SITE SUITABILITY ANALYSIS FOR LOCATING OPTIMAL MOBILE TOWERS IN UTTARAKHAND USING GIS

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ABSTRACT: *With the rapid growth of wireless communication and increasing size of cellular network, the task of cellular network planning and resource optimization is becoming more and more challenging. A good network planning will be the one, which results in less infrastructural expenses by utilizing optimal resources while ensuring more customers' satisfaction. The increase in number of mobile tower sites Base Transreceiver Station (BTS) with growing customers, not only raises the total cost of the cellular network but it also has a great impact on radiation hazards issues. It is vital to optimally select BTS sites in the design of cellular networks. Selecting BTS sites in a varying topographic area with non-uniform users' distribution, such as Uttarakhand, is another major challenge. With path loss estimation along with propagation prediction models coupled with careful analysis of spatial data and obtaining topographical information from Geographic Information Systems (GIS), potential tower locations can be determined.*

This paper proposes a methodology for assessing the site suitability of Base Stations of BSNL cellular radio networks in Uttarakhand with the objective of optimizing and automating the process of network planning. Geographic information, such as satellite images, topographical maps, municipal digital maps, Aster DEM, site parameters of existing BSNL towers (such as Latitude and Longitude, antenna height, frequencies) of study area are collected from different sources. Using these data various layers of road network, rivers, habitat and forest cover have been formed in ArcGIS software to locate the suitable sites. Dead zones and overlapping area of existing tower coverage has been spotted out. Hence, analysis of existing towers of the study area has been done for finding the optimal positions of tower placement.

1. INTRODUCTION

The rising of cell phone users and the usage of cell phones in remote areas have demanded the network service providers to increase their coverage and extend it to all places. Therefore, to serve an increasing number of users requires an increasing number of Base Transverse Station (BTS) which requires enormous capital investment. Further, quality of the mobile service relies on the signal strength available at the user's location. This means that mobile cellular communication companies must carefully plan the deployment and configurations of BTS in order to optimize signal coverage with best QoS, while at the same time, minimizing the cost. The cell tower must be in an area with, little reception, lots of people, good road network and an area with a minimum slope to minimize the construction costs. Furthermore, to implement a mobile radio network, wave propagation models are necessary to determine propagation characteristics for any arbitrary BTS installation. The radio wave propagation prediction algorithms give only approximate coverage, which are not suitable for detailed network design. Remote Sensing technology and Geographic Information System (GIS) can be incorporated into this procedure because most of the factors in radio wave propagation are geographic features.

This paper is organized into 5 different Sections. Literature survey on the existing site suitability models for locating mobile towers is done in section 2. Section 3 describes the study area and the methodology is proposed in section 4. Implementation and outcomes of the model are presented in section 5. Finally, section 6 concludes by Spotting out weak signal, dead zones and overlapping areas in the existing network

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2. LITERATURE SURVEY

For achieving reliable results and excellent efficiency of the problem solution, a lot of research has been done in the field. A study by Jason, Terry and Loren in 2009, suggest an efficient algorithm to identify the best tower locations by providing a three way solution, first by greedy approach, then by ratio heuristics and finally by genetic algorithm. It compares the three solutions, and demonstrates that the genetic algorithm is the best solution. The identification of the potential tower locations from any satellite image of an area is an important problem, which has been overlooked by the above paper. Since this is a problem to be implemented on practical grounds, the legitimacy of potential tower locations plays a major role. Realizing the above need, a study by Alaa and Soukaena

in 2011 uses a spatial data mining and geographical information system to find the potential tower locations. This was accomplished by using DEM (Data Elevation Model) on the satellite image of the area. Munene and Kiema, 2014 demonstrates that the spatial analysis approach can be used to optimize mobile signal coverage in any dense urban environment without resorting to lengthy field measurements thus minimizing on costs of wireless network planning. Spatial analyst (Viewshed and line of sight) and proximity analysis (buffer) tool of ArcGIS was used by Babar and Kaur (2013). Author discusses how GIS as a tool can effectively and efficiently, be used for site suitability analysis to set up more towers with minimum time and cost in a particular area. Radio-network planners rely heavily on the display of a large number of intermediate and final results, such as maps of user requirements, coverage, carrier-to-interference ratio, completed calls, rejected calls, etc. Jean and Rizk 2003, introduces specialists in GIS and geographical databases to the problems of propagation prediction and radio-network planning for cellular radio communications. Simulation result shows that the use of conventional propagation models and rough geographical databases for the planning of future cellular systems like UMTS might cause serious difficulties. The design of databases for radio-propagation tools is another subject briefly mentioned in the paper.
A new method of generating realistic radio network coverage using $K1$ parameter tuning of ASSET3G and considering clutter loss due to prominent rural terrains has been presented in [Dalela, Prasad and Mohan, 2008]. The ASSET3G generated coverage map is used by MapInfo Professional tool to generate the optimal location of base station towers. Paper demonstrates that the tuning of $K1$ parameters can be effectively utilized for predicting the network plan closer to the actual scenario. Planning of wireless networks is vital if operators wish to make full use of the existing investments. It has been analytically proved in [Rahman, Matin and Rahman, 2012] that an existing cellular network can be optimized using optimization tools and fine parameter tuning. The key performance indicator (KPI) and drive test are used in [Rahman, Matin and Rahman, 2012] to make proposals on how operators can optimize radio resources as well as provide the required QoS to the subscribers. A three stage algorithm has been proposed in [Kashyap, et.al., 2014] to find out the optimal height of the tower at a chosen potential tower location. Algorithm provides cost-effective way for tower placement specifying their optimal position and height to cover any area and population. Spatial mining with Geographic Information System (GIS) as a tool is used in [Alaa, Hamami and Soukaena, 2011] to optimize the cell towers distribution. The distribution optimization is done by applying the Digital Elevation Model (DEM) on the image of the area which was covered with two levels of hierarchy. The paper concludes that building spatial database as a flat database will make the spatial mining much more efficient that by reduce the mining to one level only so this will prevent the time and space consuming resulted in the previous work by extending the mining to multilevel.

3. STUDY AREA

Uttarakhand state, formerly known as Uttaranchal, is situated in Northern India, which has been selected for the study. It was formed out of the north-western districts of Uttar Pradesh and the Himalayas on 9 November 2000.

Figure 1 Study area: Uttarakhand

Uttarakhand shares its borders with Tibet in the north, Uttar Pradesh in the south, Nepal in the east, Haryana in the west and Himachal Pradesh in the North West. The State lies between 77°34'27" to 81°02'22" East Longitude and 28°53'24" to 31°27'50" North Latitude as shown in figure 1. Dehradun serves as the capital of state. Uttarakhand has 13 districts which are grouped into two divisions namely Garhwal division and Kumaun division. Most of the areas of the state are hilly and forested. The state covers a total area of 53,483 sq km of which 93% is mountainous and 64% is covered by forest.

4. METHODOLOGY:

The methodology used in this paper has 3 phases as shown in figure 2:

A. **Collection of Data Sets:** Satellite images, topographical maps, municipal digital maps, census data and site parameters of existing towers of study area are collected from different sources like BSNL office, Survey of India, web portals like Bhuvan, Water Resource Information System of India (India- WRIS), United States Geological Surveys USGS Earth Explorer.

B. **Working on Data sets:**

   i. Calculation of coverage range of existing towers in MATLAB. For this a Matlab code is developed to calculate path loss using parameters collected from BSNL Office.

   ii. Creation of different vector layers in form of points, polyline and polygon shape files in ArcMap. This can be done using different tools/techniques like registration, geo-referencing, mosaicing and digitization of digital maps through GIS software.

C. **Analysis of the distribution of existing tower:** It includes

   i. Mapping of existing towers on vector layers generated in step B (ii) and applying a buffer to each tower with radius equal to coverage range calculated in step B(i)

   ii. Spotting out the total coverage area including weak signal area and/or dead zones in the existing network.

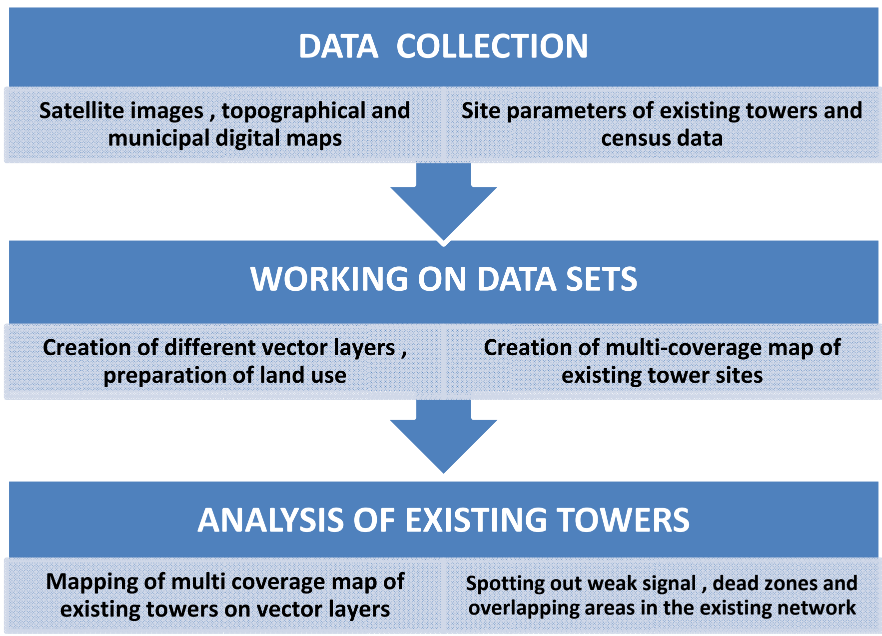

Figure 2 Methodology

5. IMPLEMENTATION AND RESULTS

1) **Creation of vector layers in ArcGIS 10.2.2:** There are many cases where the customer wants to focus on coverage and quality requirements for special areas such as highways, tourist places, high population density regions, high elevation peaks. Also dummy sites like rivers, lakes, dense forest, and very low populated area can be avoided. These zones can be easily spotted out by creating separate vector layers in ArcGIS with the help of collected GIS data. Following layers has been created in ArcGIS 10.2.2:

   a) **Uttarakhand District boundary:** Uttarakhand State is divided into following 13 districts: Almora, Bageshwar, Chamoli, Champawat, Dehradun, Haridwar, Nainital, Pauri Garhwal, Pithoragarh, Rudraprayag, Tehri Garhwal, Udham Singh Nagar and Uttarkashi. A shape file of polygon features has been created to represent each district of Uttarakhand (figure 1).

   b) **Uttarakhand Rivers:** Uttarakhand is a state which is known for its hundreds of small and big rivers. Major rivers are: Alaknanda, Bhagirathi, Ganga, Mandakini, Nandakini, Yamuna, Kali, Kosi, Saryu and Bhilangna. This vector layer of poly-line features has been created from India-WRIS (Water Resource Information System). WRIS is a well developed information system, for water related data in its entirety, at the national/state level, is a prime requisite for resource planning (figure 3).

c) **Uttarakhand Roads:** For every state, region or country, road plays a vital role in their economy and development. Uttarakhand exhibits 14 National Highways having a length of 2108km. Again a shapefile with polyline features has been created using Road Maps of Uttarakhand.

d) **Uttarakhand forest Cover:** Of the geographical area 53,483 sq km, the recorded forest area of the state is 34,651 sq km, which constitutes 64.79% of its geographical area. The state has 6 national parks, 6 wildlife sanctuaries and 2 conservation reserves covering an area of 7, 376 sq km.

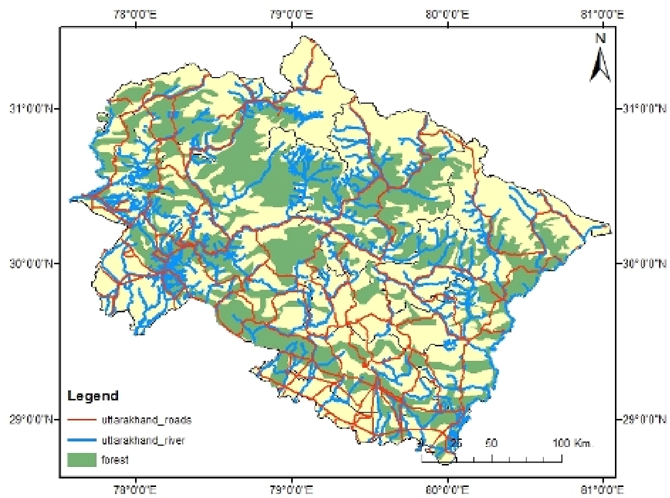

Figure 3 Uttarakhand: Forest, Roads and Rivers

e) **Aster global DEM:** ASTER GDEM provides high-resolution images of the planet Earth in 14 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light.

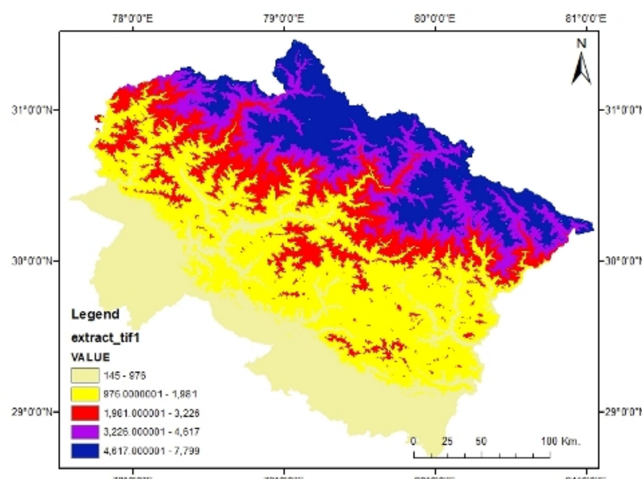

Figure 4 Uttarakhand: ASTER DEM

The resolution of images ranges between 15 and 90 meters. ASTER is available at no charge to users worldwide via electronic download from earth explorer USGS. 14 Tiff images have been downloaded. Then Mosaicing is done to merge multiple raster datasets into one entity. Last Mosaic operator provides the best and most meaning results (figure 4).

f) **Block-wise Population of Uttarakhand:** Population is another important factor in site planning. First, detailed block-wise population of each district of Uttarakhand has been downloaded from census data 2011 in form of excel sheets. For this a vector layer of blocks of Uttarakhand districts is formed. Then population of each block is added manually in its attribute table. At last, classification of population data is done using color map for better visualization (figure 5).

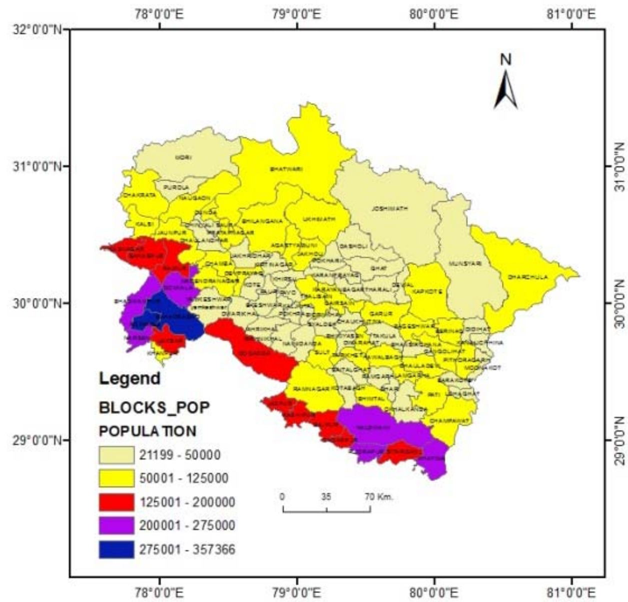

Figure 5 Uttarakhand: Block wise Population

g) **Mapping of Existing BTS Locations with coverage area:** Data related to existing towers has been collected from BSNL office, Dehradun in form of excel sheet. Then a point vector layer has been created using conversion tool of ArcGIS. At last, buffer with radius equal to coverage range is added to each tower, so that the coverage of existing towers can be analyzed further (figure 6).

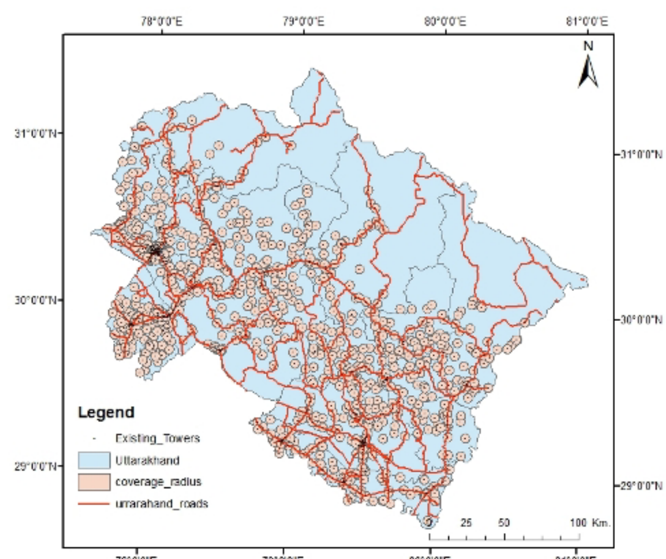

Figure 6 Uttarakhand: Existing Towers Map

2) **Analysis of Existing Towers:** For analysis all the above vector layers are overlapped along with existing tower locations. Then buffer has been created around these point, polygon and line features. New tower position should not lie in the existing tower coverage area. Also no tower can be placed on river. Dead zones and overlapping can be easily seen in figure 7. Figure shows the analysis of a area of Roorkee. Also new tower locations can be suggested by making Theissen polygon around each set of existing tower points.

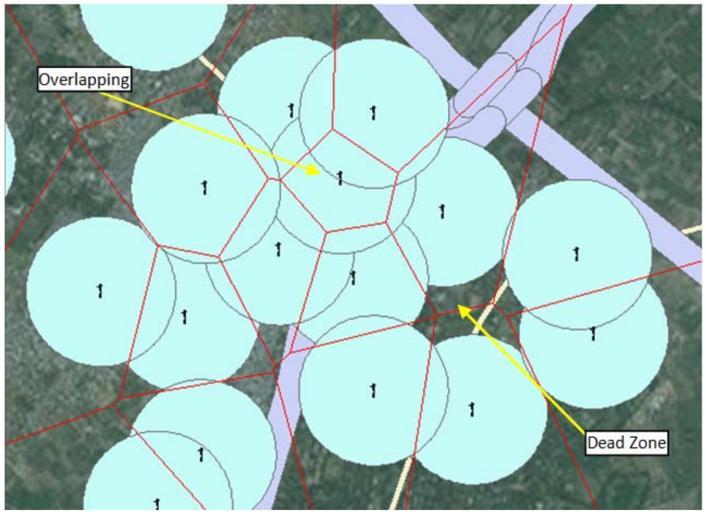

Figure 7 Analysis of Existing Towers

CONCLUSION

The analysis of existing towers has been done by using GIS information, such as satellite images, topographical maps, municipal digital maps, Aster DEM, site parameters of existing BSNL towers of study area. After creating multi coverage map of existing towers, overlapping and dead zones have been spotted out. It is observed that this methodology gives the required result as compared with available data of towers. The hilly area of Uttarakhand as extracted by the Aster DEM, is overlay with the coverage data to identify the required tower locations. This layer is also mapped with population data to justify the requirement of new towers. Therefore this methodology helps to suggest the new tower locations by removing the dead zones and overlapping. The future scope is expected to find the optimal locations of towers based on various parameters. Hence, analysis of existing towers of the study area has been done for finding the optimal positions of tower placement.

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