



Towards an Efficient Radio Network Planning of LTE and Beyond in Densely Populated Urban Areas

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Abstract: Long Term Evolution (LTE) is a fourth generation technology which is expected to be the mobile broadband platform for services in innovation for the foreseeable future. Going on with LTE radio network planning is a well-chosen challenge and a certain hot topic in the current research arena. Again, efficient radio network planning for a densely populated city adds to certain level of complexity in the overall work in terms of proper resource management and capacity requirement fulfillment. In this paper, a detailed LTE radio network planning procedure has been elaborately presented which concentrates on nominal and detailed planning considering possible network implementation in the most populated Indian city Mumbai.

Keywords: LTE, Radio Network Planning, Coverage, Capacity

1. INTRODUCTION

LTE is the next major step in mobile radio communications and is introduced in 3rd Generation Partnership Project (3GPP) Release 8. It is the last step toward the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks. The main advantages with LTE are high throughput, low latency, plug and play, frequency division duplexing (FDD) and time division duplexing (TDD) in the same platform, an improved end-user experience and a simple architecture resulting in low operating costs. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both FDD and TDD [1-3].

Whenever new cellular technology is considered for mass deployment, hundreds of its RF parameters go through tuning process with a view to find out optimum value. But this phase is time consuming and very costly. Before commercial deployment if extensive simulation can be run, this tuning phase can be facilitated in numerous ways. Cost can also be greatly minimized. All these aim at proper radio network planning of LTE. So, looking for optimization of the vital parameters in the least possible time is a very challenging issue which indeed helps network operators in a greater extent. Radio

network planning being a rather vital step for a wireless communication technology while LTE standardization work is approaching the end line; it is high time to go for efficient radio network planning guideline. For the same reason, along with the fact that in LTE radio network planning just like other cellular technologies, initial stage planning is normally guided by various industries and vendors at their own discretion; they aren't likely to disclose their expansions and findings. That makes the job even more thought-provoking [4].

The ultimate objective of this work is to come up with the detailed radio network planning guideline with respect to Mumbai-most populous city in India. It goes without saying that radio network planning for a highly populated south-Asian city with variant levels of user requirements is a daunting task. Although Aircel and Bharti Airtel have already launched 4G TD-LTE network in some parts of India, those are still in their preliminary stages and need lots of planning and optimization works for efficient coverage and capacity all over [5]. With this mission ahead, in this paper a step by step method has been followed using radio planning tool Atoll. The idea is to cover the nominal and detailed planning stages in detail with respect to Mumbai city. Performance analysis of the planned network has also been included here. Prior to that,



a brief description of the nominal and detailed radio planning has been given.

2. RELATED WORKS

An analysis of practical coverage scenario in an urban area (i.e. Kolkata) in terms of received signal levels, total noise, interference, throughput, and quality factor for downlink signal level is shown in both [7] and [8]. In [9] a detailed LTE radio network dimensioning procedure i.e. capacity and coverage analysis has been performed in order to prepare a radio planning guideline considering possible network operation in Dhaka city through link budget preparation along with link and system level simulations. For the densely populated city Dhaka, nominal and detailed radio planning stage has been covered in [10]. But the current work is different from [7-10], as it not only takes a different city for planning; but the operating frequency has also been taken as the currently available one in India i.e. 2.3 GHz, which was 2.1 GHz for [9] and [10]. That makes the current analysis quite closer to the practical scenario. Again, for capacity calculation simulation result from [11] is used in this work. [11] provides analyses of the performance of radio parameters necessary for efficient LTE radio planning: through numerous simulations in different transmission modes and network scenario using link and system level simulator [6]. It mainly highlights the throughput, Block Error Rate (BLER) with respect to Signal-to-Noise Ratio (SNR) on the physical layer and in network context covering different simulation environments. An attempt to facilitate a planned decision making stage for the mobile broadband solution- specifically focusing in the South Asian region, has been made in [12]. Quantitatively analyzing the performance of radio parameters necessary for efficient LTE radio planning appears to be the primal contribution of [13]. Future 4G network deployment strategies, complexities are highlighted in [14-15]. But these followed rather generic approach.

3. RADIO NETWORK PLANNING PROCESS

Radio Network Planning contains number of phases:

- Initial phase-which includes collection of pre-planning information and starting network dimensioning i.e. Link Budget preparation, coverage and capacity calculation by running simulations.
- Nominal and detailed planning- which includes selection and use of radio planning tool. This step involves propagation model tuning, defining thresholds from link budget, creating detailed radio plan based on the thresholds, checking network capacity against more detailed traffic estimates, Configuration planning, Site surveys, Site pre-validation and validation, eNodeB parameter planning.

- Defining KPIs and Parameter Planning- using eNodeB system parameters and counters, defining performance KPIs and its target values based on vendor's promise, verification of the KPIs and target values using planning and dimensioning tools nominally along with pre and post-launch optimization [4].

But defining KPI and parameter planning has been considered out of the scope of this paper.

4. RADIO PLANNING FOR MUMBAI CITY

Mumbai (also known as Bombay) is the capital city of the Indian state of Maharashtra. It is the most populous city in India, second most populous metropolitan area in India. Efficient radio network planning is obviously a big challenge here with the optimal utilization of limited resources considering different level of users. Related pre-planning information of Mumbai:

- Population: 12.5million
- Area: 603.4 km² (metropolitan area)

Assuming 0.75% of that population i.e. 93750 to be covered and with an overbooking factor of 50, the population number appears to be $93750/50 = 1875$ (which requires to be supported simultaneously).

From [9] taking 15 active UEs/cell for this scenario for optimum result, number of eNodeB required for capacity = $1875/(3 \times 15) \approx 42$

Using Cost-Hata propagation model

$$L = 46.3 + 33.9 \log f - 13.82 \log h_B - a(h_R) + [44.9 - 6.55 \log h_B] \log d$$

$$a(h_R) = (1.1 \log f - 0.7)h_R - (1.56 \log f - 0.8)$$

Where, L = Median path loss (dB); f = Frequency of Transmission (MHz); h_B = Base Station Antenna effective height (m); d = Link distance (km); h_R = Mobile Station Antenna effective height (m); a(h_R) = Mobile Station Antenna height correction factor as described in the Hata Model for Urban Areas.

C = 3 dB for metropolitan area. Now, with f = 2300 MHz, h_B = 33m, h_R = 1.5m

$$a(h_R) = (1.1 \log f - 0.7)h_R - (1.56 \log f - 0.8) = 0.06$$

For d = 2.27 km; achieved path-loss, L= 142.23 dB

Area of the Hexagonal shape for one eNodeB site = $3\sqrt{3}d^2/2 = 13.39 \text{ km}^2$ where, d= cell radius= 2.27km

So, number of eNodeBs for coverage= $603.4/13.39 \approx 45$ which exceeds the number required for capacity

Thus, capacity requirement should be effectively handled by taking that many eNodeBs. The target capacity and coverage values are here attempted in the nominal and detailed radio planning stage with radio planning tool-Atoll.

5. ATOLL SIMULATIONS

Digital map of Mumbai (shown in Fig.1) has been used for radio planning in this stage. These maps consisted of Mumbai airport, main road, secondary road, street, railway and water. At first to cover the whole city eNodeBs were placed (shown in Fig 2). After placing the eNodeBs coverage prediction was done that helped to justify the placement of the eNodeBs. Traffic simulations were run for each of the Mumbai map subsections. Automatic frequency planning and automatic cell planning were performed before running each of these simulations. In detail simulation results were obtained which also contains traffic state: connected UL+DL, connected DL, connected UL, no service, scheduler saturation, resource saturation scenario. Legends show each of them with different color. A separate table shows the simulation properties for each of the simulated traffic maps.

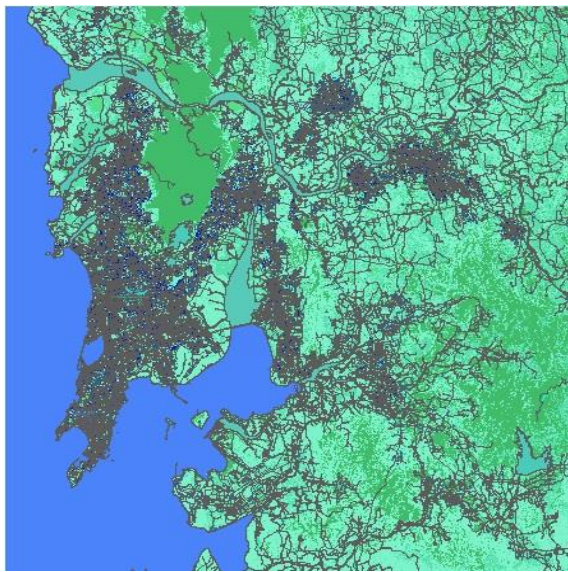


Figure 1. Mumbai Digital Map

A. Coverage Prediction

Coverage predictions have been performed by: transmitter, signal level, downlink throughput and Channel to Interference plus Noise Ratio (CINR). In Fig. 2 transmitters are shown on Mumbai map. Corresponding coverage prediction results have been shown in Fig. (3-6) with respective coverage prediction properties: How far the placed transmitters have covered is shown in coverage by transmitter map in Fig 3. Fig 4 shows coverage by signal level where signal strength of the covered regions mostly range from -90 to -105 dBm. Coverage prediction by downlink throughput in Fig 5 depicts that throughput mostly stays between 1000 to 10000 Mbps, while for near to cell-centre cases, it can go up to 18000 Mbps. In case of coverage prediction by downlink CINR from Fig 6, it is clear that as users go farther from the centre; CINR level

tends to get lower i.e. from 1 to 7 and while getting closer to centre, it approaches towards bigger values closer to 15.



Figure 2. Transmitters placed on Mumbai map

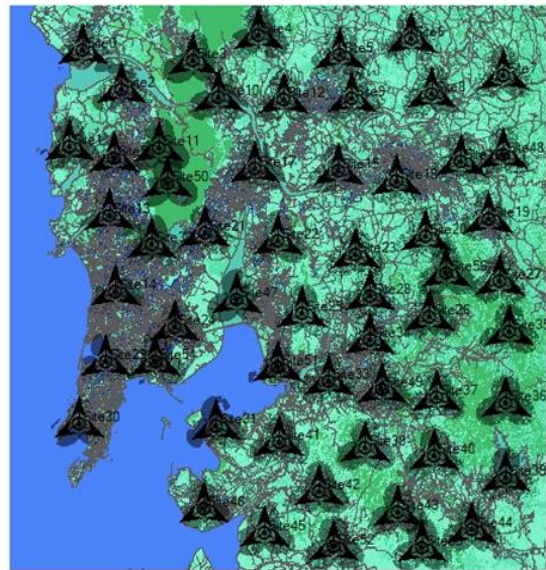


Figure 3. Coverage prediction by Transmitter

B. Traffic Simulation

LTE traffic simulation properties have been shown in Fig 7. Fig 8 to Fig 10 show Mumbai main road, street and railway traffic maps after simulation along with their respective properties. The detailed charts for properties show service, reference cell, total path loss, transmission power throughput and reference signal CINR for respective area maps.

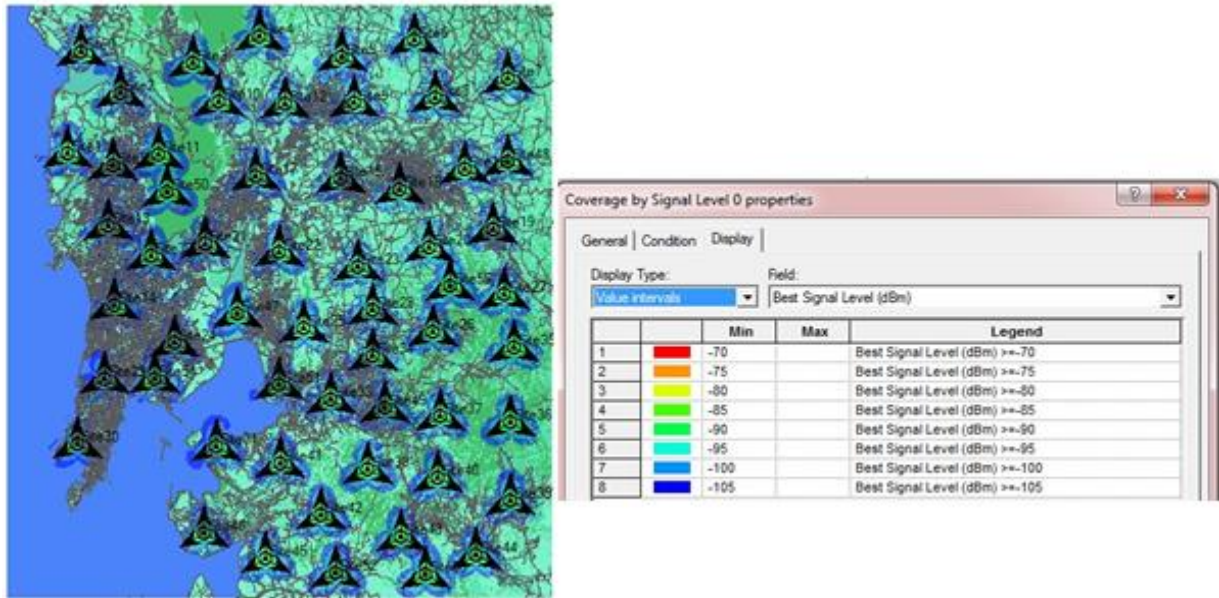


Figure 4. Coverage prediction by signal level

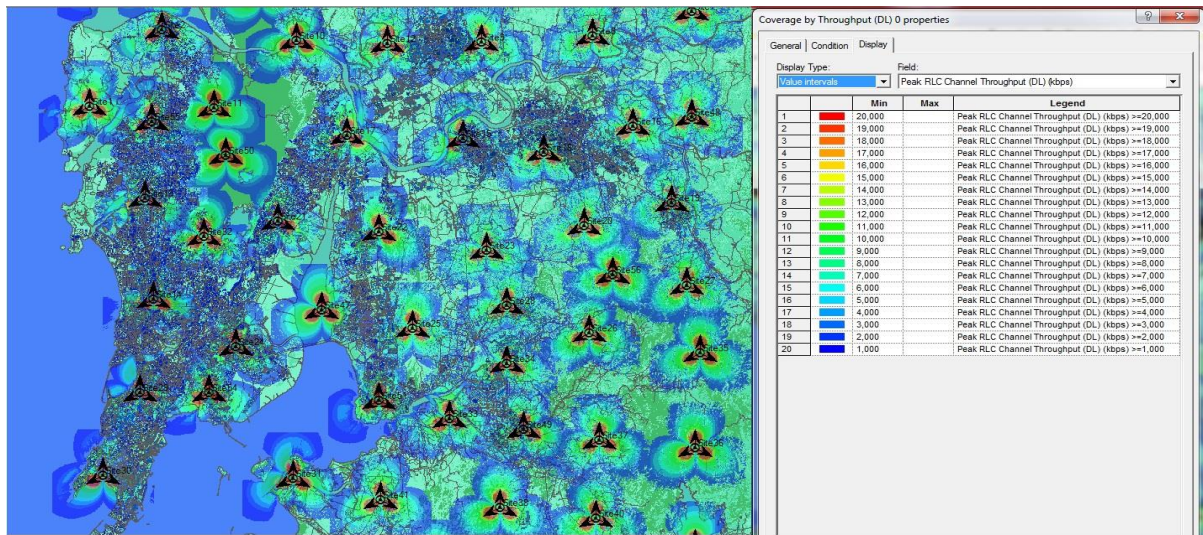


Figure 5. Coverage prediction by downlink throughput

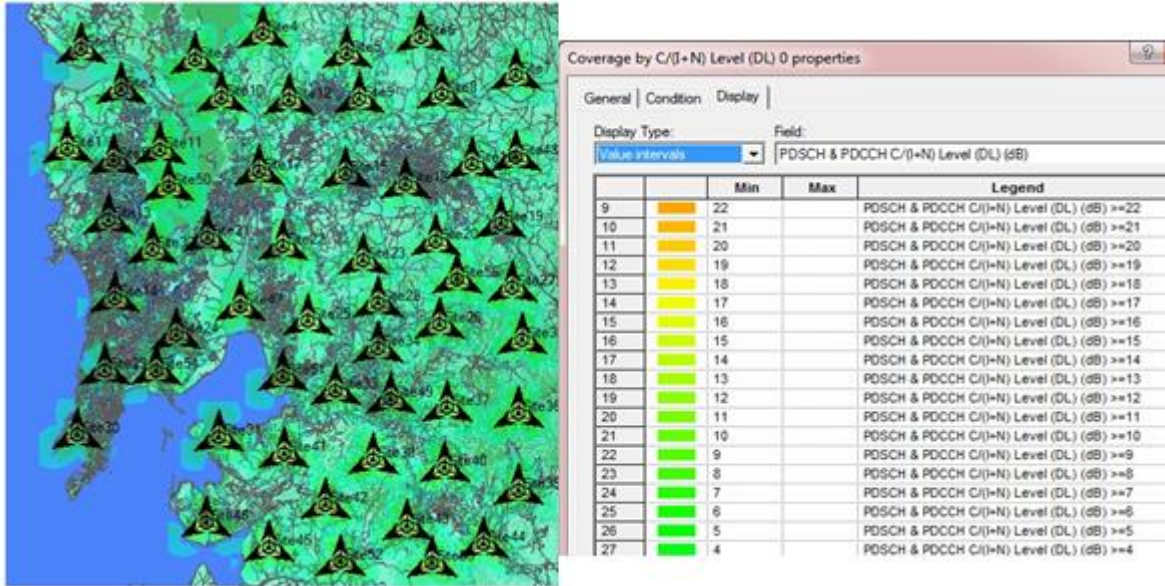


Figure 6. Coverage prediction by downlink CINR level

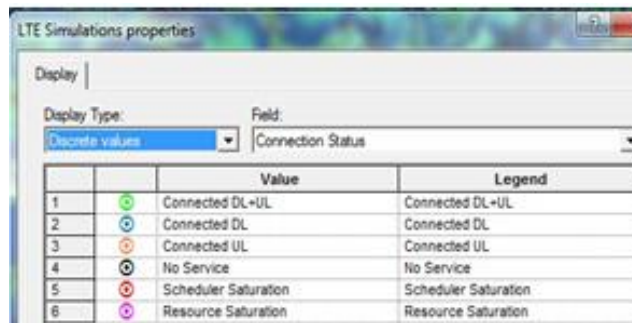


Figure 7. LTE simulation properties

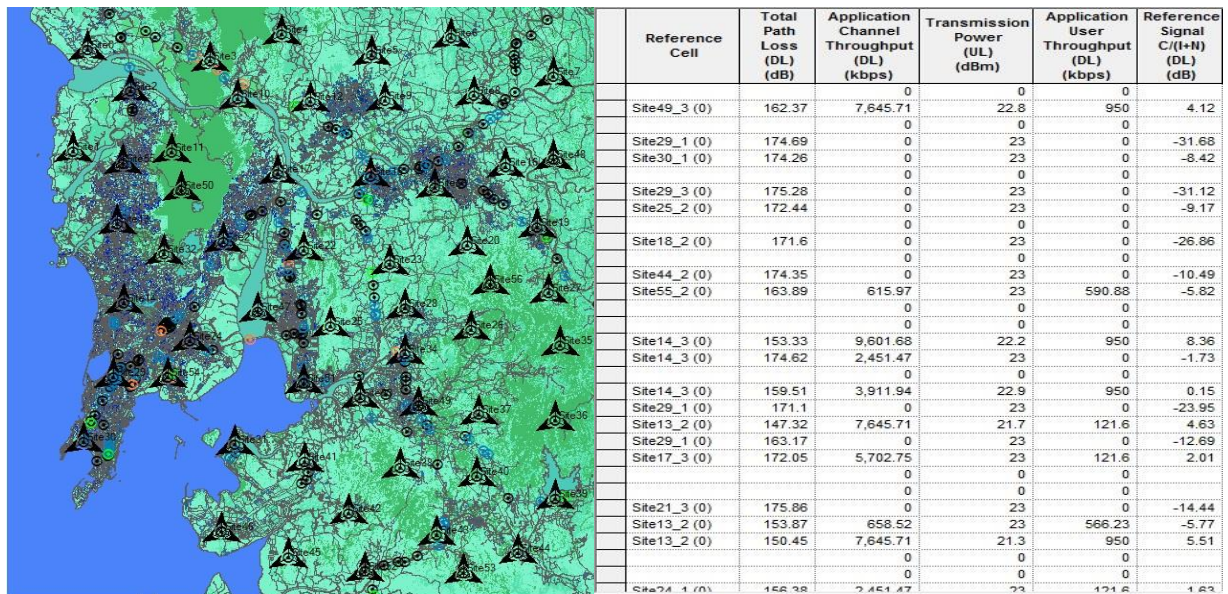


Figure 8. Simulated Mumbai Mainroad traffic map and simulation properties

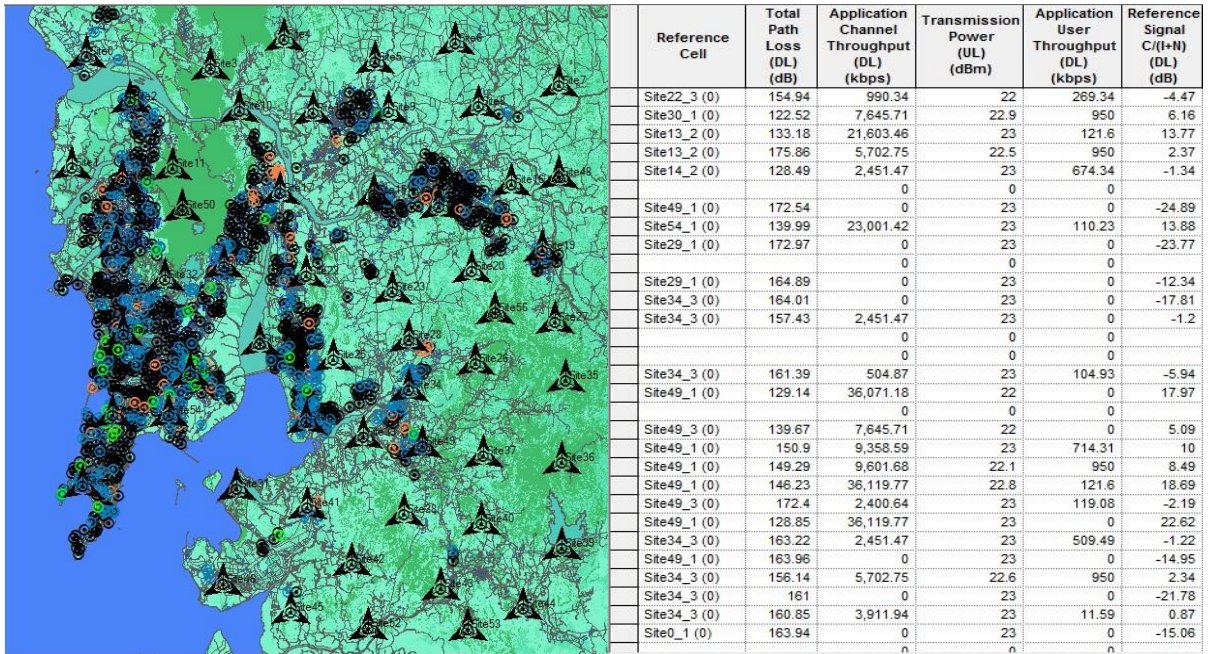


Figure 9. Mumbai Streets traffic map after simulation and simulation properties

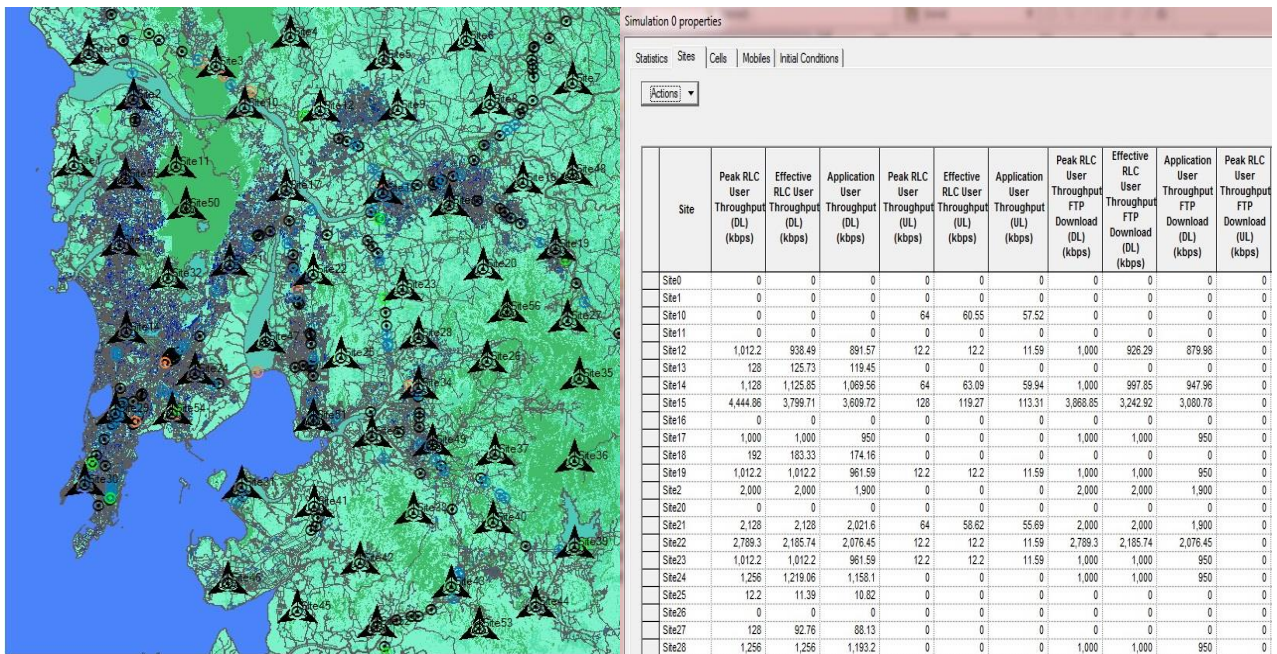


Figure 10. Simulated Mumbai Railway traffic map and simulation properties

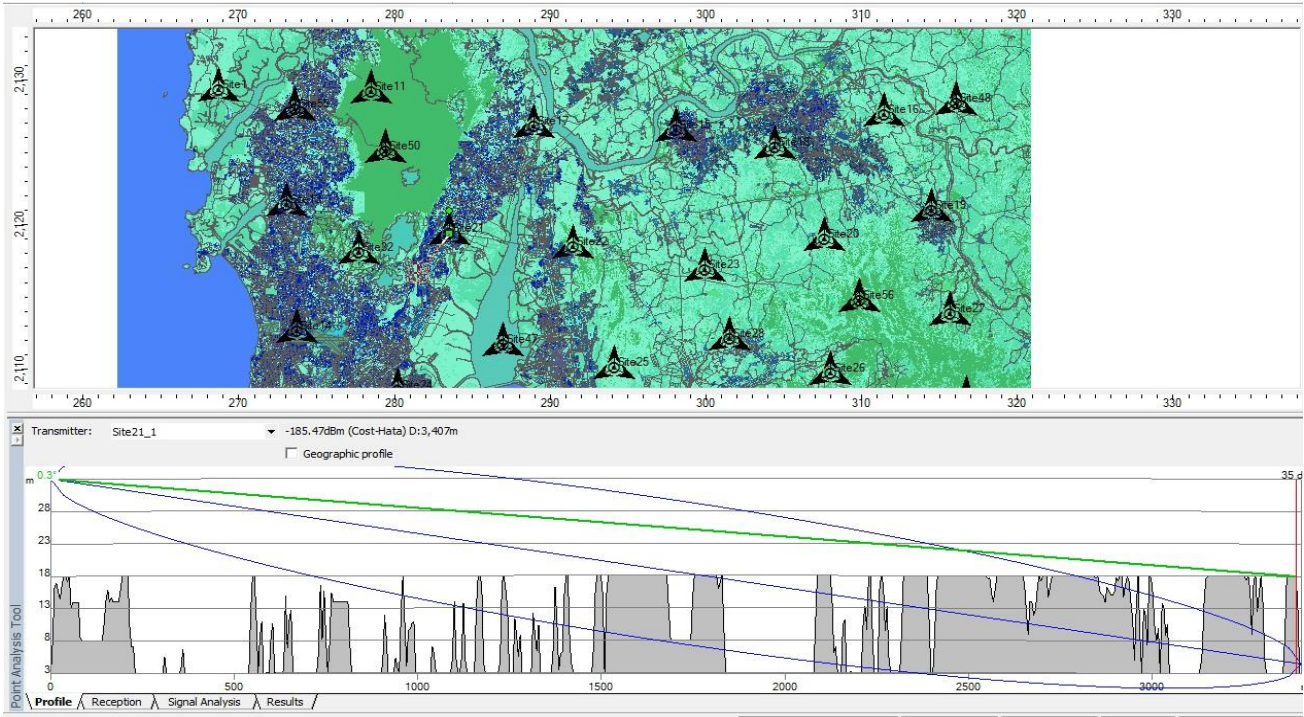


Figure 11. Point analysis with random UE location and geographic profile

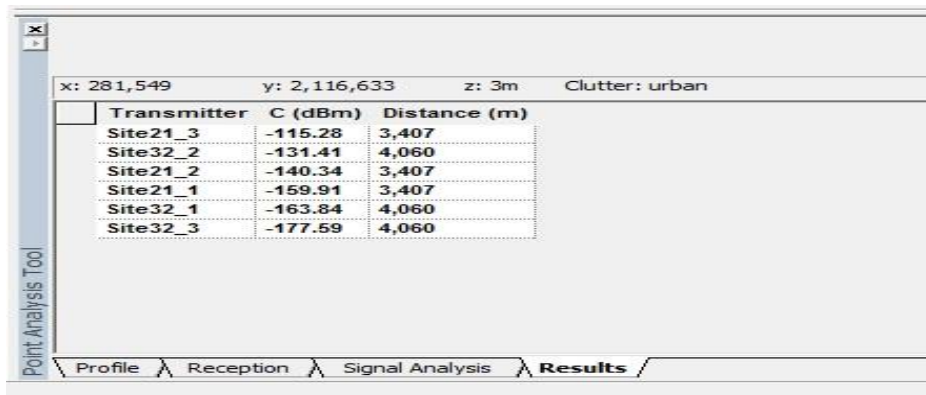


Figure 12. Analysis of received signal level

6. PERFORMANCE ANALYSIS

Using point analysis tool of Atoll, sites of eNodeB 21 and 32 were chosen from Mumbai for a random receiver placement to analyze the cell edge throughput scenario and all other uplink and downlink parameters. The point analysis results have been shown in Fig 11-13.

- Fig.11 shows the geographic profile of the site 21_1 after using the point analysis tool through Atoll simulation.

- Fig.12 shows the reception level analysis in a tabular format with respect to the placed UE where comparison has been done among the sites.
- Fig.13 provides the summarized result taking the comparatively better transmitters into account i.e. 21_2, 21_3, 32_3. Among them, in terms of received signal level result 21_3 is clearly the best one.

- As per Fig 12 and 13, from site 21_3 highest signal level of -115.28 dBm is obtained for a receiver (UE) distance of 3.407 km. It is quite acceptable as our proposed network was based on a cell size of radius of 2.27 km. Thus, performance analysis with point analysis tool for various UE positions acts as a solid base for validating the network planning process.
- Analyzing the coverage prediction results with the placed eNodeBs, it is evident that the planned network provides a satisfactory coverage.
- Again, evaluation of traffic map after simulation makes it clear that subscribers mostly remain connected at both UL & DL which also indicates a very positive sign for the planned network.

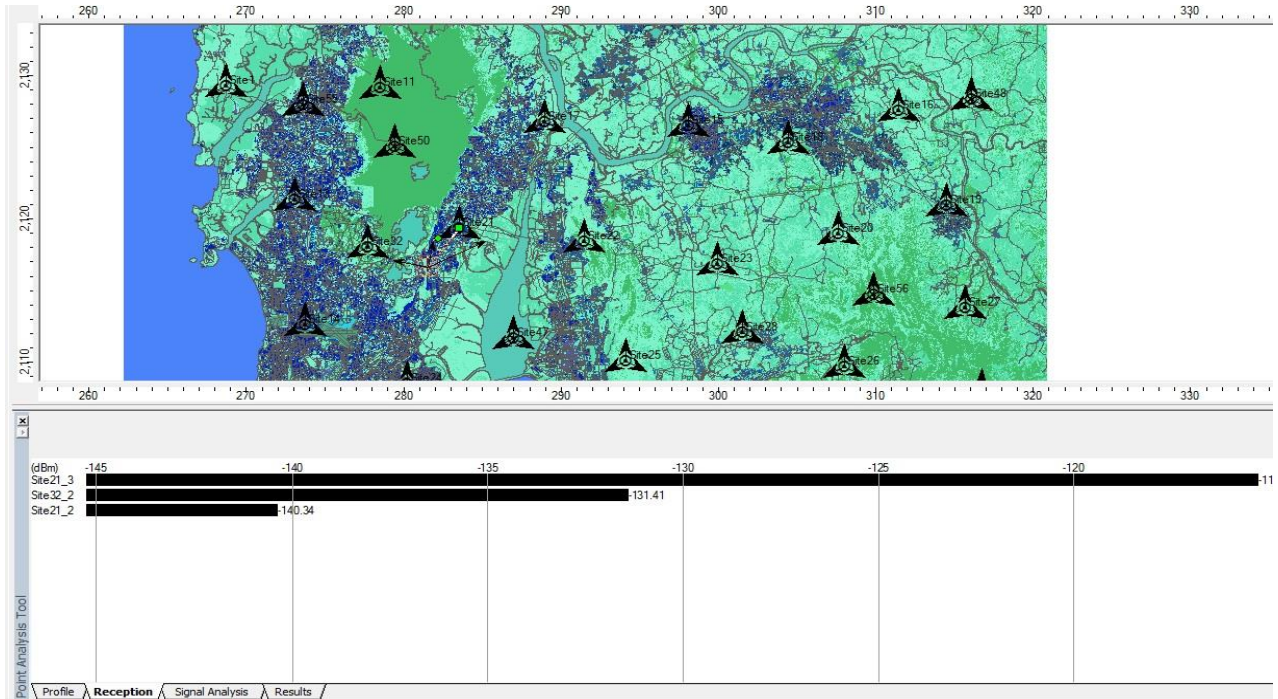


Figure 13. Point analysis tool result-comparison among sites

7. CONCLUSION AND FUTURE WORK

The ultimate objectives of the present study of LTE radio network planning guidelines are to introduce the relevant LTE features, to define the basic models for radio propagation planning, to estimate coverage and network element count for a densely populated city which poses increased level of planning challenge. These studies should be useful for optimizing the recently launched LTE networks in India and spreading the coverage all over the country. Here obtained results of coverage and capacity analysis have been used in nominal and detailed radio planning stage using Atoll and taking Mumbai digital map as input. In detail Atoll simulations containing both coverage predictions and traffic simulations have been run on Mumbai digital maps. Again, performance evaluation

has been done using point analysis tool. Considering initial stage of network deployment, a small number of subscribers have been considered for simultaneous coverage (0.75% of total population with an overbooking factor of 50) for coverage and capacity calculation. As a result, there remains the real life challenge for further capacity enhancement. Still it can be considered as a standard radio planning approach applicable for densely populated metropolitan areas where it is normally quite challenging.

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