ray-tracing techniques to compute the expected SNR in an area. We then verify its similarity with ground truth by measuring, at several locations on the ground, the received signal strength from a Wifi router on a drone.

CCS Concepts

•Networks → Wireless access points, base stations and infrastructure;

Keywords

Cellular Range Extension; Mobile Base Station; Drone; Robotic Networks; Infrastructure

1. INTRODUCTION

Increasingly more people are using 3G or 4G data on their mobile phones while outdoors [1]. However, mobile signal strength varies significantly between different locations causing variations in available data bandwidth. These regions of low data bandwidth are mostly caused by radio frequency shadows cast by impermeable buildings or other large objects [2]. To a smaller extent, they could also be caused by multipath or high absorption due to weather conditions.

Though cell tower density can be increased, practically, their placement is dictated by physical feasibility, followed by antenna gain and directionality adjustments to provide acceptable coverage. Within a reasonable budget, it might never be possible to avoid shadow regions. To test that cellular shadow regions do exist, we measured the cellular SNR around the UIUC campus. Figure 1 shows SNR variations in excess of 20dB for most areas.

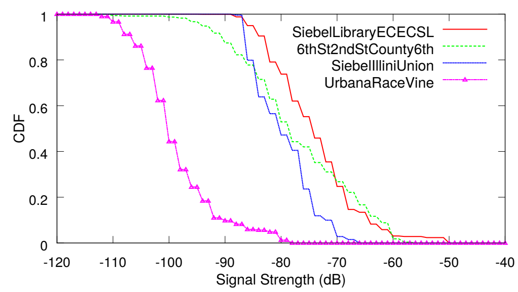


Figure 1: Cellphone RSSI variations during short walks

These weak spots can be covered by cell-on-wheels solutions [3], but it is not economical for sporadic demand patterns. We envision the use of drones to fill this gap. A small-scale cellphone tower extension, or an Wifi hotspot, can be mounted on drones to serve areas with bandwidth shortfall. The drone's height will enable it to hover outside the shadow region, obtain a strong LTE connection and serve the clients in the shadow region. As shown in Figure 2a, it might be also possible to serve multiple clients at the same time through strategic placement of the drone.

Positioning the drone to maximize utility is a challenge since getting too close to the ground aggravates multipath but reduces pathloss whereas going higher has the opposite effect. Additionally, going too high causes transmitted energy to dissipate away over the urban canopy. Our goal is to use models of the buildings in the neighborhood and perform ray-tracing to obtain hints about locations for the drone to hover improving data rates at the clients. We verify that this prediction is close to reality by measuring the actual SNR over the region and comparing it with the predictions.

2. SOLUTION SKETCH

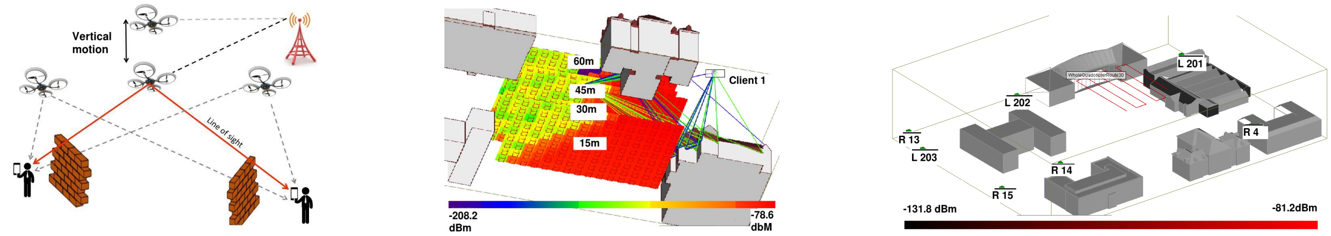
Approximate location of clients are known to cell towers and, on bandwidth shortfall, can send a drone to service that area. However, the best location for the drone to hover is not yet known. Multiple clients in the vicinity can be served if the drone is positioned strategically.

For this strategic placement, knowledge of SNR variations in the 3D space around the clients is required. Though a drone could scan the area obtaining current SNR and then position itself optimally, such an approach is expensive due to the drone's limited flight time and the client's dynamic

MobiCom'16 October 03-07, 2016, New York City, NY, USA

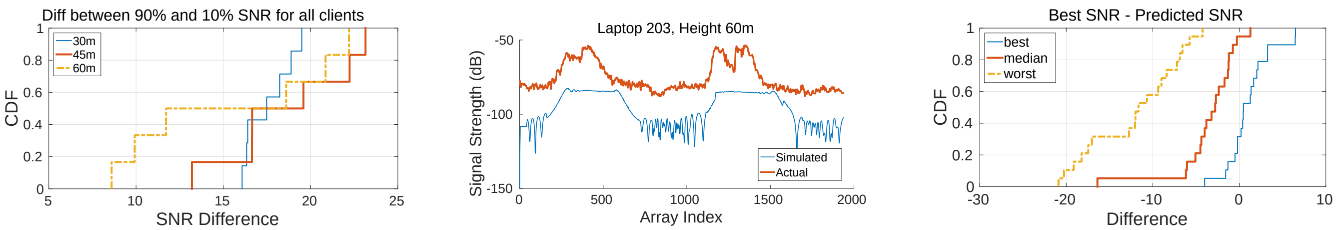
ACM ISBN 978-1-4503-4226-1/16/10.

DOI: http://dx.doi.org/10.1145/2973750.2985275



(a) (b) (c)

Figure 2: (a) Drones providing coverage for shadow regions (b) Ray-tracing Estimated SNR (color gradient) (c) Client locations



(a) (b) (c)

Figure 3: (a) CDF of SNR differences across all clients (b)Estimated SNR using ray-tracing follows the same trend as seen in practical tests (Corr. 0.73). (c) The real SNR at the predicted locations is within a few dB of the 90%tile of the real SNR

demands. Instead, if SNR could be computed beforehand, the drone can be placed at one of the predicted good locations without a full survey. It might still need to perform some local search, but now, in a reduced search space.

We perform this offline SNR estimation using 3D models of buildings in the neighborhood and ray-tracing signals from the client location to potential drone positions. For this analysis we have assumed discrete heights for the drone. An example is shown in Figure 2b where up to two levels of reflections from buildings are considered to produce the estimated SNR space.

3. EXPERIMENTAL SETUP

We flew a 3D Robotics X8 quadcopter drone with 10C 10000mAh battery over the Bardeen Quadrangle area in the UIUC campus. We placed 7 clients—3 laptops and 4 Raspberry Pis—on the ground as shown in Figure 2c. The payload composed of Securifi Almond Wifi router and a Samsung Galaxy S4 phone for collecting GPS and receiving the router's packets enabling us to synchronize the drone location with the packet ID. Clients recorded the SNR for each packet. The dorne's path is shown in Figure 2c.

We used Remcom's Wireless Insite [4] to predict the SNR at client locations from various positions of the drone.

4. RESULTS

We first explore the benefits obtained from carefully positioning the drone. Then we show that ray-tracing can provide realistic indications of good drone positions.

Drone Location Matters

Figure 3a shows that on an average, a client will notice 16-18dB of SNR variations over various drone locations. Such large variation in SNR will translate to a similar variation in the available data rate. Choosing the drone's hover position carefully is therefore crucial to improving the bandwidth.

Ray-tracing Shows Promise

Figure 3b shows good correlation between the measured SNR and results from ray-tracing. This correlation is encouraging since we have restricted our model to only large buildings. The accuracy of ray-tracing depends significantly on the details in the modeled environment and therefore we believe this correlation can be improved even further.

Ray-tracing Guides Drone Location

We intend to use the ray-tracing predictions as a guidance for fixing the drone's hover location. We select positions within the top 90%tile of the predicted SNR and check how good the corresponding positions are in the actual measurements. Figure 3c shows that, on an average, the positions predicted by ray-tracing are within 5dB of the top 90%tile measured SNR.

5. FUTURE WORK AND CONCLUSION

Changes in the channel caused by weather, foliage and people can affect the actual SNR. Formulating hovering strategies to maximize SNR is possible. Opportunistically surveying and updating of the ray-tracing model is also possible. We leave exploring these approaches to future work.

In this work, we explore if drones can be used to fill gaps in cellular coverage and bandwidth due to shadows and sudden shifts in demand. The location of the drone impacts both, the improvement in signal quality and the coverage. The problem of finding a good spot to hover reduces to a 3D search problem. We use ray tracing for reducing the search space. We see definite promise in this approach. Yet, a lot needs to be done to take this idea to completion.

6. REFERENCES

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