Visualizing Wireless Coverage Through Drone and Augmented Reality

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ABSTRACT

Imagine you enter a coffee shop to work and you are looking for the table with the best network coverage in space. How do you identify this table? We build a system that can visualize the invisible wireless coverage in outdoor and indoor settings. The system consists of three components: (1) an Android application that can scan the signal strength of all available wireless networks at any given location; (2) a real-time application that predicts nearby coverage based on information observed along visited routes; (3) an Android application that renders a visualization of wireless coverage based on the current camera view point, aka. augmented reality. Beyond visualizing coverage for end users, we believe our system can be utilized as a network diagnostic tool that can facilitate investigating on-site wireless coverage or planning deployments of wireless access points.

1. INTRODUCTION

Internet on-the-go is widely used everyday in both indoor and outdoor environments. Therefore, for a network system administrator to have a detailed knowledge of the wireless coverage of his community is a critical task. This information can be used to monitor the health status of deployed access points as well as to investigate the necessity of adding new access points to existing on-site network topology. However, monitoring wireless coverage can be challenging and requires non-negligible personnel effort. Recently, drones (quadcopters) are widely used as a economical and fast tool for spatial coverage[1][2]. In this paper, we explore using a drone with an Android device to collect wireless network information. The reason we choose utilizing Android rather than a plain RF radio based approach is to easily retrieve fine-grained wireless network information and location information as well as network connectivity support. To intuitively show the wireless coverage, we explore two approaches. One is through integrating a map, such that predicted signal strength coverage will be shown as gradient colors on the map. This is a good choice for an outdoor environment, such as a farm or a school campus. Another approach is through integrating *augmented reality* with a phone (or any device that has a camera and can interpret the location coordinates). Augmented reality proves to be an effective human-computer interaction method to present spatial data[3][4]. With its intuitive interface, we believe that it will allow for rapid, spatial-aware diagnostic of wireless networks. Furthermore, it will enable consumers, who want to make decisions informed by their surrounding networks' quality to do so.

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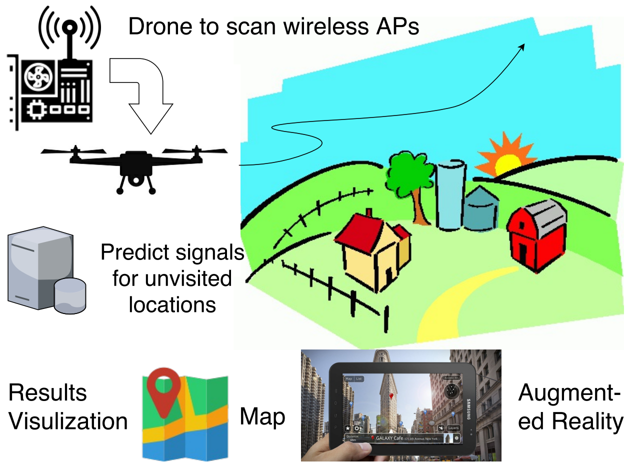

Figure 1: System architecture

2. IMPLEMENTATION

The architecture of our system is illustrated in Figure 1. It consists of three stages: **collecting**, **predicting** and **visualization**. Though they are designed as a pipeline procedure, they are not necessarily to be processed strictly consecutively. Specifically, the visualization can be accessed anytime as long as the results are in. However, we think the best practice is to utilize real-time visualization while collecting the signal strength, in order to help planning the collecting route.

In the **collecting stage**, we implement an Android application that can be run on a phone, a tablet or a cheaper device with Android system, such as Raspberry Pi. The application continuously scan visible wireless network signal strength via *android.net.wifi.ScanResult* API. Also it uses *android.location.LocationManager* to retrieve the location information based on either the GPS for outdoor or the network-based fussy location results for indoor. The application then uploads the snapshots to a machine. If Internet access is not available, it stores snapshots locally and waits for future upload attempts when an Internet connectivity is available, notified by *ConnectivityManager* API. We then attach the device to a drone which not only can minimize the human efforts to travel around but also can measure hard-to-access locations such as above gardens, above ponds, above stadium seats, above office cubicles, etc.

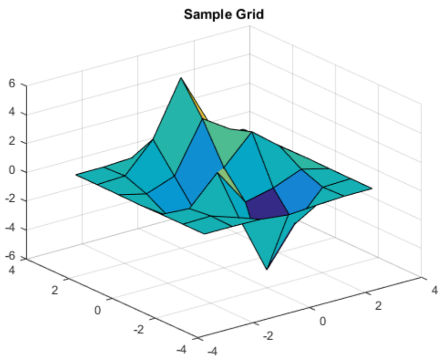

Figure 2: Spatial interpolation is used to estimate coverage in unvisited area.

In the **predicting stage**, we have results from previous stage which look like <*longitude, latitude, aggregated network id, signal strength*> for each collected location point. We then aggregate these points into grids over the longitude-latitude plane. The reason for that is to minimize the amount of the following predicting work. The size and shape of grid cells should be carefully chosen (e.g. triangle or rectangle), since these factors affect the performance and the accuracy. A careful investigations of this dependency is subject to our future work. We then take an average of all points values in each grid to represent each grid. To make it simple, we always take the latest signal strength in each visited grid, regardless any previous values in that grid. Though this can be extended later to consider time series forecasting. For grid cells where no input data is collected, we use spatial interpolation technique to estimate the signal strengths (Figure 2). We use *spline interpolation* to solve this natural neighbor interpolation problem. Previous studies show that spline interpolation is preferred over polynomial interpolation because the interpolation error can be made small even when using low degree polynomials for the spline.

In the **visualization stage**, we have the results obtained from previous stage which look like <*grid longitude, grid latitude, aggregated network id, signal strength*>. We provide two modes to present the results: map and augmented reality. The map mode is integrated with *Google Maps* API. In an outdoor environment, a user can easily realize his surrounding by referencing the information and texture on the map. The user's current location is indicated on the map and the signal strength is represented as gradient of colors overlayed on top of the map. The AR mode is implemented through *Vuforia Augmented Reality* SDK. The signal strength data used here are still based on user's current location grid and neighbors grids. The device orientation is used to determine which neighbors grids are rendered on top of the camera view (Figure 3). Due to the single camera and lack of distance reference, we estimate the approximate depth and vanishing line when rendering the neighbor values. The estimation is based on the device position and a preset baseline when device is horizontally placed. We note that this approach of visualization can be further improved in future work.

3. FUTURE WORK

Our current system design opens several avenues for future development. (1)The most important factor is the accuracy. We use spatial interpolation to estimate signal strengths.

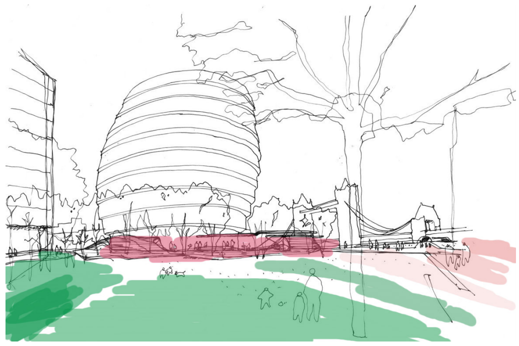

Figure 3: In AR mode, signal strength portrayed as colors overlays on top of camera view. Depth and vanishing line are estimated and do not indicate real distance. User can always switch to map view to see surrounding coverage in uniformly scaled distance.

However there are conditions when interpolation does not work well, for example with obstacles like a wall. In this case, extra measurement effort may be necessary. This requires an optimization of the pipeline processing such that a real-time feedback can be given to help determine collecting route. (2)We did not consider the altitude information though it can be a critical factor for either the signal strength variance on height levels or differentiating data from floors of buildings. (3)The data collection campaign can be crowd sourced from users who voluntarily run this application. As an exchange, they can benefit from finding a good spot to surf wireless Internet, when they go to places which have data collected. New factors may affect the uniformity of data such as the difference of users devices and the difference of device positions (in pocket or in hand). (4)While the current implementation focuses on a single-tier visualization of signal strength, we plan to extend our augmented reality view with capability for a deep-dive in wireless coverage. Specifically, beyond WiFi, we will add all other available technologies in the measured area. While signal strength will continue being our default view, users will be able to tap and get more detailed information about measured interference, number of access points, channel width, contention, and results of active performance measurements.

4. REFERENCES

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