Chapter

5

RF System Performance and Troubleshooting

Radio frequency system performance and troubleshooting remains one of the most challenging and rewarding aspects of working on a wireless network. Many wireless systems implement wireless data in addition to voice services, so there is pressure for continuous improvements in the radio environment. *RF system performance and troubleshooting* implies many things to both technical and managerial individuals within the wireless technology community. However, there are some basic concepts of RF system performance, also referred to as optimization, that transcend technology and system configurations. The concepts of performance improvement in wireless systems are based on the same fundamental principles regardless of whether the service is voice or data or whether the technology is advanced mobile phone system (AMPS), global system for mobile (GMS), IS-136, code-division multiple access (CDMA), or a fixed wireless technology like a local multipoint distribution system (LMDS), or a multichannel, multipoint distribution system (MMDS).

These central concepts involve the following three basic principles. First, you must define the key goals and objectives for the performance of the system. Second, you must define how these goals and objectives will be measured or monitored. Third, you must define the actions to be taken on a daily, weekly, and monthly basis to improve system performance. Therefore, system performance for any wireless network involves a continuous series of adjustments and refinements.

Regarding the first principle, the key goals and objectives need to be broken down into meaningful and objective criteria, and a defined time frame needs to be associated with each criteria. Very frequently a time frame of 1 or 2 years may be necessary to reach a *key* goal or objective. The goal or objective must be broken down into quarterly or monthly time scales, with a current benchmark for the foundation or starting point.

The goals and objectives also need to be defined and/or apportioned to each of the managers and engineers involved, so their specific contributions can be factored into the process. For example, when defining the specific contribution a performance engineer will make to the overall network, his or her specific area of responsibility, region, and/or cell sites need to be defined. The goals and objectives for each performance engineer must be crafted to reflect his or her area of responsibility.

Monitoring of the goals and objectives needs to be done in such a fashion that management can allocate resources to resolve issues. The monitoring, or reporting, needs to be performed on a daily, weekly, and monthly basis, and it needs to both incorporate the key factors and indicate a variance from the norm or goal. Reports should be done on a regional basis, in addition to on the overall system, with a comparison to the norm or goal for each geographic area. Both exceptions and tracking reports are required.

The third principle involves what to do after you have defined what the goals are and how they are measured. The steps to take are

1. Establish a weekly and monthly overall plan of attack.
2. Review the daily exception report and take action if needed.
3. Examine system parameter settings for errors and correct on a daily basis.
4. Examine key metrics on a weekly basis for progress and/or possible changes in plans.
5. Document changes and communicate findings to fellow engineers.

As implied earlier, many aspects exist to the role of the system performance engineer. One essential fact is that, no matter how thorough the design work is, the system performance engineer has to make the equipment really work, from an engineering point of view. Therefore, good engineering practices during system performance troubleshooting are imperative. It is the performance engineer who ensures that the lost call rate and other quality factors are at their best, thus ensuring maximum customer satisfaction and revenue potential.

System performance and troubleshooting involve applying a set of critical techniques that have passed the test of time. Revisiting the three main criteria, a sequence of steps, methods, or techniques can be defined which, when applied, will greatly improve the chances of finding a true solution to any performance problem.

Step 1. Identify your objective with the effort you are about to partake in and document it.

Step 2. Isolate the item you are working on from the other variable parameters involved with the mission statement.

Step 3. Identify what aspect of the system you are trying to work on: switch, telco, cell site, mobile, or RF environment.

Step 4. Establish a battle plan. Write down what you want to accomplish, how you will accomplish it, and what the expected results will be.

Step 5. Communicate your objective—what you want to do and why; usually this is called a test plan or resolution plan.

Step 6. Conduct the work or troubleshooting that is identified in your objective.

Step 7. Perform a postanalysis of your work and issue a closing document either supporting or refuting your initial conclusions and identifying what are the next actionable items.

It needs to be stressed that the performance and troubleshooting techniques referenced in this chapter are not the be-all and end-all of techniques. Technologies change over time, and wireless operators either replace technologies or overlay new technologies into their existing networks. This chapter provides guidance to some technology-specific issues; however, it is the concepts and troubleshooting techniques that are emphasized.

The intention of this chapter is to discuss problems that have happened in the past so that they may be avoided in the future. Topics include how to monitor the network and implement fixes that will be expedient and cost effective. Pertinent equations and why they should be used will also be covered.

5.1 Key Factors

The performance of a wireless network, from the RF perspective, has many dynamic aspects to it. The fact that the system is dynamic and many issues are interrelated makes the task of improving the performance of a system daunting. Handling issues related to the addition of new sites, changes to existing sites, new features, maintenance, customer service, and a host of other topics taxes the performance engineer's time.

Since everything in a commercial system is time- and money-related, the performance engineer needs to allocate his or her time appropriately, meeting both internal and external objectives. To maximize the RF system performance and expedite the troubleshooting process it is exceptionally important to determine the critical system metrics, or key factors, that need to be monitored and the frequency and level of detail needed.

All too often there is either an information overload or underload problem in engineering. Information overload occurs when everyone in the organization is receiving all the reports. Information underload occurs when there are too few reports being distributed. As systems continue to grow in size and complexity, the use of statistics for determining the health and well-being of the network becomes more and more crucial. Therefore, when you determine what reports and information you want to see regarding the network, it is imperative that a support system is installed. The support system will ensure that the report generation, report distribution, and analysis of the data are done in a timely and accurate manner and on a continuous basis.

Most system operators have several key metrics they utilize for monitoring the performance of their networks. The metrics are used for both day-to-day operation and for upper management reports. The particular system metrics utilized by the operator are dependent upon the actual infrastructure manufacturer being used and the software loads. The metrics that are common to all operators are lost calls, blocking, and access failures. The metrics mentioned are very important to monitor and act upon, but how you measure or calculate them is subject to multiple interpretations. The fundamental problem with having multiple methods for measuring a network is that there is no standard procedure to use and follow.

There are numerous metrics that need to be monitored, tracked, reported, and ultimately acted upon in a wireless network for both voice and data. The choice of which metrics to use, their frequency of reporting, who gets the reports, and the actual information content largely determines the degree of success an operator has in maintaining and improving the existing system quality. With the proper use of metrics a service provider can be proactive with respect to system performance issues. But when a service-affecting problem occurs in the network, it is better for the engineering and operations departments to already be aware of the problem and have a solution that they are implementing.

This brings up the issue of what metrics you want to monitor, the frequency with which you look at them, and who receives the information. The key metrics that we have found to be most effective, regardless of the wireless technology, infrastructure vendor, or software load currently being used and regardless of whether the service is voice or data, are listed here:

1. Lost calls
2. Blocking
3. Access failures
4. Bit error rate (BER), frame error rate (FER), and signal quality estimate (SQE)
5. Customer complaints
6. Usage and RF loss
7. Handoff failures
8. RF call completion ratio
9. Equipment out of service (such as radios or cell site spans)
10. Technician trouble reports

Focusing on these key parameters for the RF environment will net the largest benefit to any system operator, regardless of the infrastructure currently being used. When operating a multiple-vendor system for a wireless mobile infrastructure, you can cross map the individual metrics reported from one vendor and find a corollary to it with another vendor. The objective with cross mapping the metrics enables everyone to operate on a level playing field regarding system performance for a company, and ultimately the industry as a whole. The individual equations for each of the key metrics will be discussed in later sections of this chapter.

The key metrics identified are relatively useless unless you marry them to the goals and objectives for the department, division, and company. For example, knowing that you are operating at an access failure level of 2.1 percent, depending on how you calculate it, does not bode well when your objective is 1.0 percent. The decision to use bouncing busy hour versus busy hour for the evaluation also is an important aspect in measuring the system's performance. The use of the system-defined busy hour, however, is far better for evaluating trends and identifying problematic areas of the network.

When reporting metrics, you need to address both what metrics you are monitoring and how you report on the metrics. It is very important to produce a regular summary report for various levels of management to see so that they know how the system is operating. When crafting a metrics report, you should determine in advance who *needs* to see the information versus who *wants* to see it. More times than not there are many individuals in an organization that request to see large volumes of data, with valid intentions of acting on them, but in the process become so overcome with data input that they enter the "paralysis of analysis" phase.

Establishing regular, periodic action plans is very effective in helping maintain and improve system performance in a network. System performance requires constant and vigorous attention. Establishing a quarterly and monthly action plan for improving the network is essential in ensuring its health. In particular every 3 months, once a quarter, you should identify the worst 10 percent of your system following the list of metrics. The focus should not only be on the cell site but also on the sector, or face, of a particular cell site so that problems can be cross correlated. The quarterly action plan should be used as the driving force for establishing the monthly plans.

Coupled into long-term action plans are the short-term action plans which help drive the success or failure of the overall mission statement for the company. The key to ensuring that the long- and short-term goals are being maintained is through the requirements of periodic reports. The periodic reporting issues are covered in another chapter; however, they are essential, if conducted properly, for ensuring the company's success.

Some reports that facilitate focusing on the performance of the system are listed here. This list should be made available to essential personnel on a daily and weekly basis. It is recommended that the following key items of information be included in the reporting structure on a weekly basis.

1. Weekly statistics report for the network and the area of responsibility of the engineer trended over the last 3 months.
2. Current top-5 worst-performing cells and top-10 worst-performing sectors in the network and each region using the statistics metrics.

3. Listing of the cells and sectors which were reported on the last weekly report with a brief description of the action taken toward each, and the problem resolved, if any.
4. List of the cells on the current poor-performing list, including a brief description as to the possible cause for the poor performance and the action plan to correct the situation.
5. Number of radio channels [channel elements (CEs) for CDMA] in the network, by region point in time indicating the total number of
   - Channels
   - Radios out of service for frequency conflicts (non-CDMA)
   - Radios out of service for maintenance
6. Status of the technical trouble reports (weekly).

Of course, merely presenting the information in a timely and useful fashion is not enough—it has to be used to have an effect. For example, you identify the worst 10 sectors of a system, and they may be all physically pointing in the same area of the network indicating a possible common problem. By overlaying the other metrics, patterns may appear, which will enable the performance department to focus its limited resources on a given area and net the largest benefit.

5.2 Performance Analysis Methodology

The methodology that should be used by the performance engineer and his or her immediate management involves a layered approach to problem resolution. Remembering the seven major steps in any problem identification and resolution, we will attempt to address some basic system problems. The discussion will focus on an AMPS cellular system using lost calls, access failures, and blocked calls. All wireless technology access platforms have these three fundamental concepts, or performance issues, in common. For wireless data not only is there the contentious issue of blocked calls but also the potential degradation in throughput due to the RF environment, the radio or network system configuration, or off-net problems.

The concepts put forth in trying to identify and formulate an action plan, whether for an AMPS, CDMA, time-division multiple access (TDMA), or GSM technology platform, follow the same fundamental methodology. What changes when focusing on the individual technology platforms is the vendor-specific metrics and unique protocol issues. In a later part of this chapter some troubleshooting guidelines and flowcharts will be presented which are technology platform specific. However, we cannot overstress the importance of understanding a fundamental methodology for problem identification and resolution.

- Identify objective
- Remove variables
- Isolate system components

- Test plan
- Communicate
- Action
- Postanalysis

The chart in Fig. 5.1 represents a portion of a weekly system statistics report for a network. The chart has only four cell sites listed on it so that the example presented here is clearer. The performance criteria for the system include a lost call rate of 2 percent, attempt failure of 1 percent, and radio blocking between 1 to 2 percent.

The chart is interesting by itself, but a simple review of the data indicates that there are a few sectors which potentially need investigation. The chart can be converted to be more of a visual aid in the troubleshooting analysis. The analysis methods presented here show a step-by-step approach. The method you choose to use can combine several of the steps presented here, but for clarification they are presented separately here.

1. Sort the chart by lost call percent focusing on the worst performers.
2. Sort the chart by the raw number of lost calls focusing on the highest raw number.

The reason for the two sorts for the lost calls pertains to how the metrics are calculated. Sorting by the lost call percent alone might not net the largest system performance improvement. The sorting method needs also to incorporate the raw number of lost calls. The lost call percent number can be misleading if there is little usage on the site or there is a large volume of traffic on the site. If there is little usage on the site, one lost call can potentially represent a 10 percent lost call rate. If the site has a large amount of traffic, the site might be operating within the performance criteria, 1.9 percent, but this represents 10 percent of the entire system's lost calls for the sample period. The resulting display for the lost call percent and raw number of lost calls is shown in Fig. 5.2. There are several sectors all pointing to a general location using the data from the chart in Fig. 5.1.

The next step is to produce a similar chart for the radio blocking statistics. The radio blocking statistics need to be sorted by radio blocking percent and also the raw number of radio blocks. The rationale behind these two sorting methods is exactly the same as that used for the lost call method.

3. Sort the chart by radio blocking percent focusing on the worst performers.
4. Sort the chart by the raw number of radio blocks focusing on the highest raw number.

The resulting display for the radio blocking percent and raw radio blocking numbers is shown in Fig. 5.3. The information displayed in the figure does not indicate any system-level problems.

Sample Busy Hour System Report

Date:

Cell Site	Time	Usage	O&T	LC %	# LC	% AF	# AF	% Block	# Block	Usage/LC
1A	1700	262	238	2.1	5	1.26	3	1.26	3	52.38
1B	1700	393	357	7	25	2.52	9	0.84	3	15.71
1C	1700	183	167	1.8	3	4.20	7	1.20	2	61.11
2A	1700	770	700	1	7	0.43	3	—	0	110.00
2B	1700	147	133	1.5	2	1.50	2	1.50	2	73.33
2C	1700	770	700	2	14	1.29	9	0.14	1	55.00
3A	1700	367	333	1.2	4	0.30	1	2.70	9	91.67
3B	1700	419	381	2.1	8	2.10	8	1.05	4	52.38
3C	1700	3438	3125	4	125	0.45	14	1.38	43	27.50
4A	1700	500	455	11	50	0.44	2	0.22	1	10.00
4B	1700	592	667	1.5	10	1.50	10	0.30	2	59.20
4C	1700	183	167	3	5	3.60	6	0.60	1	36.67

Figure 5.1 Partial example of weekly statistics report for an AMPS cellular system.

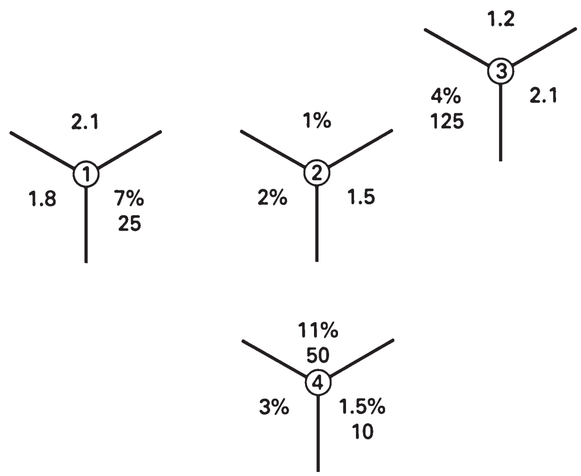


Figure 5.2 Visual display of percent lost calls and number of lost calls by sector.

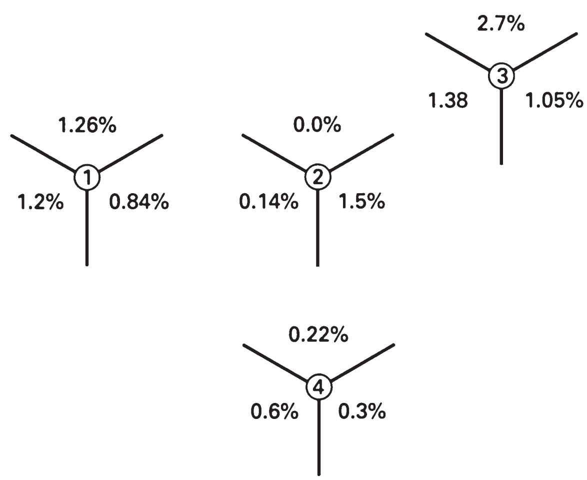


Figure 5.3 Visual display of percent radio blocking by sector.

The next step is to produce a similar chart for the attempt failure statistics. The attempt failure statistics need to be sorted by attempt failure percent and also the raw number of attempt failures. The rationale behind these two sorting methods is exactly the same as that useed for the lost call method.

5. Sort the chart by attempt failure percent focusing on the worst performers.
6. Sort the chart by the raw number of attempt failures focusing on the highest raw number.

The resulting display for the attempt failure percent and raw attempt failure numbers is shown in Fig. 5.4. The information displayed in the figure does not indicate any system-level problems.

The next step is to produce a similar chart for usage and RF losses. The usage and RF losses need to be sorted by the worst performers. The usage and RF loss worst performers are those with the lowest amount of usage between a lost call.

7. Sort the chart by usage and RF loss focusing on the poorest performers.

The resulting display for the usage and RF loss is shown in Fig. 5.5. The information displayed in the figure indicates a potential problem focusing on the same area as with the lost calls. Figure 5.6 is a composite view of the metrics evaluation.

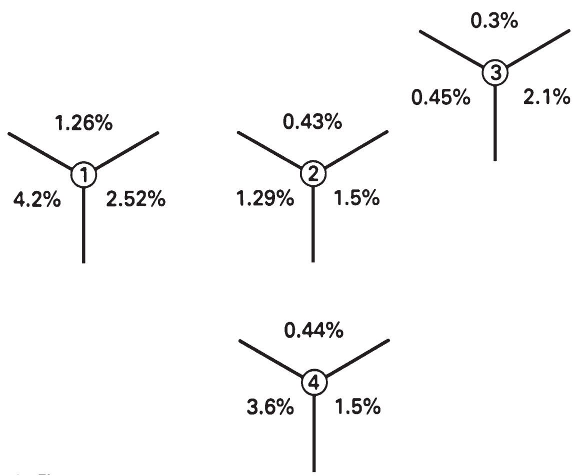


Figure 5.4 Visual display of percent attempt failures (access) by sector.

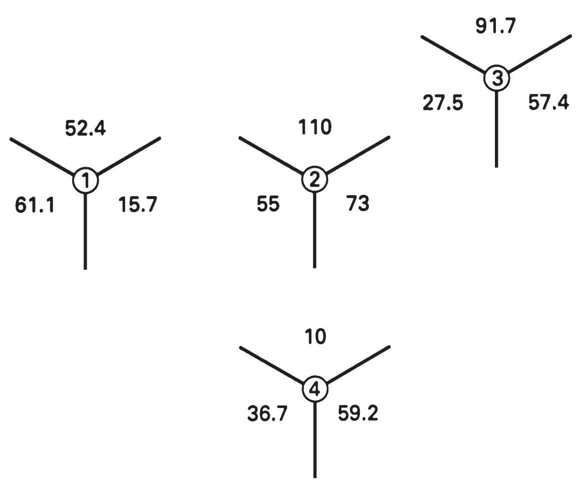


Figure 5.5 Visual display of usage/RF loss by sector.

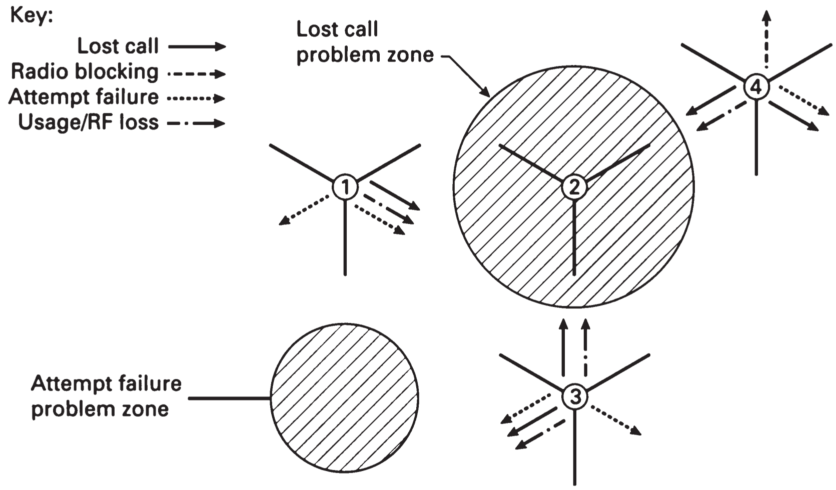


Figure 5.6 Visual display of compilation.

Obviously this procedure can and should be used with the other metrics for the network. The visual display of the information can and should be coupled into the metrics reporting mechanisms used for the network. All the key performance metrics should be checked for any correlation issues since this is one of the best methods available to identify performance-related trends.

The reports getting to upper management must be able to tell a story that is both factual and brief. Upper management needs to know that the system is running at a particular level but also that you are in control and do not require their intervention. Many times a senior-level manager that has a technical background will generate many questions and inadvertently misdirect the limited resources when given too much data. The simple rule for dissemination of reports is to minimize the information flow to only those people who really need to know the material. This is not meant to keep other people in the dark but to help ensure that the group which needs to focus on improving the network continues doing just that.

However, it is very important to let members of the technical staff know what the current health of the network really is on a regular basis. One very effective method that has been used in various forms is to have the key metrics displayed on a wall so everyone can see the network's performance. The metrics displayed should be uniform in time scale, and it is recommended that they trend over at least a year so everyone can see how well you are doing over time.

The wall chart in Fig. 5.7, if done correctly, will foster competition between fellow engineers working on the performance of the network. For example, if the data are displayed by network region, the engineer who has the worst performance in an area will feel compelled, through peer pressure, not to be on the bottom of the heap for the next reporting period. If this is handled correctly, the efforts of the various engineers will ensure that the overall

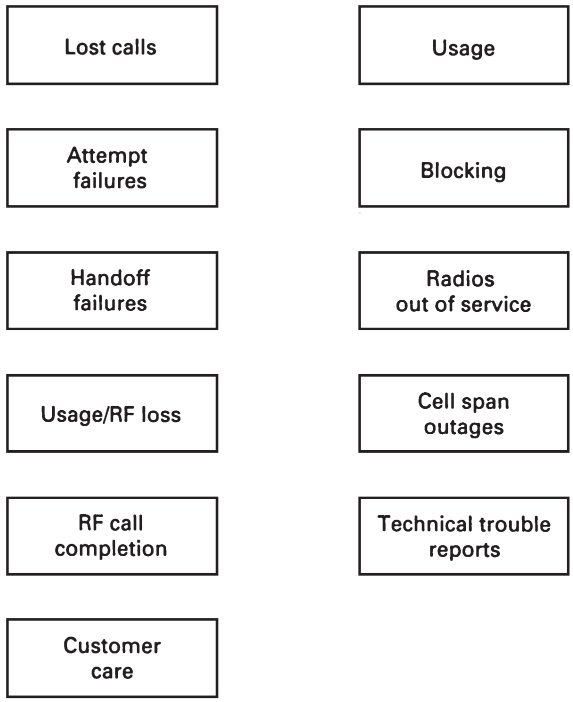


Figure 5.7 Wailing wall.

performance of the network continues to improve. The chart can, of course, be expanded upon to incorporate wireless data services.

The other item which needs to be addressed is the need to give regular presentations to the upper management of the technical arena. This is not a classic empowerment method but is meant to stress to the upper management that engineering is performing a good job. This will arm upper management with key information so that when they are confronted with irate customers who complain about the lack of good system performance they have some personal knowledge of what is happening.

Upper management reports should take place every 6 months and focus on what you have done and what you will do over the next 6 months. The critical issue here is that if you tell your superiors you are going to do something, make sure you actually do it and report on it in the next presentation, including what you did, when, and the results. It is also important that the meeting not take more than 1 hour. Based on the size of the department, i.e., the number of presenting engineers, the time frame should be well rehearsed and time minimized. Focus on three to five items which you can talk about quickly and have the answers for. It is imperative that when you bring up a problem you have a solution that goes hand in hand. The key issue, though, in presenting to upper management is to be truthful and never offer up information or proposed solutions to problems that exist when you do not have direct knowledge or control of all the issues.

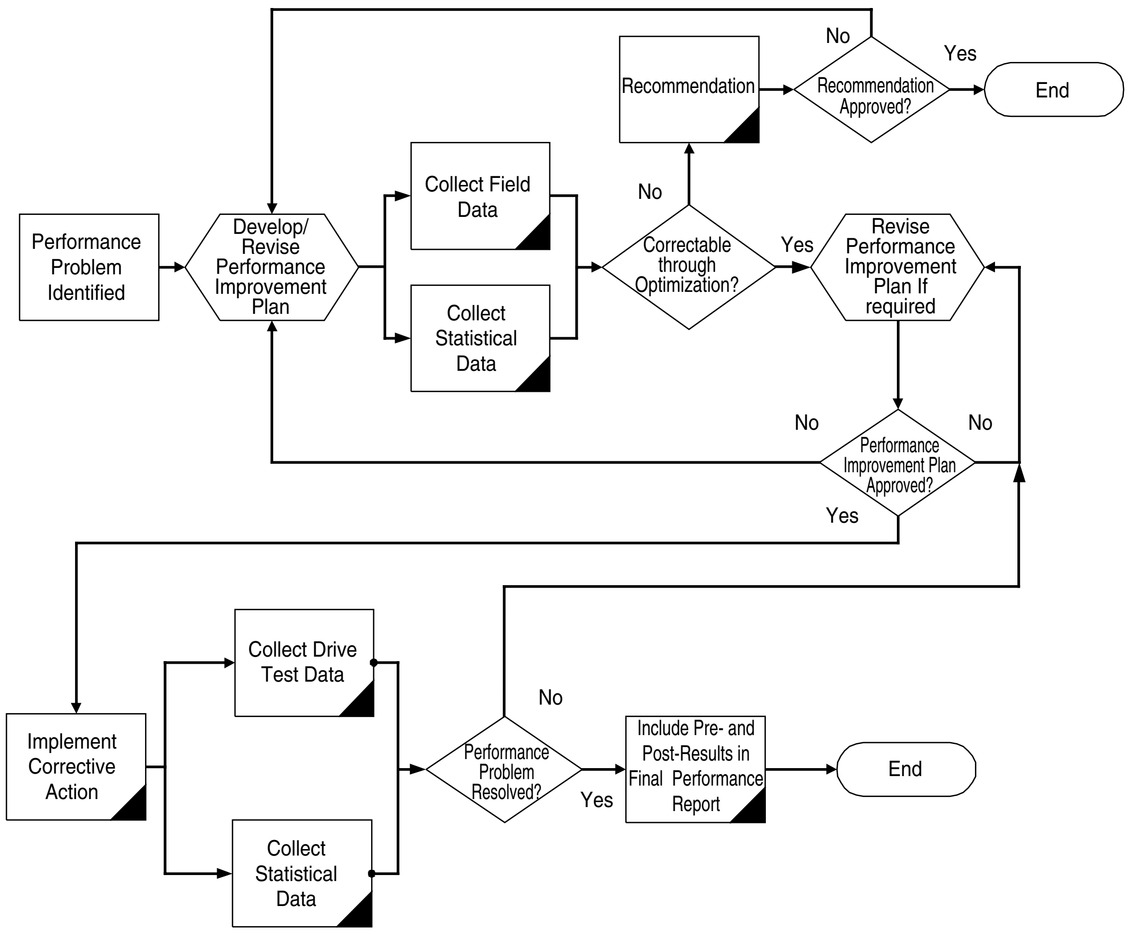


Figure 5.8 Performance improvement flow chart.

Figure 5.8 is a simple flowchart which indicates the major process associated with performance improvements. Please note that the flowchart is independent of the radio-access technology used.

5.3 Lost Calls

The lost call metric is probably one of the most discussed and focused-on parameters in the wireless industry, short of blocking and soon quality of service (QOS) for wireless data. The lost call metric is personalized because everyone who has a wireless piece of subscriber equipment has experienced a lost call and is personally aware of the frustration and aggravation it causes. Unfortunately, lost calls are a fact of life in the wireless industry and will remain so for the foreseeable future.

There have been major improvements in detecting and isolating lost calls since the inception of wireless mobile systems. However, the proliferation of wireless and its prevalence in everyday life has placed great expectations on the operators by the very subscribers who pay their bills. Additionally for many system operators a key component to engineers' and upper management's incentive is based on the lost call performance numbers. Therefore, a key step in the road to focusing on lost calls and reducing their occurrence is the setting of goals and the calculation method used.

You might be asking why goal setting is important. There are several reasons, and they are technology platform independent. The primary reason is that this is the first step in the seven steps toward problem resolution. The second reason is it prevents the "what 'is' is" syndrome. In addition the calculation method that is used needs to be established. It is important to establish a consistent lost call objective and value to strive for system performance since it is the paying customers who are having their calls dropped.

Regardless of the technology platform used when focusing on a system objective, setting the goal on a raw percentage has merit since it is easily traceable and definable. However, when you equate it to the raw volume of traffic on a network, a 2 percent lost call rate for a large network can mean over 10,000 physically dropped calls in any given system busy hour. If you had said I have 10,000 lost calls in the busy hour versus 2 percent, the system performance metrics would reflect a different picture but with the same quality impact.

The percentage lost call rate is a valid figure of merit for a system that is growing and has coverage gaps of significant size. The lost call percentage is an extremely effective tool for helping to pinpoint problems and monitor the overall health of any network. However, using the raw lost call percentage number for a large, growing network may in fact be counterproductive since more actual problems in raw volume may occur than the number represented in the percentage indicates.

For example at a 40 percent system growth rate the 10,000 lost calls at the 2 percent lost call design rate would possibly increase to 14,000 lost calls the next year. Assuming all the parameters increase with the same rate, the lost call rate would remain at 2 percent, but the raw number would increase by 40 percent. Obviously this is not the trend that you would want to take place on your own system. An alternative to using the percentage value would be to utilize an additional metric to help define the quality of the network.

Additionally when operating multiple-technology platforms in a system, it would be advisable to have different goals for each platform. For example, if there are AMPS, IS-136, and GSM platforms being used in the same market, the goal might be to have the subscribers migrate to the GSM platform. Therefore the tightest lost call goal may be placed on GSM, with IS-136 next, and the most lax goal placed on AMPS.

The percentage of lost calls should be set so that every year the percentage of lost calls is decreasing as a function of overall usage and increased subscriber penetration levels. Specifically the lost call rates need to be set so that the ultimate goal is 0 percent lost calls in a network. While we do not believe this is feasible at the present state of technology and capital investment, it is still the proper ultimate goal to set. Anything less should not be acceptable.

But reality dictates that setting of reasonable and realistic goals needs to be done in such a fashion that the real lost call rates are reduced and at the same time the methods utilized are sustainable. How to set the actual lost call rate is an interesting task since one lost call is too many. The suggested method is to provide at the end of the third quarter of every year the plan for the lost call rate to be striven for in the next year. The goals should be set so that you have a realistic reduction in the lost call rates for the coming year, trying to factor in where you might be at the end of the current year.

The following is a few examples on how to set the lost call objective for your network. Obviously you and your management should be comfortable with the set values. The lost call goal should not be set in the vacuum of an office and then downward directed. The goal should be driven to improve the overall performance of the network factoring into it the growth rate expected, budget constraints, personnel, and the overall network build program.

One example of lost call goal setting involves the situation where several wireless systems were owned by the same company through acquisitions. The interesting issue is that the lost call rates used for goals were different for each wireless system. The difference in the lost call rate was not necessarily the goal of, say, 2 percent, but rather the methodology of calculating the equation. This has led to many interesting situations where the individual wireless system was able to pick the method which would present the individual company in the best light to the parent company.

Specifically, one system used the lost call method of overall lost call, and another used the call segment approach. The difference between the two is dramatic and needs to be watched for. We chose the call segment method for reporting to the parent company and used the overall lost call rate for an internal method. The difference between the two techniques is best represented by a simple example using the same system performance statistics.

$$\text{Originations and terminations (O\&T)} = 10{,}000$$

$$\text{Handoffs (HO)} = 10{,}000$$

$$\text{Lost calls (LC)} = 200$$

$$\text{Overall lost call} = \frac{\text{LC}}{\text{O\&T}} = 2\%$$

$$\text{Call segment} = \frac{\text{LC}}{\text{O\&T} + \text{HO}} = 1\%$$

The difference between the two methods is rather obvious using the simplistic numbers listed for the example. Therefore, when you hear or see a lost call percent value, the underlying equation and methodology used needs to be known to best understand the relevance of the numbers presented.

Resolution of the different methods of reporting was never attempted. However, the overall method calculation is not necessarily the best method to use when analyzing system performance since handoffs are part of the overall situation. Some infrastructure vendors do not have the ability to record originations and terminations on a per-sector level.

Whether you use the overall method or the call segment method, it is important to be consistent. The relative health of the network can be determined by either method using simple trending methods that compare past and present performance.

When reviewing the example, the concept of the technology platform was not used. The reason the technology platform was not introduced is that it is not relevant. All wireless mobile systems require subscribers to either place or receive a call or data session with the possibility that during the service delivery the connection will be prematurely terminated. Understanding the fundamental implications of overall versus call segment methods of presenting lost calls is essential in the drive to improve system performance.

When reporting the lost call rates to upper management, the method chosen should be visual. Visual methods are extremely useful for conveying a story quickly. However, charts and graphs can be extremely deceiving especially if the *x*-axis and *y*-axis scales and legends are not defined.

For example, one situation of scaling involved two engineering divisions in the same company. Both of the engineering groups were using the same equations and time frames to calculate their lost call rates. However, both divisions utilized different *y*-axes to display the data. The division with the poorer lost call rate used a larger *y*-axis with the lost call rate placed in the middle of the chart. The division with the better lost call rate chose scales which exemplified the lost call rate. The difference in *y* scales between the divisions was close to a 2:1 margin.

The most interesting point with this example is that the group using the more granular *y* axis had a lower lost call rate with the higher system usage. The perception of upper management was that the division using the more granular reporting scheme was performing the worst since the line on the chart was higher. There were many lessons learned with this example, and one of them was that perception is very important.

The time used for conducting lost call analysis should also be clearly delineated. For example, if you use a bounding busy hour method for determining your lost call rate, no matter which equation type you use, it will be difficult to trend. Therefore, when monitoring the trend of the system, it is important to establish a standard time to use from day to day and month to month. The standard time to use is the busy hour of the system on weekdays, Monday to Friday, excluding holidays. The same hour should be used for each of the days for the entire sampling period.

The system busy hour, barring fraud, is usually between 4 to 6 P.M. in the United States. The establishment of the actual system busy hour can be done through a simple analysis of the system traffic usage broken out by hour and day for several months to establish a comfort level that the time picked is valid. It is important to take a snapshot of what the system busy hour is on a regular monthly basis to verify that traffic patterns are not changing.

It is important to set yearly and, at a minimum, quarterly lost call goals. Setting overall and interval goals serves two primary purposes. The first purpose is that short-term goals help direct the efforts of the company. The second purpose is that interval goals ensure that the overall goal is being met, thereby avoiding an end-of-year surprise of not meeting the goal.

Figure 5.9 shows one way to set the lost call goal for the network. The lost call rate at the beginning of the year for this example is 2.2 percent, and the desired goal is 2 percent. The chart is divided into quarters, so a gradual improvement objective can be set. Please note the year on the chart and that if the trend line was to be followed, then calls would be awarded to subscribers by this time frame. The following examples are presented to help drive the methodology of establishing a lost call goal for a wireless system.

The first example involves a situation where the lost call rate was set based on what the overall corporate goal for the lost call rate was, in terms of a quality figure of merit. The lost call rate was 1.50 percent for the network. The network's current performance, however, was a 2.1 percent lost call rate. Obviously moving from a 2.1 to a 1.5 percent lost call rate in 1 year while experiencing a 40 percent growth rate may not be a realistic, obtainable goal. Achieving the final number immediately within the single management cycle would require over 28 percent reduction in the current lost call rate, regardless of the method chosen for calculation.

In establishing the lost call objective for the network, the goals may be unobtainable if additional resources are not allocated by management, for a sustained level of time, in order to facilitate the reduction effort.

For the example chosen management did not permit additional resources in terms of the work force or equipment to facilitate the reduction. The objective chosen was to do more with less, which is a common methodology used by many who have never done any of the work. Instead the value chosen was 1.9 percent which involved a 10 percent improvement as a minimum and an overall stretch of 1.8 percent for the final lost call rate. The final numbers were going to be the last month's lost call rate which was to be the total lost calls during the busy hours of all the days in the month.

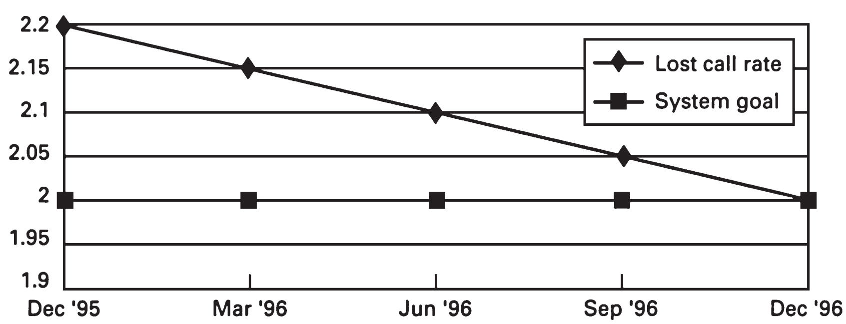


Figure 5.9 Yearly lost call rate.

Another example of setting goals for the department involves the upper management picking a value. A senior director picked a value for the lost call rate to commit to corporate for the next year's goals and objectives. The goal set was not discussed with any of the management of the engineering department nor with operations to receive their input as to the feasibility of the number being set. The end result was that there was a serious problem with meeting the number, and in fact the goal was altered during the midpoint of the year so it could be easily met. Surprisingly no one was held accountable for altering the performance numbers that determined the yearly bonuses. The revised number used was the one determined by the engineering department working level managers.

While it is important to set aggressive goals to work toward, it is also equally important to involve members of the staff whose job it is to ensure that the mission statement is met. In particular a meeting should have been established to arrive at a realistic value to submit to upper management. The setting of the value without subordinate involvement left the final goal as being the senior director's number and not the number that the department believed in, creating a fundamental friction point within the organization.

However, when you set a value, there is a midpoint between the examples discussed here. To arrive at a midpoint goal you need to know what the lost call rate trend is and determine what percentage improvement is needed for the coming year, factoring in the network subscribers, usage volume, and cell growth.

For example, setting a goal to reduce the lost call rate by 25 percent from 2 percent, i.e., a goal of 1.5 percent, is not realistic if you are growing the network at a 40 percent rate and allocate no additional resources to help in the effort. Instead the goal should be to maintain or improve the network by, say, a minor increment ensuring that the rapid growth rate does not negatively impact the network. This seems simple in concept, but the reality of determining this value is very difficult.

The ability to focus on an incremental improvement is based on the fundamental premise that the lost call rate has been successfully managed. If the lost call rate was say at 10 percent, regardless of calculation method, then focusing on a small improvement may prove futile, and in this instance the current resources, methodology, and skills used need to be revisited in a very hasty manner.

Obviously, arriving at the methodology for calculating the lost call rate is exceptionally important. In the process of determining the method to use it is equally imperative to arrive at the intervals to use also. For example do you use a monthly average, weekly average, or yearly average to determine the end result? We recommend using a quarterly average using the system busy hour, most likely 4 to 5 P.M. for weekday traffic.

This recommendation will eliminate weekly and monthly fluctuations in the lost call rate. It will also compensate for the first few months of the year when the lost call rate is normally lower due to demographic patterns that seem to always take place. The methods will also compensate for a bad cell site software load that is potentially put into the system.

We also recommend using the overall method for deterring the lost call rate of the network since this is the value the subscriber sees. In particular, if the subscriber hands off 3 times during a call and then experiences a lost call, the lost call rate is only 33 percent using the call segment method. But in the example presented the customer really experiences a lost call rate of 100 percent for that call.

After arriving at the time frame and methodology to use, the actual value will need to be set. The best method for setting the value to be arrived at is dependent upon what the current level of performance is. If your current overall lost call rate is 3 percent during the busy hour, then setting the goal of a 33 percent reduction in the lost call rate is reasonable. But if your lost call rate is 2 percent, currently setting a goal of reducing the rate by 33 percent for the coming year means a 1.34 percent level.

This brief discussion has only focused on the percentage method of determining the lost call rate. If you use the raw number of lost calls in a network, based on the system growth projection, then be very careful to look at what the relative performance improvements will be versus the resources available to combat this issue.

Specifically if you are currently operating at a lost call rate of 2 percent, but the raw number of lost calls during the busy hour is 200, reducing the raw lost calls by 10 percent from the initial number might be a larger percentage when you factor in the actual growth of the network.

At a 40 percent growth rate the O&T level would be 14,000 in the busy hour at the end of the next year, up from 10,000. Reducing the overall lost calls from, say, 200 to 180 would mean going from a 2 percent lost call rate to a 1.28 percent rate, which is a very aggressive goal. A more realistic goal would be to tie the lost call rate to the system growth level by having the raw lost call rate not exceed an overall percentage number but at the same time not increase, and the raw number not increase by more than 50 percent of the system growth rate or stay the same, netting a real improvement. Specifically the goal using this method should be a raw number of 240 as the minimum goal and 220 as the stretch goal to work for.

Whatever the value picked for use as the benchmark for determining the system health of the network, it is imperative that all the groups involved with achieving the objective help set the goals. However, you need to watch out for paralysis of the committee deciding the actual value. The end result is that there is no real magical solution to setting the value for lost calls. However, you must know what your objective is before trying to set the value, i.e., step 1 in the system performance and troubleshooting process.

Once you set your goals for the lost call rate for the system, the next issue you must face is how to identify the poor performers in the network. There are many techniques used for deterring the poor performers in the network, all of which have a certain level of success in trying to reduce the lost call rates.

One technique is to use the same report used for reporting the health of the network to your upper management and determining what sites are the poorest performers from this set of data. There are two fundamental ways to focus on problems when looking to rate the lost call numbers. The first method is to sort the list by poorest performance, determined by the percentage of lost calls reported on a per-sector or per-cell basis. This list will include the whole system, but you should focus on, at most, the top 10 site for targeting action plans. The second method is to focus on the raw number of lost calls. Both techniques should be used when determining which cell sites to focus attention on first.

For example, using the first percentage method, the poor performers will be identified regardless of the traffic load. The percentage method will help identify if there is a fundamental problem with the site. However, if the cell site has virtually no usage, say 10 calls and has one lost call, the percentage calculation is 10 percent indicating that there is a serious problem at this site. However, a site operating at a 1.9 percent lost call rate may be contributing 10 percent of the overall lost call rate to the network, but since it is such a high-volume cell, it is showing a lower overall percentage issue by itself. Obviously the focus of attention should be on the site contributing the largest volume of lost calls in this case, not the cell which has the highest percentage of lost calls.

The primary point with these two examples is that you must think in several dimensions when targeting poor-performing cell sites. The individual lost call rates should be looked at, plus the overall impact to the network as a whole needs to be addressed when focusing on what sites to deploy resources at.

Another successful technique used in lost call troubleshooting is to utilize another parameter. Use of the parameter of usage per number of lost calls on a per-sector and per-cell basis has met with great success in system troubleshooting. This parameter is exceptionally useful for identifying the worst performers in a network, regardless of the vendor or software loads used.

The parameter of usage per number of lost calls will also give you a figure of merit for determining the level of problems experienced at a site. For example, if you have five lost calls with 50 usage minutes, this equates to one lost call every ten min. When you are troubleshooting a system, the interval between the lost calls themselves is very important, since the shorter the interval the more problematic the problem is and the higher the probability of finding the root cause in a shorter period of time.

When looking at these three methods of lost call analysis, it is imperative that you try to find a pattern. Use the data in Fig. 5.10 for the sample system. The pattern search is best achieved through a three-step method. The first step is to sort the worst performer by lost call percent (Fig. 5.11). The second step involves generating a sort by raw lost call numbers (Fig. 5.12). The third step in the process is to sort by the usage/RF value (Fig. 5.13). You then take each of the worst 10 or 15 sites and put them onto a map or other visual method and look for a pattern as shown in Fig. 5.14.

More times than not there are several sites that focus on a cluster occurring in a given area. As shown in Fig. 5.14, the identification of the worst performers will in most instances show a pattern of an area that is experiencing a problem.

The key issue here is that you need to focus on a given area, besides the individual sites involved. The root cause of the problems could be as simple as a handoff table adjustment to a frequency plan problem. There are, of course,

Sample Busy Hour System Report

Date:

Cell Site	Time	Usage	O&T	LC %	# LC	Usage/LC
1A	1700	262	238	2.1	5	52.38
1B	1700	393	357	7	25	15.71
1C	1700	183	167	1.8	3	61.11
2A	1700	770	700	1	7	110.00
2B	1700	147	133	1.5	2	73.33
2C	1700	770	700	2	14	55.00
3A	1700	367	333	1.2	4	91.67
3B	1700	419	381	2.1	8	52.38
3C	1700	3438	3125	4	125	27.50
4A	1700	500	455	11	50	10.00
4B	1700	592	667	1.5	10	59.20
4C	1700	183	167	3	5	36.67

Figure 5.10 Lost call statistics.

Sample Busy Hour System Report

Date:

Cell Site	Time	Usage	O&T	LC %	# LC	Usage/LC
4A	1700	500	455	11	50	10.00
1B	1700	393	357	7	25	15.71
3C	1700	3438	3125	4	125	27.50
4C	1700	183	167	3	5	36.67
1A	1700	262	238	2.1	5	52.38
3B	1700	419	381	2.1	8	52.38
2C	1700	770	700	2	14	55.00
1C	1700	183	167	1.8	3	61.11
2B	1700	147	133	1.5	2	73.33
4B	1700	592	667	1.5	10	59.20
3A	1700	367	333	1.2	4	91.67
2A	1700	770	700	1	7	110.00

Figure 5.11 Lost calls sorted by percent lost calls.

situations where there is no real solution to the problem. However, there are always methods available to minimize the problem at hand. Sometimes the problem at hand may not be the site producing the poor statistics.

To illustrate the concept of one site causing another site to perform poorly, consider a system retune. Shortly after a system retune took place, a series of problems were reported at one site involved in the retune effort. Looking at Fig. 5.15, site 1 was reporting that it was producing a high volume of lost calls. Analysis of the data at hand indicated that this was the primary culprit to the problem. The drive team dispatched to investigate the situation confirmed that there was a major problem with the problematic site. Analysis of the cell parameter and neighbor lists of the site itself and the surrounding sites indicated no database or cell site parameter problems.

Sample Busy Hour System Report

Date:

Cell Site	Time	Usage	O&T	LC%	# LC	Usage/LC
3C	1700	3438	3125	4	125	27.50
4A	1700	500	455	11	50	10.00
1B	1700	393	357	7	25	15.71
2C	1700	770	700	2	14	55.00
4B	1700	592	667	1.5	10	59.20
3B	1700	419	381	2.1	8	52.38
2A	1700	770	700	1	7	110.00
4C	1700	183	167	3	5	36.67
1A	1700	262	238	2.1	5	52.38
3A	1700	367	333	1.2	4	91.67
1C	1700	183	167	1.8	3	61.11
2B	1700	147	133	1.5	2	73.33

Figure 5.12 Lost calls sorted by number of lost calls.

Sample Busy Hour System Report

Date:

Cell Site	Time	Usage	O&T	LC%	# LC	Usage/LC
4A	1700	500	455	11	50	10.00
1B	1700	393	357	7	25	15.71
3C	1700	3438	3125	4	125	27.50
4C	1700	183	167	3	5	36.67
3B	1700	419	381	2.1	8	52.38
1A	1700	262	238	2.1	5	52.38
2C	1700	770	700	2	14	55.00
4B	1700	592	667	1.5	10	59.20
1C	1700	183	167	1.8	3	61.11
2B	1700	147	133	1.5	2	73.33
3A	1700	367	333	1.2	4	91.67
2A	1700	770	700	1	7	110.00

Figure 5.13 Lost calls sorted by usage per lost call.

There was one aberration, the low usage on one sector of an adjacent cell site, number 2. The site technician was contacted and indicated that the problem being experienced was always there. However, a historic plot of the site, Fig. 5.16, showed a dramatic reduction of the usage on that sector over the same period that the problems appeared at the problematic site.

A site visit was performed by the site technician, who found that a receive antenna was physically disconnected at the antenna input on the tower. This problem was corrected with the aid of an antenna rigging crew which was immediately dispatched to the site, and the problematic site returned to normal operation and traffic levels resumed on the other site.

This example simply highlights that the problems at an area might not be as directly apparent when just using statistics. Adjacent sites performing

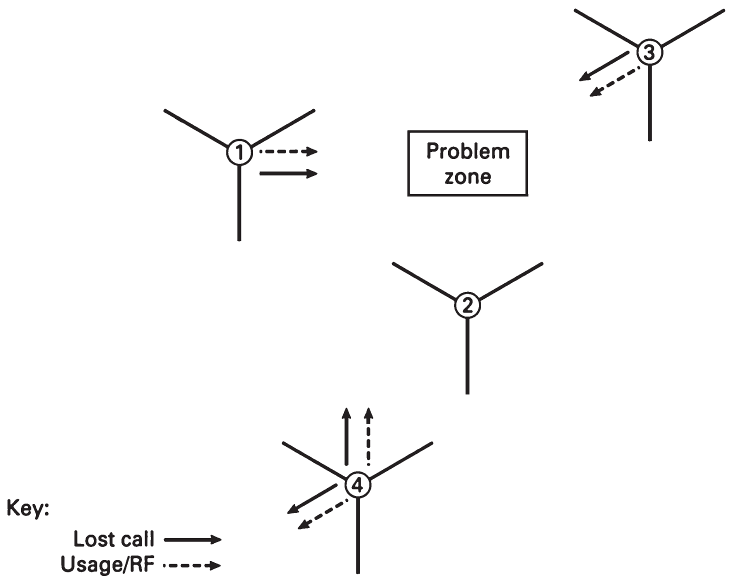


Figure 5.14 Visual display of lost call data from Fig. 5.9.

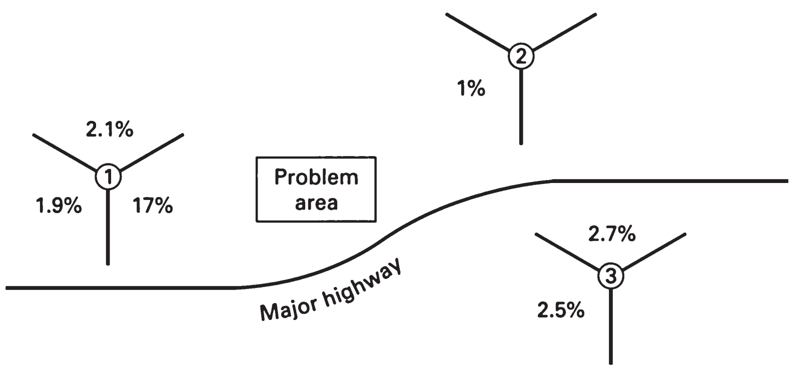


Figure 5.15 Problematic area.

poorly, either through low usage or parameter misadjustments, can directly affect the lost call rate.

Another successful technique for helping identify areas to focus on for system troubleshooting is to utilize input from customer service. Based on the sophistication that exists between the technical group and customer service the level and volume of information exchanged can range from great to sporadic.

It is recommended that customer service information regarding reported lost calls be identified and mapped to identify cluster areas. The identified problem areas should cross correlate with the data collected from the statistics. However, this customer service data should be used to check the data coming

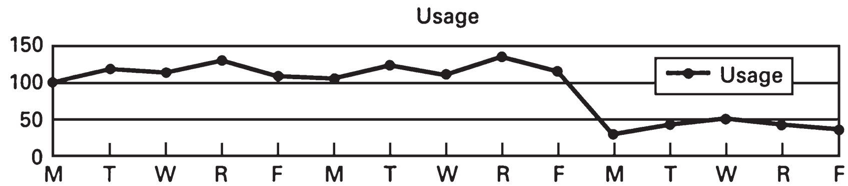


Figure 5.16 Cell site 2, sector 3 usage.

from the metric system and identify the volume of problems for a given area. For example, if 20 percent of customer complaints were coming from one major roadway and the static data did not corroborate the same story, this could be an indication that other problems are occurring in the network.

The basic questions to consider when identifying the worst performers in the network are

1. What changes were made to the network recently in that area?
2. Are there any customer complaints regarding this area?
3. Who are the reusers, what is the co-channel, and what is the adjacent channel for the area, two or three rings out? (Not applicable for CDMA)
4. What is the site's configuration, hardware, antennas, etc.?
5. Do the topology handoff tables indicate one-way handoffs, either into or out of the site?
6. Are there any unique settings in the cell site parameters?
7. Does an access failure problem also exist for the same area?
8. What is the signal-level distribution for the mobiles using the site?
9. Is there a maintenance problem with the site?
10. Does one individual radio cause most of the problems?
11. Is there a software problem associated with the cell site load?

If you use this list as a general reminder when initially looking at a poorly performing site, it will expedite your efforts. Most of the time the problems leap out at you, though, of course, at times they do not. It is when the problems are not obvious that it is imperative to utilize a checklist. There are many causes of lost calls in a network, and the effort to minimize or eliminate them is an ongoing process.

5.4 Access Failures

Access failures, also known as access denied levels and attempt failures, are another key metric to monitor and continuously work on improving. The attempt failure level is important to monitor and act on since it is directly related to revenue. Attempt failures can occur either as a result of poor coverage, maintenance problems, parameter settings, or software problems. Regardless of the exact cause for the attempt failure, when you deny a customer access on the network due to its received signal level, this is lost revenue. It is important to note that from the customer's aspect, whether the call or data session is denied because of access problems or because of radio congestion, the frustration level is the same.

The value and methodology used for setting and troubleshooting is very important for determining and improving the health of a network. Most vendors have a software parameter that can be set for establishing the actual received signal strength, or access threshold, level for denying a subscriber service on the network. One constant theme from the ranks of engineering is that the value needs to be set at a level that will ensure a good-quality call because subscribers would rather experience no service than marginal service. However, what constitutes marginal service versus good service is very subjective. We will argue that the ultimate litmus test for determining what the correct access level is can be derived by monitoring actual system usage and customer care complaints.

The other argument that constantly arises is that if the access parameter is set too low, this will increase the lost call rate of the network. Conceptually these two items appear to be directly related. However, in reality the parameter setting and the lost call rate are not as strongly related as initially believed. Specifically in a dense urban environment using three different vendors' equipment the lost call rate is not coupled to the access denied level on a one-to-one basis. In fact access values were set to almost correspond to the noise floor of the system with an improvement in the lost call rate still taking place at the same time.

It must be cautioned that just setting the threshold parameter to near the noise floor will not necessarily result in reduction in the lost call rate. If the access threshold settings are just changed with no other proactive action taken, the net result could easily be an increase in the lost call rate. However, as part of a dedicated program of system performance improvements the attempt failure rate can be successfully reduced at the same time the lost call rate is being reduced.

There are several methods for measuring the attempt failure level in a network. Two of the methods used are identified here:

Method 1:
$$\text{Attempt failures} = \frac{\text{no. of access denied}}{\text{total seizures}} \times 100$$

Method 2:
$$\text{Attempt failures} = \frac{\text{no. of access denied} - \text{directed retry}}{\text{total seizures} - \text{directed retries}} \times 100$$

Using some simplistic numbers, a simple comparison of these two methods for calculating attempt failures can be accomplished.

$$\text{No. of attempt failures} = 1000$$
$$\text{No. of directed retries} = 500$$
$$\text{Total seizures} = 50{,}000$$

Method 1: $$\text{Attempt failures} = \frac{1000}{50{,}000} \times 100 = 2\%$$

Method 2: $$\text{Attempt failures} = \frac{1000 - 500}{50{,}000 - 500} \times 100 = 1.01\%$$

The first method of calculating the access failure rate for the network will indicate the true level of problems associated with access issues. However, if you utilize method 2 for your attempted failure calculation, the actual level of problems being experienced could easily be misleading.

Another comment about method number 2 pertains to the directed retry value reported by the network. Specifically the directed retry will cause another attempt failure at the new target cell site and also add to the total seizure count for the network. The use of directed retry for any reason has to be tightly controlled and monitored to ensure adverse system performance does not take place. The reason the directed retry parameter needs to be tightly controlled is that using it can easily mask system problems. The primary lesson you can derive from this simplistic example is that once again it is exceptionally important to understand the equation that is being used in the metric calculation.

The next logical issue concerns how you define the system goals and how you monitor your progress and report it to upper management. Like the lost call rate there are several methods from which to calculate attempt failures. However, it is important to keep in mind that it is important to have any system performance report reflect what the subscriber experiences.

Two methods were shown for calculating the attempt failure levels in a network. Method 1 is referred to as the overall method for determining the access failures on a network. Method 2 is referred to as a diluted method for determining access failures onto a network.

Whether you use the overall method or the diluted method, it is important to be consistent. The relative health of the network can be determined by either method using simple trending models that compare past and present performances. However, the diluted method will mask actual problems in the network. If your goal is to improve the overall quality of the network and the revenue potential for the company, the overall method is best.

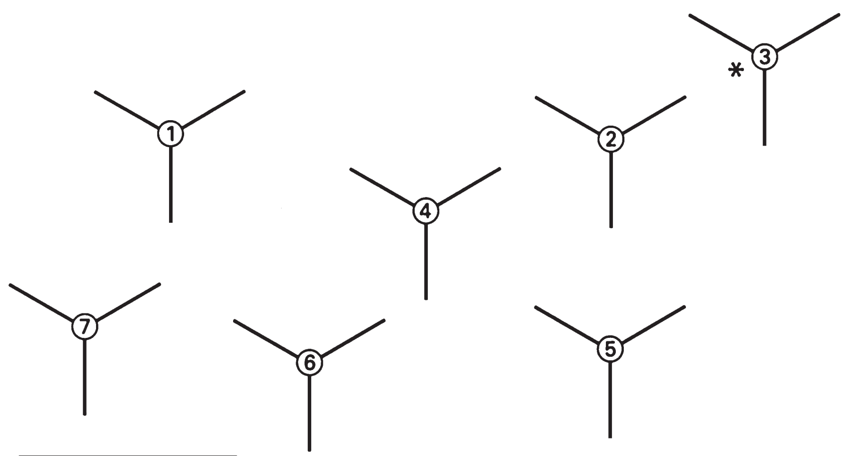
Several equipment manufacturers have the ability to report attempt failures on a per-sector basis. An obvious issue is that many vendors have each sector populated as a separate cell. Another issue is determining the proper level of granularity to utilize for monitoring this important parameter. Obviously the goal ultimately desired is to have no denied access to the network as a result of signal strength levels received. However, until there are no coverage or double-access problems in a network, an interim value must be used as part of the path for improving the network.

A similar approach should be used for setting the value for access failures as that used for the lost call value method discussed previously. The time frame used for the attempt failure rate should be identical for the lost call metrics because you should use these parameters together as a method for qualifying the site's overall performance. Also, as for the lost call goals, it is important to set yearly and quarterly access failure goals and to have all the groups involved with achieving the objective help set the goals.

Now that you have determined the access failure level to use for the system, the next step is the same as for the lost call goals: You need to identify the poor performers in the network. The methods used are the same as that for the lost calls, percentage and raw numbers. For example, using the percentage number method, the poor performers will be identified, regardless of the traffic load. Using the percentage method will help identify if there is a fundamental problem with the site for attempt failures. However, if the site is co-setup, co-DCC with another site, the problem might not be with the site itself but with the actual frequency assignment for the setup channel.

With a co-setup, co-DCC situation an attempt failure will be recorded by the system for the call being placed, but the subscriber will gain access to the network. The system will either report an attempt failure due to the signal level being inadequate or a facility assignment failure due to the mobile not arriving on the target channel. This situation is best represented in a series of diagrams.

The mobile is near cell site 7 in Fig. 5.17 and originates a call on the network. The mobile scans all the setup channels and determines which cell it is receiving the most forward energy on. The mobile selects the strongest channel and responds with a request to access the system on the reverse control channel, 321 for this example (see Fig. 5.18).



Cell	Setup	DCC
1	323	1
2	331	0
3	321	1
4	325	2
5	329	0
6	327	0
7	321	1

* Indicates problem sector.

Figure 5.17 Access failure example.

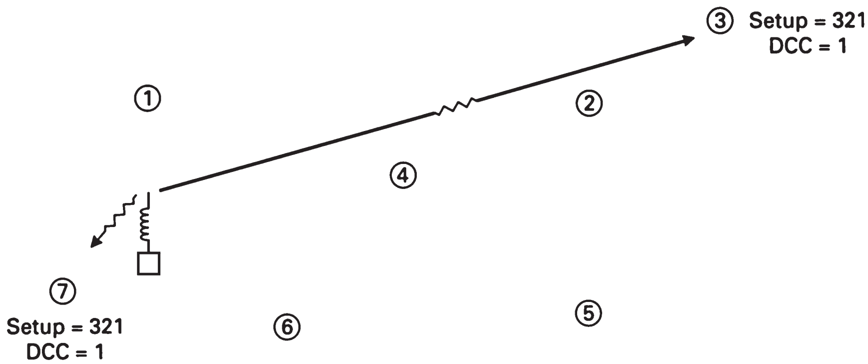


Figure 5.18 Access failure example.

When the subscriber unit responds on the reverse control channel, cell 7 evaluates the mobile for access on the network as part of its call-processing algorithm. However, cell 3 is using the same setup channel and DCC as cell 7 is. The mobile's signal, which is sent on the reverse control channel 321, is not only detected by cell 7 but also by cell 3.

In this situation cell 3 will attempt to assign the mobile a voice channel at the same time cell 7 is doing the same. Depending on the system configuration and software, a channel could be assigned or an attempt failure would be recorded at cell 3. If cell 3 tries to assign the subscriber a voice channel, it will ultimately record a facilities failure for this assignment since the subscriber will have really arrived on cell 7.

In this example the subscriber will have been assigned channels at several potential cell sites at the same time but will successfully arrive at the closer site and be assigned a channel, while the problem site identified is reporting problems, but this does not really impact on the subscriber. This situation described could be simply resolved by assigning a different DCC value, possibly DCC = 2, for site 10.

An example of another attempt failure problem occurred due to a serious imbalance in the link budget for a site. The effective radiated power (ERP) for the site was incorrectly specified by engineering for the location. In particular the ERP for the site was in excess of 200-W ERP when the site should have been operating at a maximum of 50-W ERP. The disparity in signal level was driven by the miscalculation of feedline loss. The operations department set the value for transmit power according to the engineering department's recommended value. The real ERP from the site set up a major disparity in talk-out versus talk-back paths. The additional 6 dB of talk-out power than the site was designed for resulted in mobiles originating on the site outside of the receive path's radius. The imbalance in talk-out versus talk-back paths resulted in numerous attempt failures due to the sign levels received at the site. The situation was corrected after a site visit to the area with the technician when the feedline miscalculation was noticed.

Access failures can also point to a bad receive antenna where the access failure levels increase right after rainstorms and heavy moisture. Since all the sites utilize switching or maximum ratio combining for diversity receive, a bad leg of the receive path can adversely affect the access failure levels of a site.

These examples point out again that just altering a parameter by itself is not necessarily the solution. There are many aspects that can cause an access failure, and it is only through isolation of the variables that the real problem can be uncovered.

When looking to help minimize the access failure levels in a network, it is imperative that you look for a pattern. The pattern search is best achieved through a two-step method. The first step is a pattern search that involves sorting the worst performer by access failure percentage number. The next step in the pattern search involves sorting the list by the highest raw access failure. You then take each of the worst 10 or 15 sites and put them on a map or other visual method and look for a pattern.

The basic questions to consider when identifying the worst performers in the network are

1. Does a lost call rate problem also exist for the same area?
2. What are the co-setup, co-DCC sites [digital control channel (DCCH), pilot pollution, etc.]?
3. What is the signal level distribution for the originating signals on the site?
4. Are there any customer complaints regarding this area?
5. Is there a maintenance problem with the site?
6. Does one individual radio cause most of the problems?
7. Is there a software problem associated with the cell site load?
8. Were most of the problems caused by one mobile or a class of mobiles?

One of the major problems associated with attempt failures is the lack of a dominant server for the area. This is often referred to as a random origination location. The lack of a dominant server for CDMA systems is referred to as *pilot pollution.* The primary problem with random originations is that there is no one setup, or control, channel that dominates the area where the problem occurs. The lack of a dominant server leads to mobiles originating on distant cells creating interference problems in both directions, uplink and downlink.

The uplink problem occurs since the mobile is in the wrong geographic area and is now in a position to spew interference into a reusing cell site's receiver. The downlink problem occurs simply because the frequency set designed for the area is not being used, or potentially not being used. The downlink problem is more pervasive since the subscriber unit is the victim due to the transmit power reusing cell site.

One key concept to keep in mind is that any reduction or increase in ERP has a dramatic impact on a cell site's coverage. While the concept of the relationship between ERP and the cell's coverage area seems trivial and obvious, the reality behind it is staggering. For example, reducing a cell's ERP by 3 dB will significantly reduce the overall coverage area involved. The relationship is easier to follow if you look at the equation for the area of a cell.

$$\text{Area of cell} = \pi R^2 \tag{5.1}$$

where R = radius of cell. This concept eluded two design engineers.

When you adjust the ERP of a cell, the overall area it serves is significantly altered. The usual attention placed on ERP is the forward portion of the link budget, i.e., base to mobile. However, the reverse link needs to also be accounted for since a significant imbalance can easily impact the system's performance in a negative fashion.

The most important point of this is that when you reduce the coverage of one cell a new dominant server is created, expanding the coverage area of another. Using the single issue design concept could lead to more attempt failures and lost calls through focusing only on an individual cell site and not on the system.

5.5 Radio Blocking (Congestion)

Another key element in system performance and troubleshooting involves radio blocking levels of the system. Radio blocking has a direct impact on the system's performance from a revenue and service quality aspect. Determining just what are the appropriate blocking levels for a network has been a subject of many debates. Radio blocking affects both voice and data services.

Depending on the fundamental design for the wireless system, when introduced, the data services may need to share existing radio facilities with the voice network or may occupy their own unique spectrum and facilities. Presently there is no system that will, for example, have IS-136 operational and then allow a subscriber who is denied access due to radio blocking to be passed onto the GSM network, and vice versa. This ability is available, however, for CDMA systems and even between PCS and cellular bands. It is a matter of time before the introduction of multitechnology customer premise equipment (CPE) is prevalent. Until that time radio blocking will be treated separately for each technology base.

It is also very important to address the QOS aspect with wireless data. Regardless of pundits' comments, wireless data for mobility cannot replace the digital subscriber line (DSL) or cable always-on service. The reason for this bold statement is the simple fact that wireless mobile data are contention-based, i.e., subscribers need to negotiate a link every time they initiate services.

When addressing radio blocking itself, there are primarily three schools of thought. The first philosophy is that any blocking in a network is too much and will result in lost revenue. The second philosophy is that a system should operate at a 2 percent blocking level on the macrolevel. The third philosophy is that the network should be operated within a band, or range, of blocking and, as much as possible, kept within that band.

The first philosophy has its merit for when you want to ensure the most amount of network capacity at a given time. However, this philosophy will lead to overprovisioning of the network in terms of infrastructure equipment, radios, and facilities. The end result is that the inherent operating costs to the network have been substantially increased.

One serious downside to this approach, besides the inherent costs associated with the method, is the impact it has on frequency planning and other associated resources. One of the key concepts with frequency planning is to minimize the amount of reusers in a given area; this also applies to adjacent channels and to CDMA since the level of mutual interference increases. If you constantly overprovision the network, the fundamental interference levels will naturally increase since you are using more channels. While there are many techniques for controlling interference, the overprovisioning of channels only makes frequency management more difficult.

One additional comment on this approach is that if you desire no blocking on the network, this effort involves more than just the RF portion; it will be necessary to modify the public switched telephone network (PSTN) blocking level design. For example, if you have a PSTN blocking level of 1 percent, it will be very difficult to ensure a no-blocking-level approach. When establishing a radio blocking level for the network to operate at, a complete evaluation of all the components in the call-processing chain needs to be factored into the solution. Additionally with the introduction of data services the packet data serving node (PDSN) path, whether it is for connectivity to the Internet or a virtual private network (VPN), needs to have sufficient resources to meet the service-level agreement (SLA) with the customer.

The second school of thought is the more common method employed where a top-end number is used. The top-end number is a ceiling which is the level not to be exceeded. This method is a valid approach when initially deploying a system since the system is experiencing massive growth and expansion. It is also effective when there is very limited work force to monitor and adjust a system's blocking level.

The ceiling approach has been successfully used by many operators for designing a network since it is simple and straightforward. The only real issues with the ceiling-level approach is defining the blocking levels, which equations to use, the utilization rate, and the time intervals. The most common blocking level used for designing is the 2 percent blocking level for the busy hour. The other particulars associated with the ceiling-level approach which need to be focused on will be discussed later.

The third approach (banding) to blocking level designs is more relevant to a mature system and requires constant monitoring and adjustments. It is a very efficient way to utilize a network's resources. The banding method involves setting top-end and lower-end blocking levels to operate at. It is customary to set the upper range at 2 percent and the lower range at 1 percent (Fig. 5.19).

Based on the traffic and growth of the network the adjustments needed for the network might seem daunting. However, the banding method can and has been used to keep the amount of fluctuations in network provisioning requirements

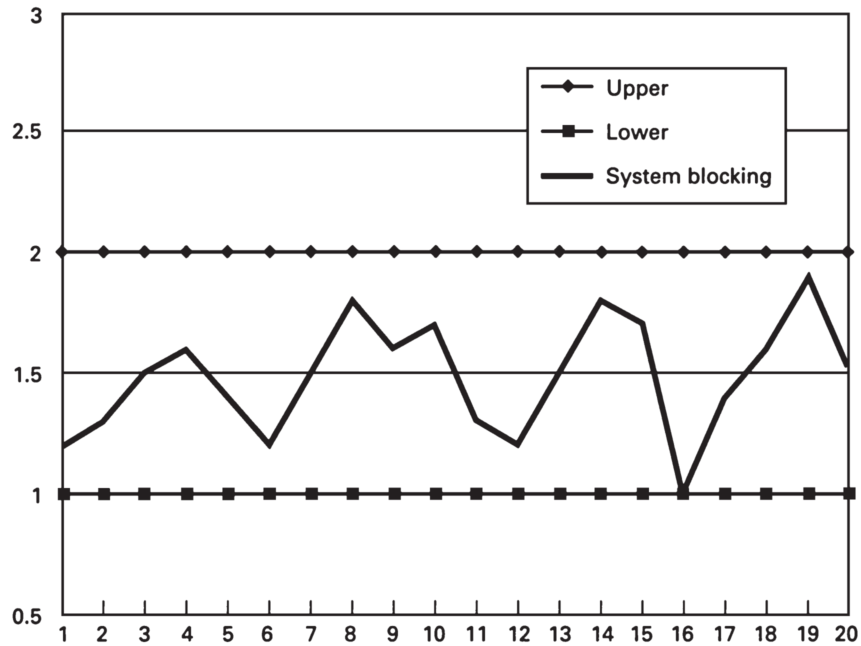


Figure 5.19 Banding method.

to a minimum. Implementing the banding approach will require a dedicated and focused approach to keep the system operating within the limits set.

The banding approach will also focus on removing channels from cell sites that are not exhibiting high usage. The advantage with removing unneeded radio channels is that this will make additional channels available for reuse or will simply reduce the aggregate interference levels in the network.

Regardless of the method utilized, ceiling or banding, for setting the blocking level of the network there are several similar methods of operation that need to be adhered to. The items to focus on for keeping system blocking levels within some design guidelines are which equations, utilization rate, time intervals, and logistics management are used.

Blocking calculations take on several forms; however, there has and will be a constant running debate between whether to use erlang B or Poisson for voice services and erlang B or C for mobile data. The equations for erlang B and Poisson are listed below for reference. Erlang B is the normal industry standard and should be applied for determining the trigger points to act from for voice services.

Erlang C is used for data services, e.g., packet, and PSTN facility dimensioning. However, erlang C does not lend itself to spreadsheet entry, i.e., a straightforward equation like erlang B. With that said, it is possible to use erlang B to approximate erlang C; e.g., erlang B 5 percent is about the same as erlang C 2 percent. The relationship between erlang B and erlang C is not linear, and you should consider whether you want to use this approach.

A key concept in all traffic engineering is the definition of an erlang. The *erlang* is a dimensionless unit since the numerator and denominator are of the same units and thus cancel out. In the wireless industry an erlang is simply defined as 3600 s of usage in a 1-h time period. Therefore, if you have two radios and each is occupied for 1 h, 3600 s, then this represents 2 erlangs of usage.

The erlang B equation is as follows:

$$\text{Grade of service} = \sum_{n=0}^{n} \frac{E^n}{n!} \tag{5.2}$$

where E = erlang traffic
n = number of trunks (voice channels) in group

There are numerous books and technical articles regarding erlang B's statistical nature and accuracy. However, the primary driving element with erlang B is that it estimates, statistically, the probability that all circuits will be busy when you try and make a call. The issue with the erlang B calculation is that it assumes the call, if not assigned a circuit, is lost from the network permanently.

The Poisson equation

$$\text{Grade of service} = e^{-a} \sum_{n=c}^{\infty} \frac{a^n}{n!} \tag{5.3}$$

where a = erlang traffic
c = required number of servers
n = index of number of arriving cells

should be compared against the erlang B value arrived at for the same amount of circuits and grade of service. The fundamental difference between erlang B and Poisson is that in Poisson you are assuming blocked calls get put into a queue instead of being discarded.

Obviously neither erlang B nor Poisson represents the real world as it pertains to wireless since neither are exact models for subscriber and traffic patterns in wireless. However, erlang B is used as the predominant statistical method for traffic calculations and growth predictions for voice and many packet services. Using erlang B as the foundation for projecting radio blocking values is the recommended method to use, but the grade of service (GOS) needs to be company and market specific.

It is very important to know what method of blocking statistics your company is using when projecting radio growth for a network. The reason is that knowing which method and equation to use has lead to some interesting discoveries on how blocking levels are determined. Two primary situations occurred which seriously affected the capital deployment of the networks involved due to homemade equations being promoted as erlang B.

In one situation the operator was using a traffic table called erlang B. The traffic table was used for defining how many radios needed to be added into a given cell site. A problem was uncovered when putting together a growth study and with the desire by engineering to use a spreadsheet for calculating channel growth requirements. Since the traffic table was touted as erlang B, a spreadsheet was structured using the erlang B equation (5.2). The error in the traffic table was uncovered when spreadsheet values were compared to the traffic table provided. The net result was that overprovisioning of radios was being done with the supplied traffic table. After many internal debates, the incorrect table was used since it inflated the system requirements to upper management for budget purposes.

The second situation occurred where another operator was using a table, again call erlang B, that was crafted by a traffic engineer. The current traffic engineer when challenged over the table inconsistencies was unaware of what the erlang B equation was and was simply using the traffic table provided. In investigating this issue it was found that there was a deliberate attempt by the engineering manager to overprovision equipment at a cell site to account for a maintenance buffer. The correct erlang B equation was then used by traffic engineering, and the amount of radios needed for the network was significantly reduced.

The primary point with these two examples is that it is very important to know the baseline equation being used for provisioning the network. An incorrect equation can lead to over- or under-provisioning of the network.

The utilization rate for the radio equipment is another key parameter that needs to be focused on and defined. The utilization rate of the radio's channels for a cell site's sector determines at what point in the process it will be necessary to start provisioning for expansion. When you are at 80 percent utilization rate for a sector, it is time to ensure that additional radios are being planned for the site. When you are at 100 percent utilization rate for a cell, based on the derived blocking level used, the turnaround time for restoration is too short.

A low utilization rate is indicative of overprovisioning, and there should be a lower limit placed on this value to keep the system from being underutilized. The utilization rate should be used as a trigger point. The rate picked by you is entirely dependent upon your internal work force and financial resources.

Once you have arrived at a utilization rate to operate from, you then perform a trend analysis. The trend analysis needs to focus on the next period of growth with the purpose of determining the amount of radios you will require.

The next step in the process is to define the time used for monitoring the network. The same system busy hour used for reporting lost calls and attempt failures should be used. However, it is important that a bouncing busy hour traffic report gets generated on a biweekly basis to ensure that there is not a fundamental shift in the traffic pattern. The bouncing busy hour report will also help identify fraudulent usage on the network or unique demographics that can help marketing.

This leads to the question of how to go about provisioning the network. The step-by-step generic process is listed here. For this process we will assume the banding method uses a 1 to 2 percent erlang B blocking level range. In addition the system busy hour and an 80 percent utilization rate are the two other key parameters. The process presented here can either be led by the manager for network or performance engineering.

On a 6-month basis

1. Determine, based on growth levels, the system needs for 1, 3, 6, and 12 months.
2. Factor into the process expected sites available from the build program, accounting for deloading issues.
3. Establish the number of radios needed to be added or removed from each sector in the network.
4. Modify the quarterly plan that is already issued.
5. Determine the facilities and equipment bays needed to support channel expansions.
6. Inform the frequency planners, performance engineers, equipment engineers, and operations of the requirements.
7. Issue a tracking report showing the status of the sites requiring action. This report should have in it as a minimum:
   - Radios currently at the site
   - Net change in radios
   - When radio exhaustion, percent blocking meeting design goals, is expected
   - When other radio element exhaustions [e.g., channel elements (CE) for CDMA] are expected
   - Radios ordered (if needed)
   - Facilities ordered (if required)
   - Radios and other related resources secured
   - Frequency issues (technology specific)
   - Cell site translations completed
   - Facilities secured (if needed)
   - Radios installed or removed
   - Activation date planned for radios
8. On a quarterly basis conduct a brief 1-h meeting to discuss the provisioning requirements and arrange for the work force.
9. Perform a biweekly traffic analysis report to validate the quarterly plan and issue the tracking status report at the same time.

The last step in the tracking system process involves the activation date planned for the radios. This particular piece will enable you to pre-position the radios in the network without actually activating them. Specifically if the radios are needed for the midpoint of March and then are installed in January, you can keep the interference levels to a minimum by having them remain out of service.

Blocking problems in a network can occur as a result of a multitude of reasons ranging from normal network growth, a localized traffic jam, changes in traffic patterns due to construction detours, hardware problems, or software problems.

5.6 Technology-Specific Troubleshooting Guides

In this section are several troubleshooting guidelines which are meant to help facilitate the identification and resolution of performance problems in a wireless network. Obviously there are numerous types of problems that can and do arise in a wireless system. However, procedures put forth should net some benefits. As with any technology, the guidelines may need to be modified to reflect vendor- and network-specific issues.

The guidelines here do not address multiple-technology platforms within any market because of the magnitude of perturbations and the simple fact that each technology platform, within a wireless network, will be configured differently starting with parameter settings.

Additionally there are some common troubleshooting issues that are relevant regardless of the technology platform used. The issues are simple in nature, but how they manifest themselves in a system is unique based on the underlying technology and, of course, infrastructure vendor and software load currently being used.

1. Neighbor list problems
2. Coverage problems
3. Frequency plan problems
4. Capacity problems
5. Base station controller (BSC) and mobile switching center (MSC) boundary problems
6. Site-specific parameters and configuration problems
7. Maintenance and equipment outage problems

Any performance engineer will be familiar with these topics. Therefore, when investigating and ultimately resolving any technical performance problem, the fundamental seven universal issues should always be considered.

With this said, we have attempted to define some of the more specific trouble-shooting issues in the next sections. As one would expect, the checklists are not all-inclusive but should prove useful.

5.7 IS-136

The troubleshooting guidelines that should be followed for any IS-136 system need to factor in whether the system uses IS-136 channels only, e.g., a U.S. personal communication service (PCS) system, or is a cellular operator that has AMPS and IS-136 channels in operation. With the advent to third-generation (3G) services most IS-136 operators at this time have chosen to migrate some or all of their systems to GSM, at least the portion of the system which is in the PCS band.

The methodology set forth in this section will focus on using the seven main performance issues. Throughout this section for troubleshooting it will be assumed, to avoid too much redundancy, that the seven-step performance troubleshooting process, which was discussed at the beginning of this chapter, is followed.

The main problems that will be covered for IS-136 include

1. Lost calls
2. Static
3. Access
4. Handoff failures

Since these four main performance issues are the more pertinent to any operation and are evident to the customer, they will be focused on. The items do not necessarily need to be checked in this order.

5.7.1 Lost calls

Typically a lost call for an IS-136 system occurs when there is a digital voice color code (DVCC) timeout. This happens when a call that is on a digital traffic channel loses the DVCC. The loss of the DVCC can take place at the mobile or cell site, and the tolerable amount of time for the loss of the DVCC is set by the wireless operator. Typically this value is a default value which is established by the infrastructure vendor.

The three main causes of lost calls for IS-136 are

1. Coverage problems
2. Interference, both cochannel and adjacent channel
3. Neighbor list problems

When reviewing data, if the site is experiencing a high lost call rate, or any lost call rate which requires focusing resources on, the following items need to be checked:

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).*

2. *Verify that there are no coverage problems with the prediction and field data.* You need to verify that the prediction and field data (if available) confirm or deny that there is a problem. If there is a coverage problem, then there exists the distinct possibility that this may be the leading, but not the only, source of the problem. Coverage problems could be caused by terrain or the existing system configuration. Sometimes the adjacent site configuration is the cause or can be altered to resolve the issue.

Many of the infrastructure vendors have internal diagnostics available which are able to plot the nominal signal level, the reverse signal strength indicator (RSSI), for the subscriber unit from the cell site's aspect at a minimum. What you want to check is that there is sufficient C/N to ensure the call is sustainable for 90 to 95 percent of the reported signals.

3. *Review the neighbor list for the primary site.* Check the site's neighbor list to verify that there are no missing or incorrect neighbors, and check and verify that there is not an excessive number of neighbors. You should also check for reciprocity for the neighbor list, but this will not manifest itself in a high lost call rate for this site, only the neighboring site which may not be reciprocal. Also check the hysteresis value for the handoff. At times the hysteresis value could be set to preclude the handoff from taking place.

Most vendors have built into their operations and maintenance center (OMC), or like product, the ability to look for one-way handoffs and to define the amount of handoffs that occur on a per-candidate basis. For example, handing off from cell A to B might occur 60 percent of the time, while from cell A to C it might occur 5 percent of the time. What you want to look for is the proximity of the sites and if the candidate selection process makes sense from your experience. Keep in mind that time of day plays a major role in mobility issues, but stationary coverage, e.g., building, may be worth checking. For the stationary situation the frequency of handoffs may be an indication of a ping-pong effect and in this case attention to hysteresis may be appropriate.

4. *Check the frequency plan.* You need to review the frequency plan that is in place for the site and sector involved. Things to look for involve cochannel and adjacent channel interference, including when the adjacent channel is in the same or adjacent sector or when the cell with that sector overlaps the problem sector. What you want to do is check the frequency plan on a per-sector and per-channel basis for any obvious issues with cochannel reusers. If there is an interference issue, it might be resolved temporarily by placing the offending channel out of service, provided there is sufficient capacity to warrant this approach. However, depending on the severity of the problem, rendering a channel out of service can cause additional problems at the sites adjacent to the site with the channel taken out of service.

5. *Check traffic loading.* Next review the traffic load at the surrounding sites and ensure that each site has sufficient capacity so that a mobile can hand off to it. If the neighbor site is blocking, this could be a cause of the lost call rate. Also directed retry may be activated resulting in subscriber units (SUs) operating outside of their designed coverage area. Things to look for involve the amount of DTCs in use and where any of the messaging channels have to discard packets due to loading issues. Also the amount of measurement requests initiated by the cell site need to be reviewed to determine if the frequency of them could be reduced.

6. *Check cell site parameters.* This part of the check involves reviewing the site's specific configuration and software settings. Things to check involve topics beyond the neighbor list and possibly the ERP for the site. For example, you need to review the power control settings for the site and existing software load. For any of the parameters checked relative to the site or sector you need to compare them to the design standard which is used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the root source of the problem.

One mentioned item to look for besides the dynamic power control (DPC) and fade time is the digital mobile attenuation code (DMAC) value for the sector. Additionally the site's software configuration needs to be checked, i.e., the channels and DVCC associated with each channel. In other words check the datafill for anything out of the norm.

7. *Check the MSC borders.* Verify the location of the MSC borders and ensure that high traffic areas are not on an MSC border. If they are, then the source of the problem may be the border itself where due to the time required for the handoff process to occur, the SU dropped because the fade timer initiated the premature termination.

8. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single channel. If it can, then all DTCs will be affected. You will also want to verify that there were no T1/E1 outages for the site at that time or the adjacent sites since this would negatively affect the performance of the site. One other item to look for is the possibility of an antenna system problem, which would warrant a site visit, if no other problems could be found. Some vendors have the ability to monitor the antenna system for voltage standing-wave ratio (VSWR) which would indicate whether a problem might exist or not. Also if historic antenna data are available, it might be worth it to check and see if there is any degradation and if the problems appear more prevalent after a rainstorm indicating water intrusion.

5.7.2 Handoff failures

Handoff failures should not be an issue with IS-136 with mobile assisted handoff (MAHO). However, there are still handoff failures which occur. The following is a brief listing of items to check when investigating a high handoff failure rate for a site or sector.

1. *Review the neighbor list for the primary site.* See part 3 of the list in Sec. 5.7.1. You should check for reciprocity for the neighbor list, but this will not manifest itself in a high handoff failure rate for this site, only the neighboring site which may not be reciprocal. In addition, what you want to check, besides the actual neighbor list, is the time between handoffs. There is a systemwide number which you should use as the benchmark for performance. If the time between handoffs is very small, as compared to the norm, then either the cell site is shedding traffic or it may not be the correct candidate to use from the beginning. However, coverage and terrain issues may justify a low time to handoff ratio.

2. *Check cell site parameters.* This part of the check involves reviewing the site's specific configuration and software settings. Things to check involve ERP imbalances for the site where the DCCH is operating at one power level and the other channels are operating at a lower power level, leading to possible handoff failures, and, of course, dropped calls. You should also review the power control settings for the site and existing software load. You need to compare any of the parameters checked relative to the site or sector to the design

standard which is used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the root source of the problem. This check should also be done at the potential source sites to ensure that they are set properly. Again for this part of the investigation all aspects of the datafill need to be looked at for both the source and target cells and sectors.

3. *Check the MSC borders.* See part 7 of the list in Sec. 5.7.1.

4. *Check for maintenance issues.* See part 8 of the list in Sec. 5.7.1. If historic antenna data are available, it might be worth it to check and see if there is any degradation and if the handoff failures appear more prevalent after a rainstorm indicating water intrusion.

5.7.3 All servers busy (ASB)

The problems with access to the wireless system involve both blocking, i.e., resources not available, and an insufficient signal. In the situation where resources are not sufficient to address the current traffic, the obvious response would be to just simply add radio channels. However, the traffic increase may be caused by incorrect parameter settings or a deliberate attempt to reallocate traffic. There are several items to look for in verifying that indeed you need to add channels or possibly a cell site to relieve the traffic.

1. *Determine the source of the blockage.* It is important to know the source of the blockage since it will tell you how to possibly relieve the situation both on short-term and long-term bases. You will need to determine the volume of traffic type for the cell or sector and if it is origination based or handoff based. For instance, a normally balanced cell for a typical mobile system will have one-third originations and two-thirds hand-ins; your numbers may vary, but the illustration is important. If this cell were to have two-thirds originations and one-third hand-ins, you might indicate that the blockage problem is near the site itself. If the majority of the traffic was hand-in, then the source of the traffic would be from an adjacent site.

The source is important in determining the possible solutions. For traffic originating at the site you might want to relax the MAHO hysteresis for target cells and hand off more traffic shedding the load. Or you might want to increase the hysteresis for this site since it is the target cell, reducing incoming traffic if the problem is inbound. You should also check for a directed retry situation where the cell site is the target of the directed retry.

2. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single channel. If it can, then all DTCs will be affected. You will also want to verify that there were no T1/E1 outages for the site at that time or the adjacent sites since this would negatively affect the performance of the site.

3. *Check the cell overlap.* If there is sufficient cell overlap, you might want to visit the issues of shedding traffic, origination, and possibly handoff, by reducing the site's ERP. Additionally or separately the DMAC values can be

reduced, provided, of course, that the adjacent sites have sufficient capacity and the frequency plan supports the configuration change.

5.7.4 Insufficient signal strength (IS)

Insufficient signal strength is caused by either lack of coverage or parameter manipulation by the operator. Therefore, there are a few items to check.

1. *Verify there are no coverage problems with the prediction and field data.* You need to verify that the prediction and field data (if available) confirm or deny that there is a problem. If there is a coverage problem, then there exists the distinct possibility that this may be the leading, but not the only, source of the insufficient signal level. Coverage problems could be caused by terrain or the existing system configuration. Sometimes the adjacent site configuration is the cause or can be altered to resolve the issue.

Many of the infrastructure vendors have internal diagnostics available which are able to plot the nominal signal level, RSSI, for the subscriber units which access the system. This is an important diagnostic tool to use, if available. For instance, if the IS percent goal is less than 2 percent but the diagnostics indicate that 10 percent of the SUs that access the site are below the required RSSI, prior to DPC adjustment, then this leads you to check coverage or to the possibility that the site is a directed retry candidate.

2. *Verify the dominant server.* You will need to check if there is an area the cell covers that has no dominant server. The lack of a dominant server may either lead to originations occurring on the wrong cell and being denied due the IS level setting at the potential target cell or manifest in high lost calls and handoff failures.

3. *Check cell site parameters.* See part 2 of the list in Sec. 5.7.2. In addition, the particular IS parameter setting needs to be checked, this is often the source of the problem if there is sufficient coverage for the area.

4. *Check the MSC borders.* Verify the location of the MSC borders and ensure that double originations are not taking place resulting in glare or denials due to double access caused by the location of the MSC border. If they are, then the source of the problem may be associated with the DCCH assignment methodology used.

5. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single channel; if it can, then all DTCs will be affected. IS problems will not manifest themselves with a T1/E1 outage for the site but will be caused by a possible bad antenna system.

5.7.5 Static

The need for an investigation of static for a cell will not necessarily appear on the statistics but will in all likelihood be born from customer service or internal reports. However, static is usually a result of poor voice quality which is a result of reduced BER and FER.

Identifying the source of the static problem is a combination of reviewing coverage, handoff, and possible access problems to the network.

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes were made).*

2. *Verify that there are no coverage problems (prediction and field data).* See part 2 of the list in Sec. 5.7.1.

3. *Review the neighbor list for the primary site.* Check the site's neighbor list to verify that there are no missing or incorrect neighbors and check and verify that there is not an excessive number of neighbors. You should also check for reciprocity for the neighbor list. In addition, check the hysteresis value for the handoff. At times the hysteresis value could be set to preclude the handoff from taking place.

4. *Check the frequency plan.* See part 4 of the list in Sec. 5.7.1.

5. *Check traffic loading.* See part 5 of the list in Sec. 5.7.1.

6. *Check cell site parameters.* See part 6 of the list in Sec. 5.7.1.

7. *Check for maintenance issues.* See part 8 of the list in Sec. 5.7.1.

5.8 iDEN

An iDEN system is unique in the RF performance environment since it is really two systems within one. There is an interconnect and a dispatch system which share some similar resources. For example, if the interconnect to a particular tandem is not dimensioned correctly, i.e., it has too few circuits, then the customer can experience blocking. The customer is not aware of where the problem occurs, only that it does occur. Another example is if the registration borders for both the interconnection location area (ILA) and dispatch location area (DLA) are not properly designed. This could lead to either an increase in PCCH activity or the potential for a subscriber to experience a registration problem.

Motorola has a wealth of specific troubleshooting and performance-related guidelines for the iDEN system. These guidelines should be used since the list of issues that have a direct impact on the system performance of a network is vast. In addition, as more features and equipment are implemented into the network, the complexity of the situation only increases.

We cannot realistically cover every possible performance situation that might occur in an iDEN system. However, we will attempt to list some of the more salient issues following the seven-step performance troubleshooting process which was discussed at the beginning of this chapter.

For reference it is important to note that there are 3:1 and 6:1 or 12:1 interconnect and voice calls, as well the dispatch which uses the 1:6 process in addition to any packet service. At this writing there are several enhancements being pursued for iDEN which should greatly improve its traffic-handling capability while not sacrificing voice quality.

5.8.1 Lost calls

Typically a lost call for an iDEN system can be traced to one of the following three culprits (assuming there is no maintenance issue which can also exacerbate the problem):

1. Coverage problems
2. Both cochannel and adjacent channel interference, either self-induced through reuse or from legacy specialized mobile radio (SMR) users.
3. Neighbor list problems

It is important to note that lost calls are not necessarily associated with dispatch calls because the very nature of dispatch involves push to talk (PTT) service and is by default short in duration. Therefore, when reviewing data, if the site is experiencing a high lost call rate for interconnect, or any lost call rate which requires focusing resources on, the following items need to be checked.

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).*

2. *Verify the 3:1 and 6:1 or 12:1 relationship.* Determine if the lost call rate is associated with the 6:1 and 3:1 or 12:1 interconnects. If the problem is 3:1 and not 6:1 or 12:1, then there might be a capacity problem or other network-related issue. If the problem is 12:1 or 6:1 and not 3:1, it could be an SQE or raw coverage problem.

3. *Verify that there are no coverage problems with the prediction and field data.* You need to verify that the prediction and field data (if available) confirm or deny that there is a problem. If there is a coverage problem, then there exists the distinct possibility that this may be the leading, but not the only, source of the lost calls. Coverage problems could be caused by terrain or the existing system configuration. Sometimes the adjacent site configuration is the cause or can be altered to resolve the issue.

4. *Review the neighbor list for the primary site.* Check the site's neighbor list to verify that there are no missing or incorrect neighbors. You also need to check and verify that there is not an excessive number of neighbors. You should also check for reciprocity for the neighbor list, but this will not manifest itself in a high lost call rate for this site, only the neighboring site which may not be reciprocal. Also check the hysteresis value for the handoff. At times the hysteresis value could be set to preclude the handoff from taking place. Review the time between handoffs, i.e., the usage or minutes between handoffs. If the number is really low, then it is likely that the cell, as a source, is incorrect, and this might be the nature of the problem. Other parameters that fit this condition are requests for handoff, successful handoffs, and intracell handoffs. Also check that the color code for all the neighbor sites is correct in the datafill. Determine if the lost call occurred during handoff and, if so, whether it was a cochannel or adjacent channel base radio (BR).

5. *Check the frequency plan.* See part 4 of the list in Sec. 5.7.1. You need to also check for SMR interference by reviewing all known SMR operators that could be using the same channel or adjacent channels in the area of concern.

6. *Check traffic loading.* Next review the traffic load at the surrounding sites and ensure that each site has sufficient capacity so that a mobile can hand off to it. If the neighbor site is blocking, this could be a cause of the lost call rate. Also reselection and handoff classes may be nondefault resulting in SUs operating outside of their intended service area.

Make sure that the 6:1, 3:1, or 12:1 relationship is also checked for capacity-related issues. More specifically check the utilization of the time slots for 12:1, 6:1, and 3:1 usage. Also check the amount of loading that is due to dispatch for target cells to see if this could contribute to the problem.

7. *Check cell site parameters.* This part of the check involves reviewing the site's specific configuration and software settings. Things to check involve topics beyond the neighbor list and possibly the ERP for the site. For example, you need to review the power control settings for the site and existing software load. For any of the parameters checked relative to the site or sector, you need to compare them to the design standard which is used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the root source of the problem. In other words check the datafill for anything out of the norm.

Some additional issues to look for involve verifying that the transmit and receive frequencies are indeed 45 MHz in separation, depending on the software load. You should also verify that the carrier number matches the frequency for the site on a BR level.

8. *Check ILA borders.* Verify the location of the ILA borders and ensure that high traffic areas are not on an ILA border. If they are, then the source of the problem may be the border itself.

9. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single BR. If it can, then all traffic on that particular BR will be affected. You will also want to verify that there were no T1/E1 outages for the site at that time or the adjacent sites since this would negatively affect the performance of the site. One other item to look for is the possibility of an antenna system problem, which would warrant a site visit, if no other problems could be found. Some vendors have the ability to monitor the antenna system for VSWR which would indicate whether a problem might exist or not. Also if historic antenna data are available, it might be worth it to check and see if there is any degradation and if the lost calls appear more prevalent after a rainstorm indicating water intrusion. In many situations the BR could have an unterminated antenna port on the receiver leading to ingress noise.

5.8.2 Access problems

Access problems for an iDEN system can be associated with the interconnect as well as the dispatch parts of the system. There is, however, a distinct difference associated with access problems between the dispatch and interconnect parts of the system which relates to the provisioning aspects. Most of the access problems associated with dispatch are provisioning related, provided there are facilities available.

For this section a dispatch access problem followed by an interconnect access problem will be addressed. In both cases the capacity at the site will need to be reviewed, but although dispatch is packet-driven and interconnect is circuit-switched, both share the same radio resource.

Dispatch access problems. For dispatch access problems the issues involve both the network configuration and provisioning. When a dispatch problem occurs, usually it is via a trouble ticket and is somewhat reactive in nature unlike the interconnect part which can be addressed in a more proactive fashion. This is not to say that the dispatch problems are all reactive issues. Interference, cochannel or co-color code, DLA location updating, PCCH collisions, and sub-rate blocking all disrupt customer access and can be monitored for performance degradations.

1. *Perform a provisioning check.* Verify that the subscriber records indicate that they are in the allowed service. This is a simple concept but very important. You also need to check to see if the subscriber is associated with the correct fleet or group. Also determine if the problem is private or group dispatch–related, and if the subscriber trying to be raised is also allowed to be dispatched to and is provisioned in the system properly.

2. *Determine if the problem is outbound or inbound.* If the problem is outbound, the issue may be provisioning which may have been overlooked or missed in the previous step. Additionally it is possible to increase the zones the subscriber is allowed to dispatch in, and again the location where this occurs is important.

Problem messages associated with constrained outbound-PCCH would be “target not available” or “PVT-in-use, PLS try again.” Outbound problems related to reuse or cochannel or co-color code contentions would create “network trouble” or “PVT-in-use” problem messages for the sending SU and/or multiple alerts, or dispatch paging chirps, muting, or received alert and mute on the receiving SU. Insufficient digital signal level 0 (DS0) allocation, at times, will allow a successful page, yet will be mute one way or both ways. On occasion, it will also generate “network trouble” messages for the sending SU. Loss of dispatch paging due to constrained outbound-PCCH will also cause a loss of SMS paging and voicemail alerts.)

If the problem is inbound, e.g., the subscriber does not get the dispatch page (or alert) on the receiving end, the problem could be the DLA border, assuming the subscriber is provisioned correctly, or PCCH collisions due to reuse, interference, or cochannel or co-color code conditions. The DLA border could be the issue if the subscriber registered as being in, say, DLA#2 and the subscriber is now in DLA#3 but the system has not updated the registration information. This is often the case when either the DLA borders are incorrectly established or cells on the borders experience excessive DLA location updates; which are characterized by high inbound-PCCH utilization.

3. *Determine if the dispatch problem is in one area or multiple areas.* If it is in multiple areas, it is most likely a provisioning or faulty subscriber unit (poor RF performance) issue, but if it is in one area, then it is likely a DLA configuration or enhanced base transceiver (EBTS) problem which is inhibiting access to the PCCH or traffic channel (TCH).

4. *Determine if the subscriber can make interconnect calls.* If the subscriber can make interconnect calls, then the subscriber is registered on the system. However, the problem still could be provisioning related, so the dispatch application processor (DAP) and EBTS datafill needs to be checked in addition to the site or sites where the problem is reported to have happened.

5. *Check maintenance issues.* Verify that dispatching operates on the site and the surrounding sites. If it doesn't, then there is a potential maintenance problem with the EBTS hardware, subrate allocations, or DAP and EBTS datafill. Also verify that the DAP and MOBIS (Motorola's GSM A-bis) datalinks are active and there are no other network-related problems, in addition to checking the frame relay link to the sites.

Interconnect access problems. Interconnect access problems are typically due to blockage, traffic, or provisioning. Blockage associated with the TCH is driven by proper traffic engineering and allocation of the TCHs for interconnect and dispatch usage. There are several items to look for in verifying that indeed you need to add channels or possibly a cell site to relieve the traffic.

1. *Determine the source of the blockage.* See part 1 of the list in Sec. 5.7.3.

2. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).*

3. *Verify that there are no coverage problems with the prediction and field data.* See part 3 of the list in Sec. 5.8.1. What you want to check is that there is sufficient SQE to ensure the call is sustainable for 90 to 95 percent of the reported signals.

4. *Check cell site parameters.* This part of the check involves reviewing the site's specific configuration and software settings. Things to check involve ERP imbalances for the site where the beacon channel is operating at one power level and the other channels are operating at a lower power level. You should also review the power control settings for the site and existing software load. You need to compare any of the parameters checked relative to the site or sector to the design standard which is used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the root source of the problem. Again for this part of the investigation all aspects of the EBTS and DAP datafill need to be looked at for both the source and target cells/sectors.

5. *Check the ILA borders.* Verify the location of the ILA borders and ensure that there are no potential location update problems as a result of the border location.

6. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single channel; if it can, then all TCHs will be affected. You will also want to verify that there were no T1/E1 outages for the site or the adjacent sites at that time since this would negatively affect the performance of the site.

Proper T1/E1 subrate allocations must also be verified. T1s which are groomed and/or have microwave links between sites could have their DS0 allocations reset to default levels when BSCs, IGX, IPX, or BPX are reset or reprogrammed.

7. *Check the cell overlay.* If there is sufficient cell overlap, you might want to visit the issue of shedding traffic, origination, and possibly handoff, by reducing the site's ERP. Additionally or separately the subscriber power level values can be reduced. This is done indirectly by modifying the serving cell's contour and lowering the ERP in undesired areas and maintaining path balance on the handheld unit. This is, of course, provided the adjacent sites have sufficient capacity, and the frequency plan supports the configuration change. Additionally the subscriber power level values can be reduced at the site.

5.9 CDMA

The guidelines for troubleshooting a CDMA-based system need to follow, as with all troubleshooting techniques, the seven-step process defined earlier in Sec. 5.7.1. With CDMA systems, as with other wireless mobile systems, the troubleshooting methodology needs to include other RF technology platforms, based on your system configuration. The other technology platforms to be included for CDMA include AMPS, which can receive CDMA handoffs; and possibly even TDMA/GSM which could be interfering with the CDMA system. Additionally the use of cellular and PCS frequency bands in addition to the existence of different CDMA versions need to be factored into the trouble-shooting process.

The version differences apply to CDMAOne and CDMA2000 systems when you are migrating to a CDMA2000 system. The inclusion of legacy issues, i.e., the existing infrastructure, also should be considered, plus the possible separation of service class, for voice and mobile IP, based on the CDMA carrier.

The six main performance issues for any CDMA system, whether it is CDMAOne or CDMA2000, include the following topics.

1. Lost calls
2. Access failures
3. Handoff failures
4. Packet session access
5. Packet session throughput
6. Capacity and blocking

These six issues are pertinent to any operation and are evident to the customer, so we will focus on them. Obviously, packet services are only related to CDMA2000 systems which have a PDSN associated with them. The items do not need to necessarily be checked in the order presented. Based on your particular system configuration and the RF access platforms being used, the performance questions, or checks, can be merged with those for another access technology, since many have similar results but are manifested with differing symptoms, and also can be merged with the list of seven performance topics common to all technologies, as mentioned earlier in Sec. 5.7.1.

5.9.1 Lost calls

Typically a lost call for a CDMA system occurs when the BTS can no longer communicate with the SU. This relatively simple concept has a multitude of possible causes. Because of the greater reliability of calls inside the core coverage area of a wireless system where more coverage and handoff options exist, some difference in lost calls performance is expected between sectors which cover the core and sectors which cover areas outside of the core.

The main issues which cause failure of BTS to MS communication in CDMA systems are

1. Coverage problems
2. Neighbor list problems
3. Hard handoff problems

One possible culprit to look for is the location of the transition zone or area where hard handoffs take place, either between CDMA carriers, or when handing off to AMPS. If the lost call is neither in a hard handoff area, nor associated with an attempted hard handoff, then CDMA system lost calls are usually associated with a high FER in either the uplink or downlink direction, leading to the breakdown in communication, and hence coordination of action, between the BTS and the SU. Knowing the first direction of high FER, immediately before control failed, can give some critical clues as to the cause of the high FER, which ultimately led to the lost call.

Therefore, when reviewing data, if the site is experiencing a high lost call rate, or any lost call rate which requires focusing resources, the following items should be checked:

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).*

2. *Verify that there are no coverage problems with the predictions, field data, and sectors or spans out of service.* See part 3 of the list in Sec. 5.8.1. Coverage issues could also be caused by the power distribution within the CDMA carrier, in that it has to dedicate a large percentage of the power budget to keep distant subscribers on the cell or sector. This, of course, leads to the breathing cell phenomenon, where problems are intermittent. Therefore, it is

important to review the predicted coverage, with the designed load, and then look for possible pilot pollution locations, where the problem may be too much signal from too many sources rather than lack of signal. If the strongest of these multiple pilots is still relatively weak, especially in relation to the other pilots being received by the SU, then this coverage problem is often described as lack of a *dominant pilot.*

You want to ensure that there is a sufficient Eb/Io for the call to be sustainable with an acceptable FER for 90 to 95 percent of the reported signals, in both the uplink and downlink directions, where possible. Also when a sector is out of service, part of the area it normally covers can revert to a pilot pollution situation, if no neighbor is sufficiently dominant to fill the coverage gap.

3. *Review the neighbor list for the primary site.* Check the site's neighbor list to verify that there are no clearly missing or incorrect neighbors. You also need to check that there are not an excessive number of neighbors. In addition, you should check for reciprocity of the neighbor list. However, lack of reciprocity will not manifest itself in a high lost call rate for this site, but rather for the neighboring sites which may not be reciprocal.

Check the T_ADD, T_DROP, and T_COMP parameter values to see if they are too lax or too tight, depending on the location of the neighbor sites. Clearly, in general,

- Lowering T_ADD will make a neighbor active sooner.
- Lowering T_DROP will hold on to an active neighbor longer.
- Lowering T_COMP will make it easier to replace an active neighbor with some other neighbor having a stronger pilot, and the reverse if the thresholds were to be raised instead of lowered.

Verify that on average there is not an excessive number of active-list neighbors (high proportion of time to be spent in soft handoff) for the sector, resulting in capacity restrictions for other subscribers, or in Walsh code and/or power budget–related problems for the sector. You may want to increase the T_COMP value if many calls for the sector have more than three active neighbors.

Additionally, CDMA systems report all pilots in the pilot signal measurement message (PSMM). You should use these values to verify that the neighbor cells that are active for the lost call have an acceptable signal level.

4. *Check for pilot pollution.* You need to review the existing system plan and field data for the site and sector involved. Check for lack of a dominant server in the problem area. Issues to contend with involve determining *why* there is not a dominant server and *if* one of the sites covering the area can be altered to provide the dominant server for the problem area.

5. *Check the round-trip delay (RTD).* Depending on the specific infrastructure vendor you may need to verify that the RTD parameter is set correctly. If it is set too long, calls can drag on border zones. Alternatively if it is set too short, this could lead to lost calls occurring on another site. Therefore, you need to review the RTD for the surrounding sites as well.

6. *Check traffic loading.* Next review the traffic load at the surrounding sites and ensure that they have sufficient capacity to accept a mobile handoff.

Lack of capacity could be caused by excessive soft and softer handoffs, or by a lack of channel elements or Walsh codes. A lack of Walsh codes is not common, except for a very small and close-in coverage area with very high traffic. If the neighbor site is blocking, this could be a cause of the lost calls. Also, directed retry, through service redirection, may be activated; resulting in SUs operating outside of their designed coverage area. Check the mobile data usage for the sector and surrounding sites to ensure that the data portion of the network is not a culprit, and vice versa, that voice traffic is not blocking data calls.

7. *Check the global positioning system (GPS).* Check to ensure that there was not a GPS problem with the source site or sector or any of the sites on the neighbor list. If a site has a faulty GPS, its local time base may be out of synchronization with the rest of the network, leading to the "island cell" phenomenon where calls may be able to hand into the island cell successfully, but probably will not be able to hand out successfully, due to the lack of synchronization's effect on the SU's pilot search windows and on the SU's decoding of other signals.

8. *Check BTS parameters.* This check involves reviewing the site's specific configuration and software settings. Things to check include topics beyond the neighbor list and possibly the RTD for the site. For example, you need to review the power control settings for the site and existing software load. All site or sector parameters should be compared against the design standard for the system. Therefore, you will need to check the site's software and hardware configurations. A prime area to consider is the pilot parameters. If the parameters are not within nominal range, then they need to be investigated to ensure that they are not the root source of the problem. Sometimes it is hard to verify the site's hardware configuration due to documentation problems. If the configuration is required, a site visit may be in order, especially if the system is trifurcated with other services.

9. *Check BSC borders.* Verify the location of the BSC borders and ensure that high traffic areas do not fall on a border. If they do, then the source of the problem may be the border itself, due to the time required for the handoff process to occur in the SU.

10. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single frequency allocation (FA) or channel element. You will also want to verify that there were no T1/E1 outages for the site at that time, or for the adjacent sites, since this would negatively affect the performance of the site. A review of the BTS and BSC alarms may uncover the cause of the problem as well.

Another possibility is an antenna system problem, which would warrant a site visit, if no other problems could be found. Some vendors have the ability to monitor the antenna system VSWR, which could indicate the presence of a problem, but not the absence of all problems. Also, if historic antenna data are available, check and see if there is any degradation over time, and if the lost calls appear more prevalent after a rainstorm, indicating water intrusion in a cable or jumper.

If your system is newly installed or recently modified, be sure to consider the many ways in which antennas can be misconnected. For example, the alpha and beta sector transmit antenna cables (only) might be cross connected, resulting in failed call attempts in major areas of both the alpha and beta sectors, due to apparently weak uplink signal levels received from the MS.

These 10 areas of inquiry may seem like a lot to check for a “simple” problem of a few lost calls. However, the depth and diversity of these 10 areas simply reflects the many possible reasons for a spate of lost calls.

5.9.2 Handoff failures (problems)

Specific handoff failures in a CDMA system are not as prevalent as with other wireless access systems. However, handoff failures and problems usually manifest themselves as a lost call. The handoff failures, of course, can be both from the source or target. Since CDMA systems have soft, softer, and hard handoffs, the types of failures and their root causes cover a wider range of possible issues than with other technologies. Handoff failures can occur between sectors of a cell, between cells, between CDMA carriers (i.e., an f 1 to f 2 handoff), and in a transition zone with a handoff from CDMA to AMPS. Obviously, the hard handoff when you hand down from CDMA to AMPS is only applicable to the cellular band operators, where AMPS may exist, and not to the PCS operators. Table 5.1 may assist in determining the type of handoff and supporting services which can and does occur with a handoff.

Another important point to raise regarding handoffs is the radio configuration (RC) differences that could and most likely do exist in a network. For example, depending on the RC for the call in progress the active neighbors will also need to have the same RC. Why this is important to note is that a RC1/2 to RC3 is not supported which means that you either have to go from RC3 to RC3, RC3 to RC1/2 or RC1/2 to RC1/2. Therefore, the configuration of the neighbor sites focusing on the CDMA version available or active needs to be verified to ensure that this is not a contributing cause of the problem.

TABLE 5.1 Handoff Compatibility Table

Source	Target	Destination traffic channel type
AMPS	IS-95/CDMA 2000	NA
IS-95	AMPS	AMPS
	IS-95	IS-95
	IS-2000	IS-95
IS-2000	AMPS	AMPS
	IS-95	IS-95
	IS-2000	IS-2000

Regardless, the largest source of handoff failures is driven by pilot pollution or errors in the neighbor list. Therefore, here is a list of items to check when investigating a high handoff failure rate for a sector.

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).*

2. *Review the neighbor list for the primary site.* Check the site's neighbor list to verify that there are no missing or incorrect neighbors. Check and verify that there is not an excessive number of neighbors. You should also check for reciprocity for the neighbor list, but this will not manifest itself in a high lost call rate for this site, only the neighboring site which may not be reciprocal.

Verify that there are not an excess number of active neighbors for a call resulting in capacity restrictions for other subscribers, Walsh code, or power budget related problems. You may want to increase the T_COMP if there are more than three active neighbors typically for the site.

Usually excess active list sectors are measured as a percentage of time in the test area that the call is in three-way, four-way, etc. For example, you may not want your percentage of four-way or more soft handoffs (SHOs) to be more than, say, 10 percent.

Additionally CDMA systems report all the PSMM values. You should use these values to verify that the neighbor cells that are active are of an acceptable level.

A high FER in both the uplink and downlink directions is symptomatic of a neighbor list problem, which is not coverage- or resource-related. For a high FER in the uplink direction only, check the RTD values. For a high FER in the downlink direction, check the power budget.

3. *Check the handoff parameters.* Sometimes the handoff parameters used to select the active neighbor list may need to be adjusted. Check the T_ADD, T_DROP and T_COMP parameter values to see if they are too lax or too tight depending on the location.

The search window for the neighbor, SRCH_WIN_R, and remaining sets, SRCH_WIN_N, could be tightened or relaxed. They should be tightened if there are too many neighbors being included for consideration. However, note that an excluded neighbor will interfere with the active sectors.

Alternatively, the search window used for the active and candidate sets, SRCH_WIN_A, could be adjusted, thereby either relaxing or restricting the selection process. However, the search windows are not often changed within a system from the default values recommended by the infrastructure vendor

4. *Check handoff types.* You will need to check what percentage of the handoffs into and out of the site are soft or hard handoffs. Of specific interest is what triggers a hard handoff. Is it because of a transition zone between CDMA/AMPS, or because the FA being used has a limited footprint in the system?

If the problem is related to hard handoffs, then check the RTD setting and determine if the handoff should be moved closer or farther away from the source site or sector. This remedy also applies if the site is experiencing a lot of target handoff problems.

One of the most common boundary handoff failure reasons is that the datafill on one or both sides is wrong. If the handoff failures are inbound, target handoff problems for the site, then you should also review the power budget for the sector to determine if it is possibly causing pilot pollution resulting in the site being included for handoff selection when it should not be.

5. *Check traffic loading.* Next review the traffic load of the surrounding sites and ensure that they have sufficient capacity to accept a mobile handoff. Lack of capacity could be caused by excessive soft and softer handoffs, or by a lack of channel elements or Walsh codes. Check the mobile data usage for the sector and surrounding sites to ensure that the data portion of the network is not using too much capacity, or vice versa.

6. *Check the GPS.* Check to ensure that there was not a GPS problem with the source site or sector or any of the neighboring sites that are on the neighbor list. This could lead to call dragging, effectively causing the SU to use a nonoptimal candidate. Additionally a GPS failure should cause a major alarm to be tripped and calls on all sectors for that site and the surround sites would be affected.

7. *Check BTS parameters.* See part 8 of the list in Sec. 5.9.1.

8. *Check BSC borders.* Verify the location of the BSC borders and ensure that high traffic areas are not on a border. If they are, then the source of the problem may be the border itself, due to the time required for the handoff process to occur in the SU.

9. *Check for maintenance issues.* When checking for maintenance issues you need to determine if the problem can be isolated to a single FA or channel element. You will also want to verify that there were no T1/E1 outages for the site at that time, or the adjacent sites, since this would negatively affect the performance of the site. A review of the BTS and BSC alarms may produce the cause of the problem as well.

One other item to look for is the possibility of an antenna system problem, which would warrant a site visit, if no other problems could be found. Some vendors have the ability to monitor the antenna system for VSWR which would indicate whether a problem might exist or not. Also if historic antenna data are available, it might be worth it to check and see if there is any degradation and if the lost calls appear more prevalent after a rainstorm indicating water intrusion.

5.9.3 All servers busy

Problems with access to a wireless system involve both blocking, i.e., no resources available, and insufficient signal levels. If the resources are not sufficient to address the current traffic, the obvious response would be to simply add a new FA or more channel elements. However, the traffic increase may be caused by incorrect parameter settings or a deliberate attempt to reallocate traffic.

There are several items to look for in verifying that you truly need to add channels, or possibly even a cell site, to relieve the traffic.

1. *Determine if anything has changed in the system.* Did you or someone else alter another site's coverage, or add or remove a site or sector from the system?

2. *Determine the source of the blockage.* It is important to know the source of the blockage since it will tell you how to possibly relieve the situation both on short-term and long-term bases. You will need to determine the volume of traffic type for the cell or sector and if it is origination based or handoff based. For instance, a normally balanced cell for a typical mobile system will have one-third originations and two-thirds hand-ins; your numbers may vary, but the illustration is important. If this typical cell were to have two-thirds originations and one-third hand-ins, it might indicate that the blockage problem is near the site itself. If the majority of the traffic was hand-in, then the source of the traffic would be from an adjacent site.

The source is important in determining the possible solutions. For traffic originating at the site you might want to relax the T_COMP for target cells and hand off more traffic, thus shedding the load. Or, you might want to increase the T_COMP value for this site being the target cell, thus reducing incoming traffic if the problem is inbound. The T_COMP value in this case would be adjusted at the neighboring sites or sectors of the blocking site or sector. You should also check to see if the cause may be service redirection activated in the cluster of sites where the blocking cell site is the target of the traffic shedding.

3. *Check Walsh codes.* With CDMA, the Walsh codes can, depending on your aspect, be a limited resource. Therefore, you should check for any blockages due to the lack of Walsh codes. Lack of Walsh codes is probably more problematic if the same FA is being used for packet data services.

If there is indeed a Walsh code shortage, then review of whether the traffic requesting the codes is originating at the site or is soft handoff driven. If packet services are being used and this is a CDMA2000 channel, then another issue to check is the packet data usage. The more data being used on a sector, the more Walsh codes are consumed. Usually, Walsh code limitations also manifest themselves with handoff failures and lack of packet data throughput.

4. *Check for maintenance issues.* When checking for maintenance issues you need to determine if the problem can be isolated to a single FA or channel element card. You will also want to verify that there were no T1/E1 outages for the site at that time, or the adjacent sites, since this would negatively affect the performance of the site. Additionally, you should check for loss of GPS.

5. *Check for cell overlap.* If there is sufficient cell overlap, you might want to shed traffic, both origination and possibly handoff traffic, by reducing the site's coverage footprint. The limitation of the site's footprint is done typically by altering the physical configuration of the antenna system. If the antenna alteration is not possible or does not produce the desired result, then adjusting the site's pilot power could be attempted. However, care must be exercised in adjusting the pilot power to avoid unbalancing the receive side of the system. Additionally, the coverage area or footprints of the adjacent sites or sectors could be reduced depending on what the desired goal is.

Most operators prefer it the other way around. They prefer to limit coverage with the antenna pattern and keep all the pilot powers the same at the link budget value. Changing the pilot power, except on the analog border of the system, is risky as it unbalances the sector on the receive side.

5.9.4 Access problems

CDMA systems can exhibit access problems. Access problems manifest themselves as no page responses, sometimes causing a large volume of calls to go to voice mail. In addition, the access problems also result in call failed messages. The major reasons for access failures are a few common culprits, pilot pollution, or possibly registration problems.

Therefore, here are some items to check.

1. *Determine if anything has changed in the system.* Did you or someone else alter another site's coverage or add or remove a site or sector from the system? Was a new BSC added, or was there a HLR failure, etc.?

2. *Verify that there are no coverage problems (prediction and field data).* See part 3 of the list in Sec. 5.8.1. Many of the infrastructure vendors have internal diagnostics available which are able to plot the Eb/Io for the subscriber units which access the system. This is an important diagnostic tool to use, if available.

3. *Pilot pollution.* You will need to verify if the cell covers areas that have no dominant server. Lack of a dominant server may lead to originations occurring on the wrong cell and also manifest itself in high lost calls and handoff failures, due to pilot pollution. Some issues involve determining *why* there is not a dominant server, and *if* one of the sites covering the area can be altered to provide the dominant pilot channel.

4. *Check the registration area.* If the access problem occurs in a border area, either internal to the network or between systems, then the issue could be caused by the registration process itself. If the SU is on a border between CDMA and AMPS, where there is intermittent coverage from both systems, then the SU may be changing modes between digital and analog and causing call delivery problems. At heart of the matter is the updating of the home location register (HLR) or visitor location register (VLR), causing flip-flop registrations. The solution is to improve the coverage or shorten the registration interval.

Now if the access problem is internal to the network, and it is between MSC or registration borders, then either revisit the location of the border and alter it, shorten the registration interval, or global page the subscriber if not found with the first page. The last suggestion has obvious performance concerns associated with it. Registration problems will show up when reviewing the statistics for the number of registrations divided by the sum of originations plus terminations.

5. *Check cell site parameters.* This check involves reviewing the site's specific configuration and software settings. Things to check include the pilot database focusing on the RTD, sector and radio type, the FA and any restrictions or unique configuration issues associated with it. If the site or sector is on a BSC or other border, the cell ID and target sector(s) datafill, either analog or CDMA,

needs to be checked as well. A power budget imbalance between the pilot database and TCH needs to be checked, as well as all other site parameter settings.

You need to compare each of the site or sector parameters to the design standard used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the source of the problem. Again, for this part of the investigation, all aspects of the datafill, or system parameters, need to be considered for both the source and target cells or sectors.

6. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single FA or channel element. A review of the BTS and BSC alarms may produce the cause of the problem also. Lastly, access problems will not manifest themselves with a T1/E1 outages for the site, but can be caused by a defective antenna system.

5.9.5 Packet session access

CDMA2000 introduces the real use of packet data for wireless mobile systems. When troubleshooting a performance problem with the packet data network, issues need to encompass both the radio as well as the packet network, including both on-net and off-net applications. However, besides the radio environment, and along with the subscriber unit being the correct vintage, the key to the packet network is the PDSN.

Since the PDSN connects to the CDMA radio network on the access side of the system, an important issue in the troubleshooting process is that, with the exception of the radio resources, the PDSN does not interact with the voice elements directly. In general, the CDMA2000 data and voice networks are separated as much as possible. This is important since you could easily have a voice network problem and not a packet problem, or vice versa, depending, of course, on where the problem is located.

Packet data network performance problems can also be caused by the subscriber configuration, either in the authentication, authorization, and accounting (AAA) system, the network subscribers are trying to connect to, or the mobile PC's network interface card (NIC) settings. Therefore it cannot be overemphasized that to expedite the problem resolution, try to determine what elements of the system could be involved with the problem.

This list of actionable items are for a 1XRTT packet enabled system. It must be assumed that packet services are active in the entire system. However, if not, then the obvious question concerns the packet system boundaries as a possible cause for the problem.

The investigation of packet access can be initiated by a customer complaint or by monitoring the system for traffic packets. Therefore, in the proactive sense, you can begin investigating if there is no 1XRTT packet activity on the site or sector, but there was previously, i.e., one can monitor for negative activity.

The following fundamental areas need to be checked.

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).* Try and determine where the problem took place or if it is an individual subscriber.

2. *In the case of an individual subscriber, determine if the subscriber is active in the HLR and AAA for packet services.*

3. *Packet and other traffic loads.* Verify that no blocking or other facility-related issues for the site, sector, BSC, or PDSN are involved with the initiation of the packet session. The availability of channel elements should also be checked.

With CDMA the use of Walsh codes can be a limited resource. Therefore, you should check to see if there were any blockages due to the lack of Walsh codes. Walsh codes could be a problematic issue if the same FA is being used to support voice services.

If indeed a Walsh code shortage exists, then review whether the traffic requesting the codes is originating at the site itself or is soft handoff driven. Another issue to check, if packet services are being used, is what the packet data usage is, since the more data being used on a sector, the more Walsh codes are consumed. Usually Walsh code limitations should also manifest themselves with handoff failures and lack of packet data throughput.

4. *Check cell site parameters.* This check involves reviewing the BTS and BSC specific configuration and software settings. Things to check include determining whether packet services have been activated for the sector and radio type, the FA settings, and any restrictions or unique configuration issues associated with it. If the site or sector is on a BSC border, or another border, the cell ID needs to be checked as well. A power budget imbalance between the pilot database and TCH needs to be checked, as well as all the other site parameter settings.

For any of the site or sector parameters checked, you need to compare them to the design standard used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the source of the problem. Again, for this part of the investigation, all aspects of the datafill or system parameters need to be reviewed for both the source and target cells/sectors.

5. *Voice processing.* It is very important to verify if there is voice traffic on the site. Depending on whether the FA is separate or combined usage, this might help determine the source of the problem. If there is voice usage on the site and there are no FA problems, then the problem could be configuration- or PDSN-related.

6. *Check the PDSN.* For this part of the investigation you will need to verify that there have been no major core network service disruptions which could preclude the initiation of service for the subscriber. Usually, however, if there is a major outage or disruption, other sites and services will also be affected and this will not be an isolated situation.

Additionally the PDSN configuration needs to be checked as well. This is separate from the BTS and BSC configuration checks.

- Ensure that the packet zone is activated in the data fill; this is easy to overlook.
- Check for a valid range and setting in the PDSN IP address.

- Ensure that the L2TP tunnel is set up. Verify that the number of retries is not exceeded. A possible cause is the physical link, the processing capacity, or that the retries are set too low.
- Check the time and rate between which the minimum data rate forces the session to go from active to dormant. Similarly, check the values for the transition from dormant to active. These parameters should be set to prevent unnecessarily frequent transitions between the dormant and active modes for the subscriber.
- Ensure the routers used for the PDSN are not experiencing any congestion on their ports, their CPU, or their buffers.

7. *Check handoff during a session.* If a 1XRTT-capable SU is in a dormant data session, and meanwhile moves to a nonpacket system, the point-to-point (PPP) session between the PDSN and the SU will time out and be torn down. The SU will not be able to reestablish a packet data call until it is in a 1XRTT system again.

8. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single FA, BTS, or BSC. Therefore, you need to review the BTS and BSC alarms for a clue as to the cause of the problem. You also need to review the PDSN network, again focusing on any service disruptions or alarms that may have been produced during the problematic time period.

5.9.6 Packet session throughput problems

Packet session throughput is determined by the radio environment as well as by the site's configuration, overall fixed network capacity, the service being offered, the service's destination, and, of course, what SLA has been assigned to the packet user. Other factors could be the subscriber's configuration, the service configurations, and their throughput.

Throughput problems can be summed up in two basic issues:

1. Insufficient amount of kilobits per second
2. Session terminated prematurely

It should be obvious then that many issues play a role in the ability to deliver and sustain 1XRTT sessions. Since the session is packet based, the FA's Walsh codes are and should be a shared resource. Obviously, you need to determine what the available resources are for the packet session; if the desired throughput level, say 144 kbit/s, is really achievable; or if the design (or desired) level is really more like 40 kbit/s.

However, when a packet session issue arises, it will most likely be in the form of a customer complaint. Using system statistics to determine packet session throughput will only indicate usage, since each session is unique in what it is accessing and in terms of bandwidth required, both for the uplink and downlink.

With this said, here is a starting point to begin an investigation. Often, if the system is not experiencing problems, the issue is the subscriber's configuration or perception of a problem. For example, the session speed may be 15 kbit/s, but the subscriber thought the speed was 30 kbit/s. However, the additional bandwidth was not needed, based on the negotiated rate with the off-net server. Perception is difficult to overcome and should not be presumed in the investigation, since the customer is paying for the service.

Lastly, the troubleshooting process, after verifying that the subscriber is allowed packet service, requires some specificity about the location of the problem, since assuming the entire system is at fault would imply a PDSN problem that should be evident from other alarms.

The following fundamental issues need to be checked.

1. *Identify the specific problem and, if possible, the geographic area where the problem occurred.*

2. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).* Also try to determine where the problem took place.

3. *In the case of an individual subscriber, determine if the subscriber is active in the AAA for packet services and if the SLA matches what is desired or claimed by the subscriber.*

4. *Determine the type of services experiencing the problem.* If they are having a file transfer protocol (FTP) problem, but can gain access via hypertext transfer protocol (HTTP), then it might be their configuration. If possible, determine if the server or PDSN router can be pinged, that is, respond with an acknowledgment after receiving a message. The fundamental objective is to determine what service is affected and whether it can be isolated. Additionally, we'll need to know if the problem is on-net or off-net.

If the problem is on-net, then just a ping may not be sufficient, since the PDSN may be configured to deny a particular service or set of services based on the port number. In addition, if the service includes a VPN with 802.11g interoperability, then you need to determine if the link connecting the PDSN is able to communicate with the external service (including the Internet).

5. *Verify traffic usage.* Verify that the traffic usage, i.e., Walsh codes, channel elements, and other resources allocated for 1XRTT packet services, is sufficient for the traffic load. FA channels can be shared, but there is a limit to this and it is user definable. Therefore, check to see if the throughput problem could really be a voice services–related blocking problem.

6. *Review the neighbor lists.* Handoff for CDMA packet services works the same as for voice services. Therefore, if the packet session is terminated prematurely, many of the issues previously associated with handoff failures are also applicable to packet data. As part of the investigation, we would compare the voice network to the packet network and determine if there are similar problems, or determine if a setting was made to favor one service over the other and this was an unintended consequence.

Therefore, as part of the troubleshooting, check the site's neighbor list to verify that there are no missing or incorrect neighbors and check and verify that there is not an excessive number of neighbors. You should also check for reciprocity for the neighbor list, but this will not manifest itself in a high lost call rate for this site, but rather for the neighboring site which may not be reciprocal.

Check the T_ADD, T_DROP, and T_COMP parameter values to see if they are too lax or too tight depending on the site locations. Verify that there is not an excessive number of active neighbors, resulting in capacity restrictions for other subscribers, or in Walsh Code or power budget–related problems. You may want to increase the T_COMP if there are more then three active neighbors typically for the site. Another issue to verify is whether a hard handoff took place, or even whether a handoff to a more packet restricted site took place.

7. *Active or dormant data session.* If a 1XRTT capable SU is involved in an active data session and moves to a nonpacket system, then a hard handoff is denied. If the SU is in a dormant data session, the PPP session between the PDSN and the SU will time out and be torn down. The SU will not be able to reestablish a packet data call until it is in a 1XRTT system again.

8. *Check cell site parameters.* You need to verify that 1XRTT packet service is enabled for the site, sectors, and for every FA involved. Also, verify that the neighbor sites have 1XRTT packet services enabled. The allocation of available system resources, i.e., Walsh codes and power that should be associated with packet-based services, need to be checked as well.

The detach timer should be checked to ensure that it is not set too short, causing a reattachment, and ensuring that the VLR knows where the mobile is when the packet session is idle.

- *Idle timeout setting.* The time, usually in minutes, that the PDSN will wait for the PPP connection to receive traffic before being disabled.
- *Session timeout setting.* The time a PPP connection may be active before being turned off, with or without receiving traffic.

Again, for this part of the investigation, all aspects of the datafill need to be considered both for the source and for the target cells and sectors.

9. *Check voice processing.* It is very important to check whether there is TCH traffic for voice calls on the site. If there is, then the data problem could be configuration or PDSN-related issues.

10. *Check for maintenance issues.* For this part of the investigation, you will need to verify that there have been and currently are no major core network service disruptions, which could preclude the initiation of service for the subscriber. Usually, however, if there is a major outage or disruption, other sites and services will also be affected, and this problem will not be an isolated situation.

When checking for maintenance issues, you need to determine if the problem can be isolated to a single FA, BTS, or BSC. Therefore, you need to review the BTS, and BSC alarms for a clue as to the cause of the problem. You also need to review the PDSN network again, focusing on any service disruptions or alarms that may have been produced during the problematic time period.

5.10 GSM

The troubleshooting guidelines for any GSM system should follow the seven main performance techniques presented at the beginning of this chapter. Additionally you need to factor into the troubleshooting process whether the system is a pure stand-alone GSM system or is sharing spectrum with IS-136 or CDMA, U.S. PCS specific. With the advent of 3G services, GSM operators at this time have chosen to introduce general packet radio services (GPRS) into their systems enabling IP packet data services to be made available instead of using circuit-switched techniques.

The main problems for any GSM and GPRS system involve

1. Lost calls
2. Access
3. Handoff failures
4. Packet session access
5. Packet session throughput

Since these five main performance issues are the more pertinent to any operation and are evident to the customer, they will be focused on. The items do not necessarily need to be checked in this order.

5.10.1 Lost calls

Typically a lost call for a GSM system occurs when the BTS can no longer communicate with the subscriber. Although this is a simple concept, there are many reasons behind this type of occurrence. The three main issues, which cause lost calls for GSM, are

1. Coverage problems
2. Interference, both cochannel and adjacent channel
3. Neighbor list problems

When reviewing data, if the site is experiencing a high lost call rate, or any lost call rate which requires focusing resources on, the following items need to be checked:

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).*

2. *Verify that there are no coverage problems with the prediction and field data.* You need to verify that the prediction and field data (if available) confirm or deny that there is a problem. If there is a coverage problem, then there exists the distinct possibility that this may be the leading, but not the only, source of the lost calls. Coverage problems could be caused by terrain or the existing system configuration. Sometimes the adjacent site configuration is the cause or can be altered to resolve the issue.

Many of the infrastructure vendors have internal diagnostics available which are able to plot the nominal signal level, RSSI, and RXQUAL in addition to the RSSI for the various neighbor BTSs on the MAHO list. This information is available for both the uplink and downlink paths, with the exception of the neighbor BCCH RSSI values which are downlink only. This information could also indicate that there might be an out-of-band or in-band interferer.

You will want to ensure that there is sufficient C/N so that the call is sustainable for 90 to 95 percent of the reported signals in both the uplink and downlink directions, where possible.

3. *Review the neighbor list for the primary site.* Check the site's neighbor list to verify that

- *There are no missing or incorrect neighbors.* Typically, the common missed or incorrect neighbors are those within the site. Referring to Fig. 5.20 site 1, cell A is a neighbor of cells B and C, but cell B is not a neighbor of cells A and C, and this is all within the same site. In addition, a whole site could be missing or overlooked from the neighbor list. For example, Fig. 5.21 illustrates how site 1 (cell B) is a neighbor to site 2 (cell D) and site 3 (cell I),

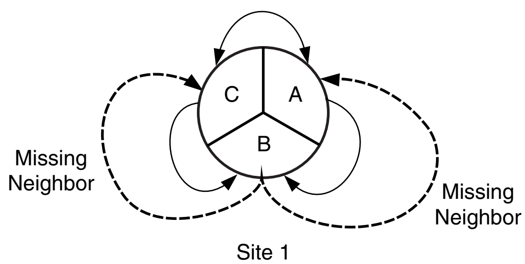


Figure 5.20 Intracell missing neighbor.

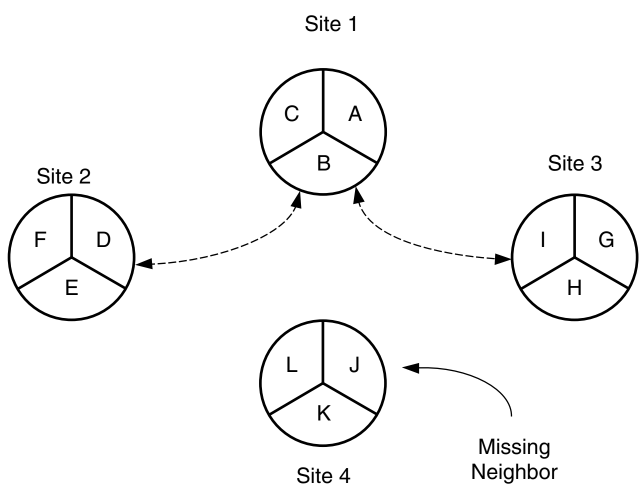


Figure 5.21 Missing neighbor.

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but not to site 4 (cells J and L). Site 4 (cells J and L), then, is missing neighbors, which could cause a dropped call depending upon the mobile's selection, signal strength, handoff, etc.

- *There is not an excessive number of neighbors.* If a cell has an excessive number of neighbors, then those extra neighbors may cause the mobile to make the wrong decision in a handoff situation and cause a dropped call when routing a call to a cell further than the nearest most logical cell to the mobile. This is best illustrated through Fig. 5.22 where site 1 (cell B) has site 3 (cell G), site 7 (cell U), site 2 (cell F), and site 8 (cell V) as unwarranted and excessive neighbors.
- *All cells on the neighbor list have reciprocal or two-way neighbors.* This allows a call from one cell to another to occur in both directions. From cell A to B and from cell B to A. For example, from Fig. 5.23, site 1 (cell B) is a neighbor of site 2 (cell D), and site 2 (cell D) is a neighbor of site 1 (cell B). Please note that this will not manifest itself in a high lost call rate for this site; it is only the neighboring site that may not be reciprocal.
- *The hysteresis value for the handoff does not preclude the handoff from taking place.*

Most vendors have built in to their OMC, or like product, the ability to look for one-way handoffs and to define the amount of handoffs that occur on a per-candidate basis. For example, handing off from cell A to B might occur 60

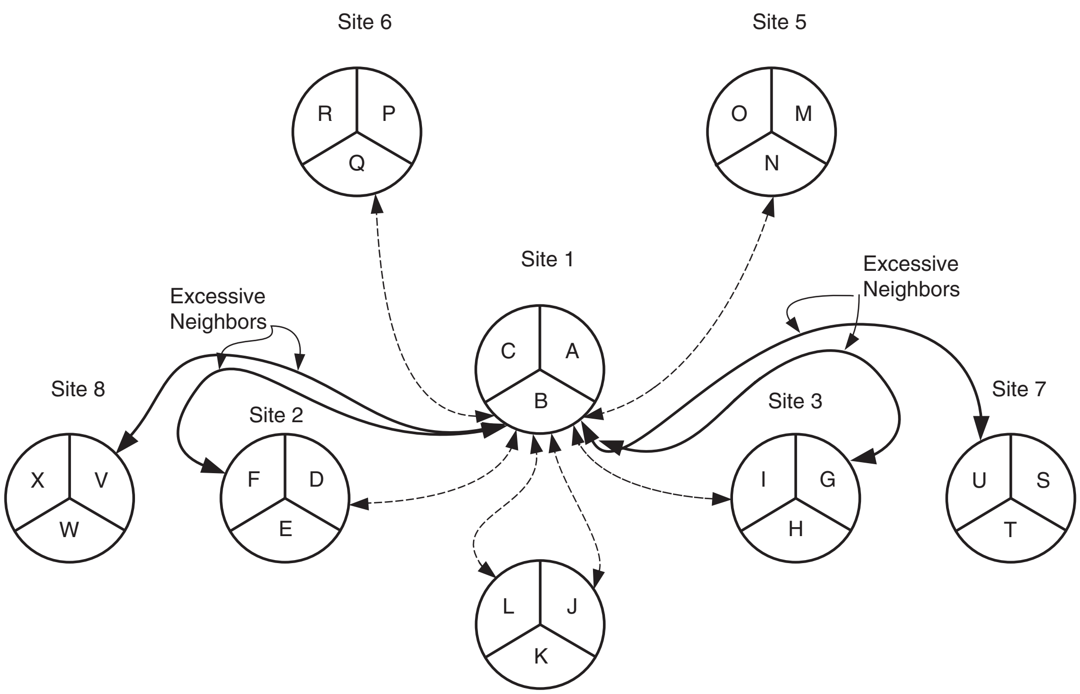


Figure 5.22 Excessive neighbors.

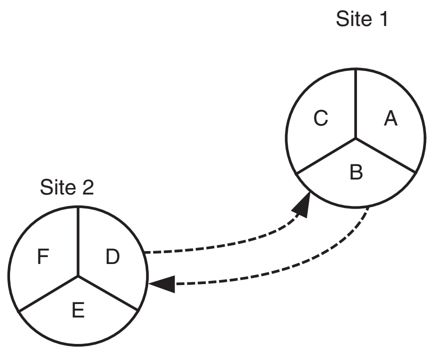


Figure 5.23 Reciprocal neighbors.

percent of the time, while from cell A to C it might occur 5 percent of the time. What you want to look for is the proximity of the sites and if the candidate selection process makes sense from your experience. Keep in mind that time of day plays a major role in mobility issues, but stationary coverage, e.g., building, may be worth checking.

For the stationary situation the frequency of handoffs may be an indication of a ping-pong effect, and in this case attention to hysteresis may be appropriate. Additionally GSM systems through the MAHO process report all the RSSI values for the respective BCCHs. You should use these values to verify that the neighbor cell chosen best matches the RSSI ranking, i.e., if cell 2 typically reports −80 dBm and cell 3 reports −85 dBm, you would expect to see more handoffs to cell 2 than cell 3.

4. *Check the frequency plan.* You need to review the frequency plan that is in place for the site and sector involved. Things to look for involve cochannel and adjacent channel interference, including when the adjacent channel is in the same or adjacent sector and when the cell with that sector overlaps the problem sector.

What you want to do is check the frequency plan on a per-sector and per-channel basis for any obvious issues with cochannel reusers. If a frequency plan is implemented and an obvious cochannel interferer is missed, this could cause a numerous amount of dropped calls within the direction that the cochannel sector is pointing and, depending upon the power setting, a number of sites away. For example Fig. 5.24 uses a $N = 5$ plan, $1 + 1 + 1$ site configuration for all sites. Site 1 (cell B) has channel 591 and site 6 (cell Q) has channel 591, which, based upon the direction of the cells, causes a cochannel interference problem.

In many cases the cochannel interferer may not be on the first TRx (a GSM radio channel), but may be present when the second or third TRx comes on-line, depending upon the traffic load. If the second or third TRx's are not hopping and have the same channel as an adjacent site's cell, depending upon the direction that the adjacent cell is pointing, and its power setting, you could have a cochannel interference problem.

If there is an interference issue, it might be resolved temporarily by placing the offending channel out of service, provided there is sufficient capacity to warrant this approach. However, in most GSM systems removing a full TRx,

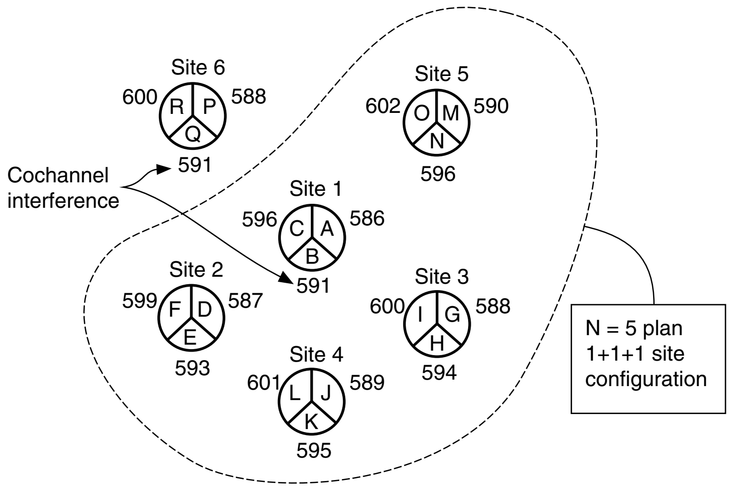


Figure 5.24 Cochannel interference.

8 potential TCHs, is not usually a viable option. Therefore, an alternative frequency assignment needs to be pursued.

You also need to check if frequency hopping is being used. There are many different frequency hopping methods being used throughout the industry, and most are driven by the amount of channels. However, when reviewing and possibly modifying the frequency hopping pattern, no one specific configuration is better than the other, provided, of course, it is properly engineered.

To help illustrate a possible frequency hopping method, Table 5.2 is an implementation of a method which would also simplify the assignment of the hopping sequence number (HSN), for each site, by use of when the BSIC [network color code (NCC) and BSC color code (BCC)] is assigned. This is a simple implementation, due to the fact that the HSNs range from 0 to 63 and the BSIC in decimal format ranges from 0 to 63. A table could be made to cross-reference and combine the two.

Therefore, if a frequency hopping method is implemented and enabled, then the following items should be checked and verified:

- Ensure that the proper mobile allocation list (MaList) is implemented per site for all second, third, and fourth, etc., TRx's. Remember that for now, the first TRx, the BCCH transmission, does not hop (Fig. 5.25).
- Ensure that the proper channel allocation within the MaList is used. Each MaList has a set of unique channels allocated to it that does not repeat within another MaList. (Table 5.3 and Fig. 5.25).
- Ensure that the proper mobile allocation index offset (MAIO) is utilized within the MaList, which allocates a starting channel within the MaList, for each TRx, of the second, third, and fourth, etc., TRx's per sector (Table 5.3 and Fig. 5.25).
- Ensure that the proper HSN is implemented per site for all second, third, and fourth, etc., TRx's (Table 5.2 and Figure 5.26).

TABLE 5.2 HSN = BSIC Combined Table Example

		NCC								
		0	1	2	3	4	5	6	7	
B	0	0	8	16	24	32	40	48	56	
C	1	1	9	17	25	33	41	49	57	H
C	2	2	10	18	26	34	42	50	58	S
	3	3	11	19	27	35	43	51	59	N
	4	4	12	20	28	36	44	52	60	
	5	5	13	21	29	37	45	53	61	
	6	6	14	22	30	38	46	54	62	
	7	7	15	23	31	39	47	55	63	
		HSN								

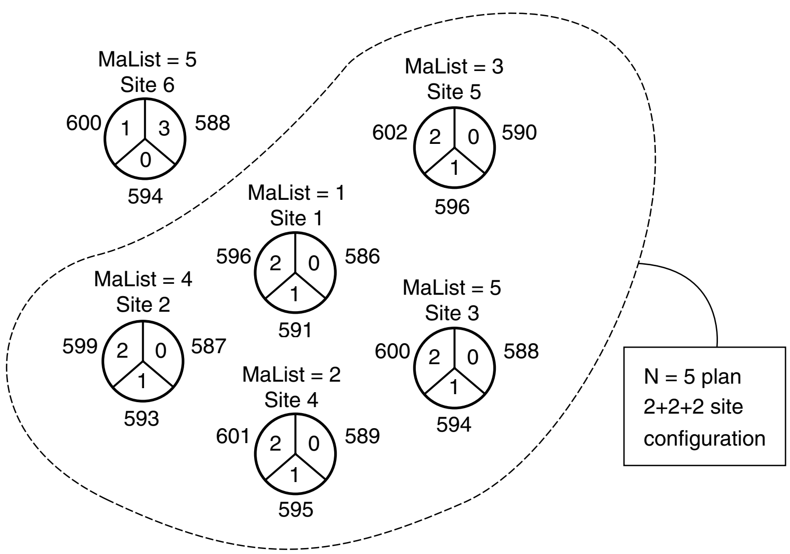


Figure 5.25 MaList–MAIO allocation example.

Performing the items listed here will ensure that the correct hopping method, table, and sequence are entered for each sector, for each site, and for the entire network.

5. *Check traffic loading.* Next review the traffic load at the surrounding sites and ensure that each site has sufficient capacity so that a mobile can hand off to it. If the neighbor site is blocking, this could be a cause of the lost call rate. Also directed retry may be activated resulting in SUs operating outside of their designed coverage area.

TABLE 5.3 MaList–MAIO Table Example

	MaList					
MAIO	1	2	3	4	5	6
0	713	714	715	716	717	
1	718	719	720	721	722	
2	723	724	725	726	727	
3	728	729	730	731	732	
4						
5						

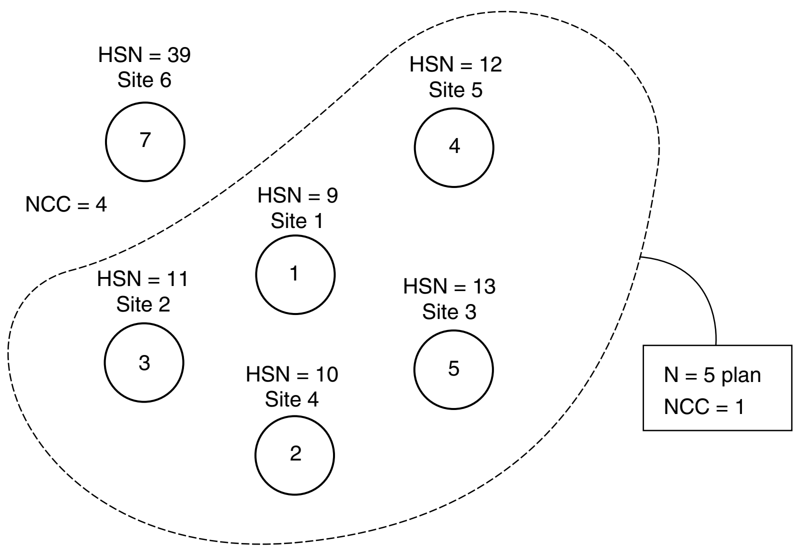


Figure 5.26 HSN–BSIC allocation example.

Things to look for involve the amount of TCHs in use and where any of the messaging channels have to discard packets due to loading issues. The inclusion of GPRS in the system will also preclude TCHs from being used, so you need to verify the GPRS allocation methodology, if applicable.

6. *Check BTS parameters.* This part of the check involves reviewing the site's specific configuration and software settings. Things to check involve topics beyond the neighbor list and possibly the ERP for the site's BCCH. For example, you need to review the power control settings for the site and existing software load. For any of the parameters checked relative to the site or sector you need to compare them to the design standard, which is used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the root source of the problem. You also need to ensure that the other transmitter channels are operating at the right power

level, after combining. Additionally, the site's software configuration needs to be checked, i.e., the channels and BSIC associated with each channel. In other words check the datafill for anything out of the norm.

7. *Check LA/RA borders.* Verify the location of the location area/routing area (LA/RA) borders and ensure that high traffic areas are not on a LA/RA border. If they are, then the source of the problem may be the border itself where due to the time required for the handoff process to occur the SU could drop.

8. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single TCH or TRx channel. If it can, then all TCHs will be affected. You will also want to verify that there were no T1/E1 outages for the site at that time or the adjacent sites since this would negatively affect the performance of the site. Review of the BTS and BSC alarms may also produce the cause of the problem.

One other item to look for is the possibility of an antenna system problem, which would warrant a site visit, if no other problems could be found. Some vendors have the ability to monitor the antenna system for VSWR, which would indicate whether a problem might exist, or not. Also if historic antenna data are available, it might be worth it to check and see if there is any degradation and if the lost calls appear more prevalent after a rainstorm indicating water intrusion.

5.10.2 Handoff failures

Handoff failures should not be an issue with GSM due to MAHO. However, there are still handoff failures, which occur. The following is a brief listing of items to check when investigating a high handoff failure rate for a site or sector.

1. *Review the neighbor list for the primary site.*

- Check the site's neighbor list to verify that there are no missing or incorrect neighbors (Fig. 5.21).
- Check and verify that there is not an excessive number of neighbors (Fig. 5.22).
- Check for reciprocity for the neighbor list (Fig. 5.23), but this will not manifest itself in a high handoff failure rate for this site, only the neighboring site which may not be reciprocal.
- Check the hysteresis value for the handoff, at times the hysteresis value could be set to encourage handoffs to occur when, in fact, they should not due to a terrain issue.

Most vendors have built into their OMC, or like product, the ability to look for one-way handoffs and to define the amount of handoffs that occur on a per-candidate basis. For example, handing off from cell A to B might occur 60 percent of the time, while from cell A to C it might occur 5 percent of the time. What you want to look for is the proximity of the sites and if the candidate selection process makes sense from your experience. Keep in mind that time of day plays a major role in mobility issues, but stationary coverage, e.g., building, may be worth checking.

Reiterating a previous issue for a stationary situation, the high occurrence of handoffs may be an indication of a ping-pong effect and in this case attention to hysteresis may be appropriate.

What you also want to check, besides the actual neighbor list, is the time between handoffs. There is a systemwide number which you should use as the benchmark for performance. If the time between handoffs is very small, as compared to the norm, then either the cell site is shedding traffic or it may not be the correct candidate to use from the beginning. However, coverage and terrain issues may justify a low time to handoff ratio.

Many of the infrastructure vendors have internal diagnostics available which are able to plot the nominal signal level, RSSI, and RxQual in addition to the RSSI for the various neighbor BTSs on the MAHO list. This information is available for both the uplink and downlink paths, with the exception of the neighbor BCCH RSSI values which are downlink only.

You will want to ensure that there is sufficient C/N so that the call is sustainable for 90 to 95 percent of the reported signals in both the uplink and downlink directions, where possible.

2. *Check the frequency plan.* You need to review the frequency plan that is in place for the site and sector involved. Things to look for involve cochannel co-BSIC resulting in wrong handoff decisions. Interference, whether it is cochannel or adjacent channel, needs to be checked to ensure that this is not the root cause of the problem (Fig. 5.24). However, if it is an interference problem, lost calls will usually be prevalent for the site also.

3. *Check handoff types.* You will need to check if the handoffs into and out of the site are synchronous or nonsynchronous. The handoffs should be synchronous, i.e., using the previous or present timing advance from the cell for handoff when on the same BTS or when handing off to adjacent cells (other sectors at the same BTS). The synchronized handoff leads to a short communication interruption of about 100 ms (Fig. 5.27). The nonsynchronous handoffs, i.e., those obtaining new timing advance information, when the SU is handing into the BTS or to another BTS, which is not collocated with itself could be the source of the handoff problems. The nonsynchronized handoff (Fig. 5.27), leads to a long communication interruption of about 200 ms.

Also if the handoff failures are inbound problems, then the possible cause is the BTS itself, i.e., the target. However, if the handoff failures are outbound, then the possible cause might be the target cell.

4. *Check cell site parameters.* This part of the check involves reviewing the site's specific configuration and software settings. Things to check involve topics beyond the neighbor list and possibly the ERP for the site's BCCH. For example,

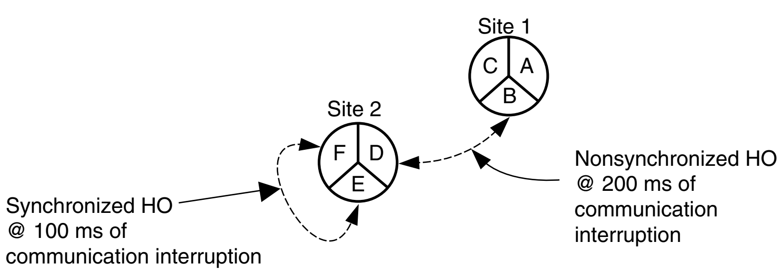


Figure 5.27 HO synch example.

you need to review the power control settings for the site and existing software load. You need to compare any of the parameters checked relative to the site or sector to the design standard, which is used in the system. If the parameters are not within nominal range, then they need to be checked to ensure that they are not the root source of the problem. You also need to ensure that the other transmitter channels are operating at the right power level, after combining. Additionally, the site's software configuration needs to be checked, i.e., the channels and BSIC associated with each channel. In other words check the datafill for anything out of the norm. This check should also be done at the potential source sites to ensure that they are set properly. Again for this part of the investigation all aspects of the datafill need to look for both the source and target cells and sectors.

The final source to check, which may not be so obvious, and is not commonly your first line to check, is if the two sites are between a BSC boundary. If so, you should check to see if the MSC parameters for those cell sites are in sync with the BSC parameters for those cell sites. If an error in the MSC and BSC comparison is found, it is normally the wrong cell identity (CI), the wrong BSC identity (BSCid), or even the wrong location area code (LAC). These are not commonly found errors and should be one of the last troubleshooting checks performed.

5. *Check the LA/RA border.* Verify the location of the LA/RA borders and ensure that high traffic areas are not on an LA/RA border. If they are, then the source of the problem may be the border itself where due to the time required for the handoff process to occur the SU could drop.

6. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single TCH or TRx channel. If it can, then all TCHs will be affected. You will also want to verify that there were no T1/E1 outages for the site at that time or the adjacent sites since this would negatively affect the performance of the site. Review of the BTS and BSC alarms may also produce the cause of the problem.

One other item to look for is the possibility of an antenna system problem, which would warrant a site visit, if no other problems could be found. Some vendors have the ability to monitor the antenna system for VSWR, which would indicate whether a problem might exist, or not. Also, if historic antenna data are available, it might be worth it to check and see if there is any degradation and if the handoff failures appear more prevalent after a rainstorm indicating water intrusion.

5.10.3 All servers busy

The problems with access to the wireless system involve both blocking, i.e., resources not available, and also insufficient signal. In the situation of resources not being sufficient to address the current traffic, the obvious response would be to just simply add radio channels. However, the traffic increase may be caused by incorrect parameter settings or a deliberate attempt to reallocate traffic.

There are several items to look for in verifying that indeed you need to add channels or possibly a cell site to relieve the traffic.

1. *Determine the source of the blockage.* See part 1 of the list in Sec. 5.7.3. If GPRS is in use for the site, check the GPRS usage and the TCH allocation to see if this might be over- or underallocated.

2. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single TCH or TRx channel. If it can, then all TCHs will be affected. You will also want to verify that there were no T1/E1 outages for the site at that time, or the adjacent sites since this would negatively affect the performance of the site.

3. *Check the cell overlay.* If there is sufficient cell overlap, you might want to visit the issue of shedding traffic, origination, and possibly handoff, by reducing the site's ERP for the BCCH and the other associated TRx channels for that sector. Additionally or separately the power level (PL) values can be reduced, provided, of course, that the adjacent sites have sufficient capacity and the frequency plan supports the configuration change. Additionally, the PL values can be reduced at the site thereby, or the adjacent cells can have their BCCH and associated TRx channels reduced in power.

5.10.4 Insufficient signal strength

Insufficient signal strength is caused by lack of coverage, which is determined by access attempts which failed when there were sufficient TCHs available to handle the traffic load. Therefore, there are a few items to check.

1. *Verify that there are no coverage problems with the prediction and field data.* You need to verify that the prediction and field data (if available) confirm or deny that there is a problem. If there is a coverage problem, then there exists the distinct possibility that this may be the leading, but not the only, source of the insufficient signal level. Coverage problems could be caused by terrain or the existing system configuration. Sometimes the adjacent site configuration is the cause or can be altered to resolve the issue.

Many of the infrastructure vendors have internal diagnostics available which are able to plot the nominal signal level, RSSI, for the subscriber units which access the system. This is an important diagnostic tool to use, if available.

2. *Verify the dominant server.* You will need to check if there is an area the cell covers that has no dominant server. The lack of a dominant server may lead to originations occurring on the wrong cell and also manifest in high lost calls and handoff failures.

3. *Check cell site parameters.* This part of the check involves reviewing the site's specific configuration and software settings. Things to check involve ERP imbalances for the site where the BCCH channel is operating at one power level and the other channels are operating at a lower power level. You should also review the power control settings for the site and existing software load. You need to compare any of the parameters checked relative to the site or sector to the design standard, which is used in the system. If the parameters are not

within nominal range, then they need to be checked to ensure that they are not the root source of the problem. Again for this part of the investigation all aspects of the datafill need to be looked at for both the source and target cells and sectors.

4. *Check LA/RA borders.* Verify the location of the LA/RA borders and ensure that double originations are not taking place resulting in glare or denials caused by double access due to the location of the LA/RA border. If they are, then the source of the problem may be associated with the BCCH assignment methodology used.

5. *Check the frequency plan.* You need to review the frequency plan that is in place for the site and sector involved. Things to look for involve cochannel co-BSIC resulting in ghosts or double access.

6. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single TCH or TRx channel. If it can, then all TCHs will be affected. Review of the BTS and BSC alarms may produce the cause of the problem also.

IS problems will not manifest themselves with T1/E1 outages for the site, but will be caused by a possible bad antenna system.

5.10.5 Packet session access

This brief list of actionable items is for a GRPS-enabled system. It has to be assumed that GPRS is active in the entire system; however, if it is not, then the obvious question arises as to the location and if it is in the GRPS network boundaries.

Packet session access requires both the wireless system elements and the SU to be configured correctly. There are state changes, modes, that the SU goes through when it is GRPS enabled. The modes are ready, standby, and idle (Fig. 5.28). The ready mode is when the SU location is known to the serving sector, site, and system and the MS is transmitting or has just finished transmitting. The standby mode is when the MS location is known to RA and the SU is capable of being paged data. The idle mode is when SU location is not known and subscriber is not reachable by the GPRS network.

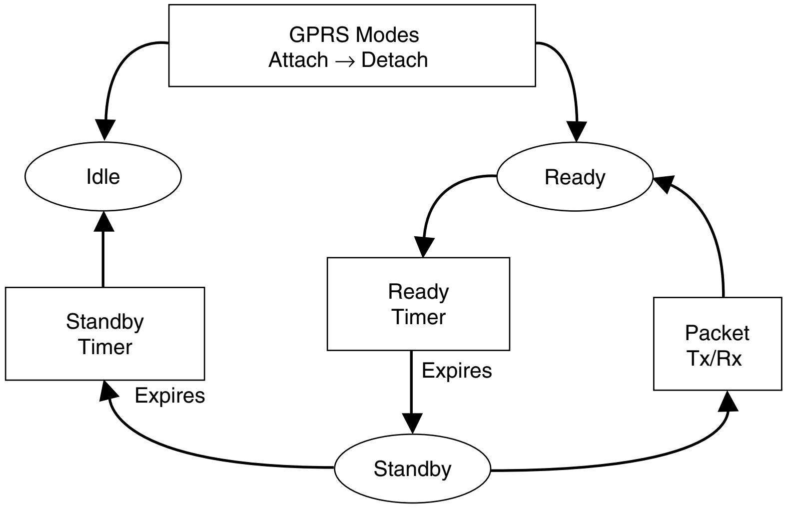
The investigation of GPRS access can be initiated by a customer complaint or by monitoring the system for traffic (packets). Therefore, in the proactive sense you can begin investigating the first few steps if there is no GPRS activity on the site or sector.

Therefore, the following fundamental issues need to be checked.

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).* Try and determine where the problem took place, if it is an individual subscriber.

2. *In the case of an individual subscriber, determine if the subscriber is active in the HLR for GPRS services.*

3. *Check the traffic load.* Verify that the traffic usage, i.e., TCHs allocated for GPRS, is sufficient for the traffic load. GPRS channels can be shared, but



Ready Mode
1. SU location is known to the serving sector, site, and system.
2. SU is transmitting or has just finished transmitting.

Standby Mode
1. SU location is known to RA.
2. SU is capable of being paged data.

Idle Mode
1. SU location is not known.
2. Subscriber is not reachable by the GPRS network.

Figure 5.28 GPRS modes.

there is a user-definable limit to this. Therefore, check to see if the access problem could be really a GPRS blocking problem.

4. *Check site parameters.* You need to verify that GRPS is enabled for the site, sectors, and for every TRx involved that should carry GRPS traffic. In addition, the allocation of how many TCHs that should be associated with GRPS service needs to be checked as well. Again for this part of the investigation all aspects of the datafill need to be looked at for both the source and target cells and sectors.

5. *Check voice processing.* It is very important to verify if there is TCH traffic for voice calls on the site. If there is, then the problem could be configuration or PDSN related.

6. *Check the PDSN.* For this part of the investigation you will need to verify that there have been no major core network service disruption which could preclude the initiation of service for the subscriber. Usually, however, if there is a major outage or disruption, other sites and services will also be affected and this will not be an isolated situation.

7. *Check the frequency plan.* You need to review the frequency plan that is in place for the site and sector involved. Things to look for involve cochannel and adjacent channel interference, including when the adjacent channel is in the same or adjacent sector and when the cell with that sector overlaps the problem sector.

What you want to do is check the frequency plan on a per-sector and per-channel basis for any obvious issues with cochannel reusers. Therefore, an alternative frequency assignment needs to be pursued. However, if this is an interference-born problem, then LC and HO failures should be prevalent also.

8. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single TCH or TRx channel. If it can, then all TCHs will be affected. Review of the BTS and BSC alarms may produce the cause of the problem also.

A field visit may be warranted to validate suspected or determined problems. If so deemed, the field visit will need to be performed on a sector-by-sector basis for those sites in question.

Listed here is a set of procedures for testing the attaching and detaching of a sector.

- Each sector of a site should be tested for GPRS capabilities and should be performed with a mobile that has engineering test software loaded.
- Switch the mobile off until you have reached the target sector. Then by checking the CELLid and LAC on the mobile's test menu, you can ensure that you are camped on the right sector.
- Perform attaching and detaching at each sector of the site. Each mobile, depending upon the vendor, indicates this in a simple and noticeable way, such as "Attached," for when you have attached to the system and "Detach" or (the word *Attached* goes away) when you are detached from the system.
- If you were unable to attach to the sector, then perform the following subtests.
  - Switch the mobile off, and then back on.
  - Check if a voice call is possible in that sector, and then check the signal level, while the voice call is up, as shown on the mobile.
  - Check to see if problem is only in that sector or in the whole site, by checking all sectors.
  - Check to see if problem is only in that site, in that BSC, or in a different site of another BSC.
  - Remove and reinsert the subscriber identity module (SIM) to verify that the test unit or rather the SU is not the root cause or adding to the problem.
  - If availability is the issue, then swap out the GPRS mobile.

Repeat these steps for all sectors of the site and for each site in question. The sole purpose of the field visit is to validate your suspicions, and is sometime not warranted. However, once your suspicions are validated, they need to be reported to the appropriate maintenance department for rectification.

5.10.6 Packet session throughput

The issue of packet session throughput is determined by the radio environment as well as by the site's configuration, overall fixed network capacity, the service being offered, the service's destination and, of course, what SLA has been assigned to the packet user, let alone the subscribers' configurations and the server or services' configurations and throughput.

The determination of whether a throughput is good or acceptable, and to know whether there is a problem or not, varies depending on the level of service provided to the customers and the costs involved. A temporary block flow (TBF) is a one-way session for packet data transfer between MS and BSC (PCU). It uses either uplink or downlink, but not both, except for associated signaling. It can use one or more time slots and takes two TBFs (uplink and downlink) to allow bidirectional communication.

With the above mentioned, a completion success rate is one way that a client can determine if the throughput is acceptable or not. A normal rage for a TBF completion success rate is between 95 and 100 percent, per BSC. In order to get a thorough and reliable statistic, there should be a minimum of 5000 TBF establishments in an uplink for each BSC. The formula for the TBF completion success ratio is

$$\text{TBF completion \%} = \frac{1 - (\text{TBF establishments} - \text{normal TBF releases} - \text{releases due to flush} - \text{releases due to suspend})}{\text{TBF establishments} - \text{releases due to flush} - \text{releases due to suspend}}$$

The TBF completion success rate is one network monitoring method that should be used to determine if there might be a packet throughput problem.

From this discussion, it is obvious that many issues can and do play a role in the ability to delivery and sustain GRPS sessions. Since the session is packet based, the TCHs are and should be a shared resource. When this question or issue arises, it will most likely be in the form of a customer complaint. Using system statistics to determine packet session throughput will only indicate usage since each session is unique in what it accesses and needs in terms of bandwidth, both uplink and downlink.

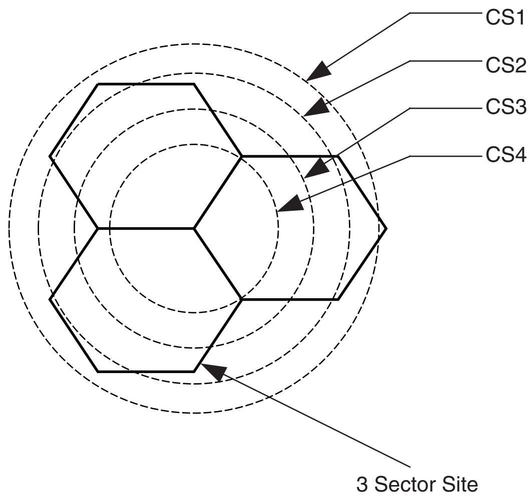
When troubleshooting GPRS throughput issues the coding scheme needs to be factored into the analysis. GPRS has four coding schemes which are used to determine the rate of the throughput for data in addition to C/N, coverage, and signal strength. The four current coding schemes and their data rates are shown in Table 5.4.

Figure 5.29 shows the relationship between coding schemes and the radio environment. The example is only meant for illustrative purposes, but the concept tries to show the relationship between RF coverage and changing data rates.

The following is a brief starting point to begin the investigation. Often, if the system is not experiencing problems, the issue is the subscriber's configuration

TABLE 5.4 GRPS Coding Schemes

Coding scheme	Data rate, kbit/s
CS1	9.06
CS2	13.4
CS3	15.6
CS4	21.4



CS	QOS	C/N Nonhopping (dB)	C/N Frequency Hopping (dB)
1	BLER <10%	10.3	7.5
2	BLER <10%	12.6	11.1
3	BLER <10%	14.0	13.3
4	BLER <10%	18.3	20.6

Figure 5.29 GRPS coding scheme illustration.

or perception of a problem. For example, the session speed for accessing a server may be 9.06 kbit/s, but the subscriber thought the speed was 13.4 kbit/s, using only one TCH. The important concept here is that additional bandwidth is not needed based on the negotiated rate. The perception is difficult to overcome and should not be presumed in the investigation since the customer is paying for the service.

Lastly the troubleshooting process, after verifying the subscriber is allowed GPRS service, requires some specificity about the location of the problem, since assuming the entire system is at fault would imply a PDSN problem and should be evident on other alarms.

The following fundamental issues need to be checked.

1. *Determine what changes were made to the network recently in that area (if the area worked well before the changes).* Try and determine where the problem took place.

2. *In the case of an individual subscriber, determine if the subscriber is active in the HLR for GPRS services and the SLA.*

3. *Determine the type of services.* See part 4 of the list in Sec. 5.9.6.

4. *Verify traffic usage.* Verify that the traffic usage, i.e., TCHs allocated for GPRS are sufficient for the traffic load. GPRS channels can be shared, but there is a limit to this, and it is user definable. Therefore, check to see if the throughput problem could really be a GPRS blocking problem.

5. *Check RA borders.* Ensure that there are no apparent issues or problems with the RA borders. Routing areas are used for GPRS mobility management and are each served by only one serving GPRS support node (SGSN). The size of the RA is dependent upon the capacity loads, size of the service area, etc., that the carrier is trying to provide to the customer. A small RA increases RA updates, while a large RA increases the paging load and, depending upon the particular vendor, has a limit to the number of active subscribers per RA (Fig. 5.30).

In addition verify that the locations of the RA borders do not coincide with any high traffic areas. If they do, then the source of the problem may be the

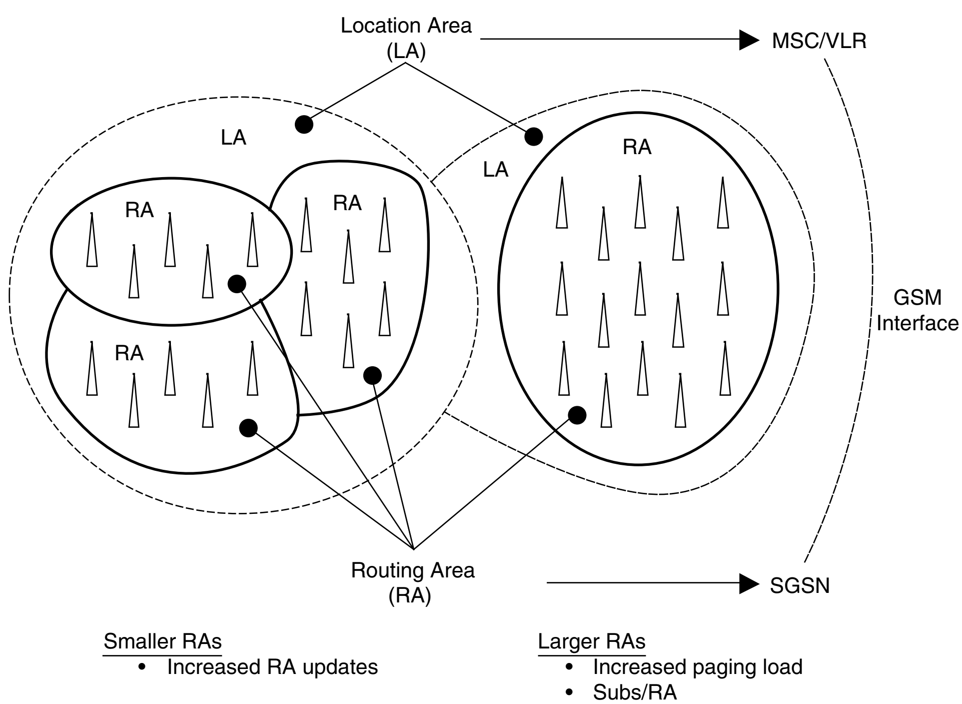


Figure 5.30 Routing areas.

border itself where due to the time required for the handoff process to occur the SU causes the session to slow down or be prematurely terminated.

6. *Check site parameters.* You need to verify that GRPS is enabled for the site, sectors, and every TRx involved that should carry GRPS traffic. In addition the allocation of how many TCHs that should be associated with GRPS service needs to be checked as well. Also verify that the neighbor sites are GRPS enabled.

The detach timer should also be checked to ensure that it is not set to short causing a reattachment and ensuring the VLR knows where the mobile is when the packet session is idle. Again for this part of the investigation all aspects of the datafill need to be looked at for both the source and target cells and sectors.

7. *Voice processing.* It is very important to verify if there is TCH traffic for voice calls on the site. If there is, then the problem could be configuration or PDSN related.

8. *PDSN.* For this part of the investigation you will need to verify that there have been and are currently no major core network service disruptions, which could preclude the initiation of service for the subscriber. Usually, however, if there is a major outage or disruption, other sites and services will also be affected and this will not be an isolated situation.

9. *Check the frequency plan.* You need to review the frequency plan that is in place for the site and sector involved. Things to look for involve cochannel and adjacent channel interference, including when the adjacent channel is in the same or adjacent sector, and when the cell with that sector overlaps the problem sector.

What you want to do is check the frequency plan on a per-sector and per-channel basis for any obvious issues with cochannel reusers. Therefore, an alternative frequency assignment needs to be pursued. However, if this is an interference-born problem, then LC and HO failures should be prevalent also.

10. *Check for maintenance issues.* When checking for maintenance issues, you need to determine if the problem can be isolated to a single TCH or TRx channel. If it can, then all TCHs will be affected. Review of the BTS and BSC alarms may produce the cause of the problem also.

5.11 Retunes

Any wireless mobile system will at some time require a frequency adjustment, commonly referred to as a retune. The retune can either be channel related, as in the case with GSM, IS-136, iDEN, and AMPs, or be PN code driven, as in the case with CDMA.

Most mature systems experience different levels of retunes on a regular basis. How successful your frequency plan is depends directly upon your approach to retunes. The level and scope of the interference control in a network needs constant attention especially with a rapid cell and radio expansion program.

There are several approaches to dealing with system retunes, based upon your configuration and experience level. Retunes can and do take on many shapes and forms. Depending on your own perspective a retune can be viewed as a fundamental design flaw or as part of the ongoing system improvement process. We firmly believe that retunes are part of an ongoing system improvement process.

The rationale behind this philosophical approach is that there is no real grid, contrary to popular belief. The primary driving point of the lack of a true grid focuses on real estate acquisition. There is rarely a site that is selected and built in a network where some level of compromise is achieved with it from the RF point of view alone.

The typical retunes that take place, which most people associate with cellular, involve adjustment to the surrounding sites when a new site is introduced into the network. The other type of retunes that occur are the result of a problem found in the network where there is a cochannel or adjacent channel interference problem.

Based on the volume of new sites being introduced into the network, the frequency of problems will most likely track with them. With every site added into the network the adjustments which are made can either help or hinder future expansions for the area, either new cells or radio.

There are several methods used for retunes and each has its pros and cons. The main retune methods used are

1. Systemwide flash cuts
2. Cell-by-cell retunes
3. Sectional retunes

The systemwide cuts were probably the most favorite at the beginning of cellular due to the size of the networks at the time. The usual comment made during a systemwide flash cut is, This systemwide cut will put the system on a grid and will eliminate the need for more retunes. However, as long as there is system growth the aspects of no more retunes will never materialize no matter what the underlying technology is.

The method of performing individual sites for retunes is valid for a rural statistical area (RSA) and basic trading area (BTA) type environment. However, for a metropolitan trading area (MTA) and metropolitan statistical area (MSA) type environment utilizing individual site retunes as the primary method for resolving many of the system's frequency management problems is not viable. Specifically the time frame and effort needed to retune an area that, say, has 50 cells will take multiple visits to the same sites as the adjacent sites or subsequent rings are worked on.

There are two key parameters that need to be looked at for any retune, besides improved service, and they are time, opportunity cost, and personnel logistics. When putting together a retune, the need for completing it in a timely fashion is important. In addition when you are focusing resources on retunes, the same resources are not working on other projects for the network. The personnel logistics, which tie into lost opportunities, will be strained and general maintenance will suffer which will impact the system performance of the network.

The specific method recommended for use involves sectioning the network into major quadrants. The shape of the quadrants is directly dependent on the size and scope of the system and personnel available. For example, if your system has 300 cell sites, it would be advisable to partition the network into three, possibly four, sections for retunes. The direction, i.e., clockwise or counterclockwise, is more dependent upon where you think it is more applicable to begin the efforts.

In addition it is necessary to limit the scale of the retune itself. The scale of the retune can be contained by predefining the specific items you are desiring to change for this retune. During this design process, there is a tendency to continually increase the size and scope of the retune due to a variety of reasons. To prevent the size of the retune from increasing to a level which is unmanageable, it is advisable that the manager or director for the engineering department establish a line in the sand after where no changes can take place. Ultimately the line established will probably be compromised, but the extent of that compromise will be less and the size and scope of the retune will be within the logistics available to be successful.

An example of how to set the line is shown in Figs. 5.31 and 5.32. The retune regions are defined as well as the do-not-exceed line (DNEL), which is different in area from the quadrants set up for the network. The amount of cell sites within the DNEL are more than for the retune section itself. The actual starting point for the retune sequence and the rotation pattern is a function of several issues. The first issue is the amount of problems, adjacent system interaction, growth plans, and a swag.

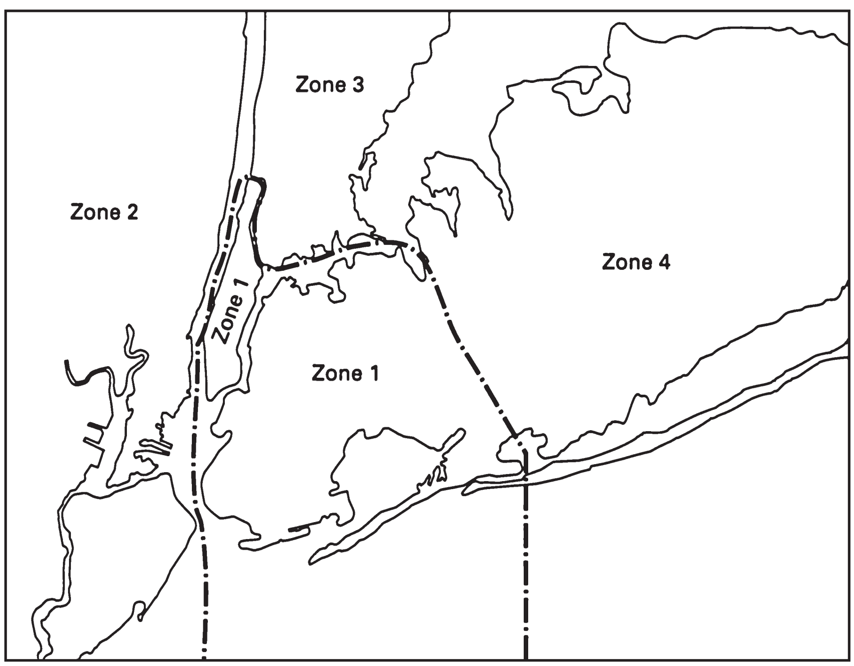


Figure 5.31 Retune zones.

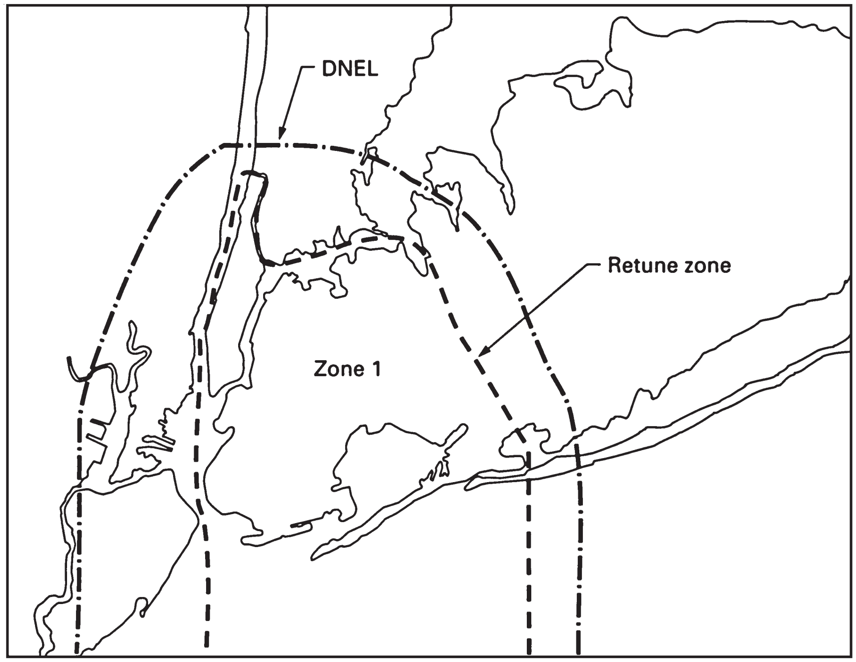


Figure 5.32 Do not exceed line (DNEL).

When setting up a retune, it is important to ensure that everyone you need for the retune effort is involved with this. Failure to ensure that all the groups are involved with the up-front planning will only complicate things at a later stage. The rationale for involvement lies in the fact that the frequency plan is always a point of contention for every department. Since retunes are a point of contention, having all the major groups in the process involved will eliminate finger pointing and keep the focus on improving the network.

To ensure that the retune process moves as smoothly as possible it is recommended that the following procedure be followed.

Pre-retune process

X-X-XX	Retune area defined.
X-X-XX	Project leader(s) defined and time tables specified as well as the scope of work associated with the project.
X-X-XX	Traffic engineering provides radio channel count.
X-X-XX	Frequency planning begins design.
X-X-XX	Phase 1 of design review (frequency planning only).
X-X-XX	Phase 2 of design review (all engineering).
X-X-XX	Phase 3 of design review (operations and engineering).
X-X-XX	Phase 4 of design review (adjacent markets if applicable).
X-X-XX	Frequency assignment sheets given to operations.

X-X-XX	Retune integration procedure meeting.
X-X-XX	Executive decision to proceed with retune.
X-X-XX	Adjacent markets contacted and informed of decision.
X-X-XX	Secure post-retune war room area.
X-X-XX	Briefing meeting with implementers of retune.
X-X-XX	MIS support group confirms readiness for postprocessing efforts.
X-X-XX	Customer care and sales notified of impending actions.

Retune process (begins X-X-XX at time XXXX)

X-X-XX	Operations informs key personnel of retune results.
	Operations personnel conduct brief post-retune test to ensure call processing is working on every channel changed.
	Operations manager notifies key personnel of testing results.

Post-retune process (begins X-X-XX at time XXXX)

	Voice mail message left from engineering indicating status of retune (time).
	Begin post-retune drive testing phase 1 (time).
	Database check takes place.
	Statistics analysis takes place.
	Voice mail message left from RF engineering indicating status of post-retune effort (time).
	Phase 2 of post-retune drive testing begins.
	Commit decision made with directors for retune (time).
	Phase 3 of post-retune drive testing begins.
X-X-XX	Continue drive testing network.
	Statistics analysis.
	Conduct post-retune analysis and corrections where required.
X-X-XX	Post-retune closure report produced.

During the design reviews it is important to ensure that the frequency planning checklist used for regular frequency planning is used for the entire process. The following are some checklists that need to be used for a regional-wide or systemwide retune and are somewhat technology platform specific.

These checklists present the minimum required to ensure that a proper design review takes place. It is suggested that several reviews take place at different stages of the design process to ensure a smooth integration process. Also the method of procedure (MOP) defined for the retune needs to have internal and external coordination delineated. In addition to all the coordination, the actual people responsible for performing the various tasks need to be clearly identified at the beginning of the process, not in the middle of it.

The following is the checklist that needs to be used for a regional or systemwide retune for AMPS and should be used as a starting point for a checklist.

Voice channel assignments

1. Reason for change
2. Number of radio channels predicted for all sites
3. New sites expected to be added
4. Proposed ERP levels by sector for all sites
5. Coverage prediction plots generated
6. C/I prediction plots generated
7. Cochannel reusers identified by channel and supervisory audio tone (SAT)
8. Adjacent channel cell sites identified by channel and SAT
9. SAT assignments checked for cochannel and adjacent channel
10. Link budget balance checked

Control channel assignments

1. Reason for change
2. Coverage prediction plots generated
3. Cochannel C/I plots generated
4. Proposed ERP levels by sector
5. Cocontrol channel reusers identified by channel and digital color code (DCC)
6. Adjacent control channels reusers identified by channel
7. DCC assignments checked for dual originations
8. 333/334 potential conflict checked

Frequency design reviewed by

1. RF design engineer
2. Performance engineer
3. Engineering managers
4. Adjacent markets (if required)

The following is the checklist that needs to be used for a regional or system-wide retune for an IS-136 system. The checklist assumes a dual-mode situation for cellular and can be easily modified to reflect IS-136 for PCS alone and should be used as a starting point for a checklist.

Voice channel assignments (AMPS)

1. Reason for change
2. Number of radio channels predicted for all sites for analog
3. Number of time slots and, therefore, radios predicted for all sites for digital
4. Digital and analog spectrum allocations
5. Guard band defined
6. New sites expected to be added
7. Proposed ERP levels by sector for all sites
8. Coverage prediction plots generated
9. C/I prediction plots generated
10. Differences noted between analog and digital reuse patterns and groups
11. Cochannel reusers identified by channel, SAT, and DVCC

12. Adjacent channel cell sites identified by channel, SAT, DVCC
13. SAT assignments checked for cochannel and adjacent channel
14. Link budget balance checked

Control channel assignments

1. Reason for change
2. Coverage prediction plots generated
3. Cochannel C/I plots generated
4. Proposed ERP levels by sector
5. Cocontrol channel reusers identified by channel and DCC
6. Adjacent control channels reusers identified by channel
7. DCC assignments checked for dual originations
8. 333/334 potential conflict checked

Digital control channel assignments

1. Reason for change
2. Coverage prediction plots generated
3. Digital control channel assignments matched to preferred channel list
4. Cochannel C/I plots generated
5. Proposed ERP levels by sector
6. Codigital control channel reusers identified by channel and DCC
7. Adjacent digital control channel reusers identified by channel
8. DCC assignments checked for dual originations

Frequency design reviewed by

1. RF design engineer
2. Performance engineer
3. Engineering managers
4. Adjacent markets (if required)

The following is the checklist that needs to be used for a regional or system-wide retune for a GSM system and should be used as a starting point for a checklist.

Channel assignments

1. Reason for change
2. Number of radio channels predicted for all sites
3. Number of time slots and therefore radios predicted for all sites
4. Spectrum allocation restrictions
5. Guard band defined
6. New sites expected to be added
7. Proposed ERP levels by sector for all sites
8. Coverage prediction plots generated
9. C/I prediction plots generated
10. Cochannel reusers identified by channel and BSIC
11. Adjacent channel cell sites identified by channel and BSIC
12. Link budget balance checked

Frequency design reviewed by
1. RF design engineer
2. Performance engineer
3. Engineering managers
4. Adjacent markets (if required)

The following is the checklist that needs to be used for a regional or system-wide retune for a iDEN system and should be used as a starting point for a checklist.

Radio channel assignments
1. Reason for change
2. Number of time slots predicted for all sites for 3:1 interconnect traffic
3. Number of time slots predicted for all sites for 6:1 and/or 12:1 interconnect traffic
4. Number of time slots predicted for dispatch traffic
5. Number of time slots predicted for DCCH traffic
6. Total number of radios, BRs, defined from time slots required
7. Spectrum allocation available for the market
8. Guard band defined
9. New sites expected to be added
10. Proposed ERP levels by sector for all sites
11. Coverage prediction plots generated
12. C/I prediction plots generated
13. Cochannel reusers identified by channel and DVCC
14. Adjacent channel cell sites identified by channel, and DVCC
15. Link budget balance checked

Frequency design reviewed by
1. RF design engineer
2. Performance engineer
3. Engineering managers
4. Adjacent markets (if required)

The following is the checklist that needs to be used for a regional or system-wide retune for a CDMA system. The retune here is based on the PN codes and not the RF allocations. However, there is a check for microwave clearance which is included for reference and should be used as a starting point for a checklist.

CDMA carrier assignments
1. Reason for change
2. Number of traffic channels predicted for all sites for analog
3. Spectrum allocation restrictions
4. CDMA channels available defined
5. Guard band defined
6. New sites expected to be added
7. Proposed pilot power level distribution defined

8. Coverage prediction plots generated
9. Pilot pollution problems identified
10. PN codes defined
11. PN reusers identified, including shift
12. Link budget balance checked

Frequency design reviewed by
1. RF design engineer
2. Performance engineer
3. Engineering managers
4. Adjacent markets (if required)

The following is the checklist that needs to be used for a regional or system-wide retune for a cellular CDMA system. The checklist assumes a dual-mode situation for cellular and should be used as a starting point for a checklist.

Voice channel assignments
1. Reason for change
2. Number of radio channels predicted for all sites
3. Number of traffic channels predicted for CDMA carrier
4. Digital and analog spectrum allocations
5. Guard band defined
6. New sites expected to be added
7. Proposed ERP levels by sector for all sites
8. Coverage prediction plots generated
9. C/I prediction plots generated
10. Cochannel reusers identified by channel and SAT
11. Adjacent channel cell sites identified by channel and SAT
12. SAT assignments checked for cochannel and adjacent channel
13. Proposed pilot power level distribution defined
14. Pilot pollution problems identified
15. PN codes defined
16. PN reusers identified, including shift
17. Hard handoff sites identified
18. Link budget balance checked

Control channel assignments
1. Reason for change
2. Coverage prediction plots generated
3. Cochannel C/I plots generated
4. Proposed ERP levels by sector
5. Cocontrol channel reusers identified by channel and DCC
6. Adjacent control channels reusers identified by channel
7. DCC assignments checked for dual originations
8. 333/334 potential conflict checked

Frequency design reviewed by
1. RF design engineer
2. Performance engineer

3. Engineering managers
4. Adjacent markets (if required)

Reiterating the retune method, which is recommended regardless of the technology platform used, is the regional retune process since it takes a systematic approach to frequency management. The systematic approach stresses that there is no perfect frequency plan, and the dynamics of the network in terms of channel and cell site growth necessitate a regular program for correcting the system compromises that are introduced. We have found this method to be very successful in improving the network's performance since this ensures that the system compromises introduced into the network over the year can be eliminated or simply improved upon.

The systematic retune process is advantageous but at the same time fraught with many potential downsides. It will enable a dedicated group to focus on an area of the network and optimize it to the best of their and the system's ability. Frequency reassignments are not the only factor looked for in a retune. Some additional issues are the current and future channel capacity, cell site growth, handoff, and cell site parameters. Basically in a retune you are scrubbing a section of the network involving many aspects besides channel assignments.

The reason you need to look at a multitude of additional parameters for the retune lies in the inherent fact that frequency management is the central cog for cellular engineering. Handoffs, cell site parameter setting, and overall performance of the network are directly impacted by the frequency plan. Periodically scrubbing a section of the network on a continuous basis will ensure that the compromises made during cell introductions and temporary retunes will be rectified at a predetermined time in the near future. This simple concept will enable the designers to seek more short-term fixes to the multitude of problems they face. Since the knowledge of the systematic retune date for the region is known in advance, the designers can use this future date as design completion date.

The stop point is important in this process quite simply because how you approach a problem and propose a solution is entirely dependent upon whether it is for 6 months or 5 years. If it is a 5-year solution, the time to bring the solution and the volume of unknown variables makes the problem all the more daunting and unmanageable. While it is important to design certain items for 10 to 20 years of useful life, frequency management should be considered short term.

When conducting region retunes, the scope of the project can easily be expanded to an unmanageable level. For example, a period retune used to help introduce close to two dozen cells occurred. The initial scope of the project involved retuning some 70 cells and introducing into the network the new cells at the same time. During the course of the efforts management lost sight of the actual work being done by the engineers, and the overall plan resulted in over 130 cells being returned and over 100 new channels being added to the existing sites, besides the new cells.

The expansion of the size of the project created a severe strain on both operations and implementation, not to mention the rest of engineering. The strain was caused largely by the frequency planners repeatedly altering their project scope and management not stepping in to stop it. The end result was operations, as usually is the case, pulled engineering bacon out of the fire. However, the level of system problems introduced due to the strain of the retune took over a month to correct.

Regardless of the method used for establishing retunes, it is important to always conduct a pretest and posttest. The pretest level for the retune is usually a few drive tests of selected road and a large volume of statistics analysis prior to the switch being thrown. The post-retune analysis is one of the most important aspects of the retune process because the accuracy of the design is done. It is also important because without it you will miss many opportunities for additional system performance improvements. The most important aspect is that you will never know if your design efforts were successful and how you can improve upon them unless you perform the post-retune analysis. Continuous refinement is the only way you can improve the network on a sustained basis.

One key element that was listed in the retune MOP is the time that the retune will take place over. It is strongly suggested that when you retune a network, the subscriber impact be considered. While this seems rather elementary, the person who is actually paying your salary, the customer, may be forgotten in the heat of the battle to get the task done.

It is recommended that all retunes take place in the maintenance window and over a weekend period. This will enable the least amount of negative impact on customers and will allow for maximum time for the groups, primarily engineering, to correct any issues.

The recommended post-retune process is listed below:

1. *Identification of the key objectives and desired results prior to the retune taking place.* For example, if the goal is to facilitate adding five new cells into the network, then this is *the* goal. Identifying key metrics and anticipating their relative change and direction is very important. If you are operating at a 2 percent lost call rate and you are aiming for a reduction in lost calls by 10 percent to say 1.8 percent with this retune, this might prove to be an unrealistic goal. This would be a difficult proposition if your before and after channel count remained the same, meaning the overall channel reuse in the network would stay about the same. A better objective in this case would be to position the network for future growth without degrading the service levels already there and aiming for improvements in selected zones.

2. *Statistics analysis for 2 weeks prior to the effort, using the same time frames and reference points.* One week is the minimum, but the more weeks you have in the analysis, the better it is to identify a trend. Obviously more than a couple of months worth of data is not relevant for this effort since traffic, system configuration, software, and seasonable adjustments makes comparison very difficult.

3. *Full cooperation of operations, implementation, customer service, MIS, and, of course, engineering for staffing levels.* Support from each of these groups is critical for the mission to succeed.

4. *Staffing during changes.* It is important that the crew which is on duty during the retune document all the problems which occurred during the process and list what they have checked to prevent the need to reinvent the wheel.

5. *Post-retune statistics analysis.* While the drive tests are initially collecting the first tier of data for analysis, it is important for the engineers to validate that the entire system is configured in a fashion per the design. There has never been a case where problems have not been found during this stage for a multitude of reasons ranging from data entry mistakes to outright design flaws.

6. *Identification of the most problematic areas in the network.* Initial statistic analysis is done at this time during or right after the configuration is checked for the network. The problem sites need to be identified by following the key metrics listed before, which are

- Lost calls
- Attempt failures
- Blocks
- BER, FER, and SQE
- Channel failures
- Usage and RF loss
- Customer complaints
- Field reports from the drive test teams

The initial statistics will only focus on an hourly basis due to the freshness of the retune itself. The data are then checked against the expected problem areas identified before the retune itself and are also plotted on a map of the system so that patterns can be identified.

This process is repeated every 4 h for the first 2 days after the retune and then daily for the next 2 weeks. Obviously the degree of detail employed is relevant to the scope of work and the ultimate level of problems encountered.

7. *The initial drive test data are then analyzed for the key potential problem.* The focus is on the nature of the lost calls and any other problems reported, including dragged calls, interference but no drop, and dropped calls. The nature of the problems are then prioritized according to the severity perceived and cross checking with the statistic and anticipated problem areas. An action plan is then put together for each of the problems identified. Sometimes the problem is straightforward, like a missing handoff table entry, or nothing is determinable which requires additional testing as part of phase 3 of the drive testing.

8. *Drive test data are then analyzed for the general runs for the rest of the retune area.* This involves again focusing on any problems that occurred in phase 2.

9. The third phase of testing analysis involves the follow-up tests and post-parameter change corrections needed to the network, and, if required, additional tests are then performed.

10. Over the next 2 weeks a daily statistics and action report is generated showing the level of changes and activities associated with the effort. This effort is concluded by issuance of a final report.

5.12 Drive Testing

The concept of drive testing a network is usually well understood in terms of its importance and relevance for determining many design issues. Drive testing is used to help define the location of potential cells for the network, integrate new cells into the network, improve the existing network through pre- and postparameter changes, and retune support to mention but a few.

It is always interesting to note that it is usually the drive test team which sets up the test for collecting the data to qualify a potential new site. A well-trained drive test team is exceptionally critical for the success of a network. As most engineers know, any test can be set up to fail or succeed if the right set of conditions are introduced. Therefore, it is very important to have a strong interaction between various engineering departments and the drive test teams.

There are several types of drive tests which take place, for example,

1. Pre site qualification
2. SQT
3. Performance testing
4. Pre- and postchange testing
5. Competition evaluations
6. Post cell turn-on
7. Post retune efforts

Obviously these items need to be performed exceptionally well. To ensure that the testing is done well a defined test plan needs to be generated and reviewed with the testers so that they understand what the overall objective really is. Often there are many alterations to a test plan that are left to the test team. If the test team understands what the desired goal and/or results are for the test, they have a better chance of ensuring that the alterations and observations they make during the test are beneficial and not detrimental.

One of the key critical elements which needs to be monitored and checked on a periodic basis is the maintenance and calibration of the equipment. Vehicle maintenance needs to be adhered to in order to ensure the fleet is at key operational readiness at all times. Since major problems in the network requiring full deployment of resources is never a planned event, having the fleet in top operational condition is a high priority. It would be a tragedy if half the fleet, assuming more than two vehicles, were in for some level of repair when a major system problem occurred.

The one area which requires continued attention is the calibration of the field equipment. For the SQT equipment the transmitters used need to be stress tested on a periodic basis to ensure that they are functioning properly. It is important to ensure that a transmitter used for an SQT that will be operational for, say, 6 h maintains the same output power for the duration of the testing. One simple way to check this fact is to ensure that a wattmeter is in line for the test and before and after test readings are done to ensure that there were no ERP alteration issues that took place during the test.

The antennas and cables used for the SQT need to be validated on a regular basis. A full depot check on all the equipment needs to be performed on a 6-month basis. However, spot checks can be done for each test and recorded in the test log to ensure that these components are operating properly.

The cables and antennas used need to be swept at 3-month intervals to ensure that nothing abnormal has occurred with them. The test should be done on a more regular basis but with the per-test snapshot and the quarterly SQT equipment integrity check, the level of confidence with the test equipment functionality should be high.

Equipment used for measuring power should be calibrated yearly as should the spectrum analyzer, network analyzer, and service monitors. Since so much reliance is placed on the accuracy of the data collected by the test equipment, it is only logical that the test equipment be checked on a routine basis to ensure its integrity.

The test vehicle measurement equipment itself needs to be validated on a regular basis due to continued problems which happen to all drive test vehicle equipment. It is strongly recommended that the equipment be tested on a monthly basis using a full calibration test which checks out, among other items, the functionality of the antennas, receiver sensitivity, RSSI accuracy, adjacent channel selectivity, transmit power, and data deviation.

The calibration of the test equipment needs to be recorded and stored in a central book that is available for quick inspection by all in the department. The calibration of the field measurement equipment and other SQT pieces needs to be listed on the test forms as “in calibration.” The calibration records should also include the equipment serial number. In the event that the equipment turns up missing, you will then have a source to track it from.

Whatever the field measurement equipment used in the drive test vehicle is, it is exceptionally important that you know the accuracy of the equipment. This involves the adjacent channel selectivity, which is an important value to know because when you are monitoring, say, the control channels of the cell sites, you obviously are trying to measure an adjacent channel signal level from the dominant server in the area. The ability of the receiver to reject adjacent channel signals is imperative for making rational decisions on problems or potential problems. For example, if you do a single channel plot and notice that it is rather hot in an area near another site, the cause might be that the adjacent channel selectivity is not sufficient to isolate the desired signal from the undesired signal.

The receiver sensitivity is also an important value to know for the equipment since a receiver sensitivity of −102 dBm is not sufficient to measure signals at, say, −110 dBm. The difference in the two is an 8-dB signal and in most cases if you are designing for a 17- or 18-dB C/N level, the desired serving level might be mistaken for a −85 instead of a −93 dBm which has a major impact on the design criteria for the area.

There are many other variables for just the test equipment in terms of how it collects the signals which are imperative to understand. There are many source documents which help determine the sampling intervals required for an accurate RSSI measurement to take place.

The postprocessing of the data is a key area which many people overlook. With the large amount of data collected many times, there is a significant amount of postprocessing done to reduce the amount of data displayed at the end for the engineer to see. Obviously if you average many points and are performing an interference analysis, then a problem area might be masked due to the peak interfering signal being averaged with many other bins of data to come out with some nominal level. An example of this would be when driving a large area and going over a bridge or a high elevation on a highway and the interference is only a two-block area compared to the 20-mile data collection run. It is imperative that all postprocessing steps be defined in advance of any data reduction process so the tradeoffs made are understood before they take place.

The SQT role of the drive team is critical in the capital deployment process for any company. As stated before, if the SQT is not done properly, a wrong decision can easily be made either to build or not to build a cell site at that location. To ensure the SQT is performed properly it is necessary to establish and follow a test plan.

As mentioned in the design guidelines for the SQT it is imperative that the test plan be made in advance of the site visit by the testing team. The objective for this effort is to ensure that the mounting of the antenna and the other ancillary pieces is done according to the design. The drive routes used for the testing must be sufficiently clear to enable the team to follow the desired direction.

In addition to the SQT is performance testing which we have labeled pre- and postchange testing. This is a very important aspect of the drive team, and the feedback the group gives the engineers is critical for determining the nature and cause of the problem at hand.

Therefore, to ensure maximum output for the drive team the engineer requesting the test must explain the test's objective exactly to the team. Knowing the objective of the test beforehand will ensure critical feedback regarding particular issues that arose during the testing is collected. An example of feedback might be that when the test team was helping to determine why an area was experiencing a high lost call rate, part of the major road they drove on was almost below grade and would have had a significant influence on the lack of signal for the test area.

For performance drive tests there are functionally two general classifications of tests, internal and external. The two test objectives both focus on trying to identify and help correct a real or perceived problem in the network. Both internal and external performance testing follow the same general testing format. The objective as with all optimization techniques is defining what the objective is and then what you are going to do prior to any action taking place.

There are several types of performance drive tests that can be conducted. The following is a listing of the major items.

1. Interference testing (cochannel and adjacent channel)
2. Coverage problem identification
3. Customer complaint validation

4. Cell site parameter adjustments
5. Cell site design problems
6. Software change testing
7. Postchange testing

When scheduling the testing, it is important to identify a priority level for these testing types. The objective of defining a priority level is to have a brief procedure in place when a problem occurs, which it always will, so that the highest priority level item will be taken care of first. This will prevent the first in, first out (FIFO) effect of drive test scheduling being the only criteria for scheduling tests.

Regarding all performance changes made to the network, the need to have a pre- and postchange test conducted can never be overstressed. Pre- and postchange tests ensure that the problem is truly identified. The prechange test data should be used as part of the design review process. Often many good ideas seem great, but when you actually put them down on paper and submit them for peer review they may not be as valid as initially thought.

Once a change is implemented into the network, it is equally important to conduct a postchange test. The postchange test is meant to verify that the design change worked. It is also meant to verify that the changes made to the network do not cause any unanticipated problems to appear. The postchange test plan also needs to be presented at the design review.

Regarding competitive evaluations the nature of how this is done is more of an art than a science. Competitive evaluations are an art since the methods used and the benchmarking calculations are primarily nebulous. The reason why they are so nebulous is that the variables involved are subjective and they define quality. Our personal definition of quality is probably different from your definition of quality and since there is no specification to truly benchmark against, this quality figure is left to the determination of an outside consulting firm or the senior management office.

Several methods for attempting to evaluate the current quality of the network and the ranking against the competition have been devised. A few companies offer a device which measures the audio levels on both the uplink and downlink paths. The audio level measurements are made quantitatively, which enables the evaluation to be done the same way time and time again. However, the parameters used in the testing and postprocessing are user defined leaving quite a lot open to interpretation. Using this method will produce the best results since it gets rid of many of the subjective items associated with quality testing.

Another method used is to hire people to drive sections of the network and make a series of calls on your system and the competitor's systems. Presumably the calls placed are similar enough in time of day, location, and duration to make a direct comparison. However, the people on the landline or the mobile are left to describe the call by listing it as good, poor, or excellent. Obviously the skills and subjectivity of this type of test leaves a lot to be desired.

An example of some subjectivity problems occurred once when a quality test came back saying an area of the system was performing exceptionally when engineering and operations knew better. Specifically the area reported to be performing great was a known trouble area which during this time was receiving a lot of attention. The good report was hailed as a success. However, on the next competitive test that was done for the same area the report came back that the area was performing poorly. Upper management was shown the previous test and the current test which caused much teeth gnashing in engineering and operations. There was an exceptional amount of effort then placed in trying to refute the report which previously was hailed as a very good report. The fundamental problem in this case was not the report itself but the fact that when good news is presented, but it is incorrect, it rarely gets challenged. What should have happened here is that the test should have been challenged when it said things were very good when it was known that in fact it was not.

The post-turn-on, or activation, testing is exceptionally critical to ensure that the system is not degraded by the entrance of a new cell site. However, there has never been a site introduced into a network that has not had some level of problem with it. The argument here is that when there are no problems found, no one is really looking.

The key to the post-turn-on testing involves two simple principles. The first principle is that you have to define the test prior to the site becoming commercial. The second principle is that you need to have the post-turn-on testing done immediately after the new site goes commercial to ensure that the problems the site has will be found quickly and rectified.

The problems associated with the new site should not be impossible to overcome, provided the design guidelines listed in a previous chapter are followed. Instead the issue is the handoff table adjustment, power level setting, or bias adjustment which needs to take place right after turn-on.

An example of the post-turn-on test request is shown in Fig. 5.33. The post-turn-on test needs to be an integral part of the post-turn-on MOP discussed later in this chapter. The actual form utilized as a trigger point for requesting resources should be well defined. A suggested format to use is proposed, but like all the other forms and procedures presented it is essential that they are crafted to reflect internal organization structures.

The last major area of drive testing involves post-retune efforts, which are similar to many of the other tests done, except that these are done in a tiered approach. Specifically it is recommended that these are done in a three-phase approach where each phase has a unique mission statement. An example of the retune zone is shown in Fig. 5.34.

Phase 1 is the identification and characterization of the most highly probable problem areas for the design which need to be validated first. Generally this involves bridges, the major roadways, and areas on C/I plots which show anything 19 dB C/I or less for AMPS, or where the testor suspects a problem (Fig. 5.35) based on the wireless technology used. Once the potential problem areas are identified, a drive route is designed corresponding to the potential problem areas previously identified (Fig. 5.36).

Cell site code: ______________________

MOP: ______________________

Requester: ______________________

Expected drive test start date: ______________________

Expected drive test start time: ______________________

Number of test vehicles needed: ______________________

Estimated drive test duration: ______________________

Data to be collected: ______________________

Report any problems to: ______________________

Special comments: ______________________

Drive map attached (Y/N)

Figure 5.33 Cell site activation post-turn-on test form.

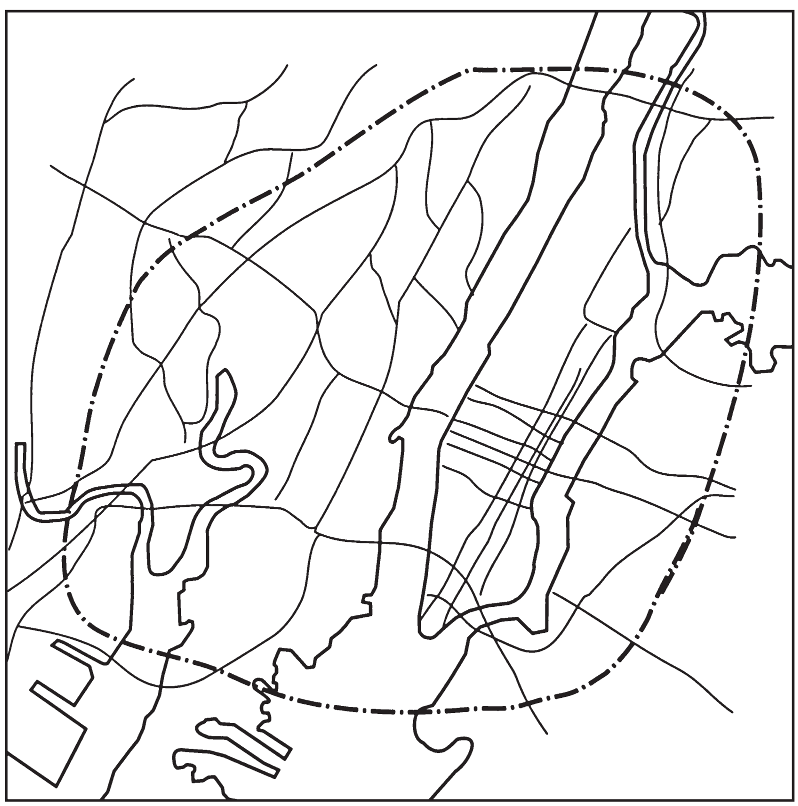


Figure 5.34 Retune zone.

Figure 5.35 Potential problem areas.

Phase 2 involves the characterization of class 1 and 2 roads in the retune zone (Fig. 5.37). This is meant to identify any problems along the major arteries in the network. The objective is to ensure that the major throughways do not have any apparent problems with them prior to a full system load.

Phase 3 involves testing all the areas which showed up as problems in phases 1 and 2 for either further clarification of the problem or validation that the fixes implemented worked.

This tiered method enables resources to be focused on resolving the problems in a timely and efficient method. A key to all the posttesting activities is that they are conducted immediately after the action takes place. This immediate time frame is important so that problems can be found by the testing team before subscribers discover them.

5.13 Site Activation

The philosophy of site turn-on varies from company to company. Some of the philosophies are driven by engineering; others are driven by financial objectives. There are several philosophies used in the wireless industry. The first

Figure 5.36 Phase 1 retune drive routes.

philosophy is that when a site is finished being constructed, it should be activated into the network. The second primary philosophy is that the site's depreciation should be minimized or maximized, depending on the accounting method employed by the company. The third method is where the sites are not activated until the implementation plan put forth by engineering dictates the timing of the new cells.

The first philosophy of cell site activation (turn it on immediately) has an emotional and upper management appeal. The appeal is that the site is being constructed to resolve some system problem, and the sooner it is put into service, the sooner the problem the site is designed for will be resolved. While this simple philosophy has its direct merit, it also has a few key drawbacks which if done incorrectly can create more system problems than it was intended to fix.

Specifically the drawbacks involve timing and coordination of the engineering plan to bring the site into the network. If site A requires handoff changes and is activated when the last ATP function is completed, the possibility of the handoff changes being implemented at this time is low. One alternative to this is to have the topology changes done in advance of the site's activation, but if it is done incorrectly, then handoff problems and lost calls could result. Another situation

Figure 5.37 Phase 2 retune drive routes.

could occur where there are too many handoff candidates in the topology tables of the sites complicating the frequency plan for the area.

Another major problem with this activation philosophy is the coordination of resources. As in most cases a site needs some level of intrasystem and intersystem coordination. If the site is activated at a seemingly random time, there is no guarantee that all the required coordination has been completed.

The third disadvantage with this method is the queuing of post-turnoff resources for the system troubleshooting phase of a site turn-on. The post-turn-on efforts to be fully effective require coordination in terms of timing. If a site is expected to be turned on anywhere within a 3-day window based on implementation problems, it is difficult to ensure that post-turn-on testing will begin right after turn-on. If you, however, want to ensure that post-turn-on testing begins right after turn-on of the cell, then there will be additional opportunity costs associated with this effort since resources will be significantly mismanaged.

The fourth disadvantage with this effort is the most important aspect, and it is the customer impact. Turning on the site when the implementation process is finished will most likely occur during the day. It is strongly advised that any site or major system action be conducted in the system maintenance window. The simple objective here is to minimize any negative impact the subscriber might experience and try and allow enough turnaround time for the engineering and operations teams to correct any problems before the subscribers find it.

The second philosophy of activating (to maximize or minimize depreciation costs) is largely driven by the financial requirements of the company. To maximize depreciation costs, the operator usually scrambles to activate as many sites as possible by the end of the fiscal year, usually corresponding with the calendar year. The objective here is to maximize the potential depreciation expense the company will have in any fiscal year.

The minimization of depreciation philosophy involves attempts to defer the depreciation of the new cell site into the next fiscal year. What is typically done here is that a site is prepared for activation into the network but will not be turned on until the next fiscal year. The objective here is to minimize the amount of expenses reported by the subsidiary to its parent company.

Usually the philosophy to maximize depreciation expenses has the activation philosophy of “turn it on now.” The minimization of depreciation philosophy usually involves a plan issued by engineering which matches the financial goals of the company.

The third philosophy for site activation (no new cell site or system change without a plan being issued and approved by engineering) ensures that the introduction of the new cell into the network has been sufficiently thought out, resources are planned and staged, and all the coordination required has or will be done in concert with the activation. This philosophy is essential to ensure that new cells are introduced into a mature system gracefully.

For this process usually more than one cell site is activated at the same time. Typically, if logistically possible, a series of cell sites in a region are activated at the same time. This philosophy enables a maximization of post-turn-on resources to focus on the issues at hand and also ensures the minimization of system alterations required. The map in Fig. 5.38 shows how combining several cell sites into a single turn-on for the system will facilitate maximizing resources and minimize the amount of changes required to the network.

The largest problem associated with trying to utilize this philosophy is getting upper management approval. The opposition occurs when a site may have to wait several weeks for activation due to configuration changes needed in the network to ensure its smooth transition. The issue of having a site ready for service and not activating it immediately is the hardest obstacle to overcome when presenting the case.

However, there are several key advantages that need to be stressed with this philosophy which might or might not be apparent.

1. Reduced system problems
   - Interference
   - Handoffs
   - Parameter settings
2. Coordinated efforts between all departments
3. Design reviews of integration plan take place
4. Intrasystem and intersystem coordination is more fluid

Figure 5.38 Group activation.

5. Pre-turn-on testing is conducted
6. Minimized negative customer impact through activation in maintenance window

There are obviously more positive attributes; however, the key issues are reduced system problems, pre-turn-on testing, and minimization of negative customer impacting issues as a result of following a plan. It is essential that for every cell site brought into a network that a plan is generated for its introduction and then carried out.

The design reviews necessary for a new site activation into the network need to be conducted by several parties. There are several levels of design reviews for this process. The first level of design reviews involve the RF engineer and the performance engineer discussing the activation plans and reviewing the plan of action put forth. The second level of design reviews involves having the manager of the RF engineering group sign off on the implementation design with full concurrence with the performance manager. The third level of design review involves reviewing the plan with the director for engineering and operations personnel to ensure that all the pieces are in place and that something has not been left out, like who will do the actual work.

After the design reviews are completed, the MOP for the activation is released. It should be noted that during the design phases the MOP should have been crafted and all the parties involved informed of their roles. A sample MOP is listed in Fig. 5.39 for comparison; obviously the exact MOP for the situation is different and needs to be individually crafted.

It is essential to always include a back-out procedure for cell site activation in the event of a major disaster taking place. The escalation procedure should be defined in the MOP and the decision to go or not to go needs to be at the director level, usually the engineering director or the operations director.

After the MOP is released and the design reviews are completed, it is essential that the potential new cell be visited by the RF and performance engineers

Date

Preactivation process

X-X-XX New cell sites to be activated defined
X-X-XX Project leader(s) named and timetables specified, as well as the scope of work associated with the project
X-X-XX Phase 1 design review (frequency planning only and RF engineer for site)
X-X-XX Phase 2 design review (all engineering)
X-X-XX Phase 3 design review (operations and engineering)
X-X-XX Phase 4 design review (adjacent markets if applicable)
X-X-XX Frequency assignment and handoff topology sheets given to operations
X-X-XX New cell site integration procedure meeting
X-X-XX Performance evaluation test completed
X-X-XX Executive decision to proceed with new cell site integration
X-X-XX Adjacent markets contacted and informed of decision
X-X-XX Secure post-cell-site activation war room area
X-X-XX Briefing meeting with drive test teams
X-X-XX MIS support group confirms readiness for postprocessing efforts
X-X-XX Customer care and sales notified of impending actions

New cell site activation process (begins X-X-XX at time XXXX)

X-X-XX Operations informs key personnel of new cell site activation results
Operations personnel conduct brief post-turn-on test to ensure call processing is working on every channel and that handoff and handins are occurring with the new cell site
Operations manager notifies key personnel of testing results

Post-turn-on process (begins X-X-XX at time XXXX)

Voice mail message left from engineering indicating status of new cell sites (time)
Begin post-turn-on drive testing, phase 1 (time)
Database check takes place
Statistics analysis takes place
Voice mail message left from RF engineering indicating status of postretune effort (time)
Phase 2 of post-turn-on drive testing begins
Commit decision made with directors for new cell site (time)
Phase 3 of post-turn-on drive testing begins

X-X-XX
Continue drive testing areas affected
Statistics analysis
Conduct post-turn-on analysis and corrections where required

X-X-XX
Post-turn-on closure report produced
New site files updated and all relevant information about the site transferred to performance engineering

Figure 5.39 Method of procedure for new cell site integration.

at various stages of the construction period. However, prior to activation it is essential that a pre-turn-on procedure take place. The pre-turn-on procedure is meant to ensure that the site is configured and installed properly so that when the site is activated into the network, the basic integrity of the site is known. The pre-turn-on procedure that should be followed is listed in a later part of this chapter.

Internal coordination involving new sites being introduced into the network is essential. The MOP listed above focuses on voice mail notifications to many groups inside and outside the company. However, it is essential that the activation of new cells and major system activities be announced to other departments in the company to inform them of the positive efforts being put forth by engineering and operations.

The primary groups to be informed to ensure some level of notification takes place are

1. Sales
2. Marketing
3. Customer service
4. Operations, real estate, and engineering
5. Corporate communications
6. Legal and regulatory

Basically, the entire company needs to be notified of the positive events that take place. One of the most effective methods is through the company's internal voice mail system. However, not everyone will have an individual voice mail account.

To ensure that all the people are notified of the new site's activation into the network, a series of communications can be accomplished. One method is to issue an electronic mail message to all the employees notifying them of the new sites and any particulars about the intended improvements, if any, to the network. Another method is to issue a memo to everyone in the company declaring the activation of the sites and the improvements that have been made.

External coordination for new sites is as essential as internal coordination. Specifically the neighboring systems should know when you are bringing new sites into the network and other major activities. The reason behind this effort is that your actions may have an unintended consequence on them, either positive or negative, which they need to know. In the same light, by providing your neighboring systems with new site activation information, you will receive reciprocal communications.

After the sites are activated into the network, it is essential that post-turn-on testing begins immediately. There has never been a site activated into a network, that we are aware of, which did not have some type of problem with it. Therefore, it is essential that the efforts put forth in this stage of the site activation process receive as much attention as the design phases did.

The key parameters which need to be checked as part of the post-turn-on activities are site configuration checks, metrics analysis, and drive test analysis.

1. *Site configurations from the switches point of view.* The objective here is to check all the cell site parameters as reported by the switch to those intended for the initial design. What you are looking for here is a possible entry mistake or even a design mistake made during the design process. Usually a data entry mistake is found in this process or an entry is left out. It is imperative that the neighbor cell sites also be checked in this stage of the process.

2. *Metrics analysis.* The objective with this part of the post-turn-on activities is to help identify and isolate for problem resolution problems reported in the network by the system statistics. This process requires continued attention to detail and an overall view of the network at the same time. The metrics that you should focus on involve the following items:

- Lost calls
- Blocking
- Usage
- Access failures
- BER, FER, and SQE
- Customer complaints
- Usage and RF loss
- Handoff failures
- RF call completion ratio
- Radios out of service
- Cell site span outage
- Reported field problems called in by technicians or the drive test team

The statistics monitored should be the primary sites activated and their neighboring cells. The issue here is to not only look at the sites being brought into service but also to ensure that their introduction did not negatively impact the system.

The actual numbers to use for comparison need to be at least 1 week's data for benchmarking, if possible. In addition the numbers used for the new cell should be compared against the design objective to ensure that the site is meeting the stated design objectives.

3. *Drive testing.* The post-turn-on drive test data analysis needs to take place here. This effort usually begins at the specified time after turn-on, usually early in the morning or late at night depending on the activation schedule. The drive tests are broken down into three main categories.

- *Phase 1.* Involves focusing on areas where there is the highest probability of experiencing a system design problem. The identification of these areas can be through use of prior experience, C/I plots, or SWAG.
- *Phase 2.* Involves targeting the rest of the areas involved with the site activation activities, usually the remaining class 1 and class 2 roads not already driven.
- *Phase 3.* Involves driving areas that were uncovered as problems in phases 1 and 2. This level of testing either verifies that the problem identified previously is still in existence or the change introduced into the network did its job.

4. *New site performance report.* The last stage in the new site activation process is the issuance of the new site performance report. The performance report will have in it all the key design documents associated with the new site. The key design documents associated with this new site should be stored in a central location instead of a collection of people's cubes. The information contained in the report is critical for the next stage of the site's life. The next stage of the site's life involves ongoing performance and maintenance issues.

To ensure that poor designs do not continue in the network it is essential that the new site meet or exceed the performance goals set forth for the network. If the site does not meet the requirements set forth, then it should remain in the design phase and not the ongoing system operation phase. The concept of not letting the design group pass system problems over to another group is essential if your goal is to improve the network.

The new site performance report needs to have the following items included in it as the minimum set of criteria.

1. Search area request form
2. Site acceptance report
3. New cell site integration MOP
4. Cell site configuration drawing
5. Frequency plan for site
6. Handoff and cell site parameters
7. System performance report indicating the following parameters 1 week after site activation
   - *a.* Lost calls
   - *b.* Blocking
   - *c.* Access failures
   - *d.* Customer complaints
   - *e.* Usage/RF loss
   - *f.* BER, FER, and SQE
   - *g.* Handoff failures
   - *h.* RF call completion ratio
   - *i.* Radios out of service
   - *j.* Cell site span outage
   - *k.* Technician trouble reports
8. FCC site information
9. FAA clearance analysis
10. EMF power budget
11. Copy of lease
12. Copy of any special planning or zoning board requirements for the site

The new cell site performance report is an essential step in the continued process for system improvements. Only once a site is performing at its predetermined performance criteria should the site transition from the design phase to the maintenance phase.

Lastly as part of the presite activation a site checklist should be completed, which is given in Table 5.5.

TABLE 5.5 Cell Site Checklist

Topic	Received	Open
Site location issues		
1. 24-hour access		
2. Parking		
3. Direction to site		
4. Keys issued		
5. Entry/access restrictions		
6. Elevator operation hours		
7. Copy of lease		
8. Copy of building permits		
9. Obtainment of lien releases		
10. Certificate of occupancy		
Utilities		
1. Separate meter installed		
2. Auxiliary power (generator)		
3. Rectifiers installed and balanced		
4. Batteries installed		
5. Batteries charged		
6. Safety gear installed		
7. Fan/venting supplied		
Facilities		
1. Copper or fiber		
2. Power for fiber hookup (if applicable)		
3. POTS lines for operations		
4. Number of facilities identified by engineering		
5. Spans load tested over 24 hours		
HVAC		
1. Installation completed		
2. HVAC tested		
3. HVAC system accepted		
Antenna systems		
1. FAA requirements met		
2. Antennas mounted correctly		
3. Antenna azimuth checked		
4. Antenna plumbness check		
5. Antenna inclination verified		
6. SWR check of antenna system		
7. SWR record given to operations and engineering		
8. Feedline connections sealed		
9. Feedline grounds completed		
Operations		
1. User alarms defined		
Engineering		
1. Site parameters defined		
2. Interference check completed		
3. Installation MOP generated		
4. FCC requirements document filled out		
5. Drive test complete		
6. Optimization complete		
7. Performance package completed		

TABLE 5.5 Cell Site Checklist (*Continued*)

Topic	Received	Open
Radio infrastructure		
1. Bays installed		
2. Equipment installed according to plans		
3. Receiver and transmitter filters tested		
4. Radio equipment completes acceptance test procedure (ATP)		
5. Transmitter output measured and correct		
6. Grounding complete		

5.14 Site Investigations

Cell site investigations can be equated to a hunting trip. If you are a good tracker and understand the game, your chances of success are greatly improved. There are two primary types of site investigations, new sites and existing sites. The new sites referred to here are those which have not begun to process commercial traffic and thus are not activated into the network when visited. The existing cell sites, however, are currently active sites in the network. The existing cell site usually has some particular problem associated with it that now warrants an engineering investigation.

5.14.1 New sites

For a new cell site the site investigation is essential to ensure that there are no new problems introduced into the network as a result of the physical configuration of the site. The objective of a new site investigation is to validate that site is built to the design specifications put forth by engineering. Some of the key areas to validate are

Antenna system orientation

Antenna system integrity

Radio power settings

Cell site parameters

Hardware configuration

Grounding system

This list of major items needs to be expanded upon since they are primarily engineering issues and do not focus on the radio and cell site commissioning aspects required by operations.

The antenna system orientation is essential to have validated prior to activation. It has a direct impact on how the cell site will interact with the network. For example, if the orientation is off by say 30°, then the C/I levels designed for it cannot be met. When inspecting the orientation of the antennas, it is essential to validate their location and installation versus the AE drawings for the site which were approved by engineering. Lastly here, if there is an obstruction to the antenna system itself, this needs to be corrected quickly.

The orientation of the site can be validated through several methods depending on whether it is a rooftop or tower installation. Ordinarily, whoever installs the antennas for the site are required to validate the orientation of the antennas through some visual proof provided to the operator.

If the installation is on a rooftop, you should use a 7.5-minute map with some type of optical alignment method, usually a transit. By referencing a point on the 7.5-minute map, it is easy to validate the orientation of the antennas with a high degree of accuracy.

When installation is on a tower or monopole, the orientation check is a little more difficult. However, the site drawings should reference the orientation of the legs of the tower itself. Once you have the orientation, you can verify that the antennas and mounts used are installed in the right locations. However, validating the orientation is more difficult; therefore, you will need to utilize a 7.5-minute map and locate three points at a distance from the tower. When traveling to each of these points, it will be necessary to establish your bearings; use an optical device (transit) and site the antennas for the sector you are in and validate that the bore site for the antenna appears to be correct.

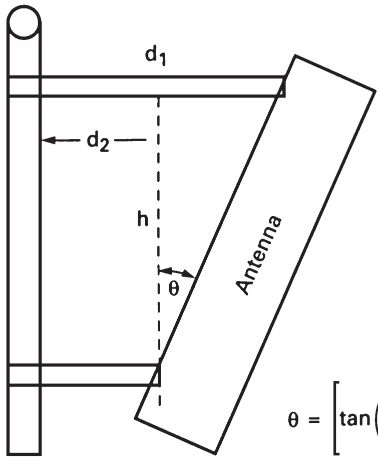
This discussion has addressed physically checking sectored sites, but obviously for an omni-cell site orientation is not the issue but rather it is the plumpness of the antenna. It is necessary, where applicable, to also validate the plumpness of every antenna at a site. This can be accomplished through use of a digital level or visual inspection where the application of a level is not practical or safe.

In validating the physical aspects of the antenna system it is necessary to check if downtilt is employed as part of the design and if so what angle is utilized. This can be checked again through use of a set of simple measurements made on the antenna itself. One word of caution, Do not just utilize peg holes for validating the downtilt angle unless the exact angle versus peg hole count is known for that antenna and installation kit used. Figure 5.40 is an example of how to calculate the degree of downtilt employed at a site.

An additional step in the inspection of the antenna system involves validating that the correct antennas are in fact installed at the site. The simplest method is to verify the make and model number by reading it right off the antenna, where applicable.

One key element to note is the physical mounting of the antenna. On several occasions an antenna that has electrical downtilt employed as an omni-antenna has been installed upside down since this is a standard installation on a monopole site. The additional interesting aspect to the antenna inverting situation was that the drain hole was now on the top and the antenna was effectively becoming a rain-level indicator, an interesting sideline but not the intended purpose. Additionally if you are using electrical downtilt and invert the antenna, the pattern result is significantly altered from the desired uptilt situation.

After the physical installation characteristics are checked for an antenna system, it is necessary to perform an S11 test on the antenna system.



$$\theta = \left[\tan\left(\frac{d_1 - d_2}{h}\right)\right]^{-1}$$

Figure 5.40 Downtilt angle.

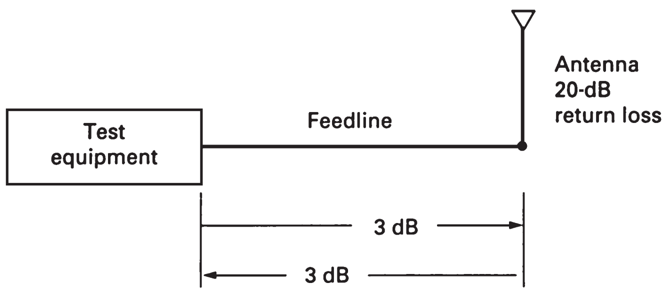


Figure 5.41 Antenna system.

When checking the antenna system, it is important to predetermine the values anticipated prior to actually making the measurements (see Fig. 5.41). For example, if you expect to get a value of 26 dB return loss

$$\begin{aligned} \text{Antenna retune loss} &= 20\text{ dB} \\ \text{Feedline loss up} &= \ \ 3\text{ dB} \\ \text{Feedline loss back} &= \ \ \underline{3\text{ dB}} \\ \text{System return loss} &= 26\text{ dB} \end{aligned}$$

you would pass the antenna system with a return loss of anywhere from 24 to 26 dB. However, if you got a 14-dB return loss, then this would indicate a major system problem since

$$\begin{aligned} \text{System return loss} &= 14\text{ dB} \\ \text{Feedline loss up} &= \ \ 3\text{ dB} \\ \text{Feedline loss back} &= \ \ \underline{3\text{ dB}} \\ \text{Antenna return loss} &= \ \ 9\text{ dB} \end{aligned}$$

The interesting point here is that most operators will pass an antenna system with a standing-wave ratio (SWR) of 1.5:1 which is a 14-dB return loss. However, when you factor in the cable loss, a SWR of 1.5:1 really means that your antenna is experiencing a real SWR of greater than 2.0:1. A SWR of 2.0:1 would have any cellular operator demanding action. Therefore, it is important to remember that the feedline can and will mask the real problem if you are not cognizant of the ramifications.

The last step in the antenna system validation involves validating that the antennas are indeed connected as specified. The real issue is to check if the antenna 1 feedline in the cell site is really connected to the actual antenna 1 for the sector.

The simple test involves using a mobile that is keyed on a particular channel and driving to the bore site of every sector, in a directional cell, and making sure that maximum smoke is measured on the antennas assigned for that sector. The key point here is that even the transmit antenna should be checked at this time, provided it is designed to pass energy in the mobile receive band also.

Figure 5.42 depicts a mobile located in the bore site of sector 1 for the cell site. The mobile operator keys the mobile's transmitter and sends energy on a cell site receive frequency. Figure 5.43 is an illustration of what the person at the cell site would be observing with either a spectrum analyzer or a service monitor.

One additional test associated with any cell site involves checking the filtering system used for the site. It is imperative that the actual filter characteristics

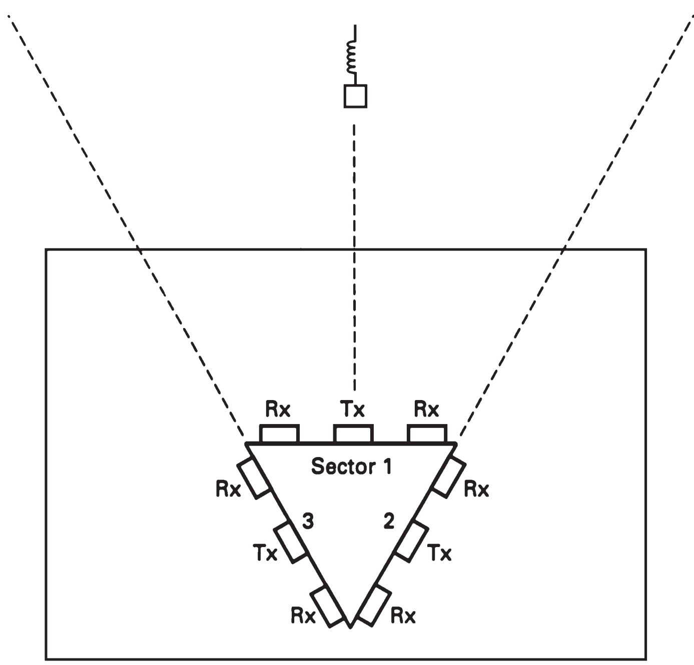


Figure 5.42 Mobile in bore site sector 1.

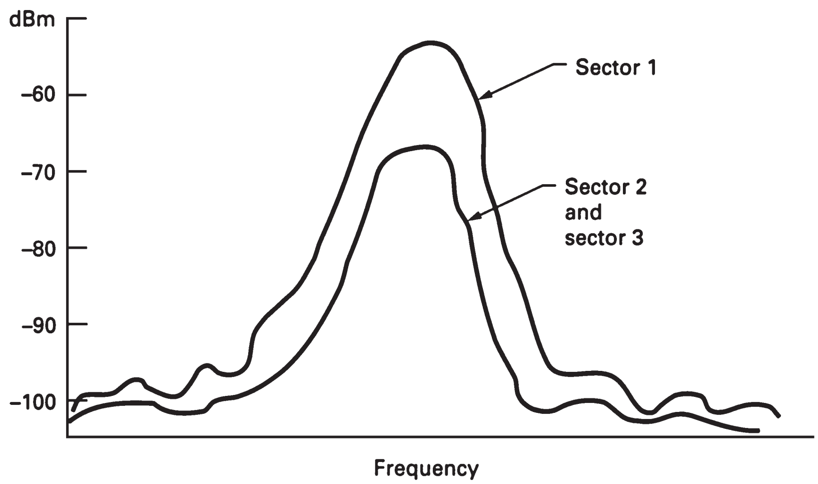


Figure 5.43 dBm display of antenna alignment test.

are checked at this time to prevent additional problems from being introduced into the network. The most effective method for performing this effort is through a S21 test or rather a through test.

The following is a brief listing of items which need to be checked for a new cell site. Some of the items in this list have previously been talked about. When reviewing the new cell site checklist, it is important to also obtain operation's input into the proposed form to ensure there is one form and not several. This list should be used as a punch list for correcting identified problems prior to the site going commercial and issues after it has.

It is essential that the checklist provided be used as a minimum and that it should be modified and expanded upon based on your own particular system requirements.

Cell site performance checklist

1. Antenna system
   a. Installation completed
   b. Installation orientation and mounting verified
   c. Feedline measurements made and recorded
   d. Return loss measurements made and acceptable
   e. Feedlines grounded and waterproofed
2. FAA
   a. Lighting and marking completed (if required)
   b. Alarming system installed and operational
3. Receive and transmit filter system
   a. Bandpass filters performance validated
   b. Notch filter performance validated (if required)
   c. Transmit filter performance validated
4. EMF power budget provided

5. Cell site parameters
   a. Frequency assignments validated
   b. Handoff topology lists checked
   c. Cell site parameters checked
   d. Cell site software load for all devices validated
6. Spectrum check
   a. Sweep of transmit and receive spectrum for potential problems
   b. Colocated transmitter identified

Many of the common problems associated with a new site investigation involve antenna orientation and obstruction issues. It is not that uncommon on a rooftop installation to have an antenna obstructed by either a neighboring building or the air-conditioning unit on the roof. The rectification to this situation is to try and relocate the antenna itself or see if possibly using the antenna for another orientation is a better application.

Regarding orientation this situation often involves someone reading a 7.5-minute map incorrectly and orienting the site according to the bad reference point. That is why it is important to have the contractor provide the orientation reference as part of the completion specifications.

5.14.2 Existing cell sites

When trying to improve a system's performance, it is often necessary to physically visit an existing cell site or location in order to try and determine firsthand the exact nature and cause of the problem for the area. As with all engineering efforts it is essential to have a battle plan laid out prior to performing the mission. It is strongly suggested that the battle plan put forth include possible problems and suggested solutions prior to conducting the field visit itself. With a predefined hypothesis as to the exact nature of the problem, you are in a position of either validating or refuting the initial hypothesis.

Before conducting a site visit to an existing cell site, it is recommended that the following checklist of items be followed to help expedite the efforts.

1. Review of the statistics for the cell site in question and the surrounding cells
2. Review of the site's frequency plan and the surrounding cells
3. Handoff topology review of the site and its neighbors
4. Expected problems to find and possible recommended action items
5. Review of the cell site's hardware configuration
6. Review of the maintenance issues for the site over the last month
7. Site access secured for the location
8. Maps of the area and directions to the site secured
9. Test equipment needed for the investigation secured

When defining the site to be investigated, it is imperative that a test plan be formulated for the effort. The methods used for defining the area or cell in question is a result of analysis of the key factors that are monitored on a continuous basis.

Regardless of the method picked and the nature of the investigation the following steps need to be taken.

1. Define the objective and specifically what the test or site visit is meant to check for.
2. Identify the area to investigate. Although this is an obvious point the geographic area for investigation is critical to the success or failure of any field test or trip.
3. Ensure that the site picked for the investigation is related to the area defined in step 2.
4. Define prior to the investigation the time you are allocating to investigate the problem, e.g., 2 weeks.
5. Define the physical resources required for the testing, equipment, and personnel.
6. Issue a status report and concluding report on the investigation.
7. Review and update the site-specific books.

There are many types of tests which can be done for a site, and each requires a different approach to uncover the real problem and determine recommended fixes.

Interference. One test that could be done is to investigate potential interference at a location. In defining the test it is essential that you identify the potential problems at this location by looking at the following items in addition to the items listed above which are part of the normal site investigation list.

1. Current frequency plan
2. Coverage plots for the area (voice and setup)
3. C/I plots for the site and the surrounding area
4. Drive tests

Design issue. Another type of test involving an existing cell site could involve investigating potential design problems overlooked in the initial site's deployment or later modifications. Some of the items to check for in this part of the investigation are

1. Receive configuration
2. Equipment provisioning aspects for the site
3. IF settings, if applicable
4. Antenna tilt angles, looking for overtilt or unbalanced tilting between sectors
5. Antenna elevations, too high or too low
6. Antenna types used

7. Cell site firmware
8. Cell site equipment vintages
9. Setup and voice channel ERP
10. Cell site parameters

Coverage. Another site investigation test involves identifying and qualifying coverage problems. For this type of testing the objective is to determine if there is insufficient coverage in an area that will promote the possibility of interference caused by the lack of coverage in the area in question.

Coverage testing is similar to interference testing in that the basic issues investigated are the same. The recommended use for a coverage investigation involves verifying if the addition of a new cell or changing the antenna system at the site, increasing the ERP, or doing nothing at all is needed.

For cell site parameter alterations and problems there is a different slant taken to the site investigation. The testing for the site focuses on evaluation of the handoff window and call-processing parameters for the site. A drive test is essential for the pre- and postchange testing. The pre- and postchange testing methodology was covered previously in this chapter.

Regardless of the type of site investigation taking place, some level of documentation needs to take place detailing the findings and recommended actions. A site improvement plan is presented here. The format used can be followed or altered based on the particular situation encountered. The situation presented here was an investigation of a site which had its antenna system redesigned. The redesigned antenna system began having network-related problems and an investigation into the nature of the problems commenced.

Site improvement plan

1. Generate propagation plots for the site at its current antenna height and at the previous antenna height.
2. Compare the current propagation predictions with the data actually measured.
3. Evaluate data to determine if the coverage presently produced by the site is the desired result for the area.
4. Conduct a S11 test of the antenna system.
5. Conduct a test utilizing the previous antenna system as a comparison.
6. Based on data collected in step 5 determine if further action is required. If further action is required, then determine if the site's previous antenna height should be used employing downtilt or another height picked.
7. Implement changes to the antenna system, and conduct a S11 test of the new antenna system.
8. Conduct additional field tests to evaluate if the desired results are achieved and make corrections if needed or possible.

Field Test Report

Date: 7-24-95

Subject site: Cell X

Reason for conducting site visit. The site was chosen to be visited as part of the ongoing process to improve area 3 of the network.

Purpose. The purpose of the site visit was to try to quantify specifically the reasons for the poor performance of sectors 1 and 2.

Site configuration. The site configuration is shown as figure 1, attached. The site consists of four bays of radio equipment and 41 physical radios. There are a total of nine antennas at the site. The site parameters and software load were validated to be correct.

Observations. During the course of the investigation into the site it was noted that there was a serious obstruction to sector 1 and partially for sector 2. Pictures of this situation were taken and are included for reference. It was also found that there was a defective transmit filter for sector 2 of the site, limiting its power output. The filter was acting as a load and therefore did not set off any SWR alarms.

Recommendations. It is recommended that the antenna design for sectors 1 and 2 be reworked to avoid the obstruction. The proposed configuration is shown as figure 2. The defective transmit filter was replaced the day of the site investigation, and no further action is required for this issue.

Engineer: ________________________

Operations: ________________________

Figure 5.44 Field test report.

9. Evaluate the cell site and its neighbors statistics performance.
10. Issue a closing report on the engineering activities by a specified date.

An example of a site visit report is given in Fig. 5.44. The cell site investigated was one of the worst-five performing cell sites in the network. Several tests were conducted with field personnel regarding the site netting marginal results. It was, therefore, decided to conduct a physical investigation of the site by engineering with operation's support. The key concept to always remember when conducting a site investigation and improvement process is to document what you have and will do. Every cell site can undergo some level of improvement, no matter how small it may seem.

5.15 Orientation

The orientation of the sectors in a wireless network directly determines the effectiveness of the frequency management scheme employed by the operator regardless of the technology platform used. The consistent orientation of the sectors is critical for getting the maximum C/I available in frequency assignment for TDMA-based systems. However, for CDMA the orientation criteria is relaxed and not required.

Frequency reuse is maximized though controlling where the potential interference will be. Using different orientations in a network will lead to increases in lost call rates and poor performance due to increased interference. There are numerous technical articles pertaining to the use of orientations and frequency management. The use of standard orientations also facilitates the system performance troubleshooting through the elimination of variables.

The orientation of the cell sites is critical not only for frequency management but also for handoffs. Orientation is not that critical a factor in a young system because most of the performance problems are directly related to coverage issues. However, coverage issues can be caused by incorrectly orienting antennas at a cell site.

5.16 Downtilting

Downtilting or altering the antenna inclination of a cell site is one of the techniques available to a radio engineer for altering a site's coverage. The rationale used to alter the concatenation of the cell site's antenna system can be varied. Some of the rationale used for altering involves reducing interference, improving inbuilding penetration, improving coverage, or limiting a site's coverage area. The concatenation of the antenna system can have a major impact on the actual performance of the cell site itself.

The alteration of the tilt angle for a cell site should be done with extreme care since this can have a major impact, both positive and negative, on the performance of the network. To maximize the benefits of altering the tilt angle for a cell site while minimizing your exposure to problems, it is suggested that you follow a test plan.

There have been several articles and papers written regarding the use of downtilting antenna systems. Generally, the reports written stress the use of tilting the antenna system, usually half the vertical beam width, to achieve a 3-dB reduction signal level at the periphery of the sector's coverage. The tilt angles are usually specified, or requested, by the frequency planners for the intention of improving the C/I at another cell site.

I have found that taking the terrain aspects near the cell site can provide large signal attenuation with just a minor tilt angle. The use of terrain to assist in the attenuation of the signal is based on diffraction of the signal. The use of diffraction on attenuating the signal is a very effective tool when trying to maximize the signal near the cell site and attenuate it near the horizon.

For example, if your objective is to improve the coverage near the cell site but contain the coverage of the cell so it does not create an interference problem to the network, altering of the antenna system's tilt angle can be considered as one possible solution, assuming the antenna system employs an antenna with a 5° downtilt. Figure 5.45 shows where the main lobe of the antenna pattern

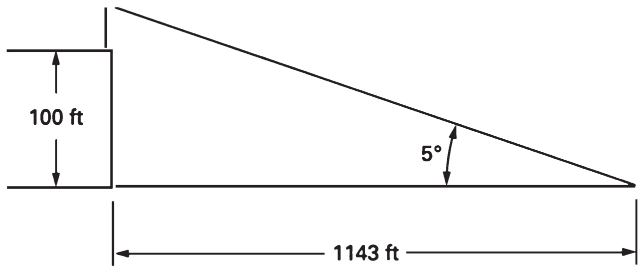


Figure 5.45 Downtilt.

strikes the ground. The main lobe of the antenna system using a 100-ft-high cell site at 5° hits the ground at 1143 ft. The example in the figure, however, assumes a flat-earth situation which is not realistic.

The tilt angle for the antenna system also has a direct impact on the coverage for the cell site. The example shown in Fig. 5.45 indicates that if a cell radius is 2800 ft, another cell site might now be required for the area to provide coverage. The coverage loss due to downtilting is often an overlooked aspect when this technique is employed as a solution.

The coverage loss to the network could be reduced or eliminated by utilizing diffraction. The use of diffraction on attenuating the signal for a cell site has a greater impact than merely tilting the antenna by half its vertical beam width.

Figure 5.46 is an example of using diffraction to attenuate the signal. The figure shows an obstruction 3000 ft away from the bore site for the sector. The desired goal is to have the signal level near the cell site but minimize the negative effects of interference at the reusing cell site, several sites away. The antenna tilt angle needed to achieve over 21 dB of attenuation in less than 2°. The use of terrain to assist in the attenuation of the signal should be exploited in order to maximize the coverage of the cell site and achieve the necessary attenuation of the signal to facilitate frequency reuse.

When planning on altering an antenna system's inclination, it is strongly advised that a test plan or MOP be used. The key element for the plan which must be done prior to altering the antenna pattern for a cell site is to define what your objective is before you begin. Defining the objective beforehand seems simplistic in nature, but it is imperative that this is done.

The following is a procedure for altering the tilt angle of an antenna system, usually a sector, for a cell site. The procedure here, as with other procedures, should be modified to reflect the particulars of the situation. The individual procedure listed here is meant for a trisector cell site. If you have a situation where the site has a different amount of sectors, a modification to this procedure involves simply increasing the number of data points to test.

An important aspect is that altering the tilt angle for a cell site can involve increasing and decreasing the angle of inclination currently used there. Many improvements to a network's performance have been achieved simply by reducing the tilt angles currently employed at a cell site.

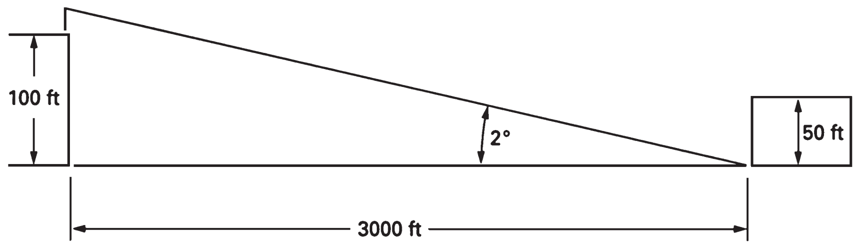


Figure 5.46 Downtilt.

Downtilt procedure

1. Identify the problem.
2. Check operations.
3. Make physical observations.
4. Perform drive testing.
5. Define cell's coverage area.
6. Perform design review. The items which need to be reviewed at the design review meeting are
   - The objective for the antenna alteration
   - Desired coverage area for cell site and sectors
   - Preliminary tilt angles desired based on the previous two items
   - Pre- and posttest plan
   - Pass/fail criteria
7. Perform test plan.
8. Perform closure activities.

5.17 Intermodulation

Intermodulation situations will present themselves to any radio engineer at various stages of one's career. The cause of intermodulation and how to remedy the situation has employed many talented engineers and will continue to do so. In order to find and ultimately resolve the intermodulation problem, it is important to know the basic concepts of just what is intermodulation.

Intermodulation is the mixing of two or more signals that produce a third or fourth frequency which is undesired. All cell sites produce intermodulation since there is more than one channel at the site. However, the fact that there are intermodulation products does not mean there is a problem.

Various intermodulation products are shown below for reference. The values used are simplistic in nature to facilitate the examples. In each of the examples, $A = 880$ MHz, $B = 45$ MHz, $C = 931$ MHz, and D is the intermodulation product. This example does not represent all the perturbations possible.

Second order: $A + B = D$ (925 MHz)

$A - B = D$ (835 MHz)

Third order: $A + 2B = D$ (970 MHz)

$A - 2B = D$ (790 MHz)

$A + B + C = D$ (1856 MHz)

$A - B + C = D$ (1766 MHz)

Fifth order: $2A - 2B - C = D$ (739 MHz)

The various products that make up the mixing equation determine the order of the potential intermodulation. When troubleshooting an intermodulation problem, it is important to prepare for the encounter in advance.

All too often when you conduct an intermodulation study for a cell site there are numerous potential problems identified in the report. The key concept to remember is that the intermodulation report you are most likely looking at does not take into account power, modulation, or physical separation between the source and the victim, to mention a few. Therefore, the intermodulation report should be used as a prerequisite for any site visit so you have some potential candidates to investigate.

Intermodulation can also be caused by your own equipment through bad connectors, antennas, or faulty grounding systems. However, the majority of the intermodulation problems encountered were a result of a problem in the antenna system for the site and well within the control of the operator to fix.

Just how you go about isolating an intermodulation problem is part art and part science. We prefer the scientific approach since it is consistent and methodical in nature. If you utilize the seven-step approach to troubleshooting listed at the beginning of the chapter, you will expedite the time it takes to isolate and resolve the problem. The biggest step is identifying the actual problem, and after this the rest of the steps will fall in line. Therefore, it is recommended that the following procedure be utilized for intermodulation site investigations.

Previsit work

1. Talk to the cell site technician and have him or her go over the nature of the problem and all the steps taken to correct the problem.
2. Examine the site-specific records for this location and see if a previous problem was investigated and if there were any changes made recently to the site.
3. Determine if there are any colocated transmitters at this facility and conduct an intermodulation report looking for hits in your own band or in another band based on the nature of the problem.

4. Collect statistic information on the site to try to determine any problem patterns.
5. Review maintenance logs for the site.
6. Formulate a hypothesis for the cause of the problem and generate a test plan to follow.
7. Secure the necessary test equipment and operations support for the site investigation.
8. Allocate sufficient time to troubleshoot the problem.

Site work

1. Perform initial test plan.
2. Isolate the problem by determining if the problem is internal or external to the cell site.
3. Verify all connectors are secure and tight.
4. Monitor the spectrum for potential intermodulation products determined from the report.
5. When intermodulation products appear, determine common elements which caused the situation.

Based on the actual problem encountered, the resolution can take on many forms.

If the problem is a stray paging transmitter, the recommended course of action is to notify the paging company and request, first, that they resolve the situation immediately. For this situation you will need to conduct a posttest to validate if the change took place and netted the desired result.

If the problem is a bad connector producing wideband interference, the situation is corrected by replacement of the connector itself.

If the problem is a bad duplexer or antenna, again the situation is rectified through replacement of the equipment itself.

If the intermodulation product is caused by the frequency assignment at the cell site, then it will be necessary to alter the frequency plan for the site, but first remove the offending channels from service.

If the intermodulation problem is due to receiver overload, the situation can be resolved by placing a notch filter in the receive path if it is caused by a discrete frequency. If the overload is caused by cellular mobiles, using a notch filter will not resolve the situation. Instead mobile overload can be resolved by placing an attenuation in the receive path, prior to the first preamp, effectively reducing the sensitivity of the receive system.

5.18 System Performance Action Plan

The following is a list of performance action plans or activities that need to be completed on a daily, weekly and monthly basis.

1. Daily check lists
2. Weekly plan
3. Monthly plan
4. New site integration
5. New service integration
6. Quarterly drive tests

5.18.1 TIC lists

The following are brief TIC lists that can be used by performance engineers and their managers as quick reminders of activities that need to be done.

Performance engineer

Daily TIC list (9 A.M.)
1. Examine exception report.
2. Review datafill conflict reports.
3. Review status operations for outages and other performance issues.
4. Review customer trouble reports for area.

Weekly TIC list (Monday 9 A.M.)
1. Examine exception reports (are there trends?).
2. Examine key factors and performance reports.
3. Generate plan for week.

Monthly (first Friday of every month)
1. Examine key factors and performance reports.
2. Identify the 10 worst-performing sectors in region by each key metric.
3. Generate a plan for what needs to be done for each sector and cluster.
4. Identify what was completed versus last month's plan

Performance manager

Daily TIC list (9 A.M.)
1. Examine exception report (system and regional level).
2. Review status operations for outages and other performance issues.
3. Review customer trouble report summary.

Weekly TIC List (Monday 12 P.M.)
1. Examine exception reports (are there trends?).
2. Examine key factors and performance reports.
3. Review regional plans for action and correct if necessary.

Monthly (first Friday of every month)

1. Examine and communicate key factors and performance reports, regional and system.
2. Identify progress against key metrics for system and each region.
3. Identify the 10 worst-performing sectors in system by each key metric.
4. Generate a plan for what needs to be done for each sector.
5. Identify what was completed versus last month's plan.

5.18.2 Weekly reports

The following is the basic material that should be included in the weekly plan of action from system performance engineers to their managers.

Weekly report material	Completed
10 worst-performing sectors identified by key factor category	
Planned activity by day (general)	
Requests for assistance	
Key factor summary of area versus monthly and quarterly goals	
New cell activations	

The following is the weekly report material that needs to be provided to the director of engineering by the system performance manager.

Weekly report material	By area	System
10 worst-performing sectors identified by key factor category		
Planned activity by day (general)		
Requests for assistance		
Key factor summary of area versus monthly and quarterly goals		
New cell activations		
Comments about planned deviations and how to correct them		

5.18.3 Monthly plan format

The following is a brief description regarding the format of the monthly plan of action that needs to be generated for each of the separate areas within system performance. The plan is meant to indicate what the general focus will be for the region over the next month. The plan is meant as a general guide from which major system problems can be identified and the department as a whole will be aware of what their counterparts are doing. Effectively the engineers for system performance with their manager show what their plan is for helping improve the performance of the network over the next few weeks. It is suggested that each area is handled separately so as to maximize the work effort by everyone else. For example, Monday afternoon and Tuesday morning could be set aside for conducting these presentations.

The informal presentation takes a maximum of 2 h the first time and 1 h from then on. A rotation program can be done for the various performance engineers. The presentation should be given to the director of engineering.

System performance engineer. The topics to include involve the following items.

1. Identification of problem areas by
   a. Customer complaints
   b. Statistics (key factors and performance indicators)
   c. FER, BER, and SQE; C/I; Eb/No
   d. Coverage < -86 dBm
2. What the suspected problems are (they cannot all be coverage) in rank order
3. What actions are to be taken (they cannot all be new cell or retune)
4. When they expect to have the problems resolved
5. The schedule of new sites and the status of datafill efforts
6. Results of last month's plans versus accomplishments
7. Performance relative to key factors and performance for each area

The following is the material that should be presented by the manager of system performance on a monthly basis to the engineering and operations management. The material is similar to the information that the individual system performance engineers generate with the exception that all the areas are incorporated into this plan.

Manager of system performance

1. Identification of problem areas by
   a. Customer complaints
   b. Statistics (key factors and performance indicators)
   c. FER, BER, and SQE; C/I; Eb/No (Eb/Io)
   d. Coverage < -86 dBm
2. What the suspected problems are and rank order them (*focus only on top 5 problems*)
3. What actions are to be taken
4. When they expect to have the problems resolved
5. The schedule of new sites and the status of datafill efforts
6. Results of last month's plans versus accomplishments
7. Performance relative to key factors and metrics for each area

Key performance indicator	Goal	Area	System
Blocking %			
Dropped lost call % (LOS)			
Access failure %			
Handoff failure %			
Usage minutes/lost call			
Radio utilization rate			
% area > −85 dBm (RSSI design threshold)			
% area >XX FER/BER/(C/I)/SQE			
% area >XX kbit/s			
Sites on-air			
No. of trouble tickets/no. of subs			
No. of trouble tickets			
Trouble ticket response time			