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Mobile Radio Network Planning: A Survey

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Abstract: Network planning and design is an iterative process, encompassing topological design, network-synthesis, and network-realization, and is aimed at ensuring that a new network or service meets the needs of the subscriber and operator. Network planning plays a critical role in the Cellular design process. Accurate planning is essential in order to ensure that the system will provide both the increased capacity and the improvement in network quality where required. A properly planned system should allow capacity to be added economically when traffic demand increases. The goal is to achieve optimum use of resources and maximum revenue potential whilst maintaining a high level of system quality. This paper focuses on the main steps and the procedure required planning a mobile radio network.

Keywords: Network Planning, synthesis, realization, network quality, cellular design system

I. Introduction

Network planning refers to the process of designing a network structure and determining network elements subject to various design requirements. Network planning is associated with network dimensioning and detailed planning.

In the early age of wireless telephony, due to the lack of planning methodology and the step by-step network implementation, pragmatic approaches were often used in network planning. At that time, planning meant implementing cell sites at locations chosen by experienced radio engineers, providing measurements of the running system, and adapting the system accordingly.

With new wireless communication technologies and the increasing size of radio networks, the tasks of network planning and resource optimization are becoming more and more challenging. This is firstly because the radio resource is scarce these days due to the increasing number of subscribers and the many different types of networks operating within the limited frequency spectrum. Secondly, deploying and operating a large network is expensive and therefore requires careful network dimensioning to ensure high resource utilization. As a consequence, manual network design and tuning for improving radio resource allocation are most likely to fail in current and future networks. This necessitates developing automated tools and optimization algorithms that are able to tackle the difficult task. Nowadays available commercial cellular planning tools, e.g. Atoll, MapInfo, GIS, TEMS, PLANET GRAND, are based on the so-called *analytical approach* to cellular network planning. This approach focuses on radio planning aspects, i.e. selection of cell sites, frequency planning, and antenna design.

By doing a proper Network Planning by keeping the future growth plan in mind we can reduce a lot of problems that we may encounter in the future and also reduce substantially the cost of optimization. On the other hand a poorly planned network not only leads to many Network problems, it also increases the optimization costs and still may not ensure the desired quality.

A good plan should address the following issues: Provision of required Capacity, Optimum usage of the available frequency spectrum, Minimum number of sites, Provision for easy and smooth expansion of the network in future & Provision of adequate Coverage of the given area, for a minimum specified level of interference.

II. Planning Procedure

Planning means building a network able to provide service to the customers wherever they may be present. The main aim of radio network planning is to provide a cost-effective solution for the radio network in terms of coverage, capacity and quality. The network planning process and design criteria vary from region to region depending upon the dominating factor, which could be capacity or coverage. The radio network design process itself is not the only process in the whole network design, as it has to work in close coordination with the planning processes of the core and especially the transmission network. A simplified process just for radio network planning is shown in Figure 1.



Figure 1 Radio Network Planning Process

A. Steps Involved in Network Planning

1. **Step 1: Network Requirements** - The process of radio network planning starts with collection of the input parameters such as the network requirements of capacity, coverage and quality. These inputs are then used to make the theoretical coverage and capacity plans. These inputs are Digital Maps of requisite resolution & accuracy, Street Maps with important areas & routes marked, Competitor Site count / coverage / other related information, Demand information – preferred and Important Buildings / Hot Spots.
 - **Coverage requirements** for network planning are Target coverage areas & Coverage area Probability, Service types for the target coverage areas. These should be marked geographically & Penetration Loss of buildings and in-cars.
 - **Capacity requirements** for network planning include Erlang per subscriber during the busy hour, Quality of service for the air interface, in terms GoS & Quality of Network (C/I values), Network capacity - Available spectrum and frequency usage restriction, if any, List of available, existing and/or friendly sites that should be included in the RF design and Limitation of the quantity of sites and radios.
 - **Dimensioning** - The dimensioning exercise is to identify the equipment and the network type (i.e. technology employed) required in order to cater for the coverage and quality requirements, apart from seeing that capacity needs are fulfilled for the next few years (generally 3-5 years). The more accurate the dimensioning is, the more efficient will be network rollout. The inputs that are required for the dimensioning exercise include: the geographical area to be covered, the estimated traffic in each region, minimum requirements of power in each region and blocking criteria, path loss, the frequency band to be used and frequency re-use. With the above parameters, the radio planner can predict the number of base stations that will be required for coverage in the specified area to meet the individual quality targets, and to meet the expected increase in traffic in the next few years.
2. **Step 2: Pre-Planning Process** - Some concrete plans related to coverage, capacity and quality are made in this stage. There are coverage-driven areas and capacity-driven areas in a given network region. The average cell capacity requirement per service area is estimated for each phase of network design, to identify the cut-over phase where network design will change from a coverage-driven to a capacity-driven process. While the objective of coverage planning in the coverage-driven areas is to find the minimum number of sites for producing the required coverage, radio planners often have to experiment with both coverage and capacity, as the capacity requirements may have to increase the number of sites, resulting in a more effective frequency usage and minimal interference.
 - **Capacity Planning** - The steps for calculating the network capacity are :
 - Find the maximum no of carriers per cell that can be reached for the different regions based on the frequency reuse patterns and the available spectrum.
 - Calculate the capacity of the given cell using blocking probability and the number of carriers.
 - Finally the sum of all cell capacities gives the network capacity.
 - **Coverage Planning** - The objective of coverage planning phase in coverage limited network areas is to find a minimum amount of cell sites with optimum locations for producing the required coverage for the target area. The basic input information for coverage planning includes Coverage regions, Coverage threshold values on per regions (outdoor, in-car, indoor), Antenna (tower height

limitations), Preferred antenna line system specifications, Preferred BTS specification & Activities such as propagation modeling, field strength predictions and measurements are usually referred to as coverage planning.

3. **Step 3: Site Selection & Survey** - When the pre-planning phase is nearing completion, the site search process starts. Based on the coverage plans, the radio planner starts identifying specific areas for prospective sites. Candidate sites are then searched for, and one of these is selected based on the inputs from the transmission planning and installation engineers. Civil engineers are also needed to do a feasibility study of constructing the base station at that site.

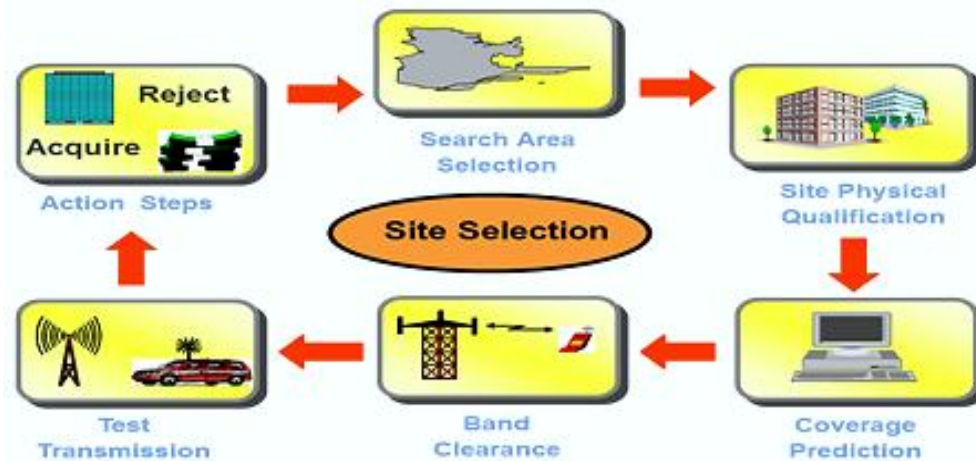


Figure 2 Process for site selection:

- **Radio Network Detailed Planning** – After pre planning phase detailed radio network planning is required. The detailed radio network plan can be sub-divided into three sub-plans:
 - (1) link budget calculation
 - (2) coverage, capacity planning and spectrum efficiency
 - (3) parameter planning
- **Link Budget Calculations** give the loss in the signal strength on the path between the mobile station antenna and base station antenna.

- **Uplink calculations**

PL_u (Path Loss in uplink) = $EIRP_m$ (Peak EIRP of Mobile) - Pr_b (Power Received by the base station)

$EIRP_m = P_{t_m}$ (Power transmitted from the MS) - Losses + G_m

Losses = L_{c_m} (cable loss at mobile) + L_{o_m} (any other loss)

$Pr_b = -G_b$ (antenna gain) - Losses + B_s (BTS sensitivity)

Losses = L_{c_b} (cable loss at BTS) + L_{o_b} (any other loss)

$$PL_u = EIRP_m - Pr_b = [P_{t_m} - L_{c_m} - L_{o_m} + G_m] - [-G_b + L_{c_b} + L_{o_b} + B_s]$$

- **Downlink calculations**

PL_d (Path Loss in downlink) = $EIRP_b$ (peak EIRP of BTS) - Pr_m (Power received by the MS)

$EIRP_b = P_{t_b}$ (Power transmitted by BTS) + G_{i_b} (antenna gain) - Losses

Losses = L_{c_b} (cable loss at BTS) + $L_{c_{c_b}}$ (combiner loss at BTS)

$Pr_m = M_s$ (Mobile sensitivity) + Losses - G_m (mobile antenna Gain)

Losses = L_{c_m} (cable loss) + L_{o_m} (any other loss)

$$PL_d = EIRP_b - Pr_m = [P_{t_b} + G_{i_b} - L_{c_b} - L_{c_{c_b}}] - [M_s - L_{c_m} - L_{o_m} - G_m]$$

4. **Step 4: Frequency Planning** - After site selection, assignment of the frequency channel for each cell is done in a manner that causes minimal interference and maintains the desired quality. Frequency

allocation is based on the cell-to-cell channel to interference (C/I) ratio. The frequency plans need to be fine-tuned based on drive test results and network management statistics.

5. **Step 5:Parameter Planning** - Parameter plans are drawn up for each of the cell sites. There is a parameter set for each cell that is used for network launch and expansion. This set may include cell service area definitions, channel configurations, handover and power control, adjacency definitions, and network-specific parameters.

The parameters used in a radio network are of two types: fixed and measured. These parameters include those related to signaling, radio resource management (RRM), power control, neighbour cells, etc. The most important parameters to plan for are frequencies, BSIC, LAC, handover control parameters, adjacent cell definitions. The final radio plan consists of the coverage plans, capacity estimations, interference plans, power budget calculations; parameter set plans, frequency plans, etc.

III. Conclusion

Network RF planning is the foundation of a mobile communication network, especially the wireless parts in a mobile communication network costs great and is of vital importance to network quality, so we must make a good planning at earlier stage, which is helpful for network expansion and service update in the future. Network planning requires engineers to analyze coverage, decide network layers, and analyze traffic based on relative technologies and parameters, and finally output the results of RF planning, including base station layout and scale that provides the good quality, coverage, and without interference.

IV. References

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