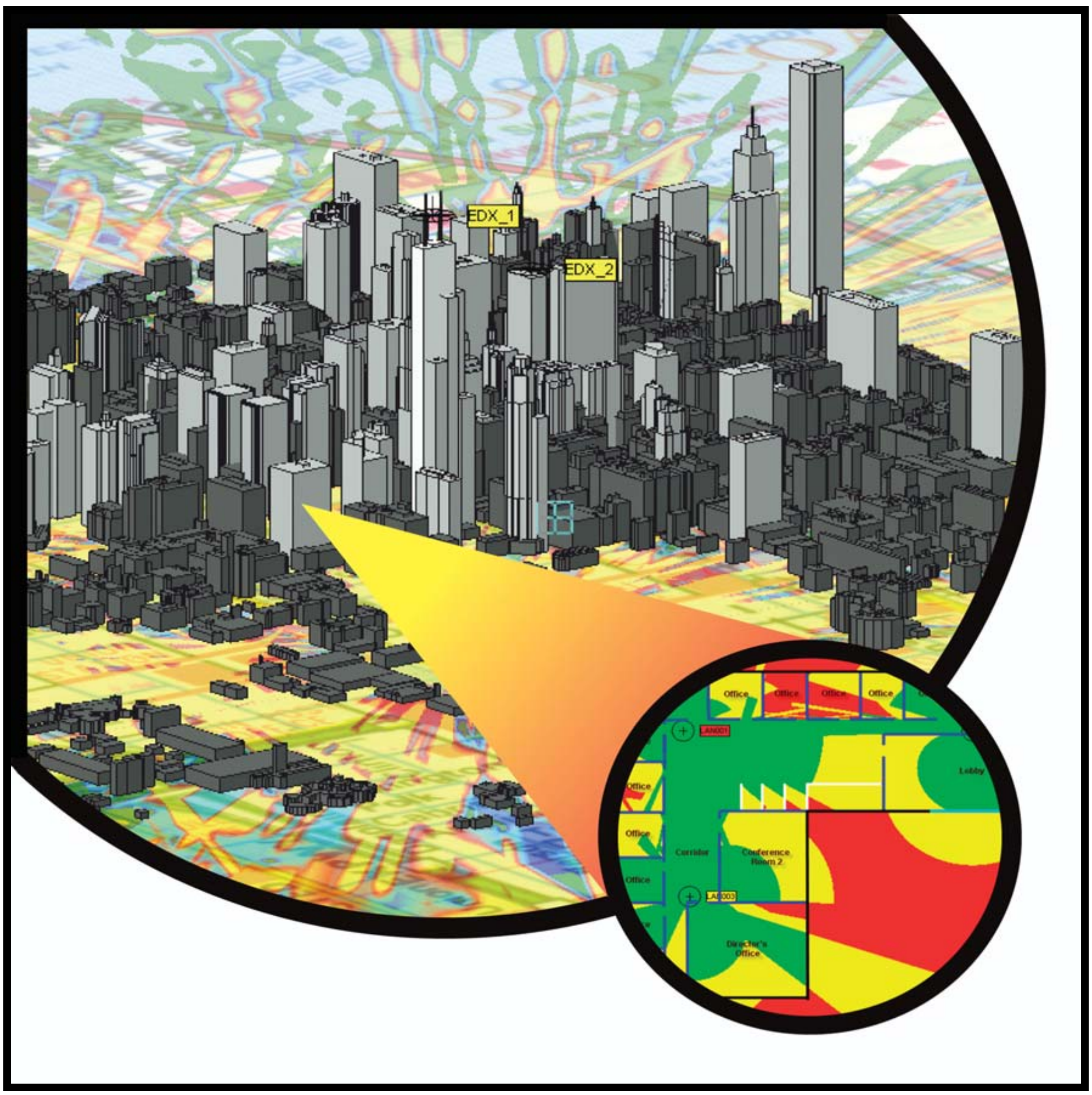
Technology White Paper
Mobile WiMAX Physical Network Best Server Modeling



The Power of Planning

Mobile WiMAX Physical Network Best Server Modeling

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March, 2008

Introduction

In a multi-sector communication system such as WiMAX the performance of the network is heavily influenced by the traffic load on each sector as well as the ability of mobile units to smoothly move from one sector to another. Accurately knowing how a sector will serve a particular geographic area is fundamental to understanding these two issues when planning or designing a network. Much of this challenge is answering the "Best Server" question. Knowing which sector is the primary server for a mobile unit will greatly enhance the understanding of the effect of that mobile's data needs on the network as well as how to properly provide a smooth mobile handoff as it moves among sectors. Obviously, only during operation of a built-out network where each mobile is reporting its real-time signal level status can the ultimate answer to the "Best Server" question be found. But, by using proper study methods, this same information can be accurately estimated during the initial system design stage. This paper explores the Best Server issues that are important to WiMAX and shows a way to more effectively use a planning tool to model the operation of the network.

Traditional Methods

In the past, planning tools and design engineers have simply run signal level studies on all the servers in the network and assigned geographical service areas on the basis of the server providing the best (strongest) downlink signal to the remote unit. While this is a straightforward way to approach the problem and works well in many cases, it is not the best approach to take when dealing with systems using adaptive modulation techniques such as those found in WiMAX networks.

Figure 1 - Sample WiMAX System

Figure one shows an example of base stations that make up a simple four site WiMAX mobile system. Each base site is comprised of three 10MHz sectors. The frequency reuse is three meaning the same three RF channels (one per sector) are used at each site. This can be seen on the map by noting the regular pattern of sector icon colors that represent each of the three channels. To show the basic coverage afforded by this system one can do a traditional propagation study that shows the received signal at a mobile unit. This study simply calculates the received signal level from all sectors at each remote location and chooses the strongest signal regardless of the channel (frequency) in use. The following study in Figure 2 shows the results of this type of study where the colors represent various ranges of received signal at the mobile unit.

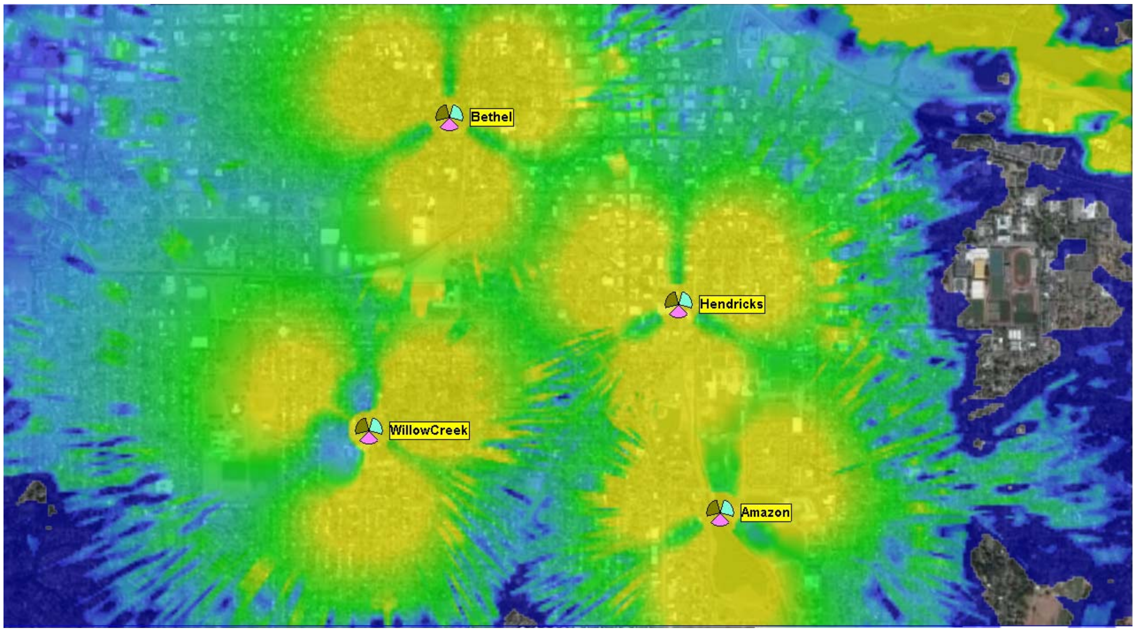

Figure 2 - Received Power at Mobile

As can be seen, the signal coverage is fairly balanced from sector to sector. The main effect on the signal intensity is the attenuation caused by the different types of clutter (land use) found in each sector.

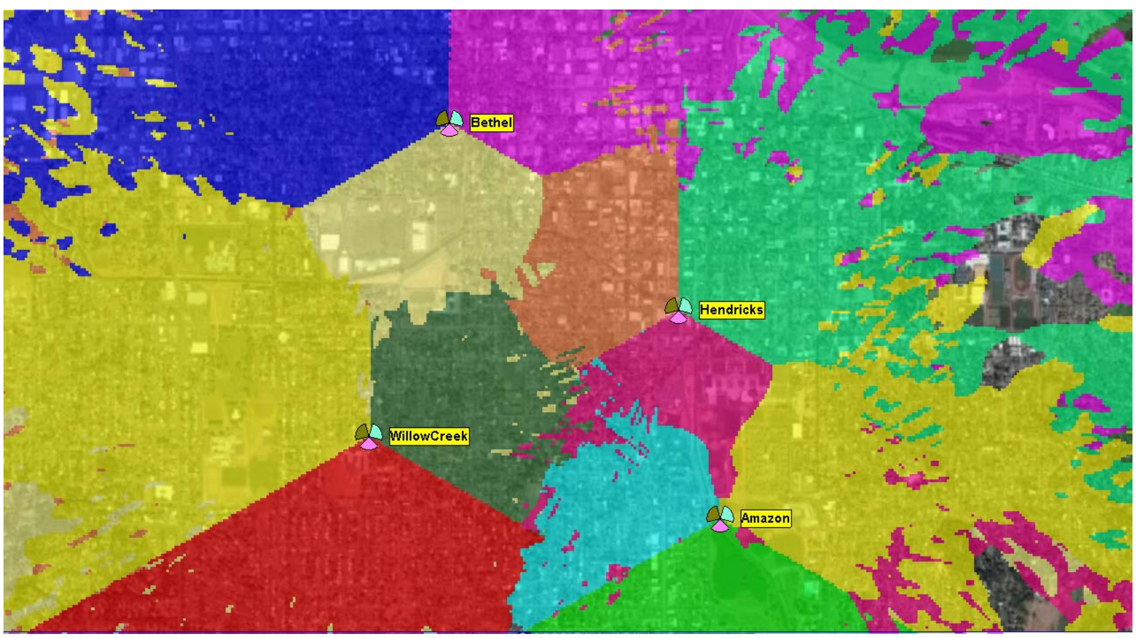

Figure 3 - Best (Most Likely) Server

In addition to displaying the ranges of received signal, this same information can be plotted such that the identity of the sector serving each geographical area with the strongest signal is shown as a unique color on the map. This type of analysis is generally known as the "Best Server" or "Most Likely Server" study as seen in Figure 3.

In this study, the variations in signal strength within a sector's service area are not shown and the generally balanced signal coverage from sector to sector is even more pronounced. Unfortunately this type of simple prediction method fails to take into account the factors that a mobile unit uses when it informs the network controller as to the quality of signal from the servers with which it can communicate. Obviously a server must be above the noise floor of the mobile receiver in order to be considered. But ultimately it is the carrier to interference ratio (C/I) and not the absolute value of signal level which directly affects the bit error rate (BER) of the data. Therefore, C/I should be used as the deciding signal quality factor in assigning a server to a mobile.

Advanced Techniques for WiMAX Networks

One of the powerful features of WiMAX is its ability to use a particular digital modulation type that best meets the needs of each individual remote (mobile) unit. Where location or propagation conditions provide for a low-loss RF path, higher orders of OFDM sub-carrier modulation methods (16QAM, 64QAM) can be used. The choice of the modulation type to use is directly related to C/I. The following table shows typical C/I ratios required for the basic modulation types used in WiMAX:

Modulation Type	Required C/I(dB)
BPSK	5
QPSK	8
16QAM	16
64QAM	22

Table 1

Below is a simple map that shows the modulation types in use in a single sector at the "Willow Creek" site. In this study, interference from other sectors was not considered so in this example case the received level at the remote in this case is referenced to noise only. Accordingly, the C/N (carrier to receiver noise) is consistently high leading to quite good coverage areas. The colors that make up the various C/(I+N) ranges in this plot were chosen to reflect the C/I values from the Modulation Type table to also show the likely modulation type being used to communication with a mobile unit.

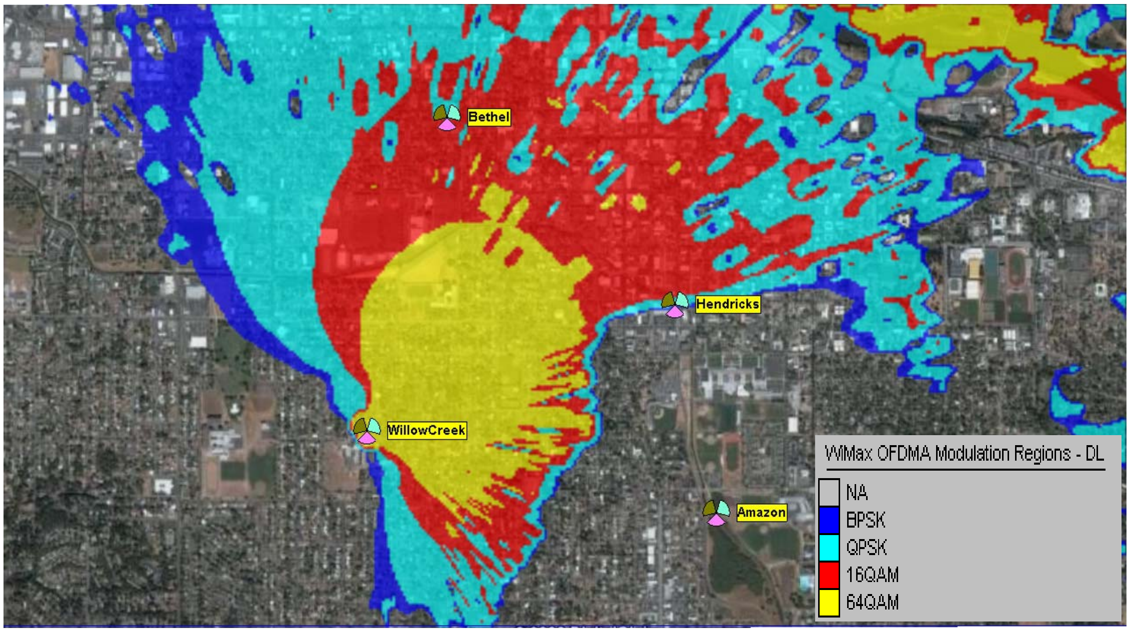

Figure 4 - Adaptive Modulation for a single sector

Ideally, a remote unit should use as high an order of modulation type as possible consistent with a reliable connection. This enables a higher maximum data rate to be sustained by the mobile; it also aids in maximizing system capacity since the higher order types such as a 64QAM have a greater bits/Hz ratio making them more efficient.

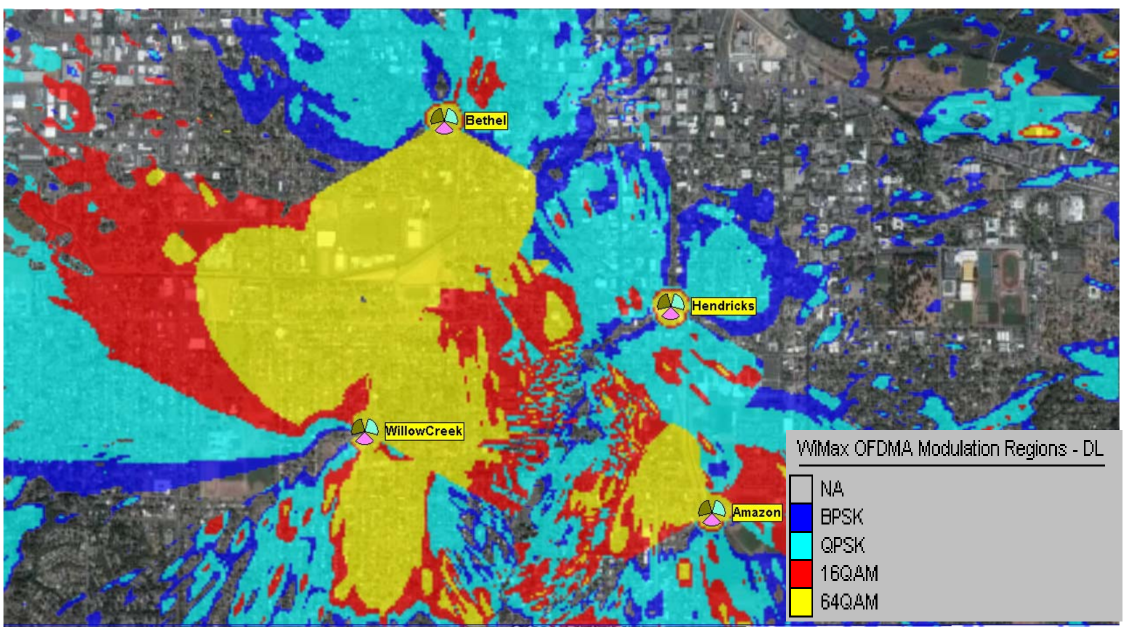

Figure 5 - C/(I+N) (modulation regions) at Mobile from Strongest server

The study plot in Figure 5 shows the C/(I+N) (carrier to interference + noise) at each remote location when all sectors in the system are active. The colors that make up the C/(I+N) ranges were chosen from the table above in order to indicate the likely modulation type being used in each area. To calculate C/I the first step in performing this study is to select the appropriate server (carrier) for each location. In this study, the sector providing the strongest signal at each remote location was used. Note that the balanced coverage from sector to sector as was seen in the Most Likely Server study continues to be preserved. But as can be seen, the actual C/(I+N) varies greatly from sector to sector resulting from the straightforward method used to select each sector's geographical service area.

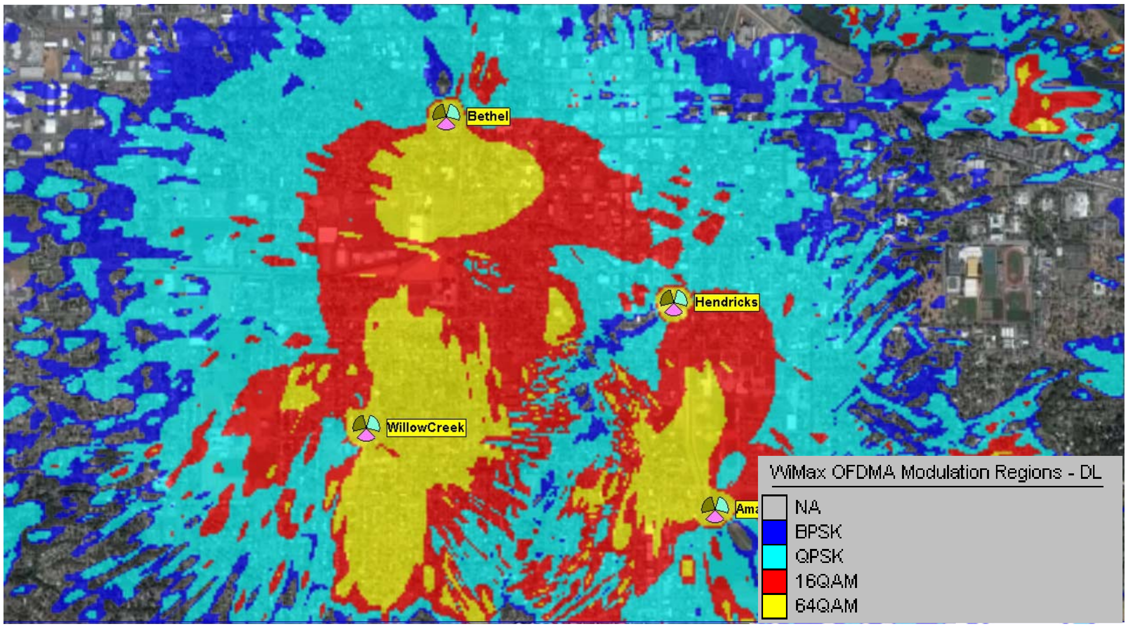

Figure 6 - C/(I+N) for Best Channel

The study in Figure 6 also maps modulation type based on C/(I+N) at each remote location. But in this case, the channel in use at each sector was taken into account so the best server for a remote was based upon the server that could provide the highest C/(I+N) rather than the strongest received signal. This was done by testing the signal from all the sectors at each remote location. Then, rather than using only the strongest sector, the C/I for each sector was calculated and finally the highest C/I was used to identify the best serving sector. As can be seen there are significant differences between this study and the C/(I+N) using the traditional "strongest server" approach.

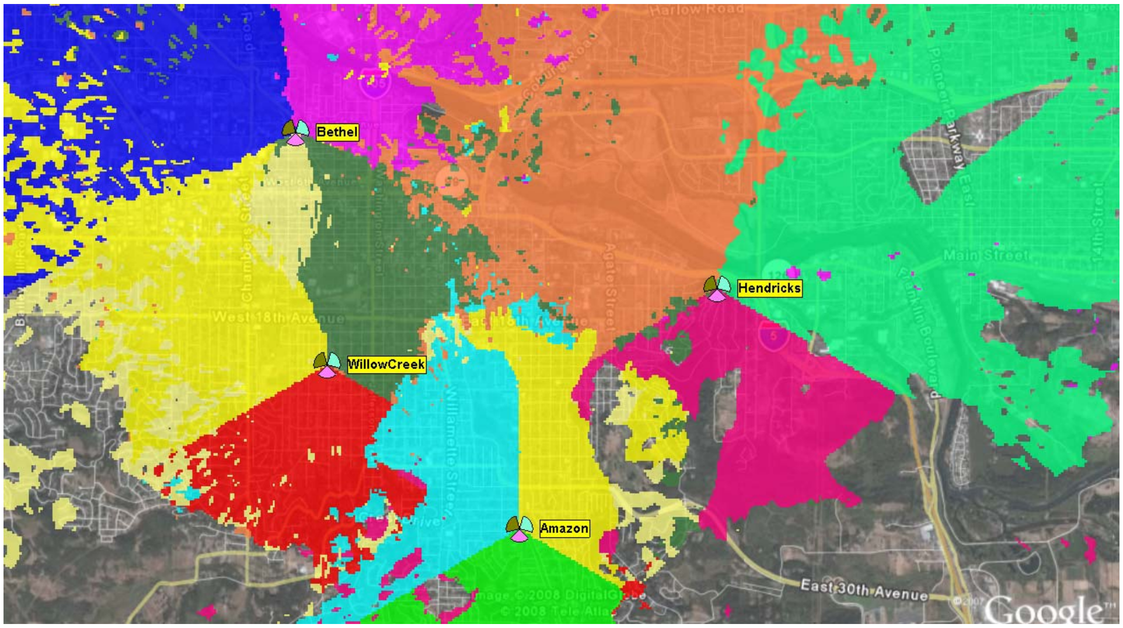

Figure 7 - Best (Most Likely) Server based on Best Channel

Figure 7 above shows even more dramatically the variation in serving sector when C/I+N is taken into account. It is obvious that the use of the Best Channel method when running simulations shows a truer picture of what the system would experience based upon the assignments of remotes to servers when actually using the reported C/(I+N) at each remote. If one was to attempt to optimize the performance of poorly-performing sectors using the strongest server assignment method, the changes made to the system would cause field measurements (drive test) to return data that wouldn't correlate with that expected by the simulation. Compare for example, the actual assignment of servers from Figure 7 above in the area to the West of the Willow Creek site to that shown in the Best Server study as illustrated in Figure 3. What appeared to be a straightforward mobile server assignment is easily seen as something greatly fragmented. Alternately, by using a best channel assignment approach changes to the system based upon the simulation return results that agree with the behavior found in the field. In addition, the Network Management System can be provided with an accurate neighbor list which leads to more successful mobile hand-off performance.

Conclusions

In a mobile-based multi-sector communications network good C/(I+N) performance and successful hand-off from sector-to-sector is critical to providing good customer service. The design of the network's physical RF layer is a fundamental requirement in providing this. During actual system operation, the Network Management System will assign remotes to servers and also make mobile hand-off decisions based upon the best modulation type. This real-time information is the best source of data in determining the accuracy of the RF design. But, it is also possible to emulate the conditions that drive mobile sector assignment and handoff by using advanced study methods. The most useful technique is to base the sector server assignment in the design software on a calculation of C/I using the best channel rather than simply assigning servers based on their signal strength at the remote. C/(I+N) is also the critical parameter in determining modulation type in a WiMAX system, so accurately determining the "C" (carrier or server) is important to understanding system performance and capacity in this new technology.

References

[1] Harry R. Anderson, "Fixed Broadband Wireless System Design". John Wiley & Sons, 2003.

[2] C. Eklund, R. B. Marks, S. Ponnuswamy, K. L. Stanwood, and N. J.M. van Waes, "*WirelessMAN: Inside the IEEE 802.16 Standard for Wireless Metropolitan Networks*". IEEE Press, New York, 2006.