Antenna selection and optimization for small cell networks

Using a radio's integrated antenna is convenient, but it will require a larger site count, and will only offer mediocre network performance.

Abstract

The careful choice of antennas improves network performance while decreasing overall capital investment. Using a radio's built-in antenna is an easy option, but more careful network planning shows an external antenna can reduce overall site count and significantly improve the experience of mobile network users. In this paper, the InfoVista networking planning tool is used to build two small cell networks in an identical downtown area, one using the radio's integrated antenna, and the other using a carefully chosen high performance external antenna. A site count reduction of 20%+ is gained using the external antenna, and data rate improvements of up to 20% across the network are achieved even when using the lower site count.

Small cell sites typically utilise a radio which can be mounted on existing street furniture. This reduces the need for complex site acquisition and planning permissions, and capacity can be located where it is most needed.

Small cell radios typically come supplied with an integrated antenna, with the option to add an external antenna if required. The integrated antenna is low gain and fixed tilt, but it can simplify mounting and planning issues. However, adding an external antenna of choice can significantly improve performance, and it will reduce the overall network site count.

Furthermore, choosing an external antenna with variable tilt allows the extent of an antenna signal within a cell to be controlled, and this will limit interference into adjacent cells. This is difficult using fixed tilt antennas, as there is no easy means to adjust the antenna beam area, and different locations will ideally need different tilt settings. For example, in dense areas you need more down tilt to make the cell smaller and to get optimal data throughput. Variable tilt antennas are a solution to this problem, and therefore they improve the overall customer experience and put control back into the hands of network operators.

The purpose of this white paper is to illustrate the improvements in both site count and network performance that can be achieved by using external antennas rather than the integrated ones supplied with the radio.

Methodology

A small cell network is built using InfoVista simulation tools. A downtown area of Atlanta, USA, is selected. Atlanta is chosen as being representative of a typical downtown area.

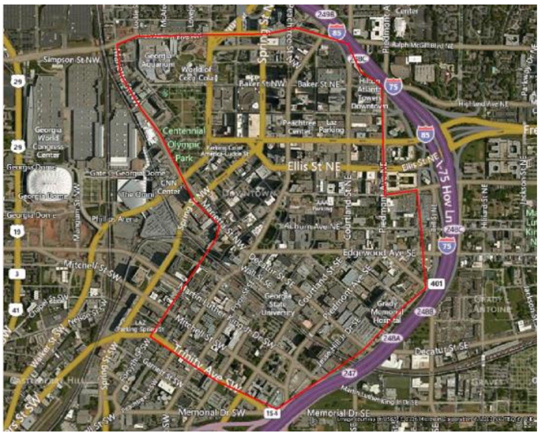
Firstly, the network area is populated with small cell radios using their integrated antennas, and an appropriate site count is calculated by the tool using a list of candidate sites. Automatic site selection removes any bias from the study. Network coverage is calculated, and this figure is used as the base line coverage figure for the remainder of the analysis. Both SINR and data rate are assessed and measured. We call this the 'Integrated Antenna Scenario.'

Secondly, the network is populated using radios and high performance external antennas with Variable Tilt (VT), and an appropriate site count is calculated by the tool to give the same coverage as the 'Integrated Antenna Scenario.' Overall network performance is again assessed – SINR and data rate. We will call this the 'VT External Antenna Scenario.'

Finally, a comparison is made between the two scenarios, any differences are highlighted and analysed, and the reasons for these differences are discussed in detail.

Downtown Atlanta Small Cell Polygon

An area of downtown Atlanta is used to build the small cell network. It is selected as it is deemed to be typical of a busy downtown area.



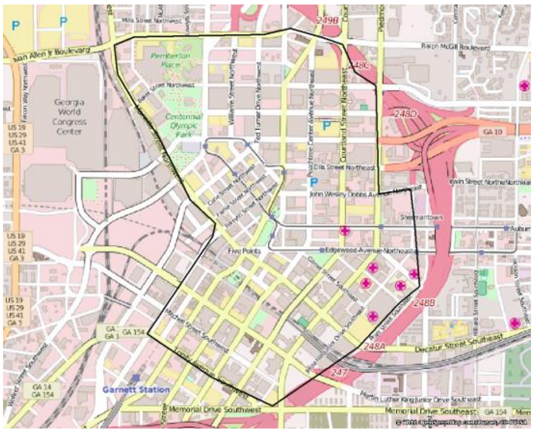


Fig. 1 – Polygon Outline

The following design assumptions are made and input to the InfoVista network simulation tool.

- Single Band MIMO system at 2600MHz.
- Small Cell Antenna Height – 7m.
- Small Cell PA Power – 5W (37dBm).
- RSRP Design Threshold – -85dBm.
- Network Analysis Loading – 50%.
- All path loss calculations use a Universal Model calibrated for a similar area in the US.
- 5m clutter, heights, clutter heights, and building polygons were used for propagation modeling.
- In order to remove any bias from the study, the simulation tool was used for site selection and to determine the number of sites required to cover the polygon.
- Site selection was based on down link coverage.
- The site count was based on a “cost vs benefit” analysis completed for the integrated antenna scenario.

A 212 site candidates list is created with a site at each intersection and midpoint between intersections. The candidates list is similar to a utility pole database that is often used for small cell planning.

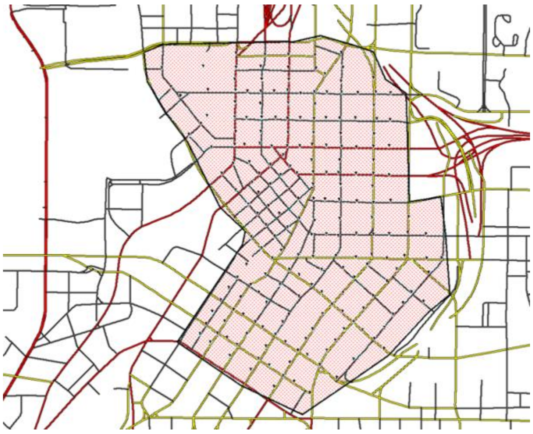


Fig. 2 – 212 Candidate Sites

Integrated Antenna Scenario

A typical radio's integrated antenna has a 2dBi gain and 0° downtilt. For the purpose of a base line analysis for the remainder of this study, 200 sites are chosen by the simulation tool. This gives 90.16% coverage.

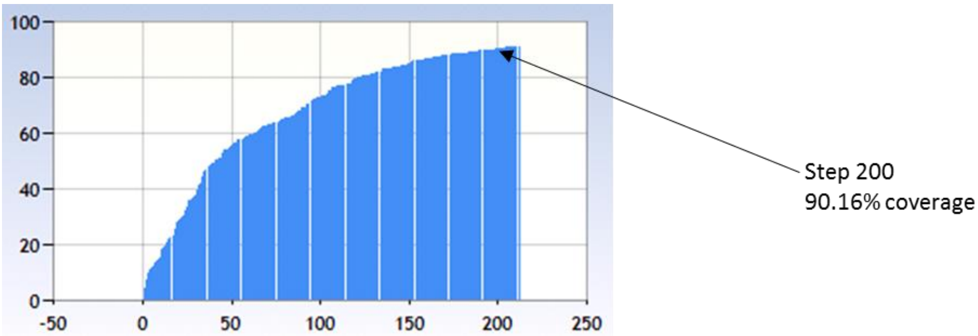


Fig. 3 – Integrated Antenna Site Count

The simulation is then used to create plots and metrics for this 200 site network, and these are displayed in the following figures.

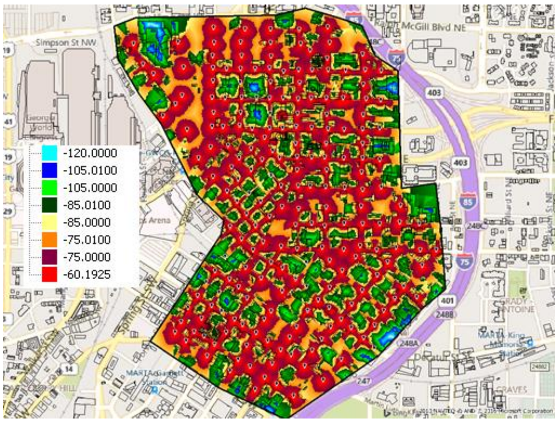


Fig 4 – Internal Antenna Coverage (dBm)

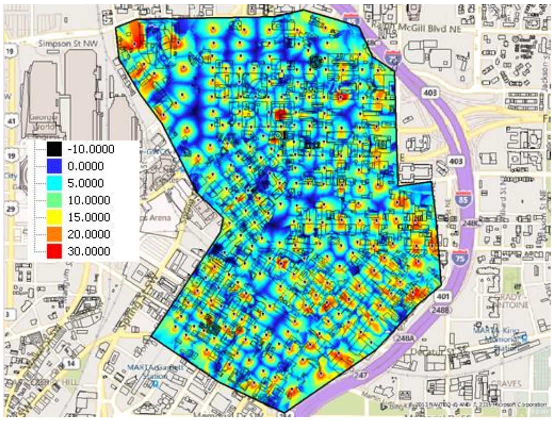


Fig. 5 – Internal Antenna SINR (dB)

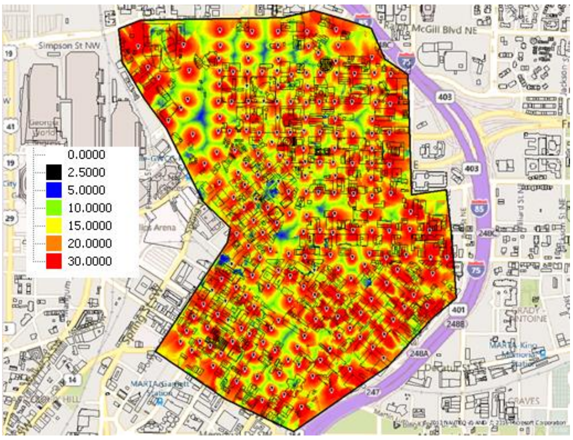


Fig 6 – Internal Antenna Data Rate (Mbps)

Ranges	Area (km²)	Percentage Sub Area
-200 ~ -100	0.00569999963	0.437351316
-100 ~ -85	0.122399993	9.391544
-85 ~ -50	1.174875	90.1461639
-50 ~ 0	0.000325	0.0249366984

Coverage – RSRP (dBm)

Ranges	Area (km²)	Percentage Sub Area
-10 ~ 0	0.077525	5.9483614
0 ~ 5	0.41775	32.05325
5 ~ 10	0.386199981	29.63247
10 ~ 20	0.377549976	28.96877
20 ~ 100	0.044275	3.39714575

SINR (dB)

Ranges	Area (km²)	Percentage Sub Area
0 ~ 10	0.077675	5.959871
10 ~ 20	0.6177	47.3950729
20 ~ 30	0.480499983	36.86795
30 ~ 65	0.127425	9.777104

Data Rate (Mbps)

Fig. 7 – Integrated Antenna Statistics

Variable Tilt (VT) External Antenna Scenario

An Alpha Wireless AW3477S is used as the external antenna. The AW3477S has a gain of 8.5dBi and has variable tilt settings from 4-18°. Due to the higher gain, less antennas are needed to build the network giving a significant capex saving. The simulation tool recommends 153 antennas to build a network with a similar coverage to the integrated antenna scenario. The tool then automatically selects the optimum tilt settings for all antennas.

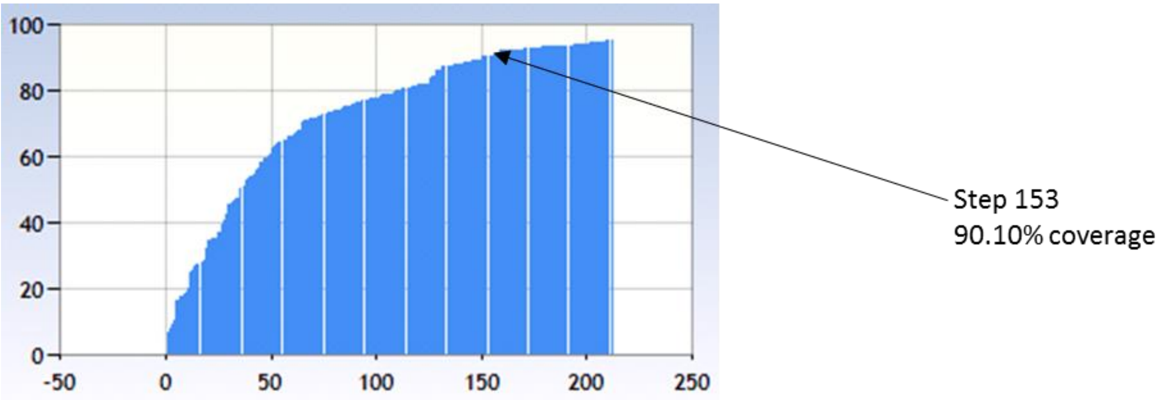


Fig. 8 – VT External Antenna Site Count

The InfoVista tool is used to measure the performance of this network, and the results are presented in the following figures 9-12.

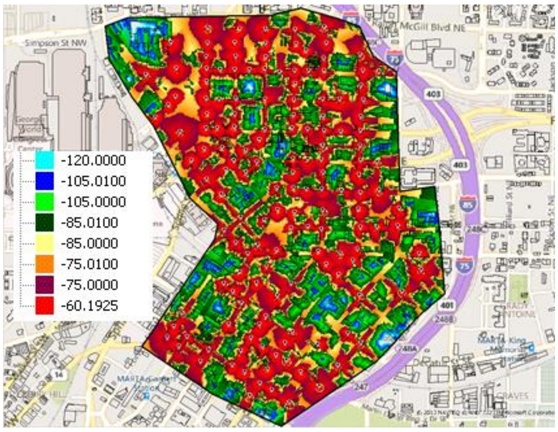


Fig 9 – VT External Antenna Coverage (dBm)

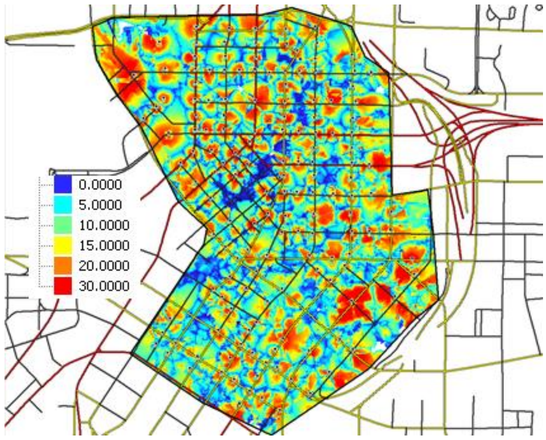


Fig. 10 – VT External Antenna SINR (dB)

Fig 11 – VT External Antenna Data Rate (Mbps)

Ranges	Area (km²)	Percentage Sub Area
-200 ~ -100	0.036475	2.798826
-100 ~ -85	0.178899989	13.7274828
-85 ~ -50	1.0877	83.46218
-50 ~ 0	0.000149999993	0.0115099084

Coverage – RSRP (dBm)

Ranges	Area (km²)	Percentage Sub Area
-10 ~ 0	0.034125	2.61850429
0 ~ 5	0.232324988	17.82693
5 ~ 10	0.290849984	22.3177128
10 ~ 20	0.520925	39.9719925
20 ~ 100	0.225	17.2648621

SINR (dB)

Ranges	Area (km²)	Percentage Sub Area
0 ~ 10	0.034125	2.61850429
10 ~ 20	0.374549985	28.740242
20 ~ 30	0.500375	38.3951378
30 ~ 65	0.394175	30.24612

Data Rate (Mbps)

Fig. 12 – VT External Antenna Statistics

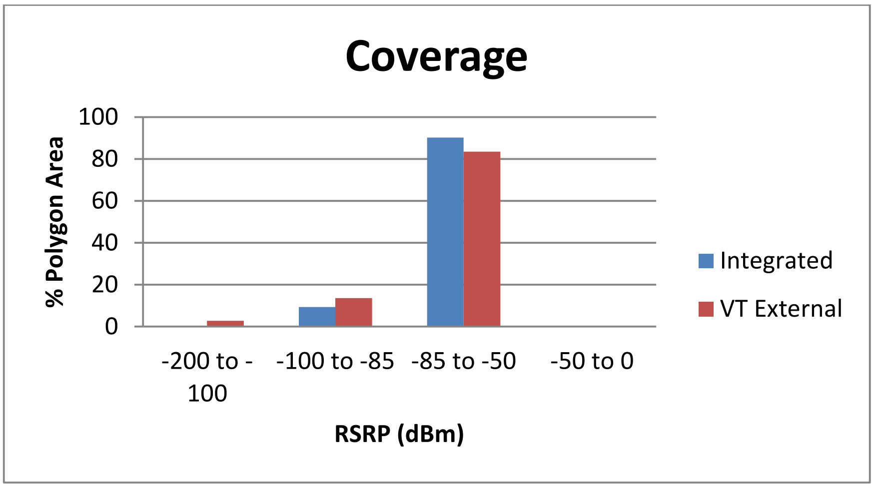
Analysis

The study is constructed so that each scenario gives a similar coverage (~90%). Graph 1 provides a coverage comparison by antenna type. However, the number of sites needed to provide this coverage varies by antenna type as outlined in table 1 below.

Antenna Types	Number of Antennas Needed	Coverage
Integrated	200	90.16%
Variable Tilt External	153	90.10%

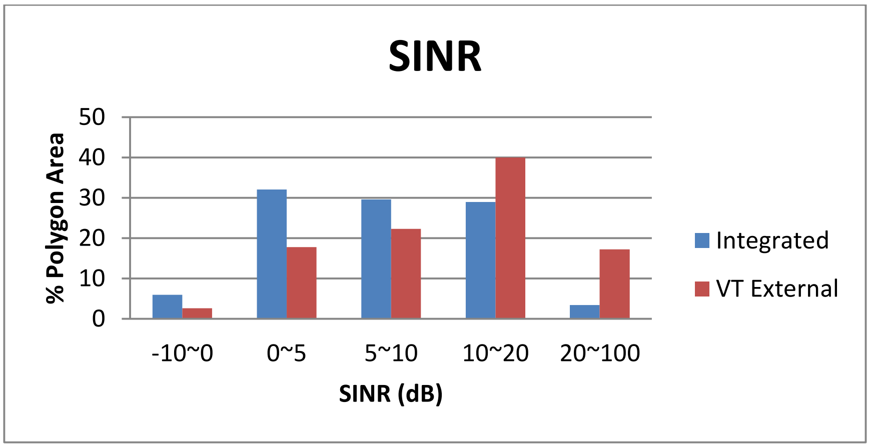
Table 1 - # Antennas Required

The use of external antennas reduces site count in this example by between ~25%, which provides a significant reduction in capital expenditure and in on-going rental and maintenance costs.



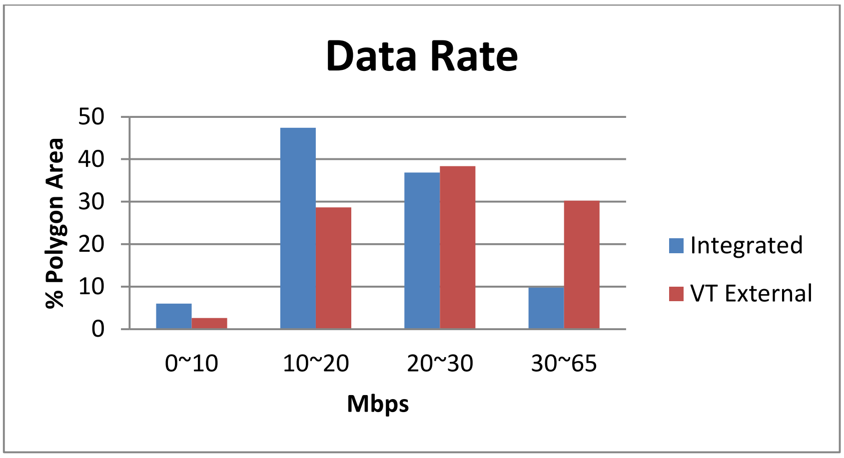
Graph 1 – Coverage Comparison

Signal-to-Interference-plus-Noise-Ratio (SINR) provides a measure of interference between cells. For the two networks, this is calculated using the InfoVista tool and these are compared in graph 2. It is clear that the use of the variable tilt external antenna gives significantly better SINR.



Graph 2 – SINR Comparison

Excellent data rates across the network is the final goal of good network design. Graph 3 compares the two antenna scenarios and it is clear that the use of the variable tilt external antenna gives the best data rates. Table 2 shows the % network area with data speeds of greater than 20Mbps.



Graph 3 – Data Rate Comparison

Antenna Type	Number of Sites	% Network where Data Rate >20Mbps
Integrated	200	46.25%
Variable Tilt External	153	68.85%

Table 2 – Data Rate Performance Comparison

Discussion

Coverage

The baseline for all calculations is the coverage area selected by the InfoVista tool for the integrated antenna. In order for meaningful comparisons to be made the coverage area for the external antenna is chosen to be the same or as close as is practicably possible. The network using the external antennas requires ~25% less sites to give the same coverage. This demonstrates that the investment needed to build the network using the external antennas is significantly less, with savings in site acquisition and rental, in the number of radios required, and in on-going maintenance costs.

SINR

Interference between cells reduces network performance. The best SINR in this study is given by the variable tilt antenna type. This is because of the ability to vary the tilt and tune the overall network. Depending on the network topography each antenna can be given a different tilt setting suited to the area in which it is located.

Data Rate

Data rate is related to SINR. Better SINR gives improved data rates, and the example throughput calculation which follows explains why this is so. The variable tilt external antenna scenario gives the best results due to its superior SINR.

Example Throughput Calculation

This example assumes the use of a 10MHz channel, and 2x2 MIMO. There are 50 Resource Blocks (RBs). Therefore:

50 RB's * 12 sub-carriers * 12 symbols = 7200 symbols/ms
7200 – (12 Ref Signal x 50 RB's) = 6600 symbols/ms

If the modulation scheme used is 64QAM (6 bits per symbol) then throughput is 6.6 * 6 = 39.6 Mbps for a single chain.

Based on table 3 below 64QAM-4/5 can be used at SINR levels >16.9dB. Therefore: 39.6Mbps * (4.8/6) = 31.68Mbps. So for 2x2 MIMO, the effective data rate is twice that, which is 63.36Mbps.

In summary, better SINR allows more efficient coding schemes to be used giving better data rates.

Name	Useful Bits per Symbol	Required C/(N+I) (dB)
QPSK-1/3	0.67	-1.100
QPSK-1/2	1.00	1.000
QPSK-2/3	1.33	3.000
QPSK-4/5	1.60	4.500
16QAM-1/2	2.00	6.200
16QAM-2/3	2.67	7.500
16QAM-4/5	3.20	10.800
64QAM-2/3	4.00	14.200
64QAM-4/5	4.80	16.900

Table 3: Encoding Schemes

Conclusions

This study compares the use of different antenna types in a small cell network, and shows how correct antenna selection can minimise site count and improve overall network performance and data rate.

Although it may seem convenient to use a radio's integrated antenna rather a higher performance external part, this can lead to a greater site count and poor network performance. This study shows that using an external antenna can reduce the site count by up to 25%, which even once the additional antenna expenditure is taken into account leads to significant capex and on-going rental and maintenance savings.

But more importantly is the improvement in performance and data rates, which ultimately drives customer satisfaction and churn rate. In the example given, data rates improvements of up to 20% are reported across the network.