IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, 23-25 September 1991, King's College London (UK)
pp. 247-251

Management System for Cellular Telephone Network

Ziny Flikop, NYNEX Science and Technology, Inc.

Abstract

This article discusses some aspects of Management System development for a Cellular Telephone Network. This System is intended to analyze and optimize the cellular network performance, however not on a call-by-call basis.

1. Introduction

The first articles addressing cellular network performance, analysis and optimization were publishing a long before actual full scale cellular networks were created. For example see [1-3]. Publications of such articles continue. For example, see [4-6]. However, the cellular network management problem is so complex that is still very far from resolution. This article does not pretend to answer all questions due to the complexity of the problems and the limitations on the length of this article. Nevertheless, we shall discuss some problem and directions, and make suggestions that can bring us closer to the solution.

Optimal design and management of the cellular radio network is a very completed task. This complexity is caused by a variety of factors including:

- Telephone traffic varies from region to region and depends on the size and shape of the service zones, covered roads and density of car traffic one of them, and and the penetration of the cellular service.
- Telephone traffic in the same region can fluctuate widely depending on the time of day, the day of week, the season of the yea,r car traffic conditions, and unusual events.
- The results of cellular network analysis are valid only for short periods of time because real networks are in a state of constant change.

The complexity of the task that system engineers encounter throughout network control and design is thus apparent. The traditional management approach relies basically on engineering know-how and fragmentally information about the system parameter's behavior. Computer power is often underused. The traditional approach can help control networks while the density of cells sites is still low. However, when density increases the relationships between cell sites parameters became so complex that the current management style proves to be inadequate for the management task.

As a result of studying the cellular network management problem one can concludes that only a global approach that considers the network as a whole and analyses its performance from a historical perspective should be used for planning and management purposes. Since cellular networks are geographically distributed, a presentation of performance information in map form on a high resolution color monitor can significantly simplify the process of the data evaluation.

Management system should provide operational personal with the selected traffic, radio signals and hardware information that is needed to analyze any situation. For each investigated problem, a special tree like menu structure can be used. The sequence of steps followed in this menu would depend on the state of the investigated object (problem). This sequence should automatically be generated by a special menu generator.

A major management task is network optimization. This task can be divided into two subtasks. The first subtask (local) is optimization of usage of the already available recourses (cell sites and radios). This subtask can be resolved by balancing the load. The second subtask defines the optimal expansion of the network, that is when and where new cell sits should be positioned and how many radios should be in each cell site.

Output can be presented in tabular, graphical or text form. In addition output can be presented in the format for the specific problem or in the free format required by an engineer. In the first case, format and information are predefined by an expert or a group of experts. The most meaningful information can be filtered and flagged. A problem solving mechanism should be suggested as well. This approach will help the engineer reuse expertise accumulated by different engineers.

To provide a classical control loop it is proposed that the Management system consists of three inter related subsystems: Monitoring, Decision Support and Executive.

2.0 The Monitoring Subsystem.

The purpose of this subsystem is to periodically collect cellular network performance information; statistically analyze received data; evaluate deviations of the controlled parameters from the expected values; detect abnormalities and provide a corresponding picture on a color monitor; maintain and the upgraded an historical database of the monitored data; and automatically or upon request print predefined reports. This subsystem creates an informational foundation for the two other subsystems.

The mechanism for detecting abnormalities in cellular network performance can utilize two algorithms.

The first algorithm assumes that fluctuations of the controlled parameters measured for the same cell site, for the same day of the week, and the same time of the day constitute a stationary stochastic process with normal distribution. After every measurement the Monitoring subsystem calculates an average and standard deviation for each parameter. For these calculations a moving time interval can be used. The corresponding information can be stored in the historical database. A moving time interval of predefined length will help accommodate the evaluation process in the cellular network.

The detection procedure compares a current value of each parameter with a corresponding average and standard deviation. When a current value is outside the three, for example, sigma limits, then the behavior of this parameter is considered abnormal and corresponding information is presented on the monitor. This algorithm is simple and relatively insensitive to short lasting changes in the network or environment which are caused, for example, by car accidents.

In reality, the assumption describe above is valid only for the short time and only for some regions that are outside the main core of the network. To improve controlling abilities, a second algorithm, employing a more sophisticated detection method based on forecasting, can be used. For detection, real values are compared with forecasting values and checked against the standard errors. Forecasting algorithms easily adapt to changes in the cellar network. However, short duration events can affect the accuracy of the forecast, so special precautions should be taken.

Radio signal information is also vitally important for cellular network performance analysis and design. In particular, it is needed to define service zones and proper threshold levels, to study the presence of “holes” in service zones, to investigate interference levels, and so on. At this time this information is available either via director field measurements or via simulation. Existing propagation models used real terrain data and signal attenuation formulas. The accuracy of these models varies and all have difficulty calculating signal levels in urban areas. As a solution, a combination of simulated results and real measurements can be used. Presenting radio signal information on the same screen with the results all the traffic analysis data will significantly improve the decision-making ability of the system engineers.

3.0 The Decision Support Subsystem.

The complexity of real cellular networks is the reason that neither adequate models nor comprehensive methodology for the management and design of such networks have not yet been created. Therefore, for some time in the future a system engineers now- how and the results of direct network studies well continue to play a vital a role in network planning and optimization.

In terms of time, the general task can be separated into short, intermediate and long term subtasks. The short term subtask is operational and limited to detection of cellular system performance abnormalities on an hour-by-hour basis. The intermediate subtask includes traffic balancing and local optimization problems. The long term subtask is oriented to the whole cellular network optimal planning and evolution. The short term subtask is carried out by the Monitoring Subsystem discussed above.

The complexity of cellular systems, insufficient theoretical background and limited experience create considerable difficulties in the resolution of the intermediate and long term subtasks. One promising direction is using cause-and-effect analysis as a knowledge acquisitions tool. This analysis is can be executed either in the active or passive mode. In active mode changes of the control variables are preplanned. Passive mode exploits changes that are unrelated to the analysis. The main problem is that one must evaluate a trial affects on the basis of a few measurements, since behavior of the network performance parameters constitute, in general, a non-stationery stochastic process.

Examples of control variables that can be used in cause-an-effect analysis are: access thresholds, transmitter power levels, and neighbor lists. Examples of controlled variables are: blocking ratio, signal to noise ratio, average duration of calls and the number of attempts to establish a call.

Some are of the opinion that knowledgeable system engineer can predict the affects of every change in a network. However, in practice this is a very difficult task. The cellular network has different sensitivity to the same changes in different service areas. Very often when the amplitude of a change is insufficient an effect can't be detected at all. Moreover, effects propagate in the network differently in different zones and in different directions and die out during propagation.

Analysis of propagation and presentation all the results on an monitor create an opportunity to decompose the cellular network in the relatively independent zones. After decomposition traffic balancing and optimization problems will be considerably simplified, since the network can be studied on a zone-by-zone basis.

Results of cause-and-effect trials can be stored in a table. This table can have many applications. For example, even before the change is actually made, a system engineer can get information about what kind of effect has been produced by a similar change in the past. To plan a desire effect a system engineer can request information about what kind of causes created this effect in the past. Thus, cause-and-effect information can be used for generating management decisions.

Very often to achieve a desired effect control variables on more than one cell site have to be changed. As a result, neighbors of the targeted cell site and even neighbors of neighbors should be included in the analysis. For example, we can try to decrease the load on some cell site by shifting it to neighbors. But neighbors can be heavily loaded also. One possible solution is to shift load from neighbors to their neighbors. After sequential shifting the unloading cell site will be to absorb load from the targeted cell. It is obvious that load and service quality parameters of all neighbors should be checked against acceptable thresholds.

When implementation of the decisions is executed via a control loop, then the table can be updated with new cause-and-effect information and purged of data that lead to inefficient decisions.

Other direction for network analysis is the use of a radio signal-traffic model that will combine radio signal propagation, cellular network set ups and traffic data. This model can be developed upon analysis of the correlation that exist between the size of a particular cell site service area, the cell site parameters and the volume of telephone traffic serviced by the cell site. Since every area covers its own sets of roads with specific car traffic patterns and since penetration of a service varies from zone to zone, calculated correlation coefficient will vary from cell site to cell site. Furthermore, the relationship between the size of the service area and traffic can be non-linear for the same cell site. For instance, doubling the size of the service area will not always cause a two-fold increase in call traffic. Nevertheless, an attempt to create such a model should be made. If successful, results of the simulation can be inserted into a table and the entire optimization process for the targeted zone will be partially automated.

4.0 The Executive Subsystem

Currently the Executive subsystem is the most difficult to design. The major reason is that neither hardware nor software installed on the cell sites are capable of receiving and executing commands sent from a remote source. (In our case, it is a computer that contains the Monitoring and Decision Support subsystems.) Only network setup information located on the switch can be manipulated remotely. Since adequate procedures for providing a fully automatic closed loop are lacking, the Executive subsystem should be activated only by a system engineer. For generating control commands, an engineer will rely on information on information prepared by the Monitoring and Decision Support subsystems.

It is expected that cell site computers of digital cellular system would be able to receive and execute commands generated by a remote source. This will help develop the Executive subsystem capable of working in automatic mode.

5.0 Global Network Planning and Optimization

For cellular network planning, zone traffic trend information should be used. This trend can be calculated on the basis of long term zone traffic data. Since traffic fluctuations have a seasonal component that varies from zone to zone, a corresponding smoothing algorithm should be applied.

Trend information is necessary for preparing a long term zone traffic forecast. On basis of such a forecast, and assuming that no changes in the targeted zone are made, the future cell site load per channel (for example) will be calculated for different time intervals. Received data can be used to create a map on the monitor that shows how the cell sites will be loaded. Pictures generated one by one with steadily increased time intervals would show a cellular system evolution. This approach can help system engineers predict where and when “hot spots” in the network will occur.

Planning tools, local optimization procedures, radio signal-traffic model, network configuration data, marketing analysis, price information, and so forth are source data and necessary tools that should be used for global network optimization. One necessary task is the development of an objective function and constrains for the optimization. For example, the whole network can be optimized upon maximization of the profit for each dollar invested in it. The following objective function can be proposed:

$$Q_{opt} = \max Q_{ratio} = (R - In - Op - Re) / (In + Op + Re)$$

Where Q_{ratio} – profit-per-investment ratio;

R – revenue;

In – new cell site installation cost;

Q_p – operational expences;

Re – cost of the real estate, cell site rental fees.

It is should be obvious that all quality constraints must be satisfying during such an optimization

Conclusion.

A comprehensive cellular radio management system is necessary for the controlling and optimal planning tasks. System engineers are unable to work optimally without such a system at this time and will depend on it even more in the future.

7.0 References

[1] D.C. Cox, D.O. Reudink. *Dynamic Channel Assignment in in High-Capacity Mobile Communications Systems.* The Bell Technical Journal, Vol. 50 #6, 1971.

[2]. T.J. Kahwa, N.D. Georganas *A Hybrid Channel Assignment Scheme in Large-Scale Cellular-Structured Mobile Communication Systems*, IEEE Transactions on Communications, Vol. COM-26, #4, 1978.

[3] M. Sengoku. *Telephone Traffic in a Mobile Radio Communication System Using Dynamic Frequency Assignments*, IEEE Transactions on Vehicular Tehnology, Vol. VT-29, #2, 1980.

[4] B. Eklundh. *Channel Utilization and Blocking Probability in a Cellular Mobile Telephone System with Directed Retry*, IEEE Transactions on Communications, Vol. Com-34, #4 1986.

[5] J. Karisson. *A Supplementary to a Cellular Mobile Telephone System with Load Sharing*. Department of Communication Systems, Lund Institute of Technology, Tech. Rep., 1986.

[6] J. Karisson, B. Eklundh . *A Cellular Mobile Telephone System with Load Sharing - an Enhancement of Directed Retry*, IEEE Transactions on communications, Vol.37, #5, 1989.