Wireless Mobile Network Planning and Optimization: A Tool Based Approach
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Abstract – Optimal mobile network planning of greenfield or new networks and continuous optimization of existing networks are the key requirements for an operator to maintain Quality of Service (QoS) and improve Average Revenue Per User (ARPU). With various conflicting parameters involved in optimization process, the planning and optimization problem become NP-hard; a real time solution is not possible. To facilitate planning and optimization for an operator, we design a tool which implements a simple and robust joint optimization technique using Clustering and Cooperative Game Theoretic algorithms to obtain near-optimal real time solution. Using our tool, we demonstrate that we can plan new networks effectively and also improve the performance of existing networks substantially.

I. INTRODUCTION

In the recent times, there has been an exponential growth worldwide in tele-traffic density, owing to increasing number of users and several smart devices and applications. The wireless telecom sector is mainly challenged by 3Cs - (i) Cost, (ii) Capacity and (iii) Coverage. In addition to these, limited availability of resources like spectrum, power and infrastructure, demand for lower service charges and other regulatory aspects also pose challenges in the planning and optimization.

From an operator's perspective, a broad classification of the total network costs is shown in Fig.1. Investment activities such as spectrum license, Base Station (BS) deployment, hardware equipment, software and back haul are categorized under Capital Expenditure (CAPEX), which constitute a major portion of the total expenditure. On the other hand, activities such as BS rental, planning (tool), power, maintenance, marketing and support contribute to Operational Expenditure (OPEX).

However, resource optimization at the BS should not only reduce the overall Cost, but also maximize network Coverage and Capacity utilization. As the number of users increase, operators plan for higher capacity through activities such as cell-splitting and addition of BS Sites. These activities result in an improved network coverage as well. However, with smaller and smaller cells in place, there is a resultant increase in hand-offs as well as interference. This can adversely affect the QoS of the network and thus result in loss of capacity. Therefore, the 3Cs should be carefully considered while designing a new network or optimizing an existing network.

In this demonstration, we attempt resource planning and optimization at BS level for a Cellular Service Provider (CSP) in India. This requires accurate Radio Frequency (RF) planning or capacity planning, deployment of Base Stations and determination of appropriate BS parameters such as power, frequency, height, tilt of the antenna and sectorization, etc.

A. Planning and Optimization studies – Academic Perspective

As understood from the existing literature, BS planning and optimization is a parameter optimization problem with a set of controlled and uncontrolled variables such as tele-traffic density, wireless channel condition, interference scenario, the existing set of BSs and their frequency of operation, etc. Due to the combined effects of these parameters, BS planning and optimization problem is treated to be an NP-hard complex combinatorial problem [2] in which finding an optimal solution in polynomial time is not possible. Lee and Kang [3] have suggested the use of Tabu Search algorithms to plan cellular networks. Hurley [4] proposed Simulated Annealing approach to locate and configure BSs. In [5], Talbi, Meunier and Reininger have formulated a multi-objective approach for radio network optimization. [6] outlines how Game Theoretic approaches can be applied to wireless networks. In [6], the game theoretic approach is being used in a non-cooperative manner which may not lead to optimization in real time. To overcome the limitations in above discussed literature, we propose a joint optimization scheme using clustering and cooperative game theoretic algorithms in [7] to optimally plan and optimize cellular networks.

B. Planning and Optimization Studies – Industry Perspective

Traditionally, Cellular Service Providers (CSP) or telecom operators resort to the use of optimization tools such as Mentum Cell Planner, TEMS Investigation, EDX SignalPro, NetAct Optimizer, ASSET ( detailed survey in [7]), etc., to manage, maintain and optimize their networks. Given a set of BS locations and using accurate geographical and clutter data, tools such as CellPlanner, ASSET and SignalPro can facilitate network dimensioning and a thorough analysis of existing/to-be-deployed network in terms of capacity, coverage, traffic, mobility, etc. NetAct optimizer does automated measurements based on operator requirements and helps optimization experts suggest corrective actions to improve network performance. TEMS investigation is a drive test optimization and troubleshooting tool. These tools basically differ in their price, ease of use and propagation models implemented. Specifically, these tools

Fig. 1 Life-cycle costs for an established Operator [1]

Based on our discussions with a leading Indian telecom operator, BS rental and planning tool attribute to a major portion of the OPEX. Besides, it is apparent from Fig.1. that BS activities such as site and operations, and backhaul attribute to about 45% of the total investment for a telecom operator. Therefore, to reduce Cost and improve profit margin, telecom operators generally attempt resource optimization at BS level.
are generally quite expensive (about INR 40,000,000 per annum per license) and thus out of reach. Moreover, optimization provided by all the above tools has primarily been region specific and based on local conditions.

Due to continuously varying traffic distributions, operators are confronted with a continuous need to plan and optimize their networks time and again. Since the solutions provided by these tools are region-specific and based on local geographic and traffic conditions, these solutions may not be globally optimal for larger service areas with varying local conditions. In this demonstration, we validate this argument by performing a 3C analysis for two different areas in India.

The solution framework is discussed in Section II. In Section III, an optimization scheme is presented and the network plans of a leading telecom operator for two different service areas in Bangalore, India are substantially optimized. We conclude this paper in Section IV.

II. SOLUTION FRAMEWORK

The BS planning and optimization problem can be mathematically formulated as [7]:

\[
\begin{align*}
\min & \sum_{k=1}^{N} E_k \quad \text{...Total CAPEX and OPEX,} \\
\max & \sum_{k=1}^{N} A_k \quad \text{...Total service coverage,} \\
\min & \sum_{k=1}^{N} A_k' \quad \text{...Total multiple coverage,}
\end{align*}
\]

subject to the following conflicting constraints:

\[
\begin{align*}
\text{SINR}_{ik} & \leq \text{SINR}_{\text{max}}, \quad \forall i, k \quad \text{(SINR experienced by } i\text{th MS,)} \\
P_k & < P_{\text{max}} \quad \forall k \quad \text{(BS parameter constraints,)} \\
\text{KPI}_{ik} & < \text{KPI}_{\text{max}} \quad \forall i, j, k \quad \text{(maximum limit KPIs),} \\
\text{KPI}_{ik} & > \text{KPI}_{\text{min}} \quad \forall i, j, k \quad \text{(minimum limit KPIs),}
\end{align*}
\]

The objectives (1) to solve the BS planning and optimization problem are to minimize cost, and maximize coverage and capacity utilization. Associated constraints (2) are the SINR experienced by Mobile Stations (MS), BS transmission power \((P_k)\), antenna height \((h_k)\), number of transceiver slots \((TRX_k)\) per BS, and Key Performance Index (KPI) expectations. We observe that the objectives as well as the constraints are conflicting in nature. Due to the conflicting nature of (1) and (2), BS planning and optimization problem is \(NP\)-hard, and an optimal real time solution is not possible.

To obtain a near-optimal real time solution to this problem, we propose a solution framework (c.f. Fig.2.) in [7]. Due to varying tele-traffic demands and varying geographical parameters such as building type, road type, vegetation, and mean sea level, a given service area is divided into smaller segments of uniform geographical characteristics and tele-traffic demands. The set of objectives, constraints and influence parameters (propagation path loss models, population density maps, average tele-traffic demand per user, feasible BS sites, available spectrum, etc.) are provided as an input to the Initial Network Planning Component (INPC). Based on these inputs, the INPC calculates total service coverage and capacity utilization for each BS site. The Local Optimization Component (LOC) then divides the entire service area into smaller segments and implements a clustering algorithm to provide a network planning and optimization solution based on conditions local to each smaller segment. This solution is then iteratively improved by a cooperative game theoretic algorithm implemented in the Global Optimization Component (GOC) to suit requirements of the entire service area. Based on a termination criteria, the iterations finally result in a solution set from GOC. Until a predefined set of service requirements are met, the GOC solution is iteratively rendered to the Planning Update Component (PUC). The PUC suggests necessary planning updates to the LOC for re-planning the network. Mathematical detail of the algorithms are explained in [7].

III. OPTIMIZATION SCHEME

In this section, we propose an optimization scheme to evaluate and optimize network plans of a leading Indian telecom operator for two different service areas in Bangalore, India.
continues to maintain a minimum capacity buffer ($CB_{\text{min}}$) even after acquiring traffic load from Candidate CID. A minimum capacity buffer ($CB_{\text{min}}$) is necessary to accommodate for future traffic requirements and sudden fluctuations in current traffic demands.

The optimization process is outlined in Fig.3. Initially, accurate coverage for each BS is estimated using MS receiving threshold power ($rtp$), modified COST – WI model, and BS parameters such as antenna heights, tilt, azimuth, and BS transmission power. Using capacity utilization statistics from the operator, scope for optimization is then determined for each overlapping CID pair based on $OL_{\text{min}}$ and $CB_{\text{min}}$ values. Whenever the optimization criterion is met, few TRX slots in the Candidate CID are switched off. The network plan is updated and iteratively evaluated for further scope of optimization. The optimization process ends when: (i) no CID pairs with coverage overlap greater than $OL_{\text{min}}$ exist or (ii) CID pairs with coverage overlap greater than $OL_{\text{min}}$ exist, but the Compensator CID fails to maintain a capacity buffer of $CB_{\text{min}}$ on load transfer.

**A. Evaluation of Our Optimization Scheme**

We now demonstrate optimization for existing network plans of a leading telecom operator for Bangalore East area. Drive Tests (c.f. Fig.4) are initially conducted for clutter factor estimation and path loss modeling. Based on available BS data, coverage plots for each BS are determined (c.f. Fig.5). With $OL_{\text{min}}$ value of 60% and $CB_{\text{min}}$ value of 40%, the aforementioned optimization scheme is employed for validation and analysis. CIDs which experience a coverage overlap greater than $OL_{\text{min}}$ are highlighted in Fig.6. The CIDs whose TRX can successfully be switched off (with their utilization load transferred to overlapping CIDs) are highlighted in Fig.7. Overall, 19 out of 200 CIDs in Bangalore East area could be switched off. As a result of this optimization, the utilization values of 81 other CIDs are affected. Load transfer details are listed in Table 1.

Similar to our analysis for Bangalore East, we also consider Jayanagar for optimization using same optimization parameters. CIDs whose TRX can be switched off are highlighted in Fig.9. Out of 520 CIDs in Jayanagar area, a total of 13 CIDs could be switched off. As a result, utilization values of 187 other CIDs were affected (c.f. Table 2). Note that several clusters of heavy traffic demands are observed in Jayanagar area. As a result, several Compensator CIDs fail to maintain $CB_{\text{min}}$ whenever TRX are turned off in Candidate CIDs. This is apparent in the substantially lower level of optimization in Jayanagar area than in Bangalore East.
IV. CONCLUSION

In this paper we propose a tool based solution using clustering and cooperative game theory to provide wireless mobile network planning and optimization. Our tool can be used by wireless service providers for rolling out greenfield network and for optimizing existing networks. We also demonstrate the usage of this tool through network optimization of a major telecom operator's network in Bangalore, India. We demonstrate that there is still a possibility of at least 10% optimization in Bangalore, which can be translated to minimization of cost as well as maximization of coverage and capacity. Though the overall design of this tool is complete, commercialization of this tool requires some more tests.

REFERENCES