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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Sir:

Transmitted herewith for filing is the PROVISIONAL APPLICATION

for a patent of Inventor(s):

John Arpee, John Peter Carlson, and Joseph P. Kennedy, Jr.

Title: SYSTEM AND METHOD OF QUANTIFYING AND OPTIMIZING THE
PERFORMANCE OF A WIRELESS COMMUNICATION NETWORK

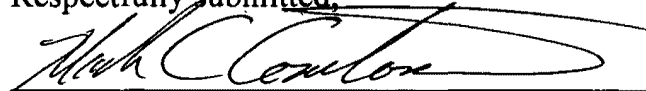
Enclosed are:

[X] A Cover Page, Nine (9) pages of specification, and an Appendix A and
Appendix B.

[X] A check in the amount of \$200.00 to cover the filing fee.

The Commissioner is hereby authorized to charge payment of any additional fees
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No. 04-1679. A duplicate of this sheet is enclosed.

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SYSTEM AND METHOD OF QUANTIFYING AND OPTIMIZING THE
PERFORMANCE OF A WIRELESS COMMUNICATION NETWORK

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The present disclosure is directed towards quantifying and optimizing the performance of a wireless communication network by collecting, managing and analyzing performance data.

Traditionally, the performance of a wireless communication system could be determined using several methods. The most prevalent method is to "drive test" the network. This typically involved using special test apparatus which is driven to specific geographic positions within the wireless network and collecting communications signals transmitted from the base station. In a wireless communications network, the communication signals transmitted by base stations and received by a mobile telephone are referred to as downlink signals and the transmissions from the mobile telephone to the base station are referred to as uplink signals. During the design and installation of a wireless communication system, signal propagation estimates are used to determine the amount of, and location of, base stations necessary to provide adequate coverage for a specified geographic area. Drive testing confirms that the wireless communication system is performing as predicted by the propagation estimates, or helps identify areas which are not performing as predicted. It can identify geographic areas in need of additional infrastructure resources such as base stations and repeaters. After installation, the wireless communication systems needs to be periodically evaluated to account for changes to topography, i.e., the construction of new buildings or other impediments to signal propagation, an increase in number of users, changes in interference levels, or the aging of the communications

equipment and its associated degradation in performance. While drive testing provides a sampling of the downlink signal propagation, significant resources must be expended to collect sufficient data if a detailed propagation evaluation is required.

However, the collection of data from these traditional sources does not provide the flexibility, robustness and accuracy that are desired in an optimization tool. Recently, wireless geolocation systems have been developed and deployed pursuant to the Federal Communication Commission's mandate that wireless carriers implement the ability to locate wireless phone users making 911 emergency service calls. The deployment of such geolocation systems provide the carrier with a tool for evaluating the uplink performance of its wireless network by measuring the quality of the uplink signals and associating the signal with the corresponding determined location of the mobile phone providing the signals.

The present application collects data from non-traditional sources and provides an improved method of quantizing the performance of the wireless communications systems. The present application is directed to several aspects. In one aspect, the present system uses the collected geocoded data for optimization of the wireless communications network. For example, the predominant interference experienced during wireless communications between a mobile telephone and a base station may be interference from other mobile telephones operating in the network. By measuring the received power level and subtracting the expected power level, an estimate of the interference signal strength can be

determined. Creating a historical profile of interference levels can help identify when a fault occurs, or when modifications to the system are required due to degradation in performance.

In another aspect, geolocation algorithms can be utilized to assist in the collection of communications data. In order to provide robustness to a wireless communication system, it is necessary that the wireless system provide the ability to reuse frequencies as much as possible, while avoiding interference from multiple mobile phones transmitting on the same frequency. One method of reducing interference is a strict power control protocol. Ideally, the transmit power level of the mobile phone will be controlled to ensure that the signal is strong enough to reach one, but not more than one, base station, thus freeing up the frequency for reuse by other base stations. Such power control protocols made it difficult to develop wireless geolocation systems since the geolocation systems require the receipt of the signal transmitted by the mobile phone at more than one base station, and preferably at many base stations in order to ensure the accuracy required by the E-911 FCC mandate.

In order to overcome this problem of limited reception at a base station other than the serving base station, algorithms were developed to help non serving base stations detect signals that would otherwise not be strong enough. The algorithms typically involve sending assist data from the serving base station to the non-serving (or secondary) base stations to help the secondary base station detect the received signal among the interference that would otherwise be masked.

In another aspect, the present disclosure seeks to take advantage of the ability of the secondary stations to measure the signal strength received at the secondary stations. Where the prior art optimization systems measured the receipt of a signal transmitted from a mobile phone at the serving base station only, the present disclosure measures the signal quality received at each base station using the existing geolocation equipment to assist in identifying and accurately measuring the signal strength at the signal at secondary base stations, even in negative carrier to interference ratio conditions through the use of aforementioned signal processing algorithms. Thus, for a given geolocation position, if the transmitted power is known, an accurate propagation loss estimate can be made for each receiving base station by measuring the received power level and subtracting it from the transmitted power level. For example, a real-time propagation loss model for a geographic area can be created based on power level measurements at a plurality of wireless location sensors (WLS) which receive a signal transmitted from the mobile phone and remove interference using signal processing techniques. The model can be used to identify trends and provide information that was not previously available, i.e., defining obscure propagation conditions, creating customized frequency plans, creating tailored interference avoidance plans, etc.

In another aspect, once interference can be accurately determined using a quantity of coordinated measurements at primary and secondary based stations, the measured interference levels can assist in the collection of optimization data.

For example, once interference levels are known, a channel having the least interference can be identified. It is not uncommon for one channel to have a significantly lower interference level than other channels. If subsequent optimization measurements are measured using the low interference channel, more accurate optimization data can be collected and thus a more accurate frequency plan can be determined. Thus, it is possible to develop a frequency plan which provides for a no/low interference channel to be assigned to each cell/sector to allow interference free measurements to be made. Over time, using interference free measurements provides a more accurate propagation loss plan. For an interference free channel, the propagation loss can be simply determined by subtracting the received power level from the transmitted level.

In another aspect of the present invention, the ability to determine the location of a mobile appliance while it is transmitting also affords the ability to track the mobile appliance while it is moving. Continuous collection of data allows the optimization software to create a relationship between the mobile power and the interference level as the mobile moves around. Thus, a more tailored power control scheme can be developed for phones on the basis of their location. Additionally, using call tracing allows the optimization system to identify anomalies in a geographic area.

In another aspect of the present application, once the performance statistics for a network have been determined, subsequent measurements can assist in the identification of a change in the performance of the network. If change in

performance is detected, the optimization system can assist in determining the cause of the performance change. Importantly, if the cause of the change can not be determined in some situations, the collection methods can be tailored in the area of the change to help pinpoint the cause. Thus, the diagnostic model being used can be adapted to determine the cause of the change.

In yet another aspect of the present application, complex path loss data can also be generated through the use of a “joint histogram” instead of the common single histogram. In cellular network design, the design criteria include coverage, capacity, and quality. Prior art designs have been based on outside measurements. In-building design was typically accomplished by applying a loss factor to account for building penetration based on the assumption that the interference is reduced by the same amount as the serving signals resulting in a net change of zero to the interference levels. In reality, the signal levels are more variable inside the building and one site or another is favored, depending on the location within the building. If the signals are separated and averaged they are each prone to a high error due to the high variability within the buildings. On the other hand if the data is maintained in a coupled manner, the optimization system can take advantage of any correlations between the signals and can certainly discount the weaker signals that are encountered when a sector is not the serving sector. By coupling the data the present optimization system can take advantage of the server versus non-server condition and the correlation between the signals which produces designs with higher quality and capacity than the prior art systems.

For example, in many instances, signal levels are known to change levels dramatically within a distance of 10 meters especially when we consider in-building measurements. Traditional planning tools produce a single estimate of the mean path loss or signal per bin for each sector (or bin) under consideration. However, producing a single measured mean value per bin results in a tremendous amount of valuable information being lost. In particular, when power levels or antennas are being optimized to minimize overall network interference it will be valuable to maintain paired signal levels or path losses. In other words, if a bin contains a tall building, at street level and in the lower levels of the building the serving and interfering signals will both be low. On upper levels of the building the interfering signal levels would increase but so would the serving level. Storing the average signal levels would completely lose this valuable information. Storing the histograms and then treating the serving and interfering signal levels would be a grossly false assumption and would lead to a substantial over-estimate of the severity of the interference.

On the other hand, if the serving cell antenna is nearby at the 2nd or 3rd story height, the serving cell might be substantially stronger and interference quite weak on the lower levels of the building. On the higher levels of the building the serving levels would be lower but the interfering levels would be higher. In this case the serving and interfering signal levels would be negatively correlated. It would be important for the higher floors to be served by a different cell. Thus, not only would it be desirable to store the joint histograms of the serving and

interfering sectors, but it would also be desirable to store separate histograms for each serving sector.

Another benefit of storing the coupled path loss values is a reduction in the effect of the variability in the mobile antenna gain. A mobile phone may report its transmit power level, but different mobile phones will have different calibrations and the antenna gain could vary substantially. Storing the differences will reduce this source of error. Thus, the essence of this aspect of the present disclosure is to collect and store the paired serving and interfering signal level.

In still another aspect of the present disclosure performance analysis can be based on customer identified problems associated with signal quality. The present system can track and collect geocoded performance data for a specific customer based on time of day, geographic area, etc and compare the collected data with historical database to identify anomalies in the signal quality. Anomalies may be identified as (a) improperly operating customer equipment, (b) cellular area with bad metrics, (c) due to customer usage patterns.

In another aspect of the current disclosure, use of performance data can also be used to monitor business aspects of the cellular telephone system such as identify lost revenue due to unnecessary handoffs to other carriers. For example, the present system can develop a geographic plot of the location of handoffs out of a network and thus map the lines of roaming between carriers and can use the data to expand areas of coverage along the lines of roaming between carriers.

Description of further aspects of the present system can be found in the attached Appendix A, and geo-coded data relationships of the present application can be found in the attached Appendix B.

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PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
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Andrew Confidential Information**Disclosures For 7.5¹ Interrelated Patents On Optimization Methods Based on Geo-Coded Data****Author: John Arpee, 703-623-9040, john.arpee@andrew.com****Supervisor: Terry Garner****Date: February 25, 2004****Inventors: Disclosures 1,3,5-8 John Arpee Disclosures 2,4: John Carlson**John Carlson +1 (703) 860-9700 x115**Disclosure Outside Andrew**

None of the disclosures in this document have been mentioned outside of Andrew with or without an NDA.

1. Up-link Interference Analysis

1239

Closest Prior Work Known: None**Description**

Up-link interference is often ignored. On those occasions when it is evaluated the histogram of the signal on the up-link signal during calls is compared to the histogram of the interference levels during idle time slots. It is reasonable to assume that the interference levels are uncorrelated with the serving signal level. Based on well-established statistical methods convolving the two input histograms can produce a histogram of the uplink C/I. This method is effective for identifying up-link interference but it does not help identify sources of interference.

To identify sources of interference the current channel assignments are examined to identify the nearby cells that are currently using the channels that are suffering from interference. A process of elimination or by considering the interference on multiple channels it is often possible to deduce the source of interference.

With geo-coded traffic weighted data we can identify cells that are sources of interference with greater confidence and we can identify specific areas that are significant sources of interference. Knowing where mobiles are located while they are causing interference is valuable for identifying solutions to reduce or eliminate the interference.

¹ The 0.5 refers to Disclosure 4, which is really only one suggested claim. John Carlson is developing the complete disclosure.

Definition Of Locations And Regions

Optimization methods that are likely to take advantage of the methods described in this patent typically seek to minimize the overall interference in a network, or equivalently they seek to maximize quality. In the process of maximizing total quality there must be some method by which the individual interference contributions from each location or region are considered.

When the word 'identified' is used in the proposed claims that does not mean that a person or process needs to define a boundary around a region. A method that considers overall interference will aggregate the overall interference. Typically the aggregation will be some kind of summing operation although it is possible that a non-linear method might be used to perform the aggregation. The point is that if one were to examine the contribution

In a down-link optimization the network is typically divided into small bins and the amount of interference to each bin is considered. On the up-link the interference occurs at a base station receiver so it does not make sense to consider the interference to a bin. Instead we must operate on the interference from each bin. In the down-link where multiple base stations may cause interference at a single location. In the up-link case mobiles at a single location may cause interference to multiple base stations and multiple locations cause interference at a single base station.

For the sake of this discussion there are a number of ideas related to identifying data concentrations or clusters. A single point might be a strong source of interference per unit area but for an area to be significant there must be a concentration of locations with significant traffic levels and high interference. How these concentrations are identified is not the focus of this patent and the definition or how the boundaries of these areas are defined does not substantially alter the validity of the claims listed below other than to acknowledge that, as a practical matter, a single point or a very small area of interference would probably not be worth optimizing.

Possible Claims

1. A method by which the interference contribution of a location(s) is based on the path loss from that location to antennas at other cells and the mobile transmit power at that location(s).
2. A method by which one or more locations is identified as a strong source of interference if the low path loss from that location to antennas at other cells combined with the traffic concentration is sufficient to cause significant interference to those other cells.
3. A method by which one or more locations is identified as a strong source of interference if the low path loss from that location to antennas at other cells combined with the traffic concentration and the mobile power level is sufficient to cause significant interference to those other cells.
4. A method that identifies optimal adjustments to antennas or other configuration changes that reduce the path loss from the serving cell or cells to the identified area thereby reducing the mobile power level and the resulting interference impact.
5. A method that identifies network parameter and configuration changes that allow mobiles to operate at lower power levels thereby reducing interference to other cells
6. A method by which modifications to antennas at sites that are subject to interference from the identified area are selected to reduce antenna gain in the direction of the identified area thereby reducing interference.
7. A method by which a desirable location for a new cell, micro-cell, pico-cell or repeater is selected based in whole or in part on its potential to reduce the mobile transmit power in a high interference location.



8. A method that identifies network faults or previously unknown sources of degradation to network performance based on unexpected mobile power levels.
9. A method that recommends changes to antennas that minimize total network uplink interference without identifying specific areas that contribute interference but minimizes the aggregation of interference. In other words, an optimization algorithm will consider the combined interference throughout the network but, implicitly, the algorithm will be considering the combination of multiple interference areas. Indeed an effective optimization algorithm depends on having a precise method for estimating total interference. This does not require the identification of interference hot spots but does require having a way of estimating the total interference based on the interference from each point.

2. Interference Suppression

1240

John Carlson should do the main write up for this one. The only thing I would add to John's original idea is the idea of using an inconclusive measurement as an upper limit to the possible received signal strength, which would put a lower bound on the path loss.

Closest Prior Work Known: John Carlson would be able to answer this.

Description

In an operational network that is being run efficiently it will often be difficult to employ the interference merely using the avoidance techniques described below. To reduce the amount of interference that must be avoided interference suppression techniques may be used. There are various methods for suppressing interference. Many common techniques use DSP however, in this discussion, the suppression technique itself is secondary. The primary idea being captured is the idea of combining interference suppression with geo-location in order to obtain essentially interference free measurements by location.

Those measurements may then be augmented with additional information about the transmit level of the remote terminal at the time of the measurement. The combination then allows a path loss value to be calculated between a base station and a particular location. The resulting path loss data may then be applied to up-link or downlink path analysis and other models of network behavior may be produced.

Possible Claims

1. A method comprising the following steps
 - a. Using interference suppression techniques to obtain a sufficiently accurate measure of signal level that would be obtained in the absence of noise and interference in order to obtain a received signal level *at a known location*
 - b. Subtracting the received signal level from a known transmit level to obtain a path loss value
2. A method comprising the following steps
 - a. Obtaining a template of a signal from a receiver with a reasonably strong measurement of a signal *at a known location*
 - b. Sweeping that template across a recorded signal of the same frequency and time period at receiver at another location
 - c. Using the maximum limit of any correlation peaks to set an upper bound to the possible received signal level at another cell. (In other words, if the correlation peak is low we may have nothing to measure except noise and we would be unable to obtain an accurate

estimate of the received signal level but we could be reasonably confident that the maximum signal level must be less than the noise and interference level minus the effective interference rejection offered by the signal template)

3. Path Loss Measurement By Avoiding Interference

1241

Closest Prior Work Known:

ScoreBoard and other companies routinely planned drive tests in which a channel was used as a beacon at each sector in an area. Later when we developed the ability to collect data off of live voice traffic we reviewed frequency plans for excessive channel/color code conflicts but we did not systematically work to avoid interference on at least one channel.

If we find that there are existing patents that overlap we could narrow the claims by including a step of suppressing interference in combination with the described steps.

Description

Some measurement systems may be unable to suppress interference on the up-link or the downlink. If inference cannot be suppressed it must be avoided or limited.

Please note that the interference discussed below may be interference to sectors that do not serve a particular location. Therefore the challenges of avoiding interference are greater than avoiding interference to sectors that serve a location and are typically among the strongest signals in the area.

In one embodiment of these methods one or several channels may be assigned uniquely to one sector at a time to ensure that any measurements on that frequency correspond to the one sector to which it is assigned. A slight improvement on this embodiment is to allow the measurement frequencies to be assigned to more than one frequency provided that the cells or sectors that are sharing frequencies are sufficiently separated by distance and or antenna orientation to ensure a minimal risk of mistakenly attributing the source of the signals.

A more efficient embodiment is to assign channels in such a way that there is a patchwork of sufficiently interference free areas associated with each potential measurement channel. Sophisticated software can be used to ensure that the patchwork of interference free areas combines into a contiguous whole for each sector to produce a complete path loss depiction for each sector.

Another preferred embodiment might involve a system that detects which frequencies are in use on any particular cell at a given moment. By having information that a particular channel is not assigned to other potentially interfering² cells or sectors a patch work of sufficiently interference free measurements could be produced opportunistically as sufficiently interference free channels randomly become available.

Possible Claims

1. A method by which signal levels are measured on the downlink and:

² Not in the sense that network performance would be degraded but rather in the sense that measurements would be degraded or unreliable.



- i. Height AGL
- ii. Orientation
- iii. Tilt

7. Network data

- a. Channel assignments
- b. Transmit power levels 
- c. Neighbor lists/handover parameters
 - i. Trigger thresholds
 - ii. Hysteresis values 
- d. Neighbor lists
- e. MAHO measurement list



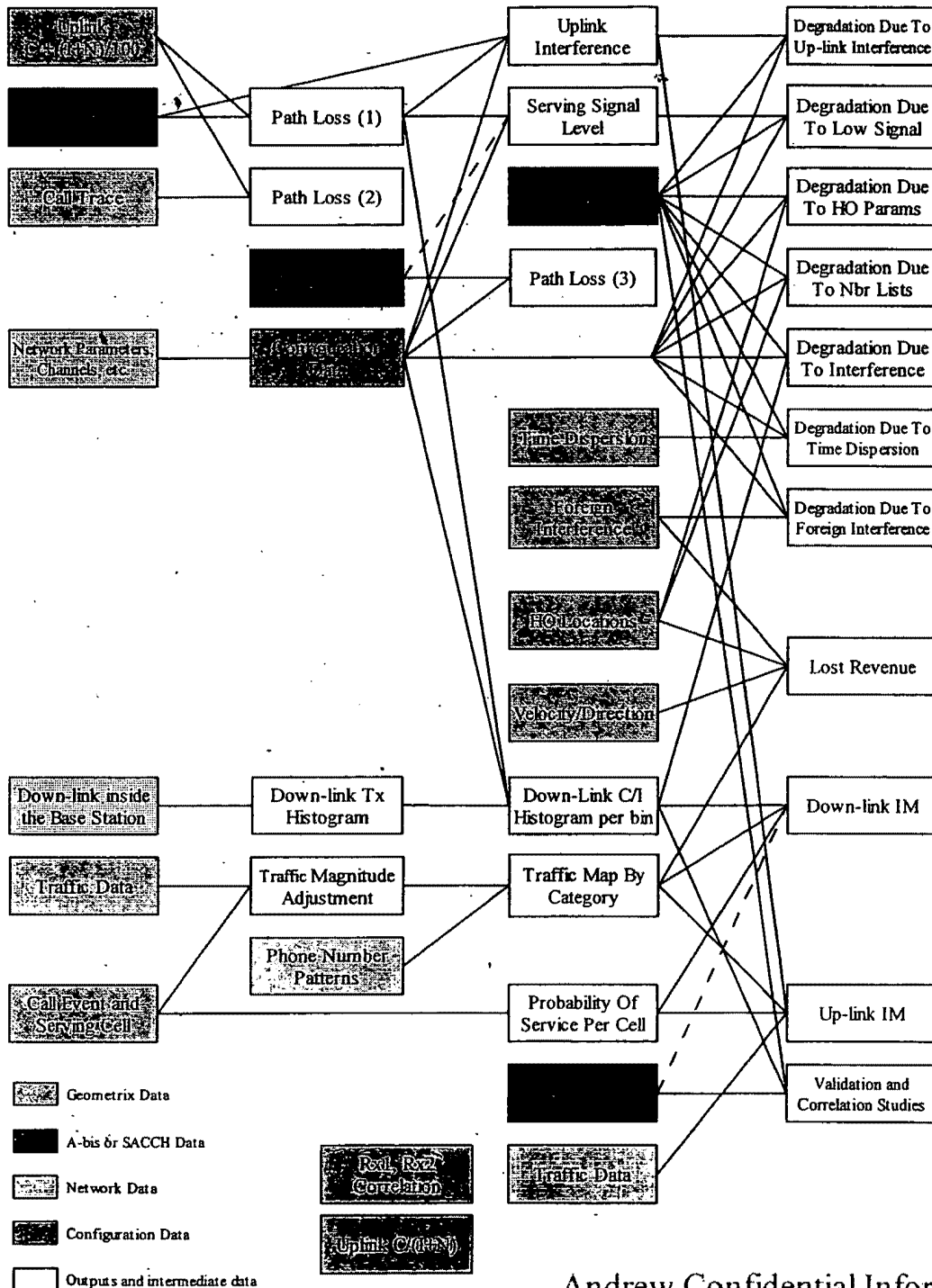
Products

1. Probability of service per sector per bin
2. Path loss
 - a. Average per sector per bin
 - b. Histogram per sector per bin
 - c. Joint histogram per sector-pair per bin
3. Relative Path Loss
 - a. Average per sector per bin
 - b. Histogram per sector per bin
4. Down-link C/I
 - a. Average⁵ per sector pair per bin
 - b. Histogram per sector pair per bin
5. Up-link interference
 - a. Average interference from each serving sector to every other sector per bin
 - b. Histogram of interference from each serving sector to every other sector per bin
6. Traffic
 - a. Total traffic per bin
 - b. Traffic by area code
 - c. GPRS traffic
7. Billing record verification
8. Identify non-network interference sources
9. Show handovers into/out of other networks that could indicate lost revenue
10. Identify sources of degradation due to
 - a. Interference
 - b. Low serving signal level
 - c. Sub-optimal HO parameters
 - d. Missing HO neighbors
 - e. None of the above ... what can we do with this?
11. Identify faulty antennas

⁵ Any average per bin value should also include a duty cycle estimate and the average should only apply to the time that the interference is present

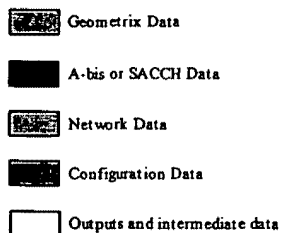
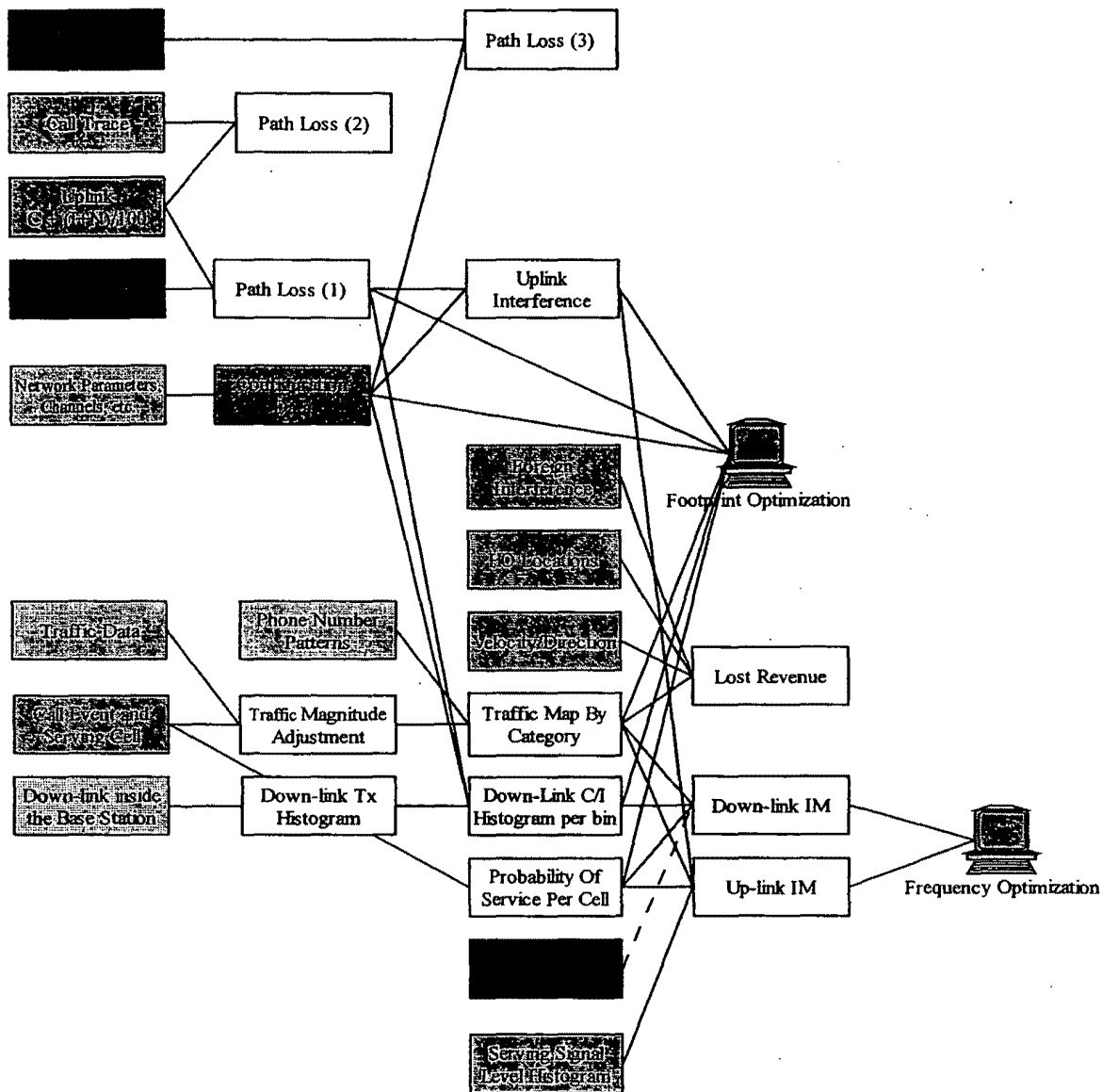


Data Relationships



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Data Relationships Without Degradation Analysis

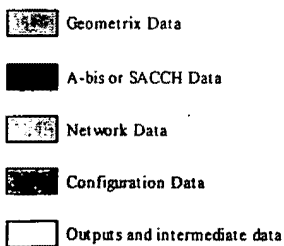
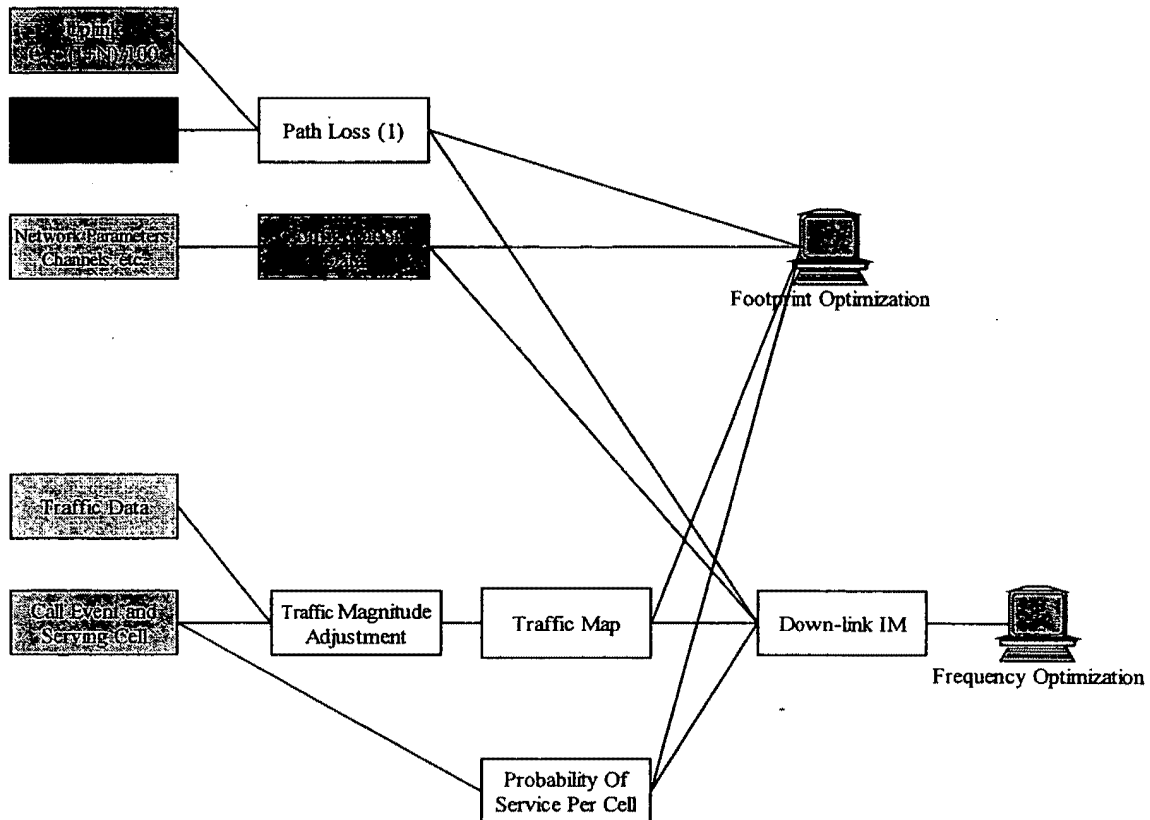


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Phase I Minimum Data Relationships



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Data Product Descriptions

A Few Comments On Binning

Geometrix will generate a river of events. In many locations there will be an abundance of events within a small area, which we call a bin. In other bins there might not be any events within the measurement period. If there are many events we may construct a histogram of signal levels. If there is not sufficient data for some sectors we may need to interpolate from data in other bins or use other PDM techniques to produce complete data for a bin.

If the data is collected over a long time and the data is sufficiently representative we may decide that we will assume that the probability of being served in a location is so low that we may ignore it. More commonly we are likely to find that there are too few measurements of interference from a sector in the vicinity of a bin to determine an accurate level. Assuming that sufficient data has been collected we may be justified in ignoring interference from that sector.

On the other hand in bins that have an abundance of data we will have a range of signal or interference levels. Here we must consider that the position accuracy of Geometrix in many cases will be insufficient to determine with confidence the bin in which the data was actually measured. Furthermore, in many instances, signal levels are known to change levels dramatically within a distance of 10 meters especially when we consider in-building measurements.

Traditional planning tools produce a single estimate of the mean path loss or signal per bin for each sector under consideration. Based on the Geometrix data we will also be able to produce a single measured mean value per bin but this would result in a tremendous amount of valuable information being lost. In particular, when power levels or antennas are being optimized to minimize overall network interference it will be valuable to maintain paired signal levels or path losses.

In other words imagine that a bin contains a tall building. At street level and in the lower levels of the building the serving and interfering signals will both be low. On upper levels of the building the interfering signal levels would increase but so would the serving level. Storing the average signal levels would completely lose this valuable information. Storing the histograms and then treating the serving and interfering signal levels would be a grossly false assumption and would lead to a substantial over-estimate of the severity of the interference.

On the other hand, if the serving cell antenna is nearby at the 2nd or 3rd story height the serving cell might be substantially stronger and interference quite weak on the lower levels of the building. On the higher levels of the building the serving levels would be lower but the interfering levels would be higher. In this case the serving and interfering signal levels would be negatively correlated. It would be important for the higher floors to be served by a different cell. This implies that we would want to store not only the joint histograms of the serving and interfering sectors but we might want to have separate histograms for each serving sector.

Another benefit of storing the coupled path loss values is a reduction in the effect of the variability in the mobile antenna gain. A mobile may report its transmit level but different mobiles will have different calibrations and the antenna gain could vary substantially. Storing the differences will reduce this source of error.



Event Data

Description

Most of the types of data described below will be geo-coded and the data will be associated with measurement events. To simplify the listings of the data inputs and outputs we will refer to 'Events'. An event is a measurement that is conducted on an active call. Each of these events will include the time and location of the event. These data fields are listed immediately below. Other types of data which are used by different modules are indicated in the description corresponding to the specific modules.

Data Fields

Time of the event

Latitude

Longitude

CEP67

Path Loss (1)

Inputs

Mobile Tx level from A-BIS or SACCH

Measured Rx Level = $C + (I + N) / 100$ from serving and potentially interfering sectors

Outputs

Uncoupled Data - For each bin:

Latitude

Longitude

For each sector with measurements:

Average path loss

Number of measurements or error margin

Type = 'measured' or 'lower limit'

Coupled Data - For each bin:

Latitude

Longitude

For each serving sector

Average path loss

Total number of measurements

For each potentially interfering sector:

Average path loss difference

Number of measurements or error margin



Description

Path loss is defined as the amount of loss between a transmitter and a receiver. More specifically:

$$L_p = P_t + G_t(\theta_t, \phi_t) + G_r(\theta_r, \phi_r) - P_r$$

We have some challenges because there are uncertainties about the mobile transmit level, the mobile radiation pattern, the pattern and position of the receive antenna. The mobile pattern is usually assumed to be an isotropic antenna with 0dBd gain. One approach used at ScoreBoard has been to include the antenna in the path loss but then the ability to deal with antenna changes is lost. The solution, as ugly as it is, is to assume that the information about the antenna position and its pattern (as installed) is accurate. The pattern may then be applied to estimate the *normalized* path loss.

One complexity that we have been able to ignore at ScoreBoard is the mixture of indoor and out-door data that will be combined in many locations. It is likely that we will need to store some information about the degree of correlation between interfering and serving signal levels. "What type of correlation data to store?" and "For how long?" will be some of the design considerations. Probably the simplest approach is to store the mean and variance of the individual values and the mean and variance of the difference between each server/interferer pair.

If each sector were accurately measured every time we would not need to store the mean differences for each pair because the difference of the means is the same as the mean of the differences. The trouble is that we don't get a valid path loss measurement for each sector every time. Even if we did get a measurement each time, we will still need to store the variance of the differences because that is not a linear operation.

Path Loss (2)

Inputs and Outputs

Please see Path Loss (1)

Description

If we only have Lbis data it is likely that we will not have accurate information about the mobile transmit level. In this case storing the path loss differences will be essential. Storing the differences without the absolute levels will still be useful for optimizing interference. What remains to be seen is how sparse the data will be. We probably won't have sufficient data to obtain a mean and variance for the difference in signal level between each pair. We will have to find creative ways to estimate the missing data.

We could chain the differences but the errors would accumulate. In other words if we have the difference between sector a and sector b and between b and c then we can infer the difference between a and c assuming that a, b, and c are all uncorrelated. It may turn out that we can tolerate a substantial amount of error without degrading some kinds of optimization. This will take some research.

Path Loss (3)

Inputs and Outputs

Please see Path Loss (1)



Description

This data should be largely redundant with path loss type 1 but there will be substantial differences that may be used to advantage. On the serving sector the type three data will be based on the base station transmit antenna. The up-link and down-link data may be compared to determine path imbalances and differences in the as-installed transmit and receive antenna patterns. This data may be used to detect faulty or mis-aligned antennas.

Another difference is which sites and sectors are measured. It may be easier to periodically update the list of channels that the mobile measures in order to produce a complete data set than it will be to modify the Geometrix software to collect data on various sites.

Down-link Tx Histogram

Inputs

The current channel assignments

Off the air measurements of received signal level

Outputs

Time period the histogram corresponds to.

Histograms of received signal level in 0.5 dB increments. One histogram for each frequency assigned to at least one sector at the base station there should be one histogram per hour.

Note

- We may want a new histogram per day or week in case there is a change in the site configuration or the channel assignments.
- We might want to see if the power levels differ by channel

Description

The antenna located inside each base station may be used to collect data that can be used to construct a histogram of the transmit power on the downlink of each sector at a base station. This data may be omitted from the early product releases but will add significant value. The current practice is to make some assumption about the affect of downlink power control. It can be simply modeled as an average power reduction or more sophisticated simulation techniques can be used to estimate the histogram. Having the actual histogram would be far more accurate.

If we do not provide the histogram the optimization tools that would be the clients for this type of data would conduct these simulations.

Traffic Magnitude Adjustment

Inputs

Per measurement event:



Event data
Serving Sector
Per sector
Erlangs of traffic per hour

Outputs

Per sector conversion factor found by dividing the traffic by the number of events.

Note

If the tipping mechanism changes then new magnitude adjustments must be determined.

Description

In order to convert measurement events to traffic density we must have a way of calibrating the conversion factor. The simplest way to do this is to divide the busy hour traffic by the total number of events. If we do this for each sector we will get a slightly different factor for each cell. This will help us to detect biases in our sampling techniques. In any case, the data from this step should probably not be presented to the customer but we will have to include it in order to produce the traffic maps.

Traffic Map By Category

Inputs

Per measurement event:
Event data
Telephone number and phone number patterns per category
Per sector
Traffic magnitude adjustment

Outputs

Amount of traffic per category per bin for various times of day, day of week, etc.

Description

If data is provided that allows traffic to be segregated by telephone number pattern or some other criteria we will be able to generate traffic layers by category, time of day, day of week, etc. These data layers can be used to generate more accurate interference matrixes (IM) than was previously possible. Alternately we can export these data layers directly to antenna optimization and site selection products.

Up-link Interference

Inputs

Probability of service per sector per bin
Option 1, uncoupled:

Andrew Corp. Confidential Information



Event data
Mobile Tx level
Path loss
Serving sector
Option 2, coupled:
Event data
Serving sector
Received signal level

Outputs

Interference per serving sector per Erlang per bin to every other sector

Note

What makes option 2 'coupled' is that we subtract the path loss from the Tx power to get the received power. By taking the difference we account for any correlation similar to what we would do for the downlink.

Description

It is well known that some areas such as hilltops are more prone to down-link interference than other areas. The converse is also true. Some areas are greater sources of uplink interference than others. For whatever reason regions may exist where the 'wrong' cell serves mobiles so that they are forced to increase power to stay on a call. If the path loss to other cells is actually lower then a significant amount of interference can result. It is not clear whether significant interference could occur if the handovers are operating correctly although anecdotal evidence suggests that these conditions may occur on IS95 networks from time to time.

Serving Signal Level

Inputs

Option 1 – Measured, includes power control:
Event data
Serving sector
The mobile reported serving signal level
Option 2 – Calculated, assumes full power on the downlink
Event data
Path loss to each serving sector
Downlink Tx Power for each serving sector

Outputs

Binned and averaged serving signal level per serving sector



Note

Option 1 is the actual serving signal level. Option 2 is the maximum level that *could* be used to serve the mobile.

Description

If we know the down-link transmit level and the path loss to a location then we can determine the serving signal level by taking the difference. We will be assuming that the base station is transmitting at full power. This is OK because we are looking for instances where quality is degraded due to low signal level. We will not find cases where the signal level is too low due to the base station transmitting at an inappropriately low level but we will catch the more typical case of signals being served in poor coverage areas.

Downlink C/I Histogram

Inputs

Max Tx power per sector

Downlink Tx Histograms

Per bin:

Serving signal level per server

Path loss to each potential interferer

Outputs

Received signal level histogram per sector per bin

Note

The results could be coupled or uncoupled or merely the average levels.

Description

The question is: How much detail do we need to store? In theory we could keep a histogram of path loss values for every server-interferer pair and then we could apply the transmit power histogram from each interferer and build an extremely detailed statistical model of all the interference. At the other extreme we could simply use the average levels and assume that everything is independent. Meaning, we can simply take the differences as has been done in the traditional planning tools.

Some optimization companies emphasize the importance of having excellent network models and simulation engines. Another approach we could take is to store detailed data for some markets or some time periods to be used to develop better network models and simulations. Having better models and simulations would then allow us to extract the more relevant data and reduce the need to store as much.

In the early releases we must make this simple so storing the average values would be the first step.



Probability Of Service

Inputs

Event data
Serving sector per event

Outputs

Probability of service per sector per bin

Description

This data is the probability of being served by a sector. We could have additional flavors such as the probability of initiating on a particular cell or the probability of westbound or eastbound traffic being served by a cell. The data is easy to generate. We divide the number of times a cell is a server by the total number of times any cell served that location.

Sparse data or limited measurement intervals will require some careful interpolation techniques.

Degradation Of Service

Inputs/Outputs

TBD

Description

For each type of degradation (BER/FER/RxQual/Voice/Data) we have a number of possible causes that we will be able to measure. Detecting the causes is a matter of having a model that relates the cause and the effect and then apply a process of elimination. The model can be as simple as a curve that relates $C/(I+N)$ to BER for example, or in the case of data latency a model that accounts for packet retransmissions may be required.

Several stages of analysis might be required to determine the ultimate cause of degradation. For example, interference conditions may be caused by the mobiles being served by a weak cell even though stronger cells which could result from incorrect handover parameters or missing handover neighbors. But further examination might indicate that the handovers are 'incorrect' only because some sector that is the usual server in a region is suffering from extreme path imbalance, which could indicate a misaligned antenna or defective cable.

These types of analysis will require substantial engineering expertise and some trial and error to determine the best data sources and methods. Therefore, these features would not be candidates for an early release. On the other hand we might be able to start with obvious diagnostics based on simple rules without doing a root cause analysis.



Lost Revenue

Inputs/Outputs

TBD

Description

This is a potentially valuable product that would open lines of business with non-technical departments within AWS and other operators. The main challenge is credibility. To estimate lost revenue we must:

- Identify areas within the legally defined service area that are served by another operator
- Estimate the amount of traffic that would be served in that area
- Estimate the revenue associated with that traffic

The difficult part is estimating the likely traffic in the areas served by other networks. If the areas are small islands we can assume traffic densities that are similar to the surrounding area. If they are border areas we might be able to use data about mobiles moving in and out of the area. If the areas are wider we will have to resort to more traditional methods to estimate traffic but we can have the most finely tuned traffic model ever.

This may seem like a reach but if we have even a little data that is unavailable elsewhere that can measurably increase revenue it will be a valuable tool for our customers.

Downlink IM (Interference Matrix)

Inputs

Traffic per category per bin

Coupled or un-coupled C/I per serving sector per bin

Probability of service per sector per bin

Outputs

C/I histogram per sector pair per bin⁶

Description

An IM is a matrix of values that reflect the cost of assigning co- or adjacent channels to a pair of sectors. This cost is estimated from MMR data or by applying some scoring function to the C/I in each bin across the service area of the cell receiving the interference. The accuracy of the estimate may be improved by weighting the scored interference by the amount of traffic in each bin.

⁶ That is, for each serving sector and every potentially interfering sector.



The accuracy of the results may be further improved with a more accurate estimate of the PDF of the interfering transmit power level.

Andrew could offer a service whereby the effects of proposed antenna changes or network parameters are modeled so that the resulting IM consists of the best available data plus well refined models that indicate the impact of configuration changes.

Up-link IM

Inputs

Up-link interference per serving sector per Erlang per bin

Traffic per bin

Probability of service per sector per bin

Serving signal level histogram per sector⁷

Outputs

Up-link C/I histogram per sector pair

Description

Similar to the downlink IM the up-link IM reflects the up-link quality impact of assigning co- or adjacent channels. If no antenna changes are planned the up-link IM may be based solely on up-link interference data collected during idle time slots or on frequencies that are not currently in use on the base station without any information about the locations of the interfering mobiles. Andrew would provide this as part of a package but this is an ante not a differentiator⁸.

A more interesting product would be a plot that indicates specific locations or regions where mobiles are generating a disproportionate amount of up-link interference. This would be a new kind of product. The only problem is: the value is unclear.

⁷ This could be derived from the serving signal level per bin or directly from other network data. If derived, it would be closely related to the code that estimates the up-link interference per bin.

⁸ ... if the customer even cares about it. Most operators seem to ignore up-link interference. If we can show that it does have a significant quality impact we may decide to go through the trouble of convincing customers of the value.



Data Relationships

Author: John Arpee - February 5, 2004

Summary

This paper describes the types of data that are available from Geometrix, products that could be based on the data and the relationships between them. The focus is on the main relationships. A task that remains is to identify the specific fields from each class of data that are required to produce each product.

E911 Data Only

If only the E911 data is available then we would lose the diagnostic capabilities, the path loss and interference information. The serving sector data would probably be sufficient for optimizing hand-over parameters. The traffic density might be adequate if the E911 data is sufficiently correlated with normal traffic patterns and is dense enough to produce statistically significant results. The E911 traffic data would not be adequate for monitoring traffic patterns dynamically.

Limited C/I information would be possible but have limited value because the data will only be available on cells that happen to be involved in the location measurement. For C/I data to be meaningful it must be possible to collect data on at least 40 other cells¹. If less than that number the data will be insufficient for optimization purposes.

How To Use This Document

There are two sections, "Data Sources" and "Products" that outline the types of data that is available and the products that could be produced. The most important data types from Geometrix that are required for optimization or troubleshooting are highlighted. The specific data fields that might be required from network configuration data are not explicitly identified.

The relationships between the data sources and products are depicted in the "Data Relationships" diagrams. The second diagram excludes those diagnostic data products that combine interference, coverage and network parameter information with performance statistics to identify probable causes of degradation.

This document focuses on data relationships. In a previous document² four categories of data (A-D) were identified. In this document the data sources indicated as colored blocks in the diagrams would correspond to the A category. The B1 products were the path loss and managed configuration data. This view does not distinguish between the input and output configuration data. There will need to be some business process to ensure the accuracy of the configuration data. The "Degradation due to ..." products correspond the C category. The traffic and "Likely Server" (renamed probability of service POS) products were identified as B2 products.

¹ This is an optimistic number. We will typically need to detect interference from over 30 other sectors but we won't be able to know *which* sectors in advance.

² We need to give it a title and we need a system track and store documents.



Disclosure

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Disclosure Outside Andrew

None of the disclosures in this document have been mentioned outside of Andrew with or without an NDA.

1. Estimation of Path Loss in Cellular Networks

Closest Prior Work Known: None

Description

There is interest in methods for obtaining path loss information between geographic areas within cellular networks, primarily for use in optimizing network capacity and performance. Some existing methods that are currently used center around a painstaking process of manually driving through a geographic area with special equipment that logs the real-time location of the equipment, and various measurement parameters made by a special test mobile phone. This data is then analyzed offline and paired with network configuration data in order to determine path loss, and offer insight into factors that affect the network, and may be used to monitor and optimize network performance.

One measurement made by this special test equipment is the path loss between the serving base station and the test mobile by comparing received signal strength at the mobile against the known transmit power of the base station. Measurement based techniques such as this have various advantages over theoretical estimation of path loss between geographic points of an area. It is commonly accepted that theoretical path loss calculations can never completely characterize the true path loss of an area due to the many factors specific to an area such as building locations, changes in terrain, etc. Therefore, performing network optimization is most effective when using measured path loss information rather than relying on potentially flawed estimates.

Due to the expensive and labor intensive process of manually driving through a geographic areas periodically to measure path loss information, there is a desire to make the collection process more automated and cover broader areas. This would potentially allow measurements to be taken more frequently in addition to reducing the cost of the making the measurements themselves. The method described in this invention disclosure describes an alternative method that addresses this need.

In the GSM network, mobile terminals constantly send the current transmitter power level to the base station on the uplink SACCH message (GSM 4.04, section 7.2). The reported power is sent as a 6 bit level which maps back to transmitter power in dBm (GSM 5.05, section 4.1). This level corresponds to the last 480ms period of the mobile transmission. When this data is paired with precise measurements of the received mobile signal strength at the base station for time periods directly mapping to the period over which MS power was reported, the true path loss can be calculated. The error of such a calculation of course lies within the tolerances of error for all components involved in the measurement and transmission process.

In cellular markets where a network overlay geolocation system is installed, there is direct access to the RF signals at the base station antennas. Through this mechanism, the received signal strengths of signals arriving at the antennas can be calculated over precise time periods. The geolocation system can also, over the air, decode the mobile transmit power as reported by the mobile and couple the received signal strength measured at one or more antennas for the exact same time period to produce path loss. In addition, the path loss calculations can be paired with the location of the mobile transmitter, as calculated by the geolocation system during the measurement process. Therefore, the network overlay geolocation system can be used to randomly locate as many callers as capacity allows, and produce a location estimate for each caller, and an estimate of the path loss between that geographic area and the serving base station. Additionally, the received signal strength of the mobile may also be measured at other cell sites in the vicinity of the mobile station, which will produce path loss estimates from that geographic area to any number of cell sites.

The result of this use of a network overlay geolocation system allows network operators to constantly assess path loss between geographic areas and cell sites, without the use of cooperative test mobiles and teams of drive tester personnel. Data backhaul and consolidation of data may be implemented with the existing infrastructure installed to support the network overlay geolocation system. Another benefit of such a system is that a much broader geographic area of measurements are provided than would be feasible to cooperatively measure with drive test equipment, such as in indoor locations, residential homes, offices, bodies of water, etc.

What is claimed is:



The remaining white boxes could be assigned to the B1 or B2 categories. One categorization could be as follows:

B1	B2
Average Down-link C/I	Traffic Maps
Down-link IM	Up-link Interference
Serving Signal Level At Max Down-link Power	Coupled Down-link C/I
	Down-link IM with power control
	Up-link IM
	Serving Signal Level With DPC
	Lost revenue

NCS Correlation data would not be a product. It is shown to emphasize that we will need to collect and manage some data relationships for validation and to identify potential new products.

Whether it makes sense to sell the downlink Tx histograms should be discussed when we eventually decide to produce it.

The 'Traffic Magnitude Adjustment' is a critical step but probably not a product per se.

For definitions and a more detailed description of each type of data please review the section titles "Data Product Descriptions".

1. A method for calculating path loss in a wireless cellular system, utilizing the estimated received signal strength measurements at base station antennas paired with the reported mobile transmitter power for a known, specific time period, at a specific geographic location.
 2. The method of (1), where the geographic location is computed by a network overlay geolocation system.
 3. The method of (1), where the geographic location is computed by any geolocation system.
 4. The method of (1), where the mobile transmitter power is provided to the path loss estimator equipment by the network overlay geolocation system.
 5. The method of (1), where the mobile transmitter power is provided to the path loss estimator equipment by any geolocation system.
 6. The method of (1), where the mobile transmitter power is provided to the path loss estimator equipment by an external mechanism.
 7. The method of (1), where the received signal strength measurements at the base station antennas are made by the network overlay geolocation system installed at the base station.
 8. The method of (1), where the received signal strength measurements at the base station antennas are made by the base station itself.
 9. The method of (1), where the received signal strength measurements at the base station antennas are made by some other external equipment.
-
10. A method for calculating path loss in a wireless cellular system, utilizing the estimated received signal strength measurements at one or more antennas paired with the reported mobile transmitter power for a known, specific time period, at a specific geographic location.
 11. The method of (10), where the geographic location is computed by a network overlay geolocation system.
 12. The method of (10), where the geographic location is computed by any geolocation system.
 13. The method of (10), where the mobile transmitter power is provided to the path loss estimator equipment by the network overlay geolocation system.
 14. The method of (10), where the mobile transmitter power is provided to the path loss estimator equipment by any geolocation system.
 15. The method of (10), where the mobile transmitter power is provided to the path loss estimator equipment by an external mechanism.
 16. The method of (10), where the received signal strength measurements at the antennas are made by the network overlay geolocation system.
 17. The method of (10), where the received signal strength measurements at the antennas are made by some other external equipment.



Data Sources

1. A-bis
 - a. Mobile phone number
 - b. Mobile transmit power level [REDACTED]
 - c. MMR data
 - d. BER/FER/RxQual
2. L-bis – 911 calls only
 - a. Mobile phone number
 - b. Mobile transmit power level (maybe) [REDACTED]
3. Geometrix position information
 - a. Location
 - b. Location accuracy (CEP)
 - c. Velocity (direction and magnitude)
4. Measured on the up-link
 - a. Serving sector
 - i. Received signal level plus noise and interference³
 - ii. Received signal level plus noise and interference suppressed by 20 dB⁴ [REDACTED]
 - iii. Error estimate
 - iv. Time dispersion
 - v. Correlation between diversity branches over 100 ms intervals
 - b. Non-serving sectors
 - i. Received signal level plus noise and interference [REDACTED]
 - ii. Received signal level plus noise and interference suppressed by 20 dB
 - iii. Error estimate
 - c. Not related to a specific call
 - i. Total up-link power (NOT geo-coded) [REDACTED]
 - ii. Error estimate
 - iii. Uplink power histogram from a bin for some types of interference (geo-coded)
5. Measured on the down-link inside the base station shelter
 - a. Signal level
 - b. FACCH [REDACTED]
 - c. SACCH
6. Planning tool data
 - a. Site locations
 - b. Antenna type
 - c. Antenna configuration [REDACTED]

³ This measurement is almost useless because there is no way to distinguish between the signal of interest and interference. We may be able to salvage some value if we can ensure that there is no interference according to the configuration data.

⁴ This is the essential ingredient for generating path loss data. We still need to change the tasking so that we get data for sectors that would not typically be included in the location measurement.

18. The methods of claim (1) or claim (10) where a precise timing mechanism is used to align the mobile transmission power with the measured received signal strength at one or more antennas for computed high precision path loss.
19. The methods of claim (1) and claim (10) where advanced signal processing methods are used to isolate the desired mobile signal, thereby improving the estimate of the received signal strength, through time, frequency, or spatial processing techniques, or any combination thereof.
20. The methods of claim (1) and claim (10) where the mobile signals of interest are GSM signals.
21. The methods of claim (1) and claim (10) where the mobile signals of interest are IS-136 signals.
22. The methods of claim (1) and claim (10) where the mobile signals of interest are IS-95 signals.
23. The methods of claim (1) and claim (10) where the mobile signals of interest are 1xRTT signals.
24. The methods of claim (1) and claim (10) where the mobile signals of interest are UMTS signals.

- a. Conservative models are used to identify any locations that might be prone to interference from one or more sectors
 - b. Based on the conservative interference analysis, a frequency plan is produced and implemented which ensures at least one channel per location that is sufficiently free of interference to produce sufficiently complete and accurate signal measurements.
 - c. Since we have minimized the likelihood that the measurements are corrupted by interference we may assume that the power level measurements are not contaminated by interference and we may subtract the received signal level from the transmit level to derive path loss at a location.
2. A method by which signal levels are measured on the up-link and:
- a. Conservative models are used to identify any cells that might be prone to interference from mobiles assigned to other sectors.
 - b. Based on the conservative interference analysis, a frequency plan is produced and implemented which ensures that at least one channel is sufficiently free of interference from interference caused by mobiles connected other sectors to produce sufficiently complete and accurate signal measurements.
 - c. Since we have minimized the likelihood that the measurements are corrupted by interference we may assume that the power level measurements are not contaminated by interference and we may subtract the received signal level from the transmit level to derive path loss at a location.
3. A method similar to 1 or 2 in which the following steps are added:
- a. Data is collected that is sufficient to ensure that there is a low probability of significant interference or between certain sectors.
 - b. The resulting data is used reduce the number of sites and sectors that must participate in the measurement process thereby reducing the consumption of resources required in the measurement process.
4. A method similar to 1 or 2 in which the step of producing a frequency plan to avoid the interference is replaced with a step in which channels in an existing frequency plan are selected for measurement based on the likely absence of interference.
5. A method in which interference free channels are identified or selected based on conservative interference criteria without resorting to a propagation model.
6. A method by which signal levels are measured on the up-link or the downlink and:
- a. The resulting data is reviewed to detect patterns which imply that data is missing due to interference at some locations
 - b. At those locations in which data appears to be missing a frequency plan is produced and implemented to avoid or reduce interference
 - c. New measurements are taken to determine if signals can be measured at or from mobiles in the suspected areas
 - d. A method similar to 1 or 2 in which it is determined that it is impossible to obtain a frequency plan that is sufficiently free of interference in all locations of interference. In the step of selecting a single frequency plan is replaced with
 1. Devising multiple frequency plans which:
 1. Ensure sufficiently interference free and complete data in some locations for at least one sector
 2. Ensure sufficiently complete data once all of the frequency plans have been implemented for some period of time

4. Using Call Trace Information

1242

Closest Prior Work Known: None

Description

This claim should be included as part of the patent John Carlson is filing that relates to using SACCH data. This method would be an alternate source of information for collecting performance data and information about the state of a mobile at a particular location.

The key idea is the idea of the system tracking the mobile on a continuous basis as opposed to logging and responding to messages generated by the mobile. In the way this is implemented today the two modes are executed very differently. In terms of the patent language it is not clear to me how much of a distinction there might be.

Possible Claims

1. A method by which selected remote stationary or mobile terminals are monitored by the serving network in conjunction with tracking by a geo-location system to generate geo-coded:
 - a. Transmit and receive levels
 - b. Performance data
 - c. Remote terminal states

5a. Terminal Location Data To Select Optimal Settings

1243

Closest Prior Work Known:

None known. However it would be worth searching OEM patents on this subject.

Description

The main idea in the first method is to hand-off the mobile or select frequencies and power levels to avoid interference to the up-link or downlink connection to the mobile *before* it experiences the interference. Most interference mitigation techniques today are *reactive*. That is, *once* degradation is experienced, mobiles may be handed off to other frequencies or cells. With this method historical or other information is used to anticipate interference or poor signal conditions and make the necessary adjustments *before* the degradation occurs based on information about the mobiles location and velocity.

The point of emphasizing communications paths in the second method is to highlight the need to consider both the up-link and the downlink. The objective is to produce the best overall quality for the greatest number of customers and whomever they may be communicating with. Of course the operator may decide to favor their paying customers at the expense of the non-paying parties they are communicating with or they may decide to treat them equally.

Similarly they may have different classes of customers, say: silver, gold, and platinum. They may prefer to serve their customers with different quality levels accordingly. Nevertheless, the goal would still be to provide the best overall quality however the quality is defined or weighted by customer, type of service or location.

Possible Claims

1. A method comprising the following steps:
 - a. Use propagation models or measurements or any other means to determine which cells are likely to provide low quality or high quality service in each location
 - b. Using information about the location and velocity of remote terminals to project the location of a mobile terminal in the near future
 - c. Apply the best settings and parameters including channel assignments and or connections to cells that are likely to offer the best service to the mobile terminals in the projected location in the projected time frame.
2. A method comprising the following steps:
 - a. Use any methods available to determine the interference impact of serving a mobile at a particular location on a particular cell and channel at a particular power level and data rate to all other communications paths in the network.
 - b. Using information or estimates about the network wide interference impact of a mobile at a particular location select the settings for the mobile that results in the best overall quality for some or all of the communications paths on the network.

5b. Using Location Information To Improve Handovers

Closest Prior Work Known: None

Description³

Current algorithms that determine when to trigger a handover process and which cell to hand the call to are based on signal level and call quality information. The performance of these handovers could be significantly improved by including location information in the handover decision.

If the handover process occurred instantaneously and if the interference impact of the mobile on other network users could be accurately determined in an instant there would be no benefit to including location information. Since this is not the case we can use location information to initiate handovers before a mobile enters a degraded state or causes excessive interference to other users of the network.

Note: This is closely related to number 6 above.

Possible Claims

1. A method in which:
 - a. The likely performance that will result when a mobile is served by a particular cell or sector at a location is gathered by some means

³ This disclosure is somewhat redundant with 5a. I had forgotten what I had written. A separate idea that might be worth patenting is the idea of using the same geo-coded data to optimize the traditional handover parameters.

- b. Based on the information in 1.a and the location and possibly the direction and speed of the mobile and possibly information about the time required to execute an handover the handover is initiated
2. A method similar to 1 in which the information in step 1.a is based on historical performance data of the network
3. A method similar to 1 in which the information in step 1.a is based on a model of network performance and information about the configuration of the network is used to estimate the likely performance of a mobile served by a particular sector at a location is estimated.
4. A method in which historical data or network models are used to select the best serving cell and parameter settings (including power levels and thresholds) *at a location* to produce the best likely overall performance for the mobile and other mobiles in the network.
5. A method in which:
 - a. The current location and velocity information are used to estimate the future location of a mobile in the time it would take to execute a handover
 - b. The methods in 4 are used to identify the best candidate serving sector so that the handover may be executed in time to be completed by the time the mobile arrives at the anticipated location
6. A method in which the proximity of a mobile to a location or area with degraded performance is used to trigger a location based handover process
7. A method in which the position and/or velocity of a mobile are used to trigger a handover process.
8. Use information about the short term and long term traffic distribution and interference per location to adjust handover parameters to shift traffic off of congested sectors onto less congested sectors in a manner that will maximize the quality of service for the reassigned traffic and the network as a whole. (I can add more detail)
9. Adjust antenna configuration, patterns, or tilts to maximize the performance of the network based on geo-coded interference and traffic data. (I can add more detail)

6. Performance Statistics

1244

Closest Prior Work Known: None

Description

A variety of performance statistics are measured by the mobile terminals and are reported back on the SACCH and/or FACCH. On a GSM system this data is further transmitted over the A-BIS interface. Using a geo-location system we can identify performance as measured by the mobile per location. We can extract the performance either directly from the SACCH or the A-BIS interface.

Once we have the performance by location and we can measure a variety of other aspects of the RF environment at the same location then we can develop hypothesis about what aspects of the environment are likely to have caused the degradation.

In other instances we may find that particular channels that perform poorly regardless of location. If there is no apparent relationship we may conclude that there is a hardware fault rather than some environmental factor. Or, similarly, if one channel in particular appears to degrade more severely with decreasing signal level on the up-link we might conclude that the sensitivity of a receiver is impaired.

Possible Claims

1. A method comprising the following steps:
 - a. Identify a location or cluster of nearby locations that is suffering from one or more type of degraded communications or telemetry or other service.
 - b. Measure one or more factors at the same or nearby locations that could directly or indirectly cause the observed degradation
 - c. Identify the measured factors that could explain the degraded performance
 - d. Identify network parameter settings on the serving and neighboring cells and cells related by network tables that could explain degraded performance in consideration of the measured conditions in the vicinity of the locations with degraded performance
 - e. Select the measured factors or network settings that are the most likely cause(s) of degradation
2. A method comprising the following steps:
 - a. Identify locations or areas that have experienced a degradation in performance
 - b. Identify sectors that have been changed in some way at the time the degradation occurred
 - c. Select the parameter (or power or antenna or any other kinds of changes) that most probably explain the degradation in quality
3. A method comprising the following steps:
 - a. Identify possible causes of degradation as described in 1 or 2
 - b. If no apparent sources of degradation exists then do one of more of:
 - i. Identify those areas for further inspection
 - ii. Modify the algorithms for identifying causes of degradation to include the newly discovered conditions
4. Augment the methods in 1 and 2 with additional data that is not available in the network configuration data or from the measurement system to allow the identification of other sources of degradation.
5. Identify differences in performance by channel or mobile terminal to isolate equipment related degradation.
6. A method comprising the following steps:
 - a. Identify a location or area of degraded service.
 - b. Estimate the maximum distance that mobile terminals are likely to travel while there is connected on a voice call or data session.
 - c. Consider characteristics of the RF environment out to the maximum distance and combination of network settings that could explain the degradation. (For example a small area where a cell is the dominant server but cells serving nearby areas are not included on the neighbor list)
7. Once potential sources of degradation have been identified and remedies have been implemented a method comprising the following steps⁴:

⁴ The idea of developing models is old. The question here is can we patent the narrower idea of using geo-coded performance data to learn about network behavior and then use that knowledge to build a system that 'learns' about performance as a function of the type of network, the network and RF configuration and the prevailing RF conditions at a location or within some distance of a location.

- a. Record the resulting success or failure in improving the performance in the affected areas. (In other words don't merely track performance but also relate it to implemented changes and the models used to predict the changes)
 - b. Record unexpected changes in performance (discrepancies between the actual outcome and the modeled outcome in non-target areas)
 - c. Over time use the results in (a) and (b) to improve the model.
 - d. And/or use the historical data to create a statistical model that indicates the probability of an outcome under various input conditions.
8. A method similar to 1 and 2 in which momentary equipment failures, outages, network congestion or other conditions are monitored and:
- a. The data related to the transitory conditions are not included in trend data thereby improving the accuracy of the trend estimates
 - b. The data related to the transitory conditions is highlighted to detect degradation caused by the transitory conditions.

7. Coupled Path Loss

1245

Closest Prior Work Known: None

Description

Please see the section titled "A Few Comments On Binning" in the "Data Relationships" document.

Key Idea

Even though measurements may be geo-coded there is a limit to the accuracy of the location information. Additionally there may be significant differences in height such as a location where a road passes under an elevated highway or in a multistory building. In these cases there may be substantially different signal conditions within a small area. By keeping information about the relationships between the different signals we may not have complete location information but we can take advantage of the positive or negative correlations between signal or path loss levels.

Possible Claims

1. A method consisting of the following steps:
 - a. Collect geo-coded path loss measurements on the same mobile to multiple base stations over a sufficiently short time frame that it is reasonable to assume that the mobile terminal has not moved significantly.
 - b. Record the relative signal levels
 - c. Build a multivariate histogram(s) of the signal levels or path loss values that link the path loss between two or more sectors
2. A method that uses the data from 1 to produce interference analyses that are more accurate than the current state of the art which merely compares the averages of the measurements on each sector.
3. A method that segregates the data according to the measured speed and direction of the mobile terminals



4. A method that combines information about the path loss or interference with information about the serving sector allowing the data to be segregated by serving sector.

8. Monitoring Specific Mobiles To Identify Quality Issues

1246

Closest Prior Work Known: None

Description

Specific users or mobiles may use geo-coded performance data to diagnose quality problems experienced. If a user complains about the quality of their service or if a customer has authorized the operator to conduct occasional audits valuable information may be collected about the quality of service they are receiving and what is causing any degradation in quality.

There are three possible causes of dissatisfaction:

1. Faulty subscriber equipment or incorrect configuration
2. Usage patterns. They might tend to use their phone in poor quality areas.
3. None of the above.

The availability of geo-coded performance information allows the cause to be determined.

This patent assumes that performance indicators may be captured off the air or from another network interface so that the performance monitoring system is able to evaluate the quality a subscriber is experiencing at any place or time.

Possible Claims

1. A method consisting of the following steps:
 - a. Log some or all of the calls the customer makes⁵
 - b. Note the fraction of time the user is using their phone in areas with known quality issues
 - c. Note the occasions that the customer is experiencing degraded quality
 - d. Is the degraded quality consistent with other customers in those locations
 - i. If yes then determine if the customers communications are disproportionately (compared to other customers) in the areas with degraded quality
 1. If 'yes' again, then we may conclude that the customer is experiencing poor quality due to their usage patterns
 2. Else we have a customer that is more demanding about the quality of service
 - ii. If the quality is worse than most other customers the customer may have a faulty or incorrectly configured terminal

⁵ A sufficiently representative sample set must be collected. We don't need all of the detail about the times during which the quality is good but we need enough information to know what portion of the time the customer is experiencing degraded service.

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Disclosure

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Disclosure Outside Andrew

None of the disclosures in this document have been mentioned outside of Andrew with or without an NDA.

Title: Enhanced RF Performance Measurements in a Geolocation System

Closest Prior Work Known: None

Description

This invention deals with the application of a network overlay geolocation system used for mobile phone location to be used for purposes beyond source localization. In this case, the purpose revolves primarily around making measurements for network optimization. It is commonly understood in the world of network optimization that interference is one of the largest contributors to poor call quality, dropped calls, poor coverage, and capacity constraints in a cellular network. Thus, much work has been done in the area of prediction and measurement of interference levels per geographic region to attempt to reduce levels to tolerable amounts. The prediction of interference levels is limited, mainly due to the fact that assumptions are made about statistical path loss and terrain morphology. Since these are assumptions, and due to the large variability of terrain and environmental conditions, there will be errors present in the prediction of interference levels. Another means for measuring interference is using sophisticated receivers that may be part of drive testing equipment used by carriers. This equipment is most likely very expensive, and limited to only providing data when used during active drive testing in a network. Therefore, the amount of data that can be collected is small in comparison to the coverage area and call volume of a network.

When a network overlay location system is installed in a carrier network, this significant equipment asset could be utilized for purposes other than simply location of wireless callers. A network overlay location system, such as Andrew Corporation's "Geometrix", is composed of sophisticated digital receivers, digital signal processors, it has knowledge of the complete network configuration, and has communication lines for remote control and configuration of the equipment. It is the subject of this invention to disclose how high sensitivity RF receiver assets, such as a network overlay location system, could be used to make high quality measurements of cellular signals for the purpose of network optimization, specifically through advanced interference detection algorithms. In addition, the location system could operate



in a mode where locations and measurements are continually being calculated, making the volume of network optimization much larger and more diverse than through controlled drive testing.

A network overlay geolocation system such as Geometrix relies on its ability to make high quality measurements of very weak and corrupted signals from many base stations in order to produce accurate location estimates. It is not uncommon to have eight or more location sensors, located in base stations, extracting useful timing or angle measurements from a target uplink mobile signal that may be even tens of kilometers away. There are many instances where the signals of interest in the remote base stations are either below the thermal noise level, or significantly lower in power than co-channel signals. The key component for achieving this high level of sensitivity revolves around the very high processing gain, realized from lengthly coherent signal integration periods. This is possible through the following mechanism: Geometrix simultaneously collects large buffers of signal data from multiple base stations, and attempts to demodulate the transmitted data from each site. The site that has the best reception is chosen as the "primary" site and from that point on, the primary site is used to demodulate the data that is transmitted over the air, which is then decoded and passed back to a central server. The central server then distributes this data to all the "secondary" base stations that contain Geometrix equipment and had collected RF signal data at approximately the same time as the "primary" site. The "secondary" sites then digitally modulate the data to form an error-free version of the transmitted RF signal, which is used to effectively boost the reception of that specific waveform by 20dB or more in power. This processing gain is realized through the calculation of a space-time-frequency cross-ambiguity function, where the maximas provide measurements on relative arrival times, frequency shifts, and possibly arrival angles of signal receipts that are highly correlated to the signal of interest. An interesting byproduct of this computationally intensive process, is that there is much more information that can be gathered about the signal environment that what is readily needed for simply computing the location of mobile phones.

It is the intent of this disclosure to claim intellectual property rights to a set of inventions that stem from the use of high sensitivity RF receiving equipment such as a geolocation system and its unique processing abilities to not only make location estimates, but to then make other signal and interference related measurements that have utility in the optimization and refinement of RF planning. The set of inventions revolve around the system's ability to use the "primary" and "secondary" measurement arrangement as described above to provide large processing gain and processing resources and algorithms, that when paired with the estimated location of a mobile, becomes a rich source of data that may be used for network optimization.

The following is a list of uses related to topic aforementioned:

1. Using an RF receiver system, such as a geolocation system, to simultaneously locate mobiles and make measurements relating to parameters of interest for network optimization, through the unique ability of the system to use the known transmitted mobile information in an effort to provide high accuracy assessments of interference levels that would otherwise be unavailable.
2. In addition to (1), to provide accurate assessments of the target signal level in the presence of high interference, for the purpose of computing the path loss between the estimated location of the mobile and surrounding base stations, or receiver sensors.
3. Using an RF receiver system, such as a geolocation system, to detect the presence of interference (as in (1)), then attempt to decode and identify the interfering signals. In addition to identification and possibly demodulation of the interfering signals, the system could be used to then locate the geographic origin of the interference source. If the interference sources could not be demodulated, it may still be possible to perform source localization of the interference. If localization is not successful, lines of bearing of the interference source may be estimated when the receiving equipment supports angle of arrival estimation.



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Network Solutions

GeoData Data Relationships

Version 3.0
March 3, 2004



Document Revision History

Revision	Date	Name	Description of Change	Reason for Change
1.0	February 5, 2004	John Arpee	Initial Draft	
2.0	February 24, 2004	John Arpee	Added inputs and outputs	To clarify development requirements
3.0	March 3, 2004	John Arpee, John Carlson	Added appendixes on data sources and a description of SACCH data	To complete the overview of available data and applications



Data Relationships

Author: John Arpee - February 5, 2004

Summary

This paper describes the types of data that are available from Geometrix, products that could be based on the data and the relationships between them. The focus is on the main relationships. A task that remains is to identify the specific fields from each class of data that are required to produce each product.

E911 Data Only

If only the E911 data is available then we would lose the diagnostic capabilities, the path loss and interference information. The serving sector data would probably be sufficient for optimizing hand-over parameters. The traffic density might be adequate if the E911 data is sufficiently correlated with normal traffic patterns and is dense enough to produce statistically significant results. The E911 traffic data would not be adequate for monitoring traffic patterns dynamically.

Limited C/I information would be possible but have limited value because the data will only be available on cells that happen to be involved in the location measurement. For C/I data to be meaningful it must be possible to collect data on at least 40 other cells¹. If less than that number the data will be insufficient for optimization purposes.

How To Use This Document

There are two sections, "Data Sources" and "Products" that outline the types of data that is available and the products that could be produced. The most important data types from Geometrix that are required for optimization or troubleshooting are highlighted. The specific data fields that might be required from network configuration data are not explicitly identified.

The relationships between the data sources and products are depicted in the "Data Relationships" diagrams. The second diagram excludes those diagnostic data products that combine interference, coverage and network parameter information with performance statistics to identify probable causes of degradation.

This document focuses on data relationships. In a previous document² four categories of data (A-D) were identified. In this document the data sources indicated as colored blocks in the diagrams would correspond to the A category. The B1 products were the path loss and managed configuration data. This view does not distinguish between the input and output configuration data. There will need to be some business process to ensure the accuracy of the configuration data. The "Degradation due to ..." products correspond to the C category. The traffic and "Likely Server" (renamed probability of service POS) products were identified as B2 products.

¹ This is an optimistic number. We will typically need to detect interference from over 30 other sectors but we won't be able to know *which* sectors in advance.

² We need to give it a title and we need a system track and store documents.



The remaining white boxes could be assigned to the B1 or B2 categories. One categorization could be as follows:

B1	B2
Average Down-link C/I	Traffic Maps
Down-link IM	Up-link Interference
Serving Signal Level At Max Down-link Power	Coupled Down-link C/I
	Down-link IM with power control
	Up-link IM
	Serving Signal Level With DPC
	Lost revenue

NCS Correlation data would not be a product. It is shown to emphasize that we will need to collect and manage some data relationships for validation and to identify potential new products.

Whether it makes sense to sell the downlink Tx histograms should be discussed when we eventually decide to produce it.

The 'Traffic Magnitude Adjustment' is a critical step but probably not a product per se.

For definitions and a more detailed description of each type of data please review the section titles "Data Product Descriptions".

SACCH Data Versus AMU Data

The AMU monitors the A-BIS interface so AMU data is really A-BIS data.

Early on in the project it was believed by some of us that A-BIS data would be required for initiating call measurements and to acquire data mobile reported measurements. Currently the prevailing wisdom is that practically all of the data of interest that is available on A-BIS can also be read from the air interface (Please see Appendix A). The remaining arguments for keeping the AMU are:

- Removing the AMU will prevent us from correcting bit errors which will reduce the location accuracy by up to 15%
- Having the AMU simplifies the tipping task
- Some data such as AMR Codec rates will be lost. We must clarify what data exactly will not be available.
- We have not done an extensive survey to see if the SACCH is ever encrypted or whether it can be encrypted. Until this is done there is a risk that we will lose access to this data at some point in the future or it will not be available in some markets.



Data Sources

1. A-bis or SACCH
 - a. Mobile phone number
 - b. Mobile transmit power level [REDACTED]
 - c. MMR data
 - d. BER/FER/RxQual
2. L-bis – 911 calls only
 - a. Mobile phone number
 - b. Mobile transmit power level (maybe) [REDACTED]
3. Geometrix position information
 - a. Location
 - b. Location accuracy (CEP)
 - c. Velocity (direction and magnitude)
4. Measured on the up-link
 - a. Serving sector
 - i. Received signal level plus noise and interference³
 - ii. Received signal level plus noise and interference suppressed by 20 dB⁴ [REDACTED]
 - iii. Error estimate
 - iv. Time dispersion
 - v. Correlation between diversity branches over 100 ms intervals
 - b. Non-serving sectors
 - i. Received signal level plus noise and interference [REDACTED]
 - ii. Received signal level plus noise and interference suppressed by 20 dB
 - iii. Error estimate
 - c. Not related to a specific call
 - i. Total up-link power (NOT geo-coded) [REDACTED]
 - ii. Error estimate
 - iii. Uplink power histogram from a bin for some types of interference (geo-coded)
5. Measured on the down-link inside the base station shelter
 - a. Signal level
 - b. FACCH [REDACTED]
 - c. SACCH
6. Planning tool data
 - a. Site locations
 - b. Antenna type
 - c. Antenna configuration [REDACTED]

³ This measurement is almost useless because there is no way to distinguish between the signal of interest and interference. We may be able to salvage some value if we can ensure that there is no interference according to the configuration data.

⁴ This is the essential ingredient for generating path loss data. We still need to change the tasking so that we get data for sectors that would not typically be included in the location measurement.



- i. Height AGL
 - ii. Orientation
 - iii. Tilt
- 7. Network data
 - a. Channel assignments
 - b. Transmit power levels 
 - c. Neighbor lists/handover parameters
 - i. Trigger thresholds
 - ii. Hysteresis values 
 - d. Neighbor lists
 - e. MAHO measurement list



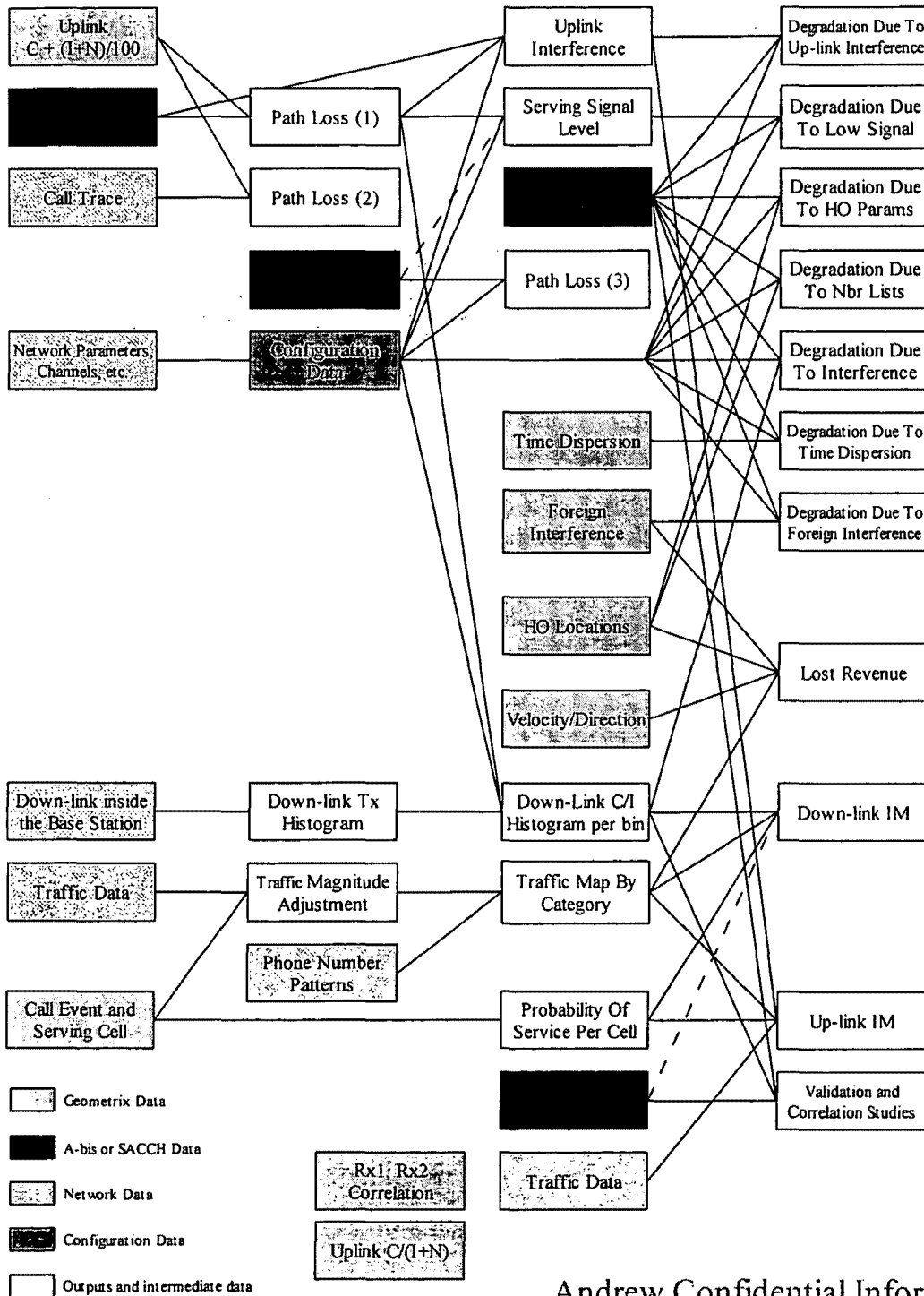
Products

1. Probability of service per sector per bin
2. Path loss
 - a. Average per sector per bin
 - b. Histogram per sector per bin
 - c. Joint histogram per sector-pair per bin
3. Relative Path Loss
 - a. Average per sector per bin
 - b. Histogram per sector per bin
4. Down-link C/I
 - a. Average⁵ per sector pair per bin
 - b. Histogram per sector pair per bin
5. Up-link interference
 - a. Average interference from each serving sector to every other sector per bin
 - b. Histogram of interference from each serving sector to every other sector per bin
6. Traffic
 - a. Total traffic per bin
 - b. Traffic by area code
 - c. GPRS traffic
7. Billing record verification
8. Identify non-network interference sources
9. Show handovers into/out of other networks that could indicate lost revenue
10. Identify sources of degradation due to
 - a. Interference
 - b. Low serving signal level
 - c. Sub-optimal HO parameters
 - d. Missing HO neighbors
 - e. None of the above ... what can we do with this?
11. Identify faulty antennas

⁵ Any average per bin value should also include a duty cycle estimate and the average should only apply to the time that the interference is present



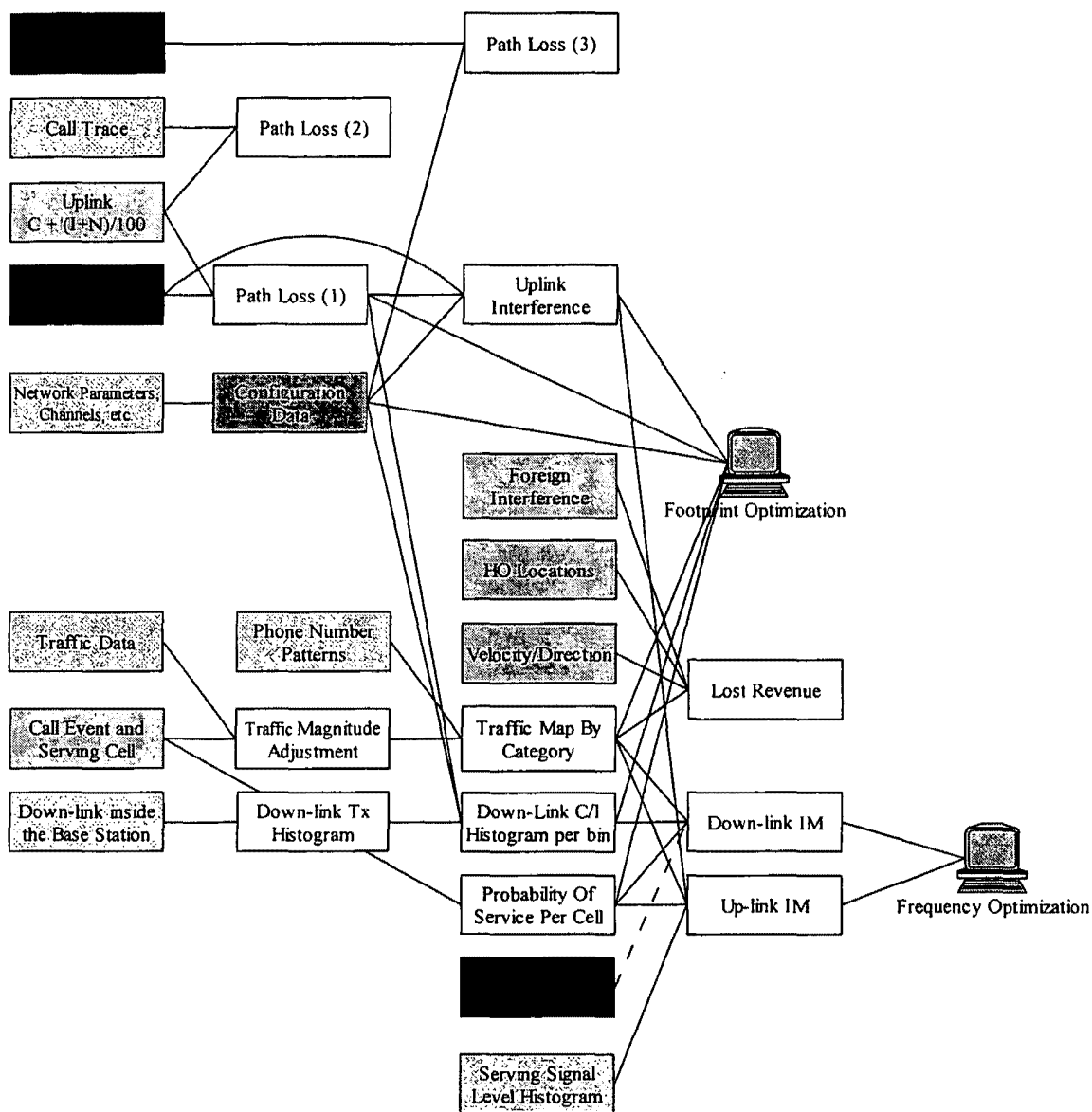
Data Relationships



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Data Relationships Without Degradation Analysis

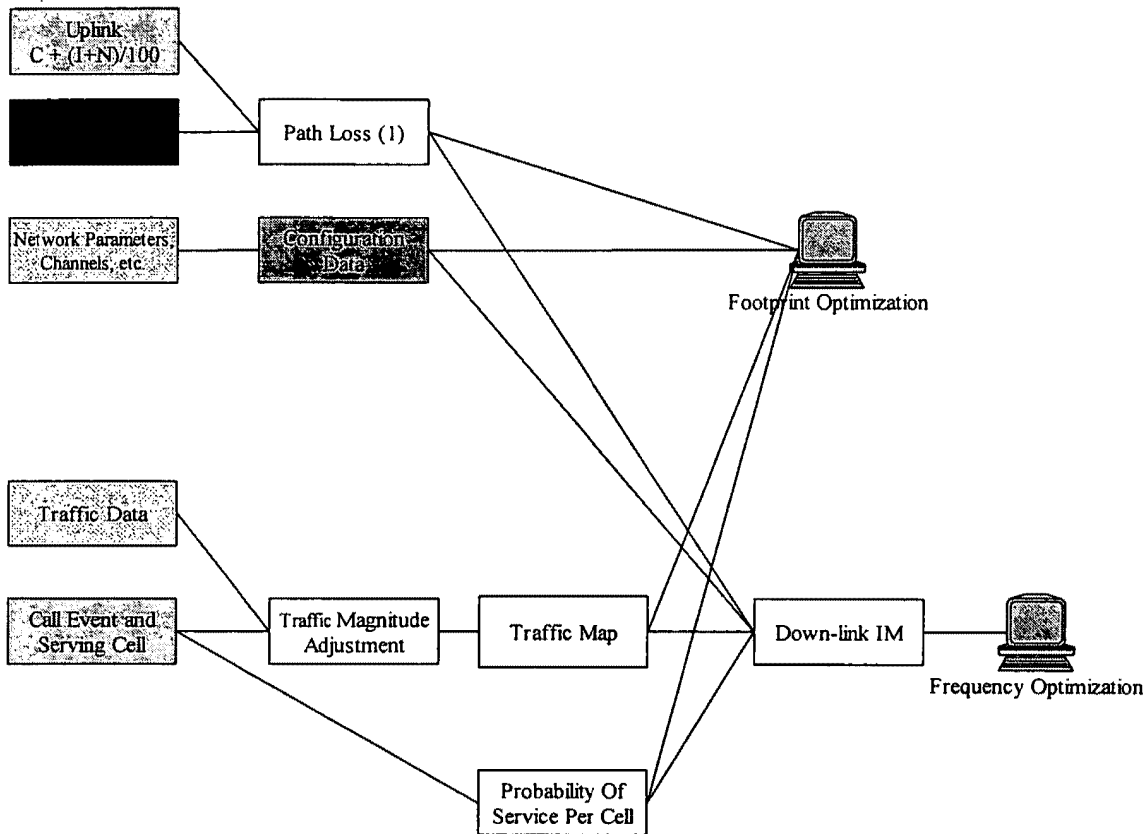


-  Geometrix Data
-  A-bis or SACCH Data
-  Network Data
-  Configuration Data
-  Outputs and intermediate data

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Phase I Minimum Data Relationships



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Data Product Descriptions

A Few Comments On Binning

Geometrix will generate a river of events. In many locations there will be an abundance of events within a small area, which we call a bin. In other bins there might not be any events within the measurement period. If there are many events we may construct a histogram of signal levels. If there is not sufficient data for some sectors we may need to interpolate from data in other bins or use other PDM techniques to produce complete data for a bin.

If the data is collected over a long time and the data is sufficiently representative we may decide that we will assume that the probability of being served in a location is so low that we may ignore it. More commonly we are likely to find that there are too few measurements of interference from a sector in the vicinity of a bin to determine an accurate level. Assuming that sufficient data has been collected we may be justified in ignoring interference from that sector.

On the other hand in bins that have an abundance of data we will have a range of signal or interference levels. Here we must consider that the position accuracy of Geometrix in many cases will be insufficient to determine with confidence the bin in which the data was actually measured. Furthermore, in many instances, signal levels are known to change levels dramatically within a distance of 10 meters especially when we consider in-building measurements.

Traditional planning tools produce a single estimate of the mean path loss or signal per bin for each sector under consideration. Based on the Geometrix data we will also be able to produce a single measured mean value per bin but this would result in a tremendous amount of valuable information being lost. In particular, when power levels or antennas are being optimized to minimize overall network interference it will be valuable to maintain paired signal levels or path losses.

In other words imagine that a bin contains a tall building. At street level and in the lower levels of the building the serving and interfering signals will both be low. On upper levels of the building the interfering signal levels would increase but so would the serving level. Storing the average signal levels would completely lose this valuable information. Storing the histograms and then treating the serving and interfering signal levels would be a grossly false assumption and would lead to a substantial over-estimate of the severity of the interference.

On the other hand, if the serving cell antenna is nearby at the 2nd or 3rd story height the serving cell might be substantially stronger and interference quite weak on the lower levels of the building. On the higher levels of the building the serving levels would be lower but the interfering levels would be higher. In this case the serving and interfering signal levels would be negatively correlated. It would be important for the higher floors to be served by a different cell. This implies that we would want to store not only the joint histograms of the serving and interfering sectors but we might want to have separate histograms for each serving sector.

Another benefit of storing the coupled path loss values is a reduction in the effect of the variability in the mobile antenna gain. A mobile may report its transmit level but different mobiles will have different calibrations and the antenna gain could vary substantially. Storing the differences will reduce this source of error.



Event Data

Description

Most of the types of data described below will be geo-coded and the data will be associated with measurement events. To simplify the listings of the data inputs and outputs we will refer to 'Events'. An event is a measurement that is conducted on an active call. Each of these events will include the time and location of the event. These data fields are listed immediately below. Other types of data which are used by different modules are indicated in the description corresponding to the specific modules.

Data Fields

Time of the event

Latitude

Longitude

CEP67

Path Loss (1)

Inputs

Mobile Tx level from A-BIS or SACCH

Measured Rx Level = $C + (I + N) / 100$ from serving and potentially interfering sectors

Outputs

Uncoupled Data - For each bin:

Latitude

Longitude

For each sector with measurements:

Average path loss

Number of measurements or error margin

Type = 'measured' or 'lower limit'

Coupled Data - For each bin:

Latitude

Longitude

For each serving sector

Average path loss

Total number of measurements

For each potentially interfering sector:

Average path loss difference

Number of measurements or error margin



Description

Path loss is defined as the amount of loss between a transmitter and a receiver. More specifically:

$$L_p = P_t + G_t(\theta_t, \phi_t) + G_r(\theta_r, \phi_r) - P_r$$

We have some challenges because there are uncertainties about the mobile transmit level, the mobile radiation pattern, the pattern and position of the receive antenna. The mobile pattern is usually assumed to be an isotropic antenna with 0dBd gain. One approach used at ScoreBoard has been to include the antenna in the path loss but then the ability to deal with antenna changes is lost. The solution, as ugly as it is, is to assume that the information about the antenna position and its pattern (as installed) is accurate. The pattern may then be applied to estimate the *normalized* path loss.

One complexity that we have been able to ignore at ScoreBoard is the mixture of indoor and out-door data that will be combined in many locations. It is likely that we will need to store some information about the degree of correlation between interfering and serving signal levels. "What type of correlation data to store?" and "For how long?" will be some of the design considerations. Probably the simplest approach is to store the mean and variance of the individual values and the mean and variance of the difference between each server/interferer pair.

If each sector were accurately measured every time we would not need to store the mean differences for each pair because the difference of the means is the same as the mean of the differences. The trouble is that we don't get a valid path loss measurement for each sector every time. Even if we did get a measurement each time, we will still need to store the variance of the differences because that is not a linear operation.

Path Loss (2)

Inputs and Outputs

Please see Path Loss (1)

Description

If we only have Lbis data it is likely that we will not have accurate information about the mobile transmit level. In this case storing the path loss differences will be essential. Storing the differences without the absolute levels will still be useful for optimizing interference. What remains to be seen is how sparse the data will be. We probably won't have sufficient data to obtain a mean and variance for the difference in signal level between each pair. We will have to find creative ways to estimate the missing data.

We could chain the differences but the errors would accumulate. In other words if we have the difference between sector a and sector b and between b and c then we can infer the difference between a and c assuming that a, b, and c are all uncorrelated. It may turn out that we can tolerate a substantial amount of error without degrading some kinds of optimization. This will take some research.

Path Loss (3)

Inputs and Outputs

Please see Path Loss (1)



Description

This data should be largely redundant with path loss type 1 but there will be substantial differences that may be used to advantage. On the serving sector the type three data will be based on the base station transmit antenna. The up-link and down-link data may be compared to determine path imbalances and differences in the as-installed transmit and receive antenna patterns. This data may be used to detect faulty or mis-aligned antennas.

Another difference is which sites and sectors are measured. It may be easier to periodically update the list of channels that the mobile measures in order to produce a complete data set than it will be to modify the Geometrix software to collect data on various sites.

Down-link Tx Histogram

Inputs

The current channel assignments

Off the air measurements of received signal level

Outputs

Time period the histogram corresponds to.

Histograms of received signal level in 0.5 dB increments. One histogram for each frequency assigned to at least one sector at the base station there should be one histogram per hour.

Note

- We may want a new histogram per day or week in case there is a change in the site configuration or the channel assignments.
- We might want to see if the power levels differ by channel

Description

The antenna located inside each base station may be used to collect data that can be used to construct a histogram of the transmit power on the downlink of each sector at a base station. This data may be omitted from the early product releases but will add significant value. The current practice is to make some assumption about the affect of downlink power control. It can be simply modeled as an average power reduction or more sophisticated simulation techniques can be used to estimate the histogram. Having the actual histogram would be far more accurate.

If we do not provide the histogram the optimization tools that would be the clients for this type of data would conduct these simulations.

Traffic Magnitude Adjustment

Inputs

Per measurement event:

Event data

Serving Sector



Per sector

Erlangs of traffic per hour

Outputs

Per sector conversion factor found by dividing the traffic by the number of events.

Note

If the tipping mechanism changes then new magnitude adjustments must be determined.

Description

In order to convert measurement events to traffic density we must have a way of calibrating the conversion factor. The simplest way to do this is to divide the busy hour traffic by the total number of events. If we do this for each sector we will get a slightly different factor for each cell. This will help us to detect biases in our sampling techniques. In any case, the data from this step should probably not be presented to the customer but we will have to include it in order to produce the traffic maps.

Traffic Map By Category

Inputs

Per measurement event:

Event data

Telephone number and phone number patterns per category

Per sector

Traffic magnitude adjustment

Outputs

Amount of traffic per category per bin for various times of day, day of week, etc.

Description

If data is provided that allows traffic to be segregated by telephone number pattern or some other criteria we will be able to generate traffic layers by category, time of day, day of week, etc. These data layers can be used to generate more accurate interference matrixes (IM) than was previously possible. Alternately we can export these data layers directly to antenna optimization and site selection products.

Up-link Interference

Inputs

Probability of service per sector per bin

Option 1, uncoupled:

Event data

Mobile Tx level

Path loss

Serving sector



Option 2, coupled:

- Event data
- Serving sector
- Received signal level

Outputs

Interference per serving sector per Erlang per bin to every other sector

Note

What makes option 2 'coupled' is that we subtract the path loss from the Tx power to get the received power. By taking the difference we account for any correlation similar to what we would do for the downlink.

Description

It is well known that some areas such as hilltops are more prone to down-link interference than other areas. The converse is also true. Some areas are greater sources of uplink interference than others. For whatever reason regions may exist where the 'wrong' cell serves mobiles so that they are forced to increase power to stay on a call. If the path loss to other cells is actually lower then a significant amount of interference can result. It is not clear whether significant interference could occur if the handovers are operating correctly although anecdotal evidence suggests that these conditions may occur on IS95 networks from time to time.

Serving Signal Level

Inputs

Option 1 – Measured, includes power control:

- Event data
- Serving sector
- The mobile reported serving signal level

Option 2 – Calculated, assumes full power on the downlink

- Event data
- Path loss to each serving sector
- Downlink Tx Power for each serving sector

Outputs

Binned and averaged serving signal level per serving sector

Note

Option 1 is the actual serving signal level. Option 2 is the maximum level that *could* be used to serve the mobile.



Description

If we know the down-link transmit level and the path loss to a location then we can determine the serving signal level by taking the difference. We will be assuming that the base station is transmitting at full power. This is OK because we are looking for instances where quality is degraded due to low signal level. We will not find cases where the signal level is too low due to the base station transmitting at an inappropriately low level but we will catch the more typical case of signals being served in poor coverage areas.

Downlink C/I Histogram

Inputs

Max Tx power per sector

Downlink Tx Histograms

Per bin:

Serving signal level per server

Path loss to each potential interferer

Outputs

Received signal level histogram per sector per bin

Note

The results could be coupled or uncoupled or merely the average levels.

Description

The question is: How much detail do we need to store? In theory we could keep a histogram of path loss values for every server-interferer pair and then we could apply the transmit power histogram from each interferer and build an extremely detailed statistical model of all the interference. At the other extreme we could simply use the average levels and assume that everything is independent. Meaning, we can simply take the differences as has been done in the traditional planning tools.

Some optimization companies emphasize the importance of having excellent network models and simulation engines. Another approach we could take is to store detailed data for some markets or some time periods to be used to develop better network models and simulations. Having better models and simulations would then allow us to extract the more relevant data and reduce the need to store as much.

In the early releases we must make this simple so storing the average values would be the first step.

Probability Of Service

Inputs

Event data

Serving sector per event



Outputs

Probability of service per sector per bin

Description

This data is the probability of being served by a sector. We could have additional flavors such as the probability of initiating on a particular cell or the probability of westbound or eastbound traffic being served by a cell. The data is easy to generate. We divide the number of times a cell is a server by the total number of times any cell served that location.

Sparse data or limited measurement intervals will require some careful interpolation techniques.

Degradation Of Service

Inputs/Outputs

TBD

Description

For each type of degradation (BER/FER/RxQual/Voice/Data) we have a number of possible causes that we will be able to measure. Detecting the causes is a matter of having a model that relates the cause and the effect and then apply a process of elimination. The model can be as simple as a curve that relates $C/(I+N)$ to BER for example, or in the case of data latency a model that accounts for packet retransmissions may be required.

Several stages of analysis might be required to determine the ultimate cause of degradation. For example, interference conditions may be caused by the mobiles being served by a weak cell even though stronger cells which could result from incorrect handover parameters or missing handover neighbors. But further examination might indicate that the handovers are 'incorrect' only because some sector that is the usual server in a region is suffering from extreme path imbalance, which could indicate a misaligned antenna or defective cable.

These types of analysis will require substantial engineering expertise and some trial and error to determine the best data sources and methods. Therefore, these features would not be candidates for an early release. On the other hand we might be able to start with obvious diagnostics based on simple rules without doing a root cause analysis.

Lost Revenue

Inputs/Outputs

TBD

Description

This is a potentially valuable product that would open lines of business with non-technical departments within AWS and other operators. The main challenge is credibility. To estimate lost revenue we must:

- Identify areas within the legally defined service area that are served by another operator



- Estimate the amount of traffic that would be served in that area
- Estimate the revenue associated with that traffic

The difficult part is estimating the likely traffic in the areas served by other networks. If the areas are small islands we can assume traffic densities that are similar to the surrounding area. If they are border areas we might be able to use data about mobiles moving in and out of the area. If the areas are wider we will have to resort to more traditional methods to estimate traffic but we can have the most finely tuned traffic model ever.

This may seem like a reach but if we have even a little data that is unavailable elsewhere that can measurably increase revenue it will be a valuable tool for our customers.

Downlink IM (Interference Matrix)

Inputs

Traffic per category per bin

Coupled or un-coupled C/I per serving sector per bin

Probability of service per sector per bin

Outputs

C/I histogram per sector pair per bin⁶

Description

An IM is a matrix of values that reflect the cost of assigning co- or adjacent channels to a pair of sectors. This cost is estimated from MMR data or by applying some scoring function to the C/I in each bin across the service area of the cell receiving the interference. The accuracy of the estimate may be improved by weighting the scored interference by the amount of traffic in each bin.

The accuracy of the results may be further improved with a more accurate estimate of the PDF of the interfering transmit power level.

Andrew could offer a service whereby the effects of proposed antenna changes or network parameters are modeled so that the resulting IM consists of the best available data plus well refined models that indicate the impact of configuration changes.

Up-link IM

Inputs

Up-link interference per serving sector per Erlang per bin

Traffic per bin

Probability of service per sector per bin

⁶ That is, for each serving sector and every potentially interfering sector.



Serving signal level histogram per sector⁷

Outputs

Up-link C/I histogram per sector pair

Description

Similar to the downlink IM the up-link IM reflects the up-link quality impact of assigning co- or adjacent channels. If no antenna changes are planned the up-link IM may be based solely on up-link interference data collected during idle time slots or on frequencies that are not currently in use on the base station without any information about the locations of the interfering mobiles. Andrew would provide this as part of a package but this is an ante not a differentiator⁸.

A more interesting product would be a plot that indicates specific locations or regions where mobiles are generating a disproportionate amount of up-link interference. This would be a new kind of product. The only problem is: the value is unclear.

⁷ This could be derived from the serving signal level per bin or directly from other network data. If derived, it would be closely related to the code that estimates the up-link interference per bin.

⁸ ... if the customer even cares about it. Most operators seem to ignore up-link interference. If we can show that it does have a significant quality impact we may decide to go through the trouble of convincing customers of the value.



Appendix A: Descriptions of Data Sources

Data Element	Abis tipped	Lbis tipped	Self- tipped	Comment
Mobile phone number	x			
Mobile transmit power level	x	opt	x	
Downlink BER/FER/RxQual (Also referred to as MMR data)	x		x	See notes below on SACCH content
Location	x	x	x	Accuracy could be slightly (10- 20%) worse for self- tipping calls. Self-tipping here implies that there is a mechanism to figure out the hopping sequences in order to follow a mobile's transmissions, which has been briefly looked at.
Location accuracy (CEP)	x	x	x	
Velocity (direction and magnitude)	x	x	x	Relies on repeated accurate locations over time. Velocity calculation based on observed differential doppler shifts may not be accurate enough due to low frequency resolution. Also, see comments on "Fading Estimates"
Received signal level plus noise and interference	x	x	x	
Received signal level plus noise and interference suppressed by 20 dB	x	x	x	



Measured Uplink C/I	x	x	x	Accurate to within ± 1 dB in the -10 to +10 C/I range under static conditions over a single GSM burst (577us).
Time dispersion	x	x	x	Reliable and accurate time dispersion is available only for multipath components within about 10dB of the largest signal, and exceeding about 3us relative to other signal receipts.
Fading estimates	x	x	x	Fade rates based on amplitude null spacing relative to wavelength could be used for mobile velocity estimation.
Diversity branch fading correlations	x	x	x	Could be used for assessment of the effectiveness of space diversity, and for assignment of quality metrics of the measurements taken.

Notes on tipping

There are three possible sources for call tipping to make locations and the measurements that follow. These are:

1. Abis tipped locations: An AMU must be installed in the market of interest in order to have access with the Abis interface. The Abis interface is the most plentiful information gathering source as it contains any data that is passed from the BTS to the BSC. Access to the Abis allows access to the encryption key Kc, which allows the system to fully decode any encrypted data collected from over-the air transmissions. The negative of this source is that it is currently being phased out.
2. Lbis tipped calls: The switch infrastructure must support Lbis tipping to utilize the Lbis as a data source. The negative of this data source is that it currently is limited to 911 calls only and has limited availability at the current time. In addition, most switch vendors have chosen not to implement the optional parameters passed on the Lbis interface.
3. Self-tipped calls: In order to pull information off the air for random targets of opportunity without the assistance of the Lbis or Abis tipping mechanisms, access to data is somewhat limited, and location accuracy could be degraded. This is primarily due to the fact that the encryption key Kc is not available, in addition to call specific information such as AMR codec rates, etc. Because of these limitations, error correction on the decoded bits will not be possible and could lead to degraded location accuracy. Fortunately, the SACCH data on the uplink is not encrypted and is fully decodable. A minimum collection period of 480 ms is required to collect an entire SACCH message. The information passed on the uplink SACCH contains:
 - a. Mobile transmit power in dBm, accurate to approximately ± 4 dB.
 - b. Timing Advance (TA) value (which is not currently needed for anything related to GeoData)



- c. MMR data: (Mobile measurement data) of BCCH channel in the current BA list (BCCH allocation list, which is broadcast on the BCCH channel of all cell sites, and can be retrieved by Geometrix from off-air data collection) The MRR, among other things, contains the following parameters of interest:
- i. **RXLEV** which is directly maps to the received signal strength in dBm of the serving BTS and the received signal strength of the BCCH channels of BTS's in the BA list over a 480ms period. It is guaranteed that at the RXLEV is provided for at least one BCCH in the BA list, and may contain the levels of all sites in the BA list. This measurement provides the RMS received signal level in the range of -110dBm to -48dBm and is accurate to within +-4dB in the range of -110dBm to -70dBm, and is accurate to within +-6dB in the range of -71dBm to -48dBm (from GSM spec 5.08, 8.1.2- 8.1.3)
 - ii. **RXQUAL** which maps to one of eight levels of BER as show in the following table from the GSM spec 5.08, section 8.2.4:

8.2.4 Range of parameter RXQUAL

When the quality is assessed over the full-set and sub-set of frames defined in subclause 8.4, eight levels of RXQUAL are defined and shall be mapped to the equivalent BER before channel decoding as follows:

RXQUAL_0		BER	< 0,2 %	Assumed value =	0,14 %
RXQUAL_1	0,2 %	< BER	< 0,4 %	Assumed value =	0,28 %
RXQUAL_2	0,4 %	< BER	< 0,8 %	Assumed value =	0,57 %
RXQUAL_3	0,8 %	< BER	< 1,6 %	Assumed value =	1,13 %
RXQUAL_4	1,6 %	< BER	< 3,2 %	Assumed value =	2,26 %
RXQUAL_5	3,2 %	< BER	< 6,4 %	Assumed value =	4,53 %
RXQUAL_6	6,4 %	< BER	< 12,8 %	Assumed value =	9,05 %
RXQUAL_7	12,8 %	< BER		Assumed value =	18,10 %



Appendix B: Lbis interface call tipping parameters

Information element	Type / Reference	Presence	Format	Length in octets
Message type		M	V	1
Transaction ID		M	V	6
Channel Description	See /4/ IE 5.8	M	TV	4
Serving Cell Identifier	See /4/ IE 5.23	M	TLV	4-n
LCS Client Type	See /3/ IE 10.14	C	TLV	3
LCS QoS	See /3/ IE 10.16	C	TLV	6
Frequency List	See /4/ IE 5.20	C	TLV	3-n
Encryption Key (Kc)	See /4/ IE 5.24	C	TV	9
Cipher Mode Setting	See /4/ IE 5.25	C	TV	2
MS Power	See /4/ IE 5.21	C	TV	2
Timing Advance	See /4/ IE 5.2	C	TV	2
Measurement Report	See /4/ IE 5.12	C	TLV	18
Geographic Location	See /3/ IE 10.9	C	TLV	2-22
LCS Priority	See /3/ IE 10.15	O	TLV	3
Response Time		O	TV	2
Generic Information		O	TLV	3-n

Note: in the presence field, **M** is for mandatory, **C** is for conditional (implying that if the information is available, it must be provided), and **O** is optional. As of March 2004, Ericsson does not supply MS Power, Timing Advance, or Measurement Report data, but does supply Geographic location, which is a coarse estimate of the mobile location. It is not yet known what is supported by Nokia, Nortel, or Siemens.

Lbis References:

- /1/ U-TDOA System Study – Architecture Document, PA3 – April 9, 2003
- /2/ RFC793, Transmission Control Protocol
- /3/ TS 49.031 v6.0.0 or latest: "Base Station System Application Part; LCS Extension (BSS-LE)"
- /4/ TS 48.071 v6.0.0 or latest: "Serving Mobile Location Centre - Base Station System (SM-LC-BSS) interface; Layer 3 specification"
- /5/ TS 43.059 v6.0.0 or latest: "Functional stage 2 description of Location Services (LCS in GERAN)"
- /6/ GP-031032, CR to TSG-GERAN Meeting #14
- /7/ GP-031064, CR to TSG-GERAN Meeting #14



Appendix C: Details on the MMR data format reported on the uplink SACCH

(from GSM spec. 5.08, or 3GPP spec 45.008)

10.5.2.20 Measurement Results

The purpose of the *Measurement Results* information element is to provide the results of the measurements made by the mobile station on the serving cell and the neighbour cells.

The *Measurement Results* information element is coded as shown in figure 10.5.2.20.1 and table 10.5.2.20.1.

The *Measurement Results* is a type 3 information element with 17 octets length.

8	7	6	5	4	3	2	1	
	Measurement Results IEI							octet 1
BA-USED	DTX USED	RXLEV-FULL-SERVING-CELL						octet 2
3G-BA-USED	MEAS-VALID	RXLEV-SUB-SERVING-CELL						octet 3
0 spare	RXQUAL-FULL SERVING-CELL			RXQUAL-SUB SERVING-CELL			NO-NCELL M (high part)	octet 4
NO-NCELL-M (low part)		RXLEV-NCELL 1						octet 5
BCCH-FREQ-NCELL 1				BSIC-NCELL 1 (high part)				octet 6
BSIC-NCELL 1 (low part)			RXLEV-NCELL 2 (high part)					octet 7
RXLEV NCELL 2 (low part)	BCCH-FREQ-NCELL 2					BSIC-NCELL 2 (high part)		octet 8
BSIC-NCELL 2 (low part)				RXLEV-NCELL 3 (high part)				octet 9
RXLEV-NCELL 3 (low part)	BCCH-FREQ-NCELL 3					BSIC-NCELL 3 (high part)		octet 10
BSIC-NCELL 3 (low part)				RXLEV-NCELL 4 (high part)				octet 11
RXLEV-NCELL 4 (low part)			BCCH-FREQ-NCELL 4					octet 12
BSIC-NCELL 4					RXLEV-NCELL 5 (high part)			octet 13
RXLEV-NCELL 5 (low part)				BCCH-FREQ-NCELL 5 (high part)				octet 14
BCCH-FREQ-NCELL 5 (low part)	BSIC-NCELL 5					RXLEV NCELL 6 (high part)		octet 15
RXLEV-NCELL 6 (low part)				BCCH-FREQ-NCELL 6 (high part)				octet 16
BCCH-FREQ-NCELL 6 (low part)		BSIC-NCELL 6						octet 17

Figure 10.5.2.20.1: Measurement Results information element

Table 10.5.2.20.1: Measurement Results information element details

BA-USED (octet 2), the value of the BA_IND field of the neighbour cell description information element or elements defining the BCCH allocation used for the coding of BCCH-FREQ-NCELL fields. Range 0 to 1.



DTX-USED (octet 2) This bit indicates whether or not the mobile station used DTX during the previous measurement period.

Bit 7

0	DTX was not used
1	DTX was used

RXLEV-FULL-SERVING-CELL and **RXLEV-SUB-SERVING-CELL**, (octets 2 and 3)
Received signal strength on serving cell, measured respectively on all slots and on a subset of slots (see 3GPP TS 45.008)

The **RXLEV-FULL-SERVING-CELL** and **RXLEV-SUB-SERVING-CELL** fields are coded as the binary representation of a value N. N corresponds according to the mapping defined in 3GPP TS 45.008 to the received signal strength on the serving cell.

Range: 0 to 63

MEAS-VALID (octet 3)

This bit indicates if the measurement results for the dedicated channel are valid or not

Bit 7

0	The measurement results are valid
1	the measurement results are not valid

3G-BA-USED (octet 3)

The value of the 3G_BA_IND field of the neighbour cell description information element or elements defining the 3G Neighbour Cell list used for the coding of 3G BCCH-FREQ-NCCELL fields. Range 0 to 1.

RXQUAL-FULL-SERVING-CELL and **RXQUAL-SUB-SERVING-CELL** (octet 4)
Received signal quality on serving cell, measured respectively on all slots and on a subset of the slots (see 3GPP TS 45.008)

CELL fields are coded as the binary representation of the received signal quality on the serving cell.

Range: 0 to 7 (See 3GPP TS 45.008)

NO-NCCELL-M, Number of neighbour cell measurements (octets 4 and 5)

Bits

1 8 7	Neighbour cell measurement result
0 0 0	None
0 0 1	1
0 1 0	2
0 1 1	3
1 0 0	4
1 0 1	5
1 1 0	6
1 1 1	Neighbour cell information not available for serving cell

RXLEV-NCELL i, Result of measurement on the i'th neighbour cell (octet 5, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16)

If the i'th neighbour cell is a GSM cell, the RXLEV-NCELL field is coded as the binary representation of a value N. N corresponds according to the mapping defined in 3GPP TS 45.008 to the received signal strength on the i'th neighbouring cell. See note 1 & 2. If the i'th neighbour cell is a 3G cell, the contents of the RXLEV-NCELL field is defined in 3GPP TS 45.008.

Range: 0 to 63.

Report on GSM cells:

BCCH-FREQ-NCELL i, BCCH carrier of the i'th neighbour cell (octet 6, 8, 10, 12, 14, 15, 16 and 17).

The BCCH-FREQ-NCELL i field is coded as the binary representation of the position, starting with 0, of the i'th neighbour cells BCCH carrier in the BCCH channel list. The BCCH channel list is composed of one or two BCCH channel sub lists, each sub list is derived from the set of frequencies defined by reference neighbour cell description information element or elements. In the latter case the set is the union of the two sets defined by the two neighbour cell description information elements.

In each BCCH channel sub list the absolute RF channel numbers are placed in increasing order of ARFCN, except that ARFCN 0, if included in the set, is put in the last position in the sub list. The BCCH channel list consists either of only the sub list derived from the neighbour cell description information element(s) in System Information 2/5 (and possible 2bis/5bis) or of that sub list immediately followed by the sub list derived from the neighbour cell description information element in System Information 2ter/5ter for the case System Information 2ter/5ter is also received. If the set of ARFCNs defined by the reference neighbour cell description information element or elements includes frequencies that the mobile station does not support then these ARFCNs shall be included in the list.

The notation 2/5 etc. means that the rules above apply to the neighbour cell description information elements received in System Information 2, 2bis and 2ter and to those received in System Information 5, 5bis and 5ter separately.

See note 1 & 2.

Range: 0 to 31/30.

Report on 3G cells:

If no more than 31 (GSM) ARFCN frequencies are included in the BA (list), the index BCCH-FREQ-NCELL 31 indicates report(s) on 3G cells.

In this case, the corresponding 'BSIC-NCELL' field in figure 10.5.2.20.1 carries the index of the i'th 3G neighbour cell in the 3G Neighbour Cell list defined in sub-clause 3.4.1.2.1.1, "Deriving the 3G Neighbour Cell list from the 3G Neighbour Cell Description". 3G cells with indexes above 63 are not reported (6 bits field).

If more than 31 (GSM) ARFCN frequencies are included in the BA (list), reporting of 3G cells is not possible with this IE.

Range: 0 to 63.

BSIC-NCELL i, Base station identity code of the i'th neighbour cell (octet 6, 7, 8, 9, 10, 11, 13, 15 and 17)

For GSM cells, the BSIC-NCELL i field is coded as the binary representation of the base station identity code of the i'th neighbour cell. See note 1 & 2.

Range: 0 to 63.

NOTE 1: If the field extends over two octets the highest numbered bit of the lowest numbered octet is the most significant and the lowest numbered bit of the highest numbered octet is the least significant.

NOTE 2: If NO-NCELL-M < 6 the remaining RXLEV-NCELL i, BS-FREQ-NCELL i and BSIC-NCELL i fields (NO-NCELL-M < i <= 6) shall be coded with a "0" in each bit.



Appendix D: MS power accuracy

The following tables have been extracted from the GSM 5.05 spec, section 4.1. The entire tables have been provided in order to illustrate the tolerances for power level accuracy as a function of the mobile transmitter power.

GSM 400 and GSM 900 and GSM 850

Power control level	Nominal Output power (dBm)	Tolerance (dB) for conditions	
		normal	extreme
0-2	39	±2	±2,5
3	37	±3	±4
4	35	±3	±4
5	33	±3	±4
6	31	±3	±4
7	29	±3	±4
8	27	±3	±4
9	25	±3	±4
10	23	±3	±4
11	21	±3	±4
12	19	±3	±4
13	17	±3	±4
14	15	±3	±4
15	13	±3	±4
16	11	±5	±6
17	9	±5	±6
18	7	±5	±6
19-31	5	±5	±6



DCS 1 800

Power control level	Nominal Output power (dBm)	Tolerance (dB) for conditions	
		normal	extreme
29	36	±2	±2,5
30	34	±3	±4
31	32	±3	±4
0	30	±3	±4
1	28	±3	±4
2	26	±3	±4
3	24	±3	±4
4	22	±3	±4
5	20	±3	±4
6	18	±3	±4
7	16	±3	±4
8	14	±3	±4
9	12	±4	±5
10	10	±4	±5
11	8	±4	±5
12	6	±4	±5
13	4	±4	±5
14	2	±5	±6
15-28	0	±5	±6

NOTE 1: For DCS 1 800, the power control levels 29, 30 and 31 are not used when transmitting the parameter MS_TXPWR_MAX_CCH on BCCH, for cross phase compatibility reasons. If levels greater than 30 dBm are required from the MS during a random access attempt, then these shall be decoded from parameters broadcast on the BCCH as described in 3GPP TS 05.08.

Furthermore, the difference in output power actually transmitted by the MS between two power control levels where the difference in nominal output power indicates an increase of 2 dB (taking into account the restrictions due to power class), shall be $+2 \pm 1,5$ dB. Similarly, if the difference in output power actually transmitted by the MS between two power control levels where the difference in nominal output power indicates an decrease of 2 dB (taking into account the restrictions due to power class), shall be $-2 \pm 1,5$ dB.

NOTE 2: A 2 dB nominal difference in output power can exist for non-adjacent power control levels e.g. power control levels 18 and 22 for GSM 400 and GSM 900; power control levels 31 and 0 for class 3 DCS 1 800 and power control levels 3 and 6 for class 4 GSM 400 and GSM 900.

A change from any power control level to any power control level may be required by the base transmitter. The maximum time to execute this change is specified in 3GPP TS 05.08.



PCS 1 900

Power Control Level	Output Power (dBm)	Tolerance (dB) for conditions	
		Normal	Extreme
22-29	Reserved	Reserved	Reserved
30	33	± 2 dB	$\pm 2,5$ dB
31	32	± 2 dB	$\pm 2,5$ dB
0	30	± 3 dB ¹	± 4 dB ¹
1	28	± 3 dB	± 4 dB
2	26	± 3 dB	± 4 dB
3	24	± 3 dB ¹	± 4 dB ¹
4	22	± 3 dB	± 4 dB
5	20	± 3 dB	± 4 dB
6	18	± 3 dB	± 4 dB
7	16	± 3 dB	± 4 dB
8	14	± 3 dB	± 4 dB
9	12	± 4 dB	± 5 dB
10	10	± 4 dB	± 5 dB
11	8	± 4 dB	± 5 dB
12	6	± 4 dB	± 5 dB
13	4	± 4 dB	± 5 dB
14	2	± 5 dB	± 6 dB
15	0	± 5 dB	± 6 dB
16-21	Reserved	Reserved	Reserved
NOTE: Tolerance for MS Power Classes 1 and 2 is ± 2 dB normal and $\pm 2,5$ dB extreme at Power Control Levels 0 and 3 respectively.			

The output power actually transmitted by the MS at each of the power control levels shall form a monotonic sequence, and the interval between power steps shall be $2 \text{ dB} \pm 1,5 \text{ dB}$ except for the step between power control levels 30 and 31 where the interval is $1 \text{ dB} \pm 1 \text{ dB}$.

The MS transmitter may be commanded by the BTS to change from any power control level to any other power control level. The maximum time to execute this change is specified in 3GPP TS 05.08.

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