The Impact of Building Database Resolution on Predicted LMDS System Performance

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Abstract- **Planning broadband multipoint wireless distribution systems in urban areas requires accurate knowledge of the propagation environment which consists primarily of buildings and trees. The impact of lateral and vertical accuracy for such building databases is investigated by examining the differences in predicted system performance as a function of database resolution. The results for LMDS system studies with a "perfect" vector database were compared with identical studies using 1, 2, 5 and 10 meter canopy building databases. The coarser the canopy database resolution, the more significant the system prediction error. When using 1 and 2 meter canopy databases, the line-of-sight decision error is on the order of 2% of the paths, a manageable figure for most LMDS system designs.**

1. Introduction

Of several recent wireless service spectrum allocations, one of the more valuable is the LMDS (Local Multipoint Distribution Service) spectrum that is planned for operation in frequency bands above 20 GHz in most countries. With sometimes more than 1 GHz of available spectrum available to an operator in a given market, LMDS systems are intended as broadband fixed systems where the system distribution hubs and user terminals will be at fixed rather than mobile locations[1].

Because of the frequencies involved, LMDS will almost always require a line-of-sight (LOS) transmission path from the system hub to the customer terminal (CT). Elements of the propagation environment, including terrain, buildings and foliage represent largely impenetrable obstacles to microwave radio energy. Therefore, a fundamental aspect of designing an LMDS system is choosing hub locations that have a high degree of visibility, at least for initial system deployments. As the number of customers increases, and frequency reuse becomes an issue, choosing hub sites with *controlled* visibility to limit interference will be required, much as microcells with limited, controlled service areas are used in PCS and cellular systems to increase system capacity. In a non-uniform urban environment, this will be an engineering challenge.

Because LMDS system design relies so heavily on detailed descriptions of the propagation environment, questions about the database and its characteristics - resolution, accuracy, and significantly, cost - become important. There currently are two widely-used approaches to describing buildings, foliage and other features of the propagation environment: vector and canopy. Both are considered in this research.

Developing adequate databases for large metropolitan areas can be an expensive undertaking. Prices currently range from approximately $250 to $1000 per square mile, depending on the type of database (vector or canopy), the average building density, the technology used, the relative and absolute accuracy required, and final data resolution. Because of the significant cost involved, it is worthwhile to know the relationship between building database resolution and the accuracy of LMDS system performance prediction. The purpose of this paper is to address this question.

2. Building Database Types

The two database types currently used for LMDS systems planning are:

Vector or polygon data. Vector data are specific x,y,z coordinates which describe the outlines of the buildings. Vector data can provide the most explicit description of where buildings are located, but this approach does not lend itself to describing more amorphous natural shapes such as foliage or terrain. To adequately account for terrain, a "bare earth" database must be used in conjunction with the vector data to describe a 3D surface on which the buildings are situated. Vector data for buildings in a city is usually developed using traditional photogrammetric techniques or more recently, laser-scanning methods from aircraft.

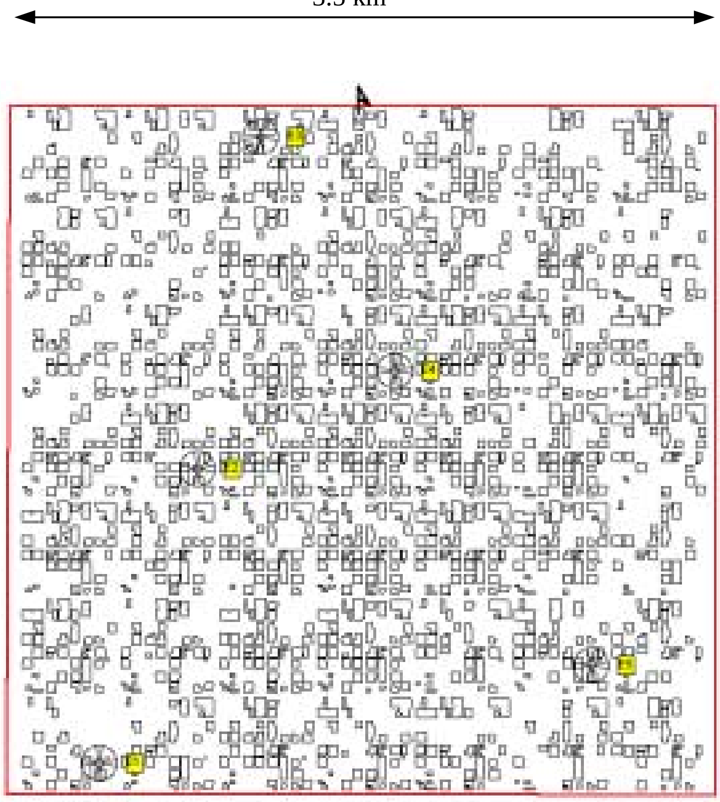

Figure 1. Building environment for studies.

Canopy data. A canopy database is a regular grid of elevation values, were the elevation is the maximum aggregate height above mean sea level (AMSL) of whatever exists at that point, whether it's terrain, a building or other structure, or foliage. It's sometimes thought of as a "shrink-wrap" covering of the surface. Because it is a regular grid of points, it cannot exactly describe the vertical walls of a building, for example, and the grid step size will directly control the precision with which walls can be represented. Though less accurate, canopies can readily represent foliage and terrain, as well as buildings, highway overpasses and other non-building structures. Canopy databases can be developed using automatic auto-correlation techniques on a stereo pair of aerial photographs, making it less labor-intensive than photogrammetric techniques. The automated process must be carefully controlled and manual remedial corrections to the auto-correlation results are often needed to produce a canopy database suitable for LMDS planning purposes.

3. Study Environment

To determine the impact of building database resolution on predicted system performance variations, a series of simulation studies were done for a set of building databases of varying resolutions in a large hypothetical database extruded from the basic downtown building layout in Eugene, Oregon. The study environment shown in Figure 1 includes 1603 buildings ranging in height from 4 to 170 meters contained in a 3D polygon vector database describing the precise location of buildings and their heights. For the purposes of this study, this database was considered "perfect" in that it is an exactly accurate description of the actually buildings. The results from system studies using the vector database were compared to the results for identical studies using canopy databases with grid step sizes of 1, 2, 5 and 10 meters.

To create canopy databases, the vector database was "rasterized," at the desired grid interval. The rasterizing process essentially samples the vector database at the canopy grid interval and determines the building height at that point.

In addition to sampling the elevation at fixed grid intervals, an elevation error was also added to the building heights. The errors were random, gaussian-distributed height changes with the following standard deviations:

Canopy grid step size	Standard deviation of error
1 meter	0.75 meters
2 meters	1.25 meters
5 meters	1.75 meters
10 meters	2.5 meters

These values are typical of the errors in canopy databases the industry is currently producing.

The typical application of these databases is to construct elevation profiles consisting of a series of points along the line of a radio path between a transmitter hub and a customer terminal in an LMDS system. For points along the path that do not fall exactly on a canopy grid point, the four surrounding grid points are found and unweighted linear interpolation used to find the point's elevation.

Figures 2 though 5 show the same radio path through the study environment when using the vector, 1, 2, 5 and 10 meter databases, all sampled at 1 meter. The slopes formed by the limited resolution in transitioning from the building top to the ground is clear, and as expected, is greater with the coarser resolution.

4. LMDS System Studies

The intent of the studies conducted here is to determine two things:

1. How an LMDS system design changes when using the coarser database.

2. Actual errors introduced by the coarser database. In particular, when does it give the engineer a false indication of whether a radio path is line-of-sight (LOS) or obstructed (NLOS)?

With modern LMDS RF system design software, the decision about where hubs are placed, and which hubs best serve a given customer, is largely an automated process. The software can adapt the design to fit the database description of the service environment, regardless of the quality of that database. So the issue with a coarser database is not one of designing a system which won't work, but rather designing a system which is not optimum because design tolerances need to be increased to accommodate the coarser database. As part of the overall system design, the coarser databases will simply results in more fundamental mistakes, such as telling the engineer a path is LOS when it is not, or vice versa.

To explore these issues, an LMDS system was set up in the building environment in Figure 1. Five hub sites were placed in this environment to achieve maximum visibility with the vector database using the automatic hub layout feature in the LMDS planning software. Each of the five hubs was configured with four 90° sectors with alternating horizontal and vertical polarizations. The hub antennas were positioned eight meters above the center of the roof top. A Customer Terminal (CT) was placed on the roof of each of the 1603 buildings at a height of 3 meters above the roof top.

System studies were then done using the vector database and each of the four canopy databases. The radio oaths in each case used a step resolution of 1 meter, except for the vector database that used a step resolution of 10 meters, but building heights are inserted at whatever arbitrary distance they might occur along a path. The studies included automatic channel or frequency assignment[2], finding the three best serving hubs for each CT, calculating downlink and uplink service availability, and determining the degree of shadowing on the radio path from every hub to every CT. The results were compared with the results from the vector analysis which was used as a performance baseline.

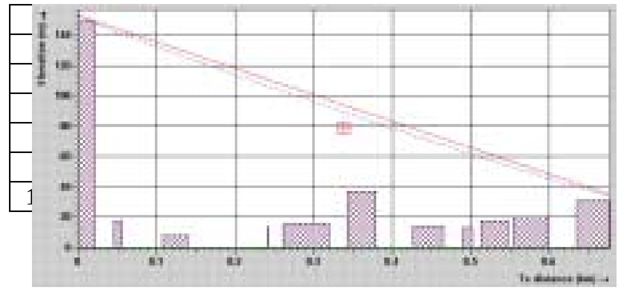

Figure 2. LMDS path using vector building data

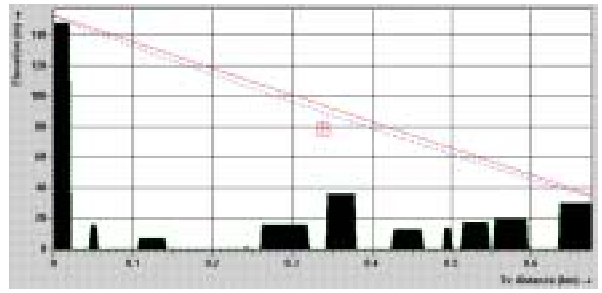

Figure 3. LMDS path using 1 meter canopy data.

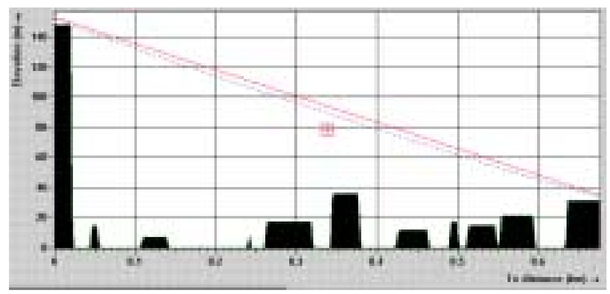

Figure 4. LMDS path using 2 meter canopy data.

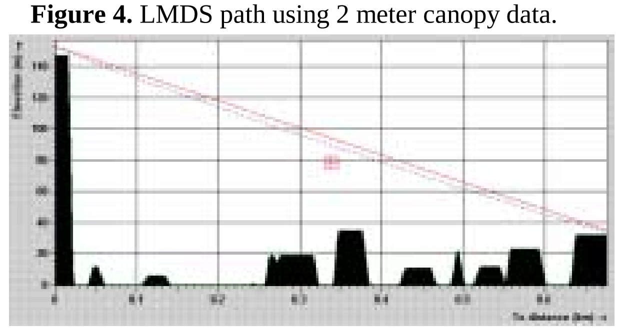

Figure 5. LMDS path using 5 meter canopy data.

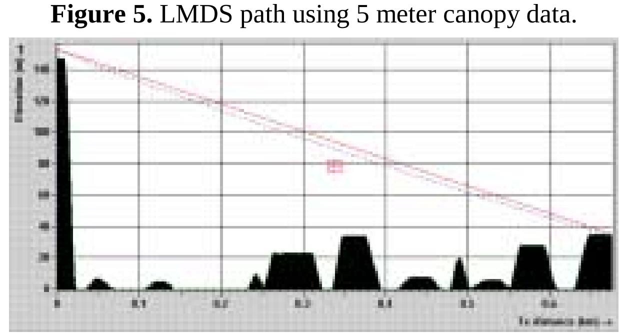

Figure 6. LMDS path using 10 meter canopy data.

5. LMDS Systems Study Results

The results of the studies show the canopy database results differ from the vector baseline results, with the amount of difference increasing as the coarser resolutions were used. Table 1 shows the number of CT's which were assigned different hub servers, and the average percent change in the service availability for links with service availability above 99.0 percent.

Table 1

Database	Number of CT servers changed	Average change in % service availability
vector	0	0.00000
1 m canopy	141	0.00337
2 m canopy	217	0.00251
5 m canopy	337	0.00485
10 m canopy	556	0.00137

As expected, the coarser the database, the greater the change in predicted performance. This can be attributed to the slopes on the building walls that result from the inability of a canopy to represent a perfectly vertical wall. It also results from the larger building height errors and the sampling method in the rasterizing process which will always sample inside the building parapet thus effectively shrinking the top print of the building in the sample study environment. Again, even with these errors, the LMDS planning tool has still devised a system configuration in which most CT's are provided high availability service. In effect, a wider system design tolerance is automatically introduced when using the coarser canopy database.

The erroneous building parapet edges and slopes on buildings have two effects – they block service where service really exists, but they also block interference where interference blockage does not exist. To some extent these effects counteract each other, except that when a CT is "falsely" shadowed, the fact that the interference is also "falsely" attenuated is immaterial – no service is available. To better understand what is happening here, the results of the study were re-analyzed to determine the number of paths that changed from LOS to NLOS, or vice versa, as the database resolution got coarser. Table 2 shows the results of this analysis.

Interestingly, for the coarser databases the paths changing from NLOS to LOS are more prevalent; i.e. the canopy databases are showing a number of paths as LOS when in fact they are NLOS. This is probably the more detrimental effect of a lower resolution building database to a LMDS system designer. However, detailed analysis of some of these paths reveal that the NLOS paths in the vector case are due to close-in shadows caused by the building parapet (the hub antennas were positioned 8 meters above the center of the building). In practice, the hub antennas are positioned on the parapet to eliminate close-in shadows. By taking this into account, it is expected the NLOS to LOS changes would be substantially reduced.

6. Conclusion

Studies of the impact of building database resolution in LMDS system design have been carried out. Several databases were developed with x,y resolutions ranging from 1 meter to 10 meters. These databases were used to study the changes in LMDS system design performance when compared to a "perfect" vector database. The results show that the canopy databases can provide prediction performance comparable to the vector database, especially for 1 and 2 meter canopies.

The results for this study are for a single hypothetical urban area. Planned on-going research will apply these study approaches to vector and canopy databases developed from standard state-of-the-art photogrammetric and auto-correlation methods rather than the simulations provided here.

7. References

[1] D.A. Gray, "A broadband wireless access system at 28 GHz", *Proceedings of the Wireless Communications Conference*, 1997, pp. 1–7. (IEEE catalog number 97TH8315).

[2] H.R. Anderson, "Simulations of channel capacity and frequency reuse in Multipoint LMDS systems," *Proceedings of the Radio and Wireless Communications Conference*, 1999. (To be published).