Processing RF Propagation Coverage Data for Optimized Display and Analysis in a Web-Based Application

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ABSTRACT

Radio frequency (RF) engineering groups often use network design and optimization software to produce wireless RF propagation coverage data. This data offers the potential to be used effectively throughout an organization for customer care, sales, marketing, planning, engineering, provisioning, service activation and network management business processes, as well as the applications that automate these processes. However, the RF data format and data structures produced by RF engineers are not always optimized for spatial analysis and map display using location intelligence and Geographic Information System (GIS) software that enables these business processes and applications.

Coverage data files are sometimes too large and complex to analyze efficiently. Numerous data processing challenges can arise when attempting to produce a visually appealing representation of coverage where wireless coverage areas are well-defined using smooth contours. Further, it can be time-consuming and cumbersome to run manual processes that seek to transform wireless data between data structures and file formats and optimize coverage objects for purposes of presentation and analysis.

This paper will examine the options available for processing RF propagation coverage data for optimized display and analysis in a web-based application developed using MapInfo Server-based software. Specifically, we will look at:

- How communication companies can display and analyze coverage data and the RF data formats and structures they are provided
- Vector, raster and grid format characteristics: strengths, weaknesses and their application in MapInfo server-based software
- How to transform wireless data between data structures and file formats
- How to optimize wireless data using grid querying, generalization (thinning and smoothing), aggregation, disaggregation, attribution, indexing and tiling (appending vs. seamless layers) techniques
- How to automate the transformation and optimization of wireless coverage data
How Communication Companies Use Wireless Coverage Data

RF engineering groups within wireless organizations produce RF propagation coverage data by using network design and optimization software such as Ericsson’s software Planet® EV, Agilent Technologies Wizard™, Forsk Atoll® and AIRCOM International ASSETTM. These network planning tools interface with leading GIS/Location Intelligence software such as that offered by MapInfo.

Ericsson’s software Planet® EV outputs a grid data format (.GRC/.GRD) that is supported by MapInfo software and has a contouring capability to convert its native grid format to MapInfo’s native vector format (.TAB).

Agilent Technologies Wizard™ software can export to MapInfo’s native vector format or export format (.MID/MIF).

The latest release of Forsk Atoll® can export to MapInfo’s export format or to MapInfo’s native vector format. Forsk Atoll can also export to Ericsson’s software Planet® EV and MapInfo’s grid data format.

AIRCOM International ASSETTM software can export to MapInfo’s export or native vector format. Safe Software FME® allows the translation of AIRCOM International’s ENTERPRISETM format into raster and vector formats supported by MapInfo software via an added-cost plug-in.

<table>
<thead>
<tr>
<th>Software</th>
<th>TAB</th>
<th>MID/MIF</th>
<th>GRC/GRD</th>
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<tr>
<td>Ericsson Planet EV</td>
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<tr>
<td>Agilent Technologies Wizard</td>
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<td>Forsk Atoll</td>
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<td>AIRCOM International ASSET</td>
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Wireless organizations use coverage data to enable numerous business processes and the applications that automate them. The coverage data is used to:

- Feed capital planning and engineering for market-driven network planning, using market analysis, demographic and spatial analysis to determine where and how to expand the network for maximum ROI as driven by customer demands.
- Help provide a quick resolution to customer-reported issues by communicating real-time network status, wireless coverage quality, and trouble tickets to service and support representatives across the organization via Call Center/Customer Service applications. (These applications give support representatives the ability to find a caller’s location on the map and quickly identify network status, predict coverage and make comparisons with any known trouble areas and future build sites.)
- Help sales and marketing staff pre-qualify prospective customers for wireless service while providing information on what services—e.g., paging, cellular, phone stores or any specials—are available in a specified area.
- Help pre-qualify prospective customers for fixed wireless service, based on whether there is line-of-site between the customer and a hub site.
- Correlate customer locations accurately with network service offerings and visually highlight geographic areas and specific business locations with the greatest revenue potential for various services in sales and marketing decision support systems.

In this context, it becomes critical that wireless organizations have coverage data that is as accurate as possible and is optimized for spatial analysis and map display. That way, customer care, planning, engineering, provisioning, service activation and network management business processes can produce the most accurate results in a timely fashion. Many of these business processes require the map display of different wireless coverages (CDMA, analog, etc.) to be thematically mapped at various zoom levels, from a local street view (e.g., 0.5 miles) to a U.S.-wide view (3,500 miles) in order to display such attributes as coverage quality and network status. Some of these business processes require a smooth contoured representation to define coverage areas with the same service quality value — as opposed to the jagged pixilated representation of coverage area found in a continuous grid surface.

Spatial analysis is often used to determine all relevant coverage information—e.g., wireless coverage quality, network status—at a specified location or in a specified area. Areas could include an address, intersection, ZIP code, city, county, cell site, point-of-interest (WIFI service provider), phone number location, point clicked on the map, radius/marque/polygon drawn on the map, route between specified locations, longitude/latitude, radius around a location or drive-time around a location. Spatial analysis can also be used to accurately correlate other coverage and location information with specified wireless coverage areas.

For example, spatial analysis can help:

- Find and display existing coverage or competitive coverage information that overlaps proposed coverage
- Calculate proportion of proposed coverage already covered by existing or competitive coverage
- Calculate the number of existing/prospective customer locations within existing and/or proposed coverage areas
- Find and thematically map existing/prospective customer locations, census or postal areas (ZIP codes, counties, etc.) within specified coverage areas to:
  - Highlight specific customer locations or geographic areas with the greatest actual or potential revenue for various wireless services
  - Profile coverage areas using demographic and/or segmentation analysis
Vector, Raster and Grid Format Characteristics

Traditionally, a GIS represents the real-world wireless coverage in one of two spatial models—vector-based, meaning points, lines and polygons; or raster-based, meaning cells of a continuous grid surface. Raster images are bitmaps that provide useful background and reference layers to maps. Grid images are a type of raster that have data associated with them that can show an interpolation of data values across an area. A grid image is created from a data file in which data is measured at evenly-spaced points. The entire map area is converted to a grid in which each grid cell represents a value. Grid values don’t have to be interpolated to produce a grid, although the data collection points need to be regularly spaced.

MapInfo Professional® and Vertical Mapper® software create grids by interpolating values using a grid handler. In addition to color gradations, grid images can also show hill or relief shading. MapInfo Professional can also create grids in vector or grid format, without interpolation, for a specified resolution based on point locations with Z values associated with each point such as signal strength.

The strengths and weakness of raster, grid and vector data formats for wireless coverage representation are summarized below:

Strengths of raster and grid formats:

- Representation of coverage areas as cells of a continuous grid surface is more appropriate for representing a wireless network, where the challenge is to show continuous variation over space, and where the network does not offer many artificial constraints.
- A raster-based network can provide faster and more efficient rendering of dense data such as wireless coverage at set zoom levels when compressed image files such as ECW, MrSID or JPEG2000 are used.
- A grid-based network provides the ability to perform spatial analysis using powerful matrix manipulation algorithms (e.g. arithmetic, grid query, cross section functions) in order to compare wireless coverage with multiple overlying grids that represent different themes. Much of this type of analysis is considerably more difficult to apply with a vector-based GIS that requires coordinate-based processing.
- A grid-based network provides faster and more efficient spatial searches of dense data such as wireless coverage.

Strengths of vector format:

- Provides a more visually appealing representation of coverage where wireless coverage areas are well-defined using smooth contours, as opposed to cells of a continuous grid surface.
- Cell sector boundaries can be clearly defined in addition to color-coding cell sectors by service quality.
- A relational data model allows for storage of and access to more than one attribute (cell site number, signal strength number, signal strength category) per coverage object.
- Provides the ability to perform spatial analysis comparing wireless coverage with other map layers in vector format.

MapInfo Offerings

MapInfo server-based software, MapXtreme® 2005, MapXtreme Java® and Envinsa™ have numerous capabilities for rendering and processing raster, grid and vector data in a Web-based application. All these software products can display coverage data in vector format and perform the types of spatial analysis for the kinds of business processes described in the previous section. The most significant issues with using vector-based coverage data in a Web application are rendering and spatial analysis processing performance and scalability; coverage data quality/accuracy resulting from data transformation processes; and a jagged pixilated representation of polygon boundaries (as opposed to boundaries defined by smooth contours).
Processing RF Propagation Coverage Data for Optimized Display and Analysis in a Web-Based Application

Using a spatial database such as MapInfo’s SpatialWare® in conjunction with MapXtreme 2005, MapXtreme Java or Envinsa can significantly improve spatial analysis performance with large volumes of vector spatial data such as when calculating the proportion of proposed coverage already covered by existing coverage or competitive coverage. MapXtreme® 2005, MapXtreme® Java and Envinsa™ can display raster and grid coverage data but have more limited capabilities for performing the desired types of spatial analysis on grid-based coverage data. MapXtreme Java is limited to search-at-point queries on grid cells to determine coverage information at a specified location. All three software products can display coverage data in various raster formats, including: MrSID (*.sid), ECW (*.ecw), TIFF, GeoTIFF (*.tif), JPEG (*.jpg), JPEG2000 (*.jp2, *.j2K), GIF (*.gif), PNG (*.png), ADRG, ASRP, CADRG and CIB, among others. Coverage data in grid formats such as MapInfo Grid (*.mig), Vertical Mapper® Continuous Grid (*.grd) and Vertical Mapper Classified Grid (*.grc) can also be displayed.

To display a raster image as a map layer, the image must contain geographic registration information, or coordinates that correspond to earth locations. The registration information will define the proper placement of the image in a map. Many raster images available today come with a registration file such as GeoTIFF, ADRG, ASRP, CADRG or CIB. A raster image can be registered as a geographically correct image in MapInfo Professional® if it is not already registered, and the registration information is stored in a .TAB file. Envinsa and MapXtreme Java require that the map display coordinate system be set to the raster layer’s coordinate system when adding a raster image to a map. MapXtreme 2005 automatically sets the rotation and projection of all the vector map layers, so that they match the rotation and projection of the raster image.

Most style changes to raster and grid raster coverage data including grid theme generation must be pre-processed in MapInfo Professional or Vertical Mapper and can’t optionally be created dynamically as it can with vector data, such as generating in real-time a style override to display cell sectors that are down. Raster styles can affect the speed of the rendering process. Translucency and transparency effects are the most time-intensive operations. Translucency has the greatest effect on the rendering speed of the image. This is because the operation affects every pixel in the image, regardless of its color. In MapXtreme 2005, brightness and contrast can be controlled and the translucency of a raster image can be set. In MapXtreme 2005, the hill/relief shading of a grid can be added or altered to give a textured appearance to grids; this works well for elevation data.

MapXtreme 2005 also supports multi-threading when using the ER Mapper® ECW raster handler. Vertical Mapper® Continuous Grid (*.grd) and Classified Grid (*.grc) formats are not supported in multi-threaded applications such as ASP.NET.

Vector, raster and grid data formats for wireless coverage data all have their strengths and weaknesses in general and in how they can be applied using MapInfo server-based mapping engines. The appropriate server-based mapping engine and coverage data format depends on required business processes and functionality. Using a combination of data formats for your wireless coverage may be just as appropriate as using a single format to meet your business process requirements.

Transformation of Wireless Data Between Data Structures and File Formats

Once you have decided upon the appropriate server-based mapping engine and coverage data formats, you will need to address the transformation of wireless data between data structures and file formats. Agilent Technologies Wizard™ software can export to MapInfo’s native vector format and export format. AIRCOM International ASSETTM software can export to MapInfo’s export or native vector format. Forsk Atoll® can export to MapInfo’s native vector format, grid data format and export format. Ericsson’s software Planet® EV
or MapInfo Vertical Mapper can be used to transform coverage data from Planet EV’s grid data format to MapInfo’s native vector format using the same contouring functionality found in both products. These contouring functions convert grids to attribute-coded vector files using processes that thread isolines, known as contours, through grid files. Contour lines are paths along which grid values are constant. Contour lines can be computed as separate polylines or closed complex regions where holes or islands have been “knocked out”.

The Region-to-Grid conversion process on MapInfo’s Vertical Mapper can be used to transform coverage data from MapInfo’s native vector format to MapInfo’s and Planet EV’s grid data format. This process involves extracting a text or numeric value from a column in the region table and assigning this value to all the grid cells that fall inside that region. If the assigned value taken from the MapInfo table is a text string, the process automatically creates a classified grid. If the assigned value is numeric, the procedure generates a numeric grid file. In both cases, the resulting grid file appears similar to the original region map; however, it often looks somewhat pixilated because it is in grid format.

MapInfo Professional can also be used to transform coverage data in various grid data formats (.DEM, .DT0, .DT1, .DT2, .GRD, .ADF) to MapInfo Grid format (.MIG). MapInfo Professional can be used to transform both vector (.TAB, .MID/.MIF, .SHP) and grid (.GRD, .MIG, .DT0, .DT1, .DT2, .DEM, .ADF, .FLT, .TXT, .ASC) coverage data to various raster image formats (.BMP, .WMF, .EMF, .JPG, .JP2, .PNG, .TIF, .GIF, .PSD) and geographically register the raster image by creating a geographically referenced .TAB file using the ‘Save Window As’ function.

ER Mapper software or ER Mapper’s ECW Compressor, which comes with MapInfo Professional, can be used to create ECW compressed image files from the following raster image formats: ER Mapper Algorithm (.ALG), ER Mapper Raster Dataset (.ERS), ESRI BIL and GeoSPOT (.HDR), Windows Bitmap (.BMP), GeoTIFF/TIFF (.TIF), JPEG (.JPG), USGS Digital Ortho Quad (.DOQ) RESTEC/NASDA CEOS (.DAT). The ECW compressed image files generated by the ECW Compressor need to be geographically registered by manually registering the image file in MapInfo Professional; by editing an existing geographically referenced .TAB file associated with the input image to reference the output ECW image; or by using the free MapImagery plugin (www.mapimagery.com/mapimagery/index.html) for MapInfo Professional to open and register the ECW compressed image files.

Several potential issues should be considered when converting vector maps to a grid structure or converting grid maps to a vector structure:

Potential issues in converting grid maps to a vector structure:
• Potentially large data volumes—fragmented grid coverage maps can create very large data files when transformed into a polygon-based vector data model.
• Line generalization may retain a somewhat jagged pixilated representation of polygon boundaries, as opposed to smooth contours.
• Topological errors such as incorrect connectivity between polygons.

Potential issues in converting vector maps to a grid structure:
• Small feature loss—features that do not occupy the greatest proportion of any one grid cell will be lost.
• Feature location shifts—feature locations can move up to half the dimension of the grid cells when transforming vector features into a fixed raster grid.
• Jagged boundaries—the nature of a fixed raster grid data model results in a jagged- pixilated representation of polygon boundaries.

THE APPROPRIATE SERVER-BASED MAPPING ENGINE AND COVERAGE DATA FORMAT DEPENDS ON REQUIRED BUSINESS PROCESSES AND FUNCTIONALITY.
In the next section, we will describe some methods that may be used to mitigate these data conversion issues and optimize wireless coverage data, including generalization functions.

Optimizing Wireless Coverage Data

Wireless organizations need coverage data that is as accurate as possible and is optimized for spatial analysis and map display. That way, customer care, planning, engineering, provisioning, service activation and network management business processes can produce accurate results in a timely manner. Several significant issues can arise when using vector-based coverage data in a Web application after converting a grid file to a vector data structure:

• Rendering and spatial search processing performance
• Unneeded or unwanted resolution that can add overhead in the display, manipulation and storage of the objects.
• Coverage data topological errors resulting from the data transformation process
• A jagged pixilated representation of polygon boundaries, as opposed to smooth contours defining cell sectors that have same service quality value
• Updating coverage cell sectors with all required attributes and allowing for optimized searching on any of these attributes

Organizations can perform generalization on a grid coverage and/or a transformed vector coverage to improve rendering and spatial search processing performance, remove unneeded resolution, remove topological errors and smooth coverage area contours. Generalization processing on a grid data structure is much less time-consuming than on a vector data structure that requires coordinate-based processing.

Vertical Mapper’s® Smoothing functionality can be used to generalize a grid coverage. Smoothing is the act of filtering a grid by modifying the values of every cell in a numeric grid to be the average of their neighboring cells. This averages out the data in the grid to provide a more high-level or relative representation of the data, thus removing any “noise” from contours created from grid data and reducing the size of those contour files. In addition, Vertical Mapper’s Grid Query functionality can be used to categorize cell sector grid cells into user-defined service quality groups (e.g., Good, Marginal, Poor) and optionally to generalize the grid coverage by specifying a greater output resolution than that of the input grid files (e.g., 100 m resolution input file vs 500 m resolution output file).

Smoothing functionality generalizes a grid coverage. The SMOOTHING WINDOW SIZE parameter controls the level of smoothness of the grid. The default value is 5, which means a matrix of 5 by 5 cells is used to look at when computing each grid cell’s value based on the average of neighboring cell values.
MapInfo Professional’s Snapping and Thinning functionality can be used to generalize a vector coverage while attempting to retain the shape and features of the region objects by using appropriate tolerance values. Snapping snaps nodes from different objects that are close to each other into the same location to eliminate overlaps and gaps. Thinning thins the number of nodes of an object to reduce unneeded complexity and resolve the coverage objects. As a side effect, Snapping and Thinning operations will remove any self-intersections and overlapping areas that exist in region data.

Aggregation can be performed on a vector coverage to define coverage area boundaries with the same service quality value and/or cell sectors that have same service quality value. For example, a transformed coverage’s contoured polygons can be combined to create a wireless coverage that consists of nine polygons for each cell site with three service quality bands for each of three cell sectors. MapInfo Professional’s Combine Objects Using Column function can be used to combine all polygons in the vector coverage file that belong to the same cell sector and/or have same service quality value. (See figure 1 on page 3.)

Disaggregating can be performed on a vector coverage to improve spatial search processing performance such as search-at-point on region objects that are too complex, with too many nodes and polygons. MapInfo Professional’s Disaggregate function can be used to break complex objects into their component parts and produce a series of single polygon region objects, one for each polygon contained in the original object. Region objects that consist of 5,000 or more nodes are generally considered too complex to query in a timely manner.

Attribution and indexing can be applied to a vector coverage file to update the coverage cell sectors with all required attributes and allow for optimized searching on any of these attributes. For example, coverage cell sector polygons may need to be updated with the service quality value (e.g., Great, Good, Marginal) to be used for the thematic color coding of service quality values on the map. Moreover, coverage cell sector polygons may need to be updated with their switch and cell number values to dynamically determine and map down cell sectors by querying the Network Operational Center (NOC) database for down cell sites. MapInfo Professional’s Table Structure and Update Column functions can be used to create, index and update all required columns. Indexed columns and a primary key should be used for Join, Filter/Search, Sort and Aggregate operations in order to improve performance.

Tiling techniques such as appending and seamless layers can be applied to vector, grid and raster regional wireless based coverage files to generate a U.S.-wide wireless coverage file to allow for rendering and spatial analysis across market boundaries on a single contiguous map layer. MapInfo Professional’s Append Rows to Table function can be used to create a single U.S.-wide coverage layer from regional vector tiles in MapInfo .TAB format that have the same
projection and the same table structure. ER Mapper® software can be used to create a single U.S.-wide ECW compressed image file from ECW raster tiles that have the same projection. MapInfo Professional’s Seamless Manager can be used to create and maintain a seamless U.S.-wide coverage layer from vector, grid or raster homogeneous tiles that have the same projection and the same table structure. A seamless layer is a MapInfo table in .TAB format that enables only the tiles that fit in the current map window to be opened and displayed. A seamless layer includes the directory path to each base table plus a description that defaults to the table name (alias). MapXtreme® 2005, MapXtreme® Java and Envinsa™ can display override styles and thematic maps applied to seamless map layers.

Zoom layering logic can be applied to the appropriate combination of vector and raster regional wireless-based coverage layers that have been generated for display at appropriate zoom ranges in order to optimize coverage display performance. For example, the most accurate vector layer (e.g., 100-meter resolution) can be displayed from 0 to 10 miles and used for spatial queries such as Search-at-Point to determine coverage information at any given location. Generalized raster coverage layers can be displayed at greater zoom levels such as 500 meter resolution from 10 to 100 miles and 1,000 meter resolution from 100 to 250 miles.

Automating the Transformation and Optimization of Wireless Data

It can be time-consuming and cumbersome to run many manual processes in MapInfo Professional®, Vertical Mapper® and/or ER Mapper® in order to transform wireless data between data structures and file formats and optimize the coverage objects for presentation and analysis purposes. The processes needed to generate the required coverage data can be automated in a data pre-processing application developed using MapBasic®, the Vertical Mapper API and/or the free ECW compression and decompression SDKs. Automation would save a substantial amount of time running manual processes and help optimize and provide consistency to the coverage data preparation process. Such an application should be easy to use because the user can complete a series of data processing tasks without having to complete any of the primitive Desktop Mapping functions to complete those tasks.

MapBasic—MapInfo Professional’s application development language—can be used to create an application that is fully consistent and integrated with MapInfo Professional’s own interface. MapBasic can interface with the Vertical Mapper API to access any of the functionality needed from the SDK. When the application is started, the GUI would consist of a pull-down menu that is added to MapInfo’s standard operating environment. The integrated design provides access to both the custom application’s and MapInfo Professional’s full functionality for both automated and manual map processing. The GUI should be task-oriented so that the user can see a whole spatial problem and not have to deal with a complex series of MapInfo functions (e.g., querying, generalization, aggregation, disaggregating, attribution, indexing and/or tiling) for performing the required transformation and optimization processes. The custom pull-down menu should provide users with the ability to easily navigate through the various options as necessary.

Example: Grid to Vector Coverage data Transformation and Optimization Work Flow

<table>
<thead>
<tr>
<th>RF Propagation Coverage in Grid format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generalize Grid Coverage using Smoothing</td>
</tr>
<tr>
<td>Categorize Grid using Grid Querying</td>
</tr>
<tr>
<td>Vectorize Grid Coverage using Contouring</td>
</tr>
<tr>
<td>Aggregate Coverage areas using Combine Objects</td>
</tr>
<tr>
<td>Disaggregate Coverage areas that are too complex using Disaggregate</td>
</tr>
<tr>
<td>Thin Coverage areas that are too jagged/pixelated using Thinning</td>
</tr>
<tr>
<td>Update Coverage areas with required attributes using Attribution</td>
</tr>
<tr>
<td>Create a Single Contiguous Coverage using Appending or Seamless</td>
</tr>
</tbody>
</table>

Example: Grid to Vector Coverage data Transformation and Optimization Work Flow
A Preferences item on the custom pull-down menu should bring up a unique dialog (or logical series of dialogs) for editing default preferences for the transformation and optimization processes when any of those values need to be changed—i.e., generalization tolerance values, input file directory path, output file directory path, a list of files to process, service quality grouping (e.g., Good = 0 to -83, Fair = -83 to -97, Poor = -97 to -105). Optimized default preferences should be determined through an analysis of the business process requirements, an analysis of the coverage data and a good understanding of the required coverage transformation and optimization operations found in MapInfo Professional, Vertical Mapper, and/or ER Mapper and how these processes work together.

A Run Coverage Optimization item on the custom pull-down menu would bring up a unique dialog for running the coverage transformation and optimization processes in their logical order. Any processing preferences that might be changed each time the application is run should be presented in this dialog. One such option might be to produce a new output coverage file or edit an existing output coverage file with the contents of the specified input files, so that the whole output file doesn’t need to be re-processed each time there is a partial update to a few coverage areas.

This application facilitates relatively rapid task performance, requiring very little of the user’s time, but still requiring substantial computer processing time and resources for running intensive operations as a batch process.

Summary

Wireless radio frequency (RF) propagation coverage data can be effectively used throughout an organization for customer care, sales, marketing, planning, engineering, provisioning, service activation and network management business processes, as well as the applications that automate these processes. However, the RF data format and data structures produced by RF Engineering are not always optimized for spatial analysis and map display using the Location Intelligence/GIS software that enables these business processes and applications.

There are many options for processing RF propagation coverage data for optimized display and analysis in a Web-based application developed using MapInfo server-based software. The nature of the source coverage data, the required business processes and application functionality will determine which coverage data format, transformation processes, optimization processes and/or data pre-processing automation options are most appropriate.

In conclusion, using a combination of data formats for your wireless coverage may be just as appropriate as using a single format to meet your business process requirements. Zoom layering logic can be applied to the appropriate combination of vector and raster wireless coverage layers that have been generated for display at appropriate zoom ranges in order to optimize coverage display performance.

A vector coverage layer based on the source data and most accurate resolution (e.g. 100 meter resolution) can be displayed from 0 to 10 miles and used for spatial queries such as search at point to determine coverage information at any given location. Generalized raster coverage layers, in a compressed image format, can be displayed at greater zoom levels, such as 500 meter resolution from 10 to 100 miles and 1000 meter resolution from 100 to 250 miles.