

# **RF Coverage Validation and Prediction with GPS Technology**

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It has taken many years for wireless engineers to “tame” wireless communications and there are still many complexities in planning wireless networks due to the unpredictable and varying RF environment. There are mainly two techniques to plan and deploy wireless networks. One uses theoretical electromagnetic models to predict RF coverage. The theoretical model requires information for the survey area, such as the presence of trees, the location of buildings, the materials that comprise the buildings, and so on. Inputting the information into the prediction software and computing the coverage takes a lot of time. In addition, the varying environment increases the difficulty to accurately predict and maintain the coverage with the theoretical model. For example, tree foliage changes from winter to summer. The real signal in the environment is also unknown with prediction software.

Another technology is to plan and deploy wireless networks based on real measurement data. A dedicated site survey is required to build stable wireless networks in a varying RF environment. Berkeley Varitronics Systems (BVS) has developed Hive software with YellowJacket hardware for in-building site surveys. It asks the user to tap the recording locations on the iPAQ during the measurement. When an outdoor network with a large area is considered, using Global Positioning System (GPS) technology to locate the measurement point makes a quick automatic measurement possible and gets site surveys done easier. The software we will use for reference is Berkeley Varitronics Systems new product – Drone Site Survey system. Since time is money, Drone software combined with YellowJacket hardware can save labor cost in deploying a wireless network and later in maintaining that network.

Currently GPS location accuracy can be controlled within several meters and the GPS information can be updated every second. The good accuracy and high update rate make it possible to use GPS to record measurement locations in collecting measurement data. The Drone Site Survey system is composed of three parts, Drone Projector, Drone Collector, and Drone Analyzer. Drone Projector and Collector are used with the BVS YellowJacket Plus (which has a GPS module) and HP iPAQ; Drone Analyzer is PC-based software. YellowJacket measures all 14 OFDM/DSSS network channels, which operate on the IEEE 802.11b/g standard. This allows the user to determine the AP's MAC address, SSID, and RSSI signal levels for all access points on or off any 802.11b/g WISP or Hotspot. A YellowJacket with GPS module is shown in Fig.1. Based on the real measurement data collected by Drone Collector, Drone Analyzer can perform a quick analysis to estimate access point's (AP) locations, validate RF coverage, and predict coverage reliability.

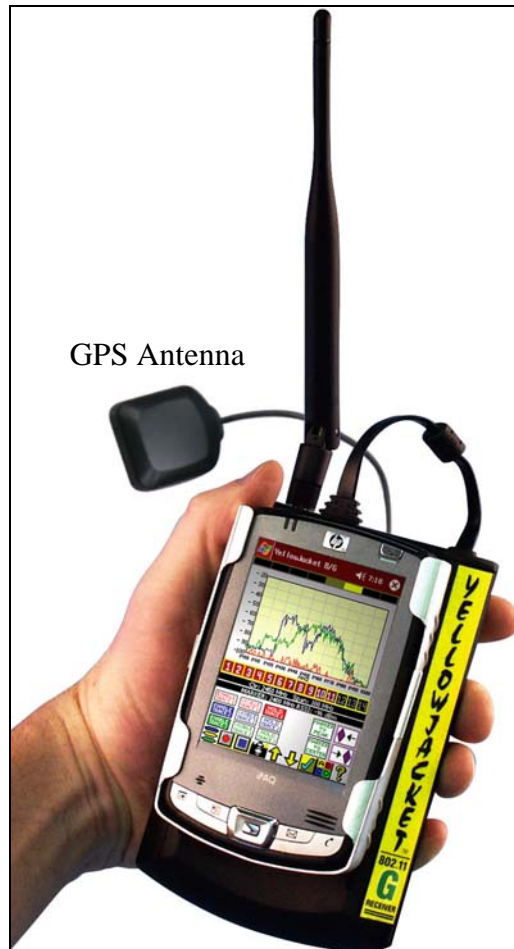


Fig. 1. BVS YellowJacket® with GPS.

### ***Drone Projector***

BVS Drone Projector is used to geo-code the user's map and projects the geographical information (latitude and longitude) into real distance information (meter/feet). The first step is to load the map (Bitmap) into an iPAQ; the second step is to take it outside and tap on the screen where the user is. After having enough points, the user's map can be projected into a geo-coded map. If the tapped points do not meet the requirements to do the projection, Drone Projector will ask the user to record more points. The customer can use any image onhand or get the image from Google, Mapquest, or other map websites. Drone Projector is shown in Fig. 2, where the black dots represent the tapped points.



Fig. 2 BVS Drone Projector for 802.11b/g.

### ***Drone Collector***

Drone Collector collects and stores geographical information and wireless network information during a walk or drive study. The measurement points will be shown on the map as the user moves. Therefore, Drone Collector can also be used to navigate the user's drive. This stored information will be used in Drone Analyzer to do coverage reliability analysis, AP's location estimation, power or signal-to-noise ratio contour analysis, and AP's overlap analysis. Drone Collector is shown in Fig. 3, where the yellow and red dots represent the measurement points.

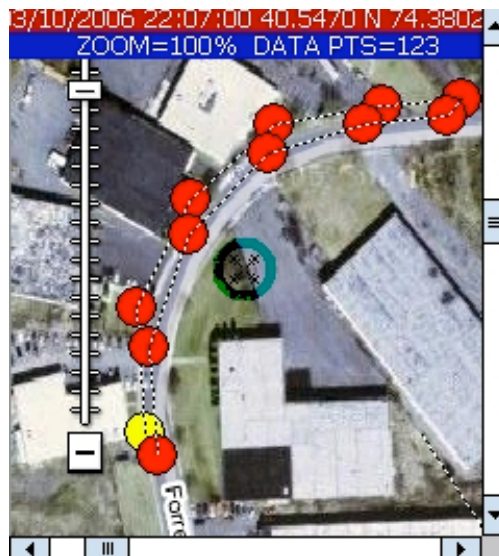


Fig. 3 BVS Drone Collector for 802.11b/g.

### ***Drone Analyzer***

The first step to use Drone Analyzer is to import the projection file. However, a map is not necessary in Drone Analyzer. If there is no projection file, Drone Analyzer can also process the measurement data based on the stored latitude and longitude information. There are two options for the user to associate a post-processing plot to a map:

1. The user can save the plot and then put it on top of the map from GoogleEarth or other maps, which must have latitude and longitude information.
2. Drone Analyzer can automatically generate a KML file, which can accurately overlap the RF coverage on top of the map of GoogleEarth.

The second step is to import the data collection file. Drone Analyzer provides the options to select multiple files and to process those files jointly or separately. After files are selected, the software begins to sort the access points and estimate their locations. Cell coverage reliability can be analyzed and predicted based on the estimated APs' locations. Drone Analyzer graphically indicates RF coverage with multicolor representation, showing,

- Location of APs
- Power, Signal-to-Noise Ratio, Number of APs in the survey area
- Reliability of an AP or a group of AP with a certain radius and power threshold

Coverage holes would show up in the resulting reports as colorless (white areas). The network administrator can also use the YellowJacket to find the reason for the network hole. Through the plot of the number of APs, the network administrator will know exactly how many APs are in a location, the MAC addresses, and the SSID of these APs. Therefore, the administrator will know which AP is an interferer and which AP belongs to his network. The administrator can take away some APs to reduce the overlap of the current network. Drone can also automatically provide a network and coverage report in HTML format. With the help of GPS technology, Drone's capability, to quickly collect the measurement data and efficiently analyze the data, will greatly help the network service provider to build stable Wi-Fi networks in the cities, outdoor areas, and university campuses and later maintain them. An example of RF coverage with contours is shown in Fig. 4. In the following section, we will present the technologies used in Drone.

### ***Coverage reliability analysis with GPS technology***

#### **1. GPS Module**

GPS is a navigational system that calculates position from 24 satellites orbiting the earth. BVS YellowJacket plus can have a Motorola 12-channel differential GPS receiver (M12). This allows YellowJacket users to geo-time stamp every measurement taken for post processing. The 12-channel platform was designed for a wide range of GPS positioning and tracking applications and superior performance: split-second reacquisition, maximum embedding flexibility, low power consumption and enhanced urban canyon and foliage performance. Some parameters of M12 performance are [1]:

**Accuracy:**

- Position 25 m SEP without Selective Availability (SA)
- 100 m 2DRMS (95%) with SA
- 1 to 5 m typical in differential mode
- Altitude 156 m RMS (95%)
- Velocity 0.02 m/s without SA
- Time pulse UTC  $\pm$  500 ns with SA on

**Dynamic limits:**

- Velocity 515 m/s maximum at altitudes  $>$  18000 m
- Altitude -1000 m minimum
- 18000 m maximum at velocities  $>$  515 m/s
- Acceleration 4G maximum
- Jerk 5m/s<sup>3</sup> maximum

## 2. Propagation Model

Based on the measured signal strength and locations, the cell radius with a certain outage probability or the cell reliability with a certain radius can be estimated through a robust method [2], [3]. The verification method is particularly useful in planning a wireless network since it effectively determines the geographic extent of reliable RF coverage. Outage probability means the possibility that signal strength is below a threshold. Reliability represents the probability that signal strength at a location or in an area is higher than a threshold. The Hata model is used here to predict the radius and the cell reliability. The received signal strength (in dBm) is modeled as a function of distance, antenna height, path loss exponent, and a normally distributed random variable due to large-scale fading [4]. Based on the measurement data, we are able to use a linear regression algorithm to estimate the parameters, such as the path loss exponent, the standard variation of the random variable, and so on. Since the signal strength is a random variable, an outage probability for any location in the survey area can be estimated with a predetermined power threshold. At the same time, a radius can also be estimated based on a given outage probability. Since outage probability for any location in the survey area can be estimated, the cell or area reliability can be estimated by averaging the reliability (1-OutageProbability) over the area. An example of RF coverage reliability analysis is shown in Fig. 5. The power threshold is set to be  $-75$  dBm and the radius is 80 feet. The reliability at the boundary is calculated as 0.9413 and the cell reliability is obtained as 0.9753.

## 3. AP Location Estimation

The distance from a location to an AP is necessary in coverage validation and reliability analysis. Thus, the location of the access point is essential to the analysis. However, in most cases, APs' locations are unknown, which indicates that the distance cannot be obtained. Based on a derived minimum mean square error (MMSE) algorithm, the AP's location can be estimated. Usually there are hundreds of measurement points for one access point during a survey study, which provides enough points to estimate AP's

location accurately. The security of the network can be improved by locating unknown APs. An example is shown in Fig. 5 to illustrate the accuracy of AP estimations.

#### 4. Spatial Interpolation Technology

When the AP location is known, we can predict the power from Hata channel model. With the measurement results, the signal strength can also be estimated by using spatial interpolation algorithms, such as inverse distance weighting (IDW) algorithm, Shepard weighting algorithm, IDW with anisotropy correction, IDW with gradient correction, and so on [5]. In the Drone Site Survey system, a combination of the spatial interpolation and RF power prediction (from Hata model) is used to show the RF coverage.

#### Conclusions

Drone software along with YellowJacket Plus hardware, provides a network administrator with an efficient tool to quickly survey an outdoor network with a large area and constantly monitor the rapidly changing RF environment. The use of GPS technology helps reduce the amount of labor cost involved with network setup and maintenance. The Drone's capability, to quickly collect the measurement data and efficiently analyze the data, will greatly help the network service provider to build stable Wi-Fi networks in the cities, outdoor areas, and university campuses.

#### References:

- [1] *M12 oncore – User Guider Supplement*, Motorola, Inc.
- [2] P. Bernardin and K. Manoj, "The postprocessing resolution required for accurate RF coverage validation and prediction," *IEEE Transactions on Vehicular Technology*, vol. 49, no. 5, Sep. 2000, pp. 1516 – 1521.
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- [5] P. Revesz and L. Li, "Constraint-based visualization of spatial interpolation data," *Sixth International Conference on Information Visualization*, 2002, pp. 563-569.

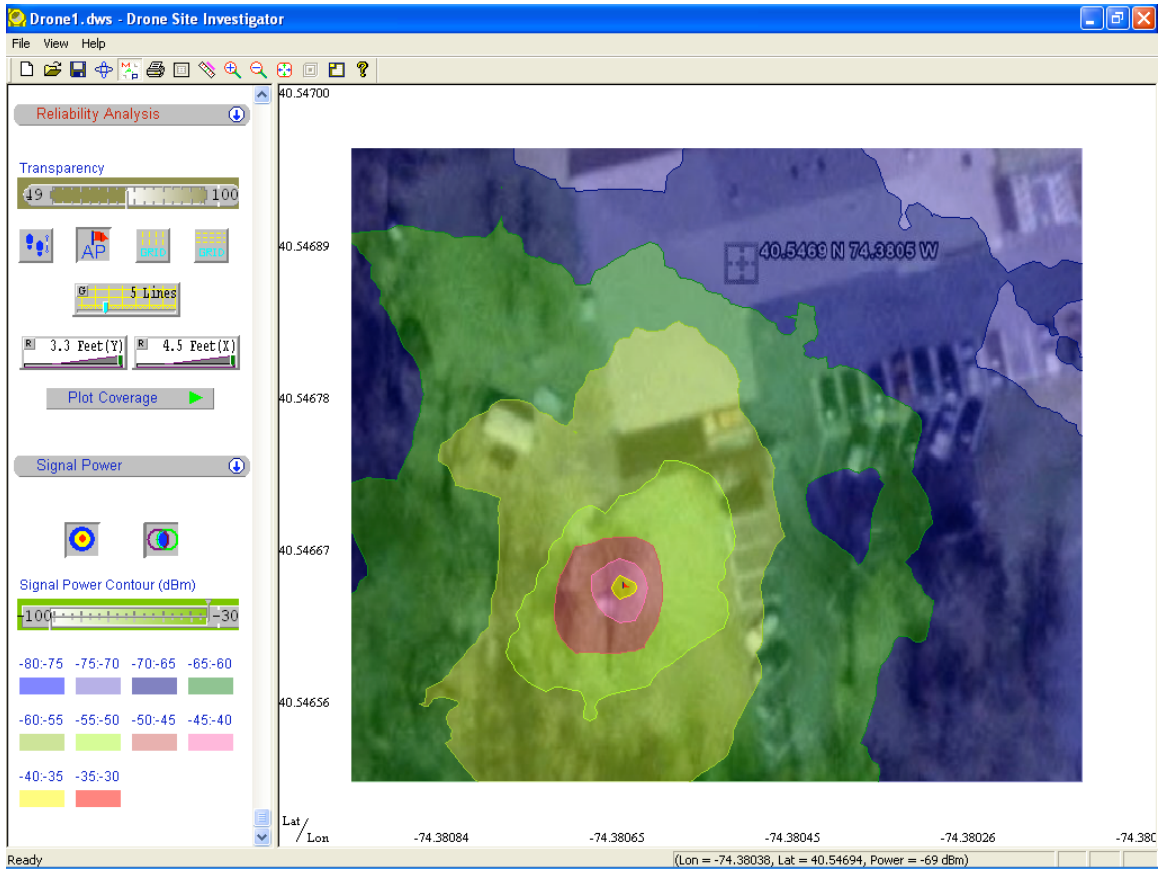


Fig. 4 BVS Drone RF coverage validation with GPS technology.

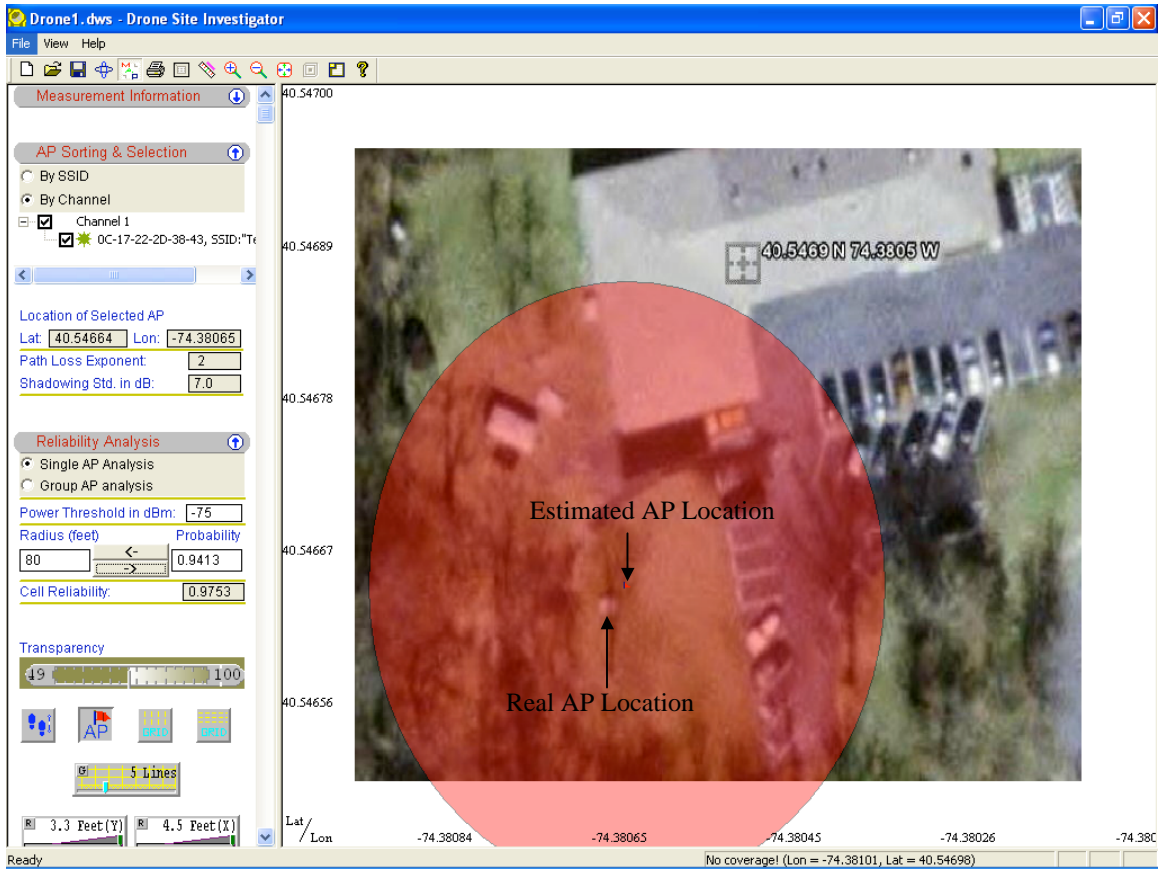


Fig. 5 BVS Drone RF coverage reliability analysis with GPS technology.