ISLAMIC UNIVERSITY OF TECHNOLOGY
DHAKA, BANGLADESH
ORGANISATION OF ISLAMIC COOPERATION

Coverage and Capacity issues of LTE Radio Network Planning involving Dhaka and Mumbai City

A Thesis Presented to
The Academic Faculty

By

Salim Abdou Hadji Student No.133414
Yahia Lawane Student No.133416
Mazen Abdellah Merfaq Student No.133420

In partial fulfillment

of the requirements for the award of the Bachelor of Science in Technical Education
with specialization in
Electrical and Electronic Engineering

Islamic University of Technology
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DECLARATION

This is to affirm that the work on hand in this thesis is the outcome of our own inquiry carried out under the Supervision of Mr. Nafiz Imtiaz Bin Hamid, in the Department Of Electrical And Electronic Engineering. It has not already been accepted for any degree or diploma, and is also not being in tandem submitted for any further degree or diploma.

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Finally, none of this would have been achievable without the love and patience of our families. Our immediate family, to whom this dissertation is dedicated to, has been a constant source of love, concern, support and strength all these years. We also thank all our friends and whoever helped us in the course of our work and our report.

ABSTRACT

The Long Term Evolution (LTE) is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements to meet up with growing need for data.

The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD) and the ability to deliver these at low cost per bit voice and data services.

This thesis tries to establish a Radio Network an efficient LTE radio network in Dhaka and Mumbai as case studies through numerous simulations.

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List of Acronyms

3G	Third generation
3GPP	Third generation partnership project
ABS	Almost Blank Sub frames
BS	Base Station
CA	Carrier aggregation
CoMP	Coordinated Multipoint Transmission/Reception
CSG	Closed subscriber group
Datacom	data communication
DFT	Discrete Fourier Transform
DL	Downlink
DSP	Digital Signal Processing
eICIC	Enhanced ICIC
eNodeB/eNB	Enhanced Node B
EPC	Evolved Packet Core
E-UTRAN	Evolved-UMTS Terrestrial Radio Access Network
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HARQ	Hybrid Automatic Repeat Request
HetNets	Heterogeneous Networks
HSPA	High-Speed Packet Access
ICIC	Inter-Cell Interference Coordination
IP	Internet Protocol
LTE	Long term evolution
MAC	Medium Access Control
Mbps	Mega bits per seconds
MIMO	Multiple input multiple output
OFDMA	Orthogonal Frequency-Division Multiple Access
QoS	Quality of Service
SC-FDMA	Single Carrier Frequency-Division Multiple Access
TB	Transport Block
TDMA	Time Division Multiple Access
UE	User Element
UL	Uplink
UMTS	Universal Mobile Telecommunication System

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Chapter 1
Overview of LTE and problem statement

1.1 Background

LTE (Long term Evolution) is a standard for wireless data communications technology and a development of the GSM/UMTS standards. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. A further goal was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture.

The 3GPP body began its initial investigation of the LTE standard as a convenient technology in 2004. In March 2005, 3GPP began a feasibility study whose key goals were to agree on network architecture and a multiple access method, in terms of the functional split between the radio access and the core network. The study concluded in September 2006 when 3GPP finalized selection of the multiple access and basic radio access network architecture. 3GPP decided to use OFDMA in the downlink direction and use SC-FDMA in the uplink direction. The specifications for the LTE standard were approved by 3GPP in January 2007. The specifications are now under change control, leading to their inclusion in 3GPP Release 8. While the LTE requirements are finalized, the standard is not fully completed.LTE released 8 was finished by late 2008.

Due to the high data rate which is provided by LTE releases comparing with the previous technologies, in addition to being a technology continuously evolving to meet future requirements and user expectations, it promises to be the basic future technology in the mobile broadband networks field and will occupy the first place in terms of the number of subscribers around the world in the next few years.
Figure 1 shows the forecast subscriptions in mobile broadband networks [1].

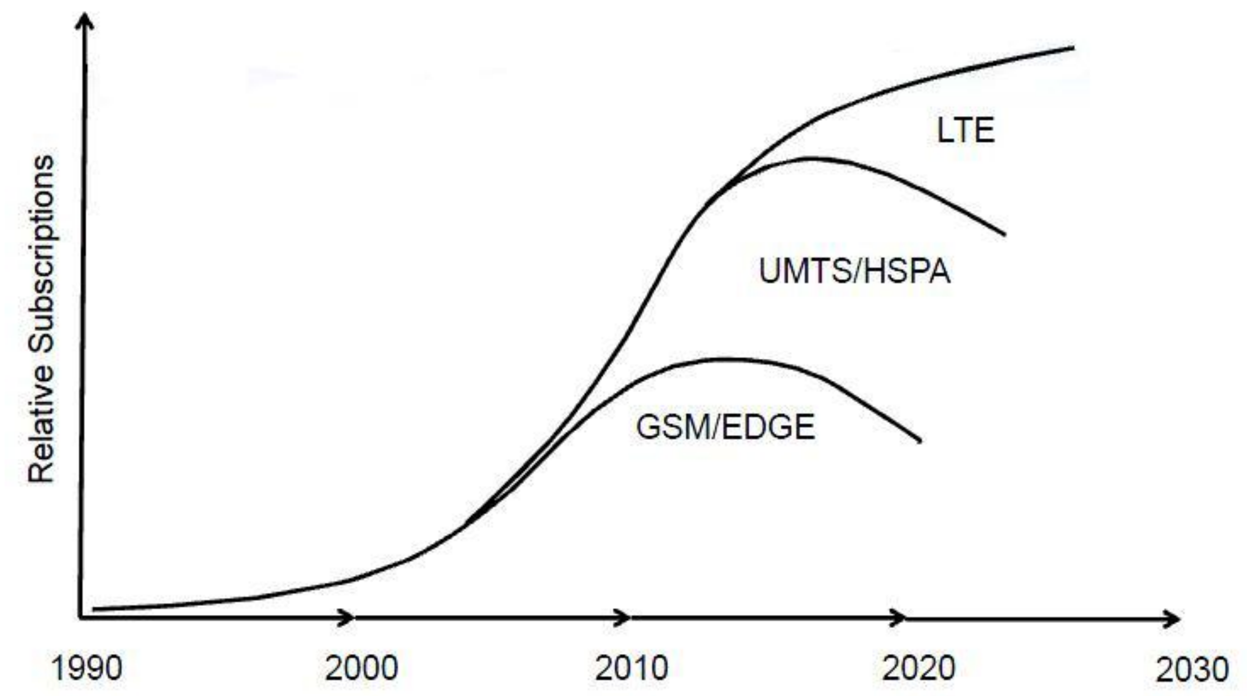


Fig 1: Forecast subscriptions in mobile broadband networks.

1.2 LTE Evolution

LTE or the E-UTRAN (Evolved Universal Terrestrial Access Network), introduced in 3GPP R8, is the access part of the EPS (Evolved Packet System). The main requirements for the new access network are high spectral efficiency, high peak data rates, short round trip time as well as flexibility in frequency and bandwidth. After five years of continued work and research, the first specification version of its first release - LTE Release 8 -completed in March 2009.

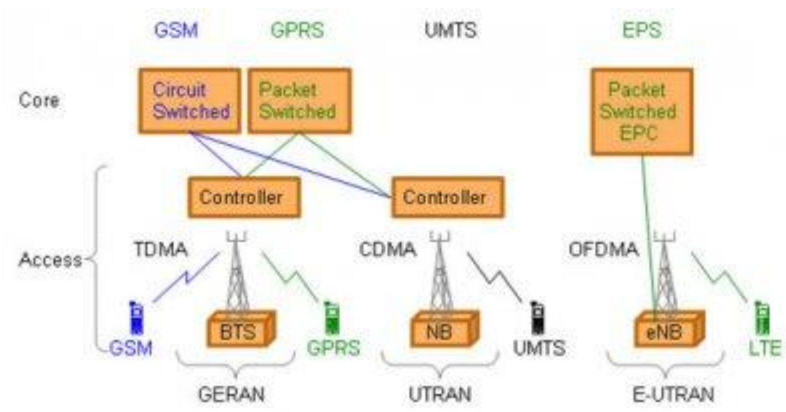


Fig 1.2 : Network Solutions from GSM to LTE

GSM was developed to carry real time services, in a circuit switched manner (blue in figure 2), with data services only possible over a circuit switched modem connection, with very low data rates. The first step towards an IP based packet switched (green in figure 2) solution was taken with the evolution of GSM to GPRS, using the same air interface and access method, TDMA (Time Division Multiple Access)

To reach higher data rates in UMTS (Universal Mobile Terrestrial System) a new access technology WCDMA (Wideband Code Division Multiple Access) was developed. The access network in UMTS emulates a circuit switched connection for real time services and a packet switched connection for data communication (datacom) services (black in figure 2). In UMTS the IP address is allocated to the UE when a datacom service is established and released when the service is released. Incoming datacom services are therefore still relying upon the circuit switched core for paging.

The Evolved Packet System (EPS) is purely IP based. Both real time services and datacom services will be carried by the IP protocol. The IP address is allocated when the mobile is switched on and released when switched off.

The new access solution, LTE, is based on OFDMA (Orthogonal Frequency Division Multiple Access) and in combination with higher order modulation (up to 64QAM), large bandwidths (up to 20 MHz) and spatial multiplexing in the downlink (up to 4x4) high data rates can be achieved. The highest theoretical peak data rate on the transport channel is 75 Mbps in the uplink, and in the downlink, using spatial multiplexing; the rate can be as high as 300 Mbps.

The LTE access network is simply a network of base stations, evolved NodeB (eNB), generating a flat architecture (figure 2.2). There is no centralized intelligent controller, and the eNBs are normally inter-connected via the X2-interface and towards the core network by the S1-interface (figure 2.2). The reason for distributing the intelligence amongst the base-stations in LTE is to speed up the connection set-up and reduce the time required for a handover. For an end-user the connection set-up time for a real time data session is in many cases crucial, especially in on-line gaming. The time for a handover is essential for real-time services where end-users tend to end calls if the handover takes too long.

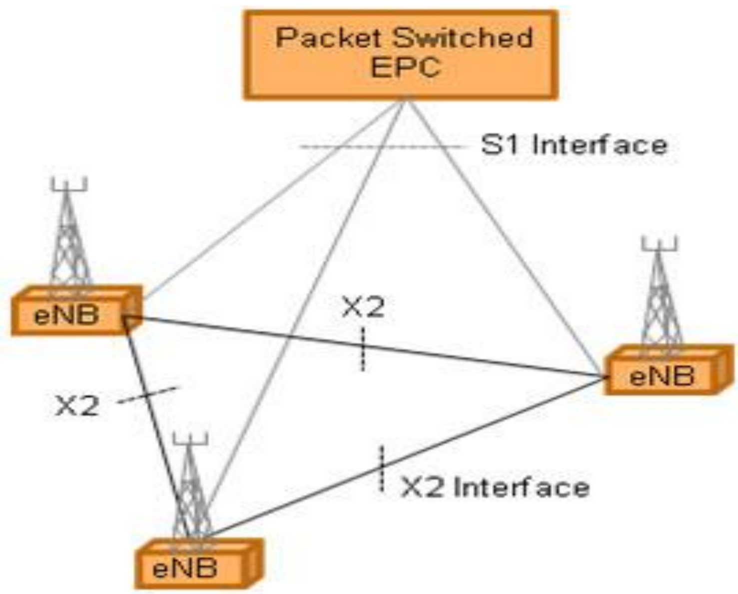


Fig 1.3: X2 and S1 Interfaces

Another advantage with the distributed solution is that the MAC protocol layer, which is responsible for scheduling, is represented only in the UE and in the base station leading to fast communication and decisions between the eNB and the UE. In UMTS the MAC protocol, and scheduling, is located in the controller and when HSDPA was introduced an additional MAC sub-layer, responsible for HSPA scheduling was added in the NB.

The scheduler is a key component for the achievement of a fast adjusted and efficiently utilized radio resource. The TTI (Transmission Time Interval) is set to only 1 millisecond.

During each TTI the eNB scheduler shall:

·Consider the physical radio environment per UE. The UEs report their perceived radio quality, as an input to the scheduler to decide which Modulation and Coding scheme to use. The solution relies on rapid adaptation to channel variations, employing HARQ (Hybrid Automatic Repeat Request) with soft-combining and rate adaptation.

·Prioritize the QoS(Quality of Service) requirements amongst the UEs. LTE supports both delay sensitive real-time services as well as datacom services requiring high data peak rates.

·Inform the UEs of allocated radio resources. The eNB schedules the UEs both on the downlink and on the uplink. For each UE scheduled in a TTI the user data will be carried in a TB (Transport Block). DL there can be a maximum of two TBs generated per TTI per UE – if spatial multiplexing is used. The TB is delivered on a transport channel. In LTE the number of channels is decreased compare to UMTS. For the user plane there is only one shared transport channel in each direction. The TB sent on the channel, can therefore contain bits from a number of services, multiplexed together.

To achieve high radio spectral efficiency as well as enable efficient scheduling in time and frequency domain, a multicarrier approach for multiple access was chosen by 3GPP. For the downlink, OFDMA (Orthogonal Frequency Division Multiple Access) was selected and for the uplink SC-FDMA (Single Carrier - Frequency Division Multiple Access) also known as DFT (Discrete Fourier Transform) spread OFDMA (figure 2.4).

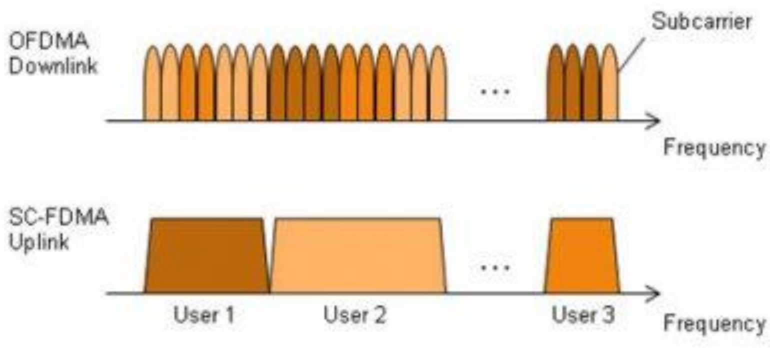


Fig 1.4 : OFDMA and SC-FDMA

1.2.1 Motivations of LTE

- Need to ensure the continuity of competitiveness of the 3G system for the future
- User demand for higher data rates and quality of service
- Packet Switch optimized system
- Continued demand for cost reduction
- Low complexity
- Avoid unnecessary fragmentation of technologies for paired and unpaired band operation

1.2.2 Features of LTE

A large amount of the work is aimed at simplifying the architecture of the system, as it transits from the existing UMTS circuit + packet switching combined network, to an all-IP flat architecture system. E-UTRA is the air interface of LTE. Its main features are:

- Support for both FDD and TDD communication systems
- OFDMA for the downlink, SC-FDMA for the uplink to conserve power

- Peak download rates up to 299.6 Mbit/s and upload rates up to 75.4 Mbit/s
- Support for cell sizes from tens of meters radius (femto and pico cells) up to 100 km (62 miles) radius macro cells.
- All physical layer steps available as individual functions/blocks:
    i. Transport channel coding/ decoding
    ii. Scrambling/ descrambling
    iii. Symbol Modulation/ demapping
    iv. Resource element mapping
    v. OFDM and SC-FDM

1.3 LTE release 8

3GPP Long Term Evolution is the name given to the 3GPP standard required to deal with the increasing data throughput requirements of the market. Working groups from 3GPP RAN started to work on standardization for LTE in late 2004. By 2007, all LTE features related to its functionality were finished and by 2008 [2], most protocol and performance specifications were finished and included in Release 8.

1.4 Problem Statement

Effective network planning is essential to cope with the increasing number of mobile broadband data subscribers and bandwidth-intensive services competing for limited radio resources. This puts mobile network operators and researchers in a unrelenting case of working, researching and developing to meet user requirements, get better services quality and coverage, increase data rates and capacity, increase overall cell-site performance and cell-edge data. Dhaka City and Mumbai City being highly populated cities which increase daily and of different topographies .In order to hauler for the ever increasing population, there is a call for to carry out proper Network Planning using a high spectral efficient standard.

1.5 Objectives

The objectives of this Thesis were:

- To get the radio parameters required for efficient radio planning through numerous simulations using Dhaka and Mumbai city for case study.
- Understand basic radio network planning process for LTE
- To set up an LTE radio Network in Dhaka and Mumbai city and to analyze their performance as wireless networks.

Chapter 2

Heterogonous Network and interference

2.1. Heterogeneous Networks Concepts

HetNets, as mentioned formerly, have been introduced in the LTE-Advanced standardization in order to provide a significant network performance leap when other advanced technologies (CA, MIMO, and CoMP) are unable to achieve that, as they are reaching theoretical limits. Such techniques may not always work well either, especially under low SINR conditions, where received powers are low due to attenuation and/or interference might be high, whereas HetNets can do.

Complementing macro cells with LPNs and dedicated indoor solutions based on the 3GPP standard is a good approach to meet the predicted requirements for higher data rates and additional capacity. This approach can include the use of pico cells, femto cells, relays and which delivers high per-user capacity and rate coverage in areas covered by LPNs, with the potential to improve performance in the macro network by offloading traffic generated in hotspots. By adding LPNs to the existing macro layer, the operator creates a two-layer cell structure with eNodeBs of different types, that is why it is called HetNet [1,2], *heterogeneous* in the deployment sense. The degree of integration that can be achieved throughout the HetNet will determine the overall network performance. HetNets improve the overall capacity as well as provide a cost-effective coverage extension and higher data rates to hot spots such as airports and shopping malls by deploying additional network nodes within the local-area range. In addition, they also increase overall cell-site performance and cell-edge data rates by bringing the network closer to end users. In that way, radio link quality can be enhanced due to the reduced distance between transmitter and receiver, and the larger number of eNodeBs allows for more efficient spectrum reuse and therefore larger data rates [3].

These LPNs can be either operator deployed or user deployed, share the same spectrum, and may coexist in the same geographical area. The following table shows specification of different elements in HetNets according to typical transmit power, coverage area, typical backhaul features and access [4].

Type of node	**Typical transmit power**	**Coverage**	**Typical backhaul features**	**Access**
Macro cell	46 dBm	Few Km	S1 Interface	Open to all UEs
Pico cell	23 – 30 dBm	< 100 m	X2 Interface with macro	Open to all UEs
Femto cell	< 23 dBm	< 50 m	User local loop	CSG
Relay	30 dBm	300 m	Wireless link with donor node	Open to all UEs
RRU	46 dBm	Few Km	Fiber link with parent site	Open to all UEs

Table 2.1: Specification of different elements in HetNets.

To obtain maximum value from the radio spectrum, operators will need flexible eNodeB site solutions that allow for ideal placement of the radio site. Operators may need to consider alternatives for site location by connecting with new partners such as municipalities, retailers and external agencies rather than traditional deals made with landlords and tower-approval committees. For outdoor HetNets deployments, reusing existing site infrastructure and maximizing the value of acquisition contracts should be the first priority for operators, together with technological and automatic solutions that reduce cell-site maintenance costs. When deploying LPNs as a complement to macro cells, careful network planning is needed to minimize the total number of cells-reducing the overall cost of ownership, and ensuring robust and seamless service [5].

In metropolitan areas, additional LPNs at street level need to be implemented using small antennae in such a way that the equipment is almost invisible. The deployment of these nodes as indoor sites makes infrastructure and interference issues easier to manage. HetNets can also be integrated smoothly with Wi-Fi, which is a more cost-effective solution for indoor mobile broadband coverage for enterprise and residential users than femto cells [3]. Figure 3.1 shows HetNets, where LPNs are deployed in different scenarios (indoor, outdoor, at cell-edge, in hotspot).

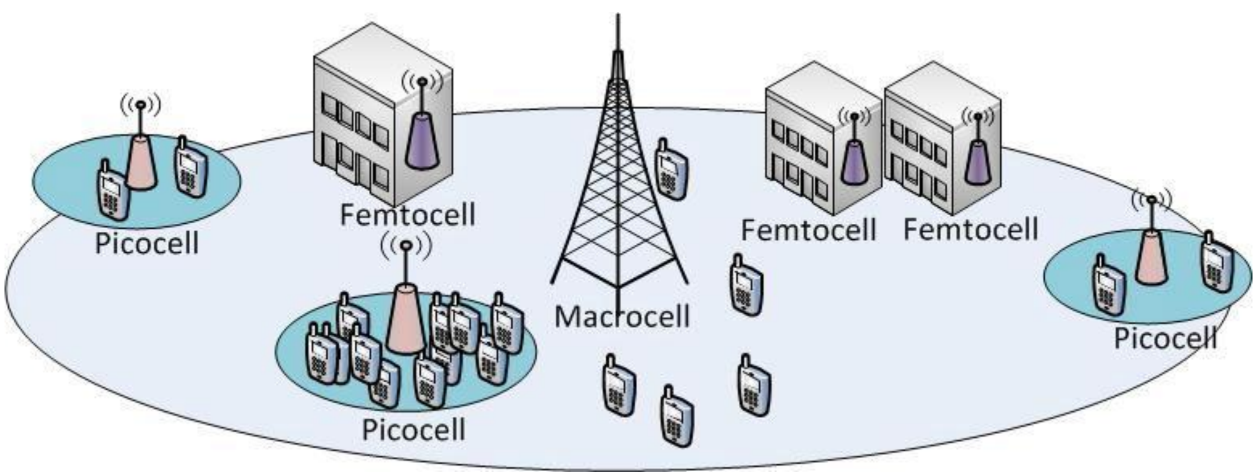


Fig 2.1: HetNets deployments scenarios.

2.2 Interference

The simultaneous use of the same spectrum between different cell layers that run on different values of transmit power creates interference that will become more severe compared to homogeneous networks. For pico cells the interference does not create coverage hole due to open access to all UEs, but that is not true when it is expanded (that will be discussed later in the range expansion and interference coordination sections).

The situation is different for femto cell due to being equipped with the CSG feature that results into new and severe interference conditions. Figure 3.2 illustrates interference scenarios in relation to femto cell deployments. There are two scenarios that create severe interference when macro UE (MUE) does not belong to femto cell CSG and being close to it [8]. In DL, MUE is being jammed by femto cell, frequency of the occurrence of this issue can be reduced by femto cell power control, with or without macro UE assistance, but it cannot completely solve the problem [11]. In UL, femto cell is being jammed by MUE Since MUE is power controlled by the macro cell, MUE will cause likely strong burst interference to femto cell. Noise padding technique which is a method of wireless communication includes detecting UL interference in a received uplink transmission of a UE, where the received UL transmission is padded with noise based on the detected interference and also based on a frequency domain partition [12]. This technique can smooth out interference in this case, but it also decreases capacity at serving femto cell and increases interference to the neighboring cells. In case the MUE is closer to femto cell that the UE that is served by femto cell, noise padding cannot solve the problem and the UE served by femto cell would experience outage [6].

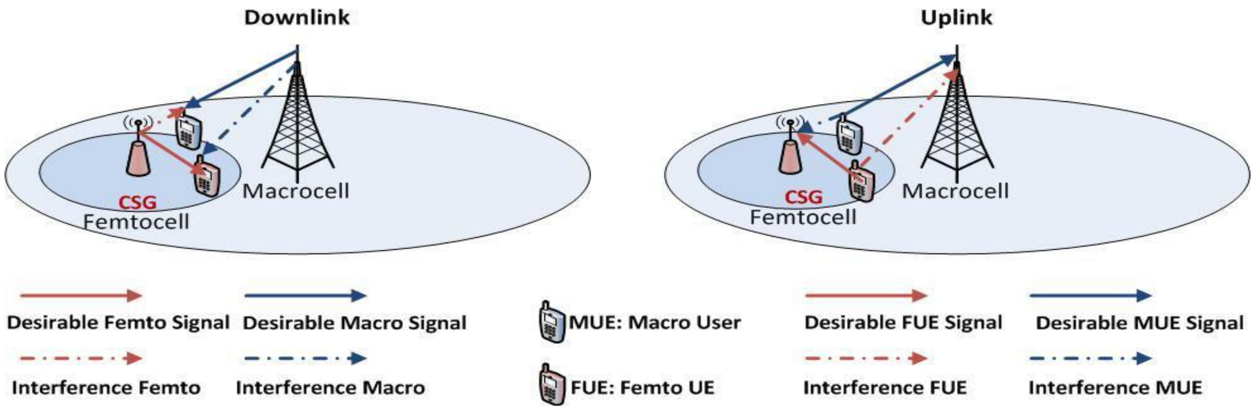


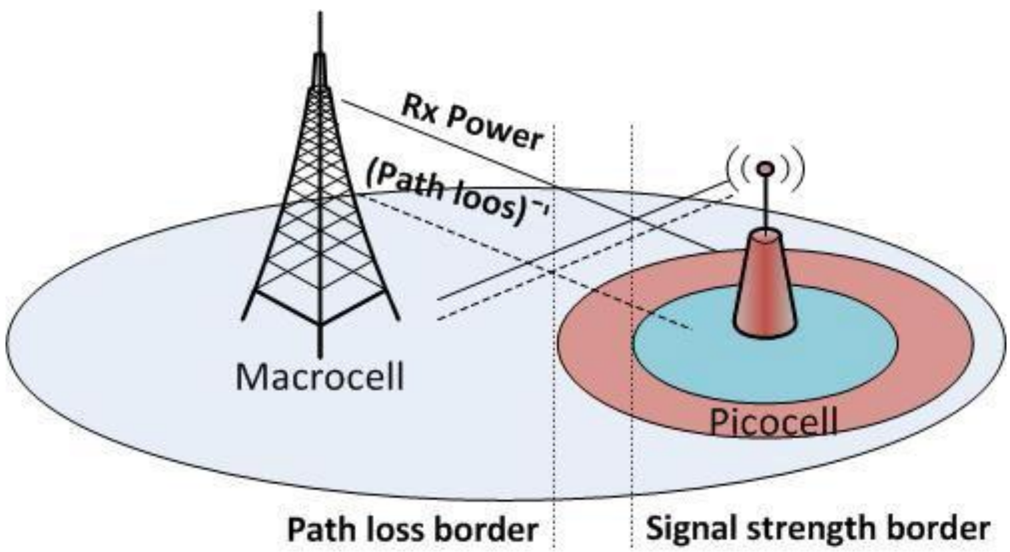
Figure 3.2: Macro-Femto Interference Scenarios.

2.3. Range Extension

LPNs coverage is quite limited by its transmission power and the strong interference from macro cells, which means that only a small percentage of users can benefit from LPN deployment, especially in cell edges where there is no many UEs as in hotspots case. This leads to a state of coverage unbalance and for that, a new technique was required to increase HetNets efficiency, offload the more macro cell traffic, i.e. attract more UEs to LPNs and solve the UL and DL coverage unbalance. Moreover, the performance of LPNs is significantly improved if UEs are allowed to connect to a weaker SINR LPNs, which refers to extend LPNs boundaries for load balancing purposes. This improves LPNs performance, since more UEs can connect to LPNs and take advantage of the spectrum offered by them, and multiple LPNs can reuse the disused resources on the macro side, allowing for cell-splitting gains.

For these purposes, RE is introduced for LPNs, pico cells and relays particularly, with a positive bias to them in the cell selection. RE is considered a key design feature to enhance HetNets efficiency, which adds an offset to the pico cell received signal strength (RSS) in order to increase its DL coverage footprint [1].

Figure 3.4 illustrates the RE concept as follows [7]. The natural LPN boundaries in DL and UL are different in HetNets, as opposed to a homogeneous and correctly planned network. In the DL, the DL SINRs observed from the macro cell and the pico cell are equivalent at a location that is closer to the pico cell, which forms the equal-SINR cell boundary. In the UL, on the other hand, the location of the natural cell boundary is where the path loss to the macro cell and the pico cell are equivalent. This is due to the fact that macro and LPN can reach different maximum power levels, however the UE has the same maximum power for both cases.



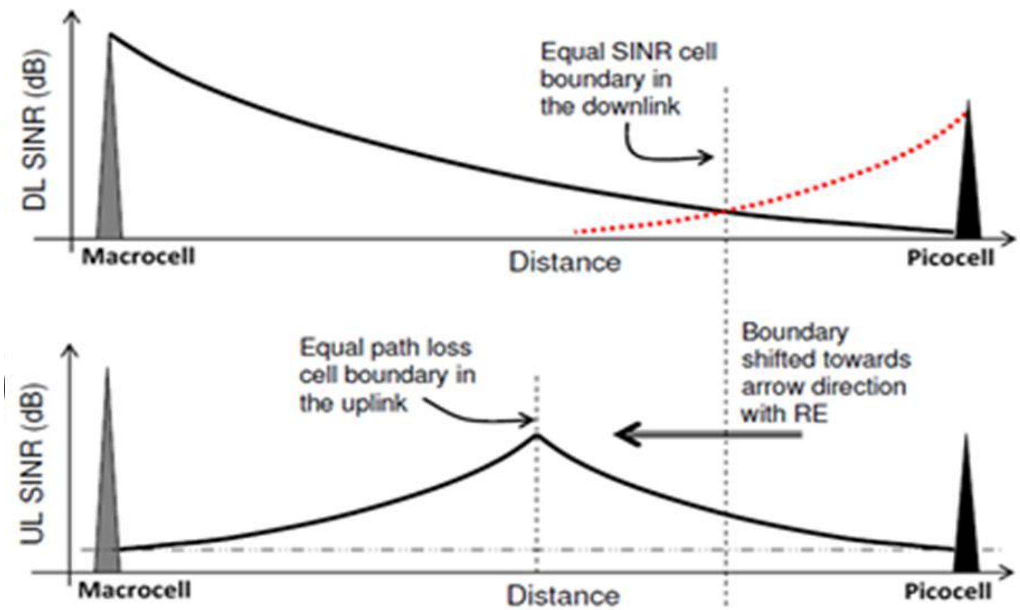


Figure 2.3: Range Expansion Concept

In the normal case without RE, the serving cell choice is determined by the highest DL received power, this technique is referred as maximum reference signal received power (Max RSRP) [13].

With RE the serving cell of a UE is selected from the set of neighbor cells Λ according to the rule given as:

$$\text{Serving Cell} = \text{argmax}_{i \in A}(\text{RSRP}_i + \text{Bias}_i) \qquad 2.1$$

Where *RSRP* and *Bias* are expressed in dB, this rule implies that a UE does not necessarily connect to the eNodeB that has the strongest DL received power.

As mentioned, the LPN boundaries in DL and UL are different in HetNets. For that, the best UL cell does not necessarily correspond to the best DL cell. With RE technique, the DL serving cell is determined based on the formula (3 - 1), whereas the UL serving cell is defined according to the minimum path loss. The following figure shows handover in HetNets with RE [5].

Even though RE significantly mitigates cross-tier interference in the UL, this comes at the expense of reducing the DL signal quality of those users in the expanded region. Such users may suffer from DL SINRs below 0 dB since they are connected to cells that do not provide the best DL RSS [4], for this reason interference coordination strategies may well help to solve this trade off and reduce DL degradation in the cell border. Thus, it is usual to find that RE is jointly designed with ICIC/eICIC schemes, which will be discussed in the next section.

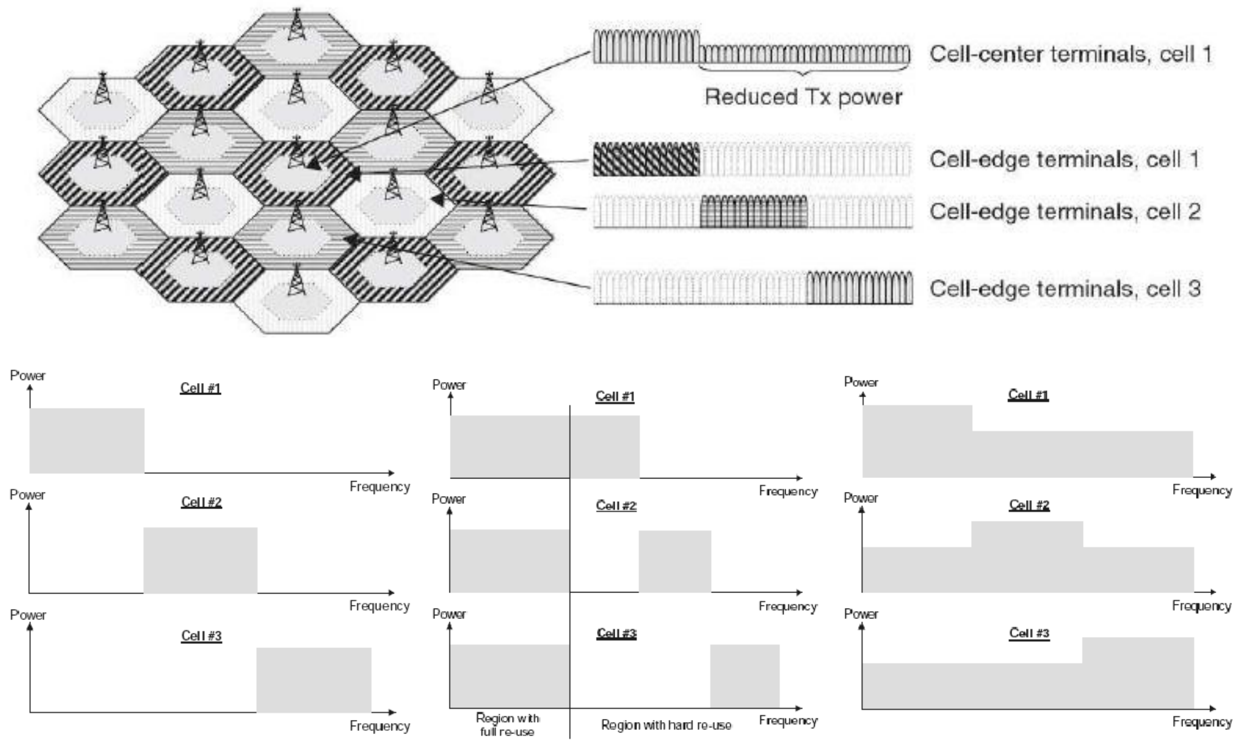
2.4. Interference Coordination

The interference issues may significantly degrade the overall system performance, which requires the adoption of coordination techniques to mitigate the interference and optimize its operation.

2.4.1. Inter-cell Interference Coordination

In order to maximize spectrum efficiency, it is desired that LTE uses a frequency reuse 1, which means that all the cells are using the same frequency channels. However, this also means that QoS will largely depend on the geographical position of the user equipment with a particular degradation on the cell edge. ICIC is introduced in 3GPP LTE Release 8 to deal with interference issues especially at cell-edge.

There are three schemes of ICIC par excellence, which use power and frequency domain to mitigate cell-edge interference from neighbor cells on traffic channels only [4]. One scheme of ICIC is where neighbor eNodeBs use different sets of resource blocks throughout the cell at given time (Hard Frequency Reuse), whereas in the second all eNodeBs utilize complete range of resource blocks for centrally located users but for cell-edge users neighbor eNodeBs do not use the same set of resource blocks at given time (Fractional Frequency Reuse), and in the third all the neighbor eNodeBs use different power schemes across the spectrum so that high power is used in the frequency blocks devoted to the edge and low power levels are allocated to the inner ones (Soft Frequency Reuse) [8]. All three options are graphically illustrated for three adjacent cells in figure 3.6.



a) Hard Frequency Reuse b) Fractional Frequency Reuse c) Soft Frequency Reuse

Figure 2.4: ICIC Schemes.

Using such schemes for HetNets, where macro cells and many LPNs are overlapping in many scenarios may lead to radio link failure (RLF) under severe interference, and experience service outage due to the unreliable DL control channels.

Another important aspect in ICIC, is collaboration with the potential interferers so that resource allocation can be coordinated in terms of power, frequency, and time to enhance network capacity and mitigate user outages. This might be particularly interesting for HetNets based on pico cells. As with other neighbor cells, macro cells are connected to pico cells through an X2 interface. In this sense, the ICIC messages defined in Release 8 that can be exchanged via the X2 interface can be listed as follows [4]:

- **Relative Narrowband Transmit Power (RNTP) Indicator:** An indicator sent by a specific cell used to coordinate with the adjacent cells about transmission power threshold in specific resource blocks (RBs) in the DL transmissions. An adjacent cell can utilize the RNTP information in the scheduling of it is own cell-edge terminals subjected to the interference from the adjacent cells who are willing to transmit with high power at certain RBs.

- **Overload Indicator (OI):** The OI is an indicator to exchange the average interference plus thermal noise power measurements for each RB between different cells for UL transmissions. It would be possible for an adjacent eNodeB that received the OI to change its scheduling to reduce the interference for the eNodeB that issued the OI.

- **High Interference Indicator (HII):** An indicator used by a certain cell to notify the adjacent cells that one of its cell-edge users will be scheduled for UL transmission in the near future. The HII indicator is a way to prevent the low SINR scenarios by avoiding scheduling of the cell-edge terminals on the same RB and hence reducing the UL interference for cell-edge transmissions to the receiving eNodeB.

Applying of the aforementioned techniques of ICIC may not efficiently cover all the HetNets interference scenarios discussed previously, as the control signaling in each sub-frame is more problematic as it spans the full cell bandwidth and therefore not subject to ICIC.

2.4.2 Enhanced Inter-cell Interference Coordination

The enhanced inter-cell interference coordination (eICIC) is introduced in 3GPP LTE Release 10 to deal with interference issues in HetNets, and mitigate interference on traffic and control channels using power, frequency and also the time domain. eICIC in the time domain introduces a resource-specific cell-selection (RS-CS) method based on sub frame blanking, known as Almost Blank Sub frame (ABS), that does not send any traffic channels and are mostly control channel frames with very low power. When macro cell configures ABS sub frames the UEs connected to the LPN can send their data during such ABS frames and avoid interference from macro cell, and the configuration of ABS is shared via O&M for femto cells or X2 interface for pico cells [7]. However, for backward compatibility, the reference signals RS-CSs still need to be transmitted from the aggressor node (macro cell), resulting in some interference to the users in the victim node, that turn to be severe in high RE biases scenarios. For that, another time domain solution is introduced to deal with RS-CSs interference that mutes RS-CSs in the data channel filled of RBs such as MBSFN (Multicast/Broadcast over Single frequency network) sub frames scheme, also known as MB scheme [9,7]. The both techniques, ABS and MBSFN sub frames, are shown in figures 3.7 and 3.8.

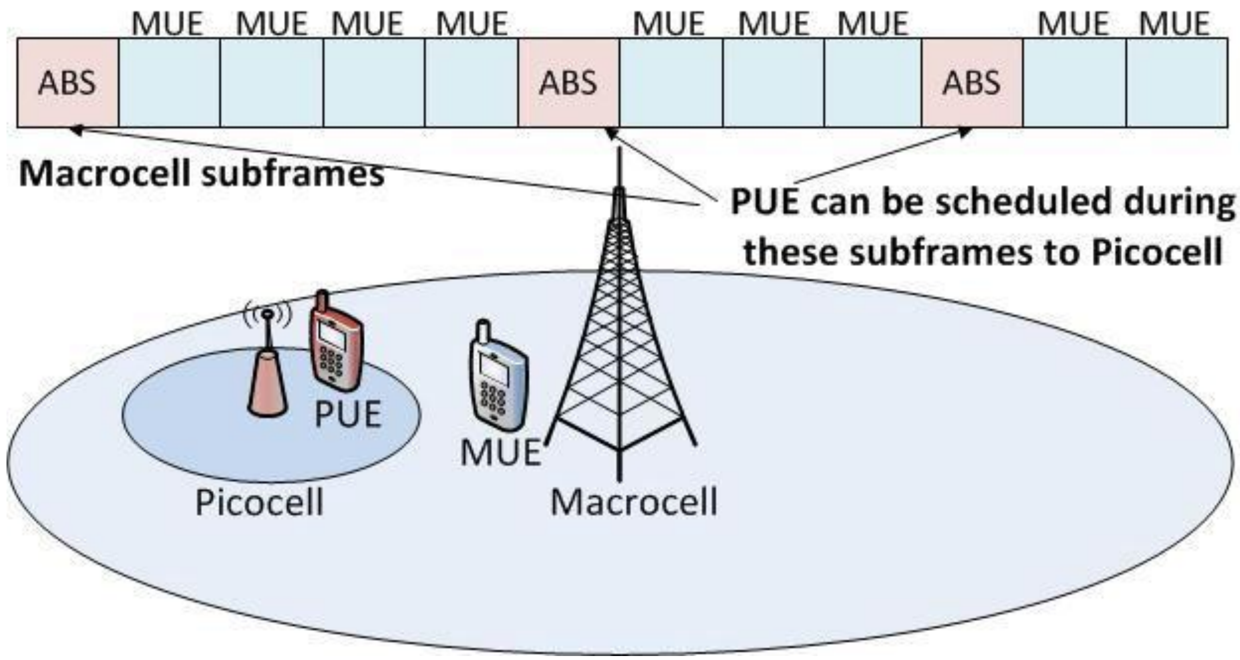


Fig 2.5: Almost Blank Sub frames (ABS) technique.

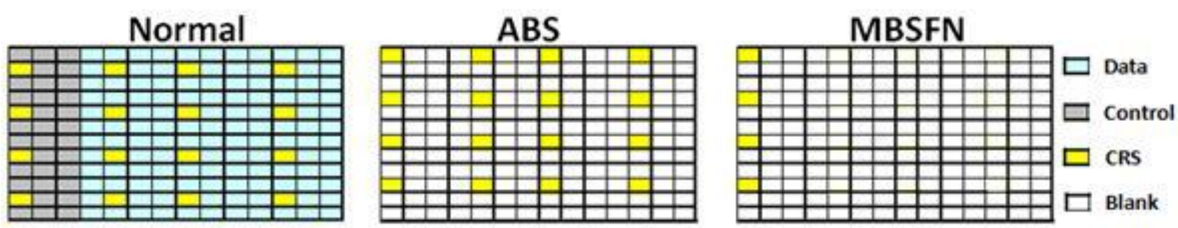


Fig 2.6: ABS and MBSFN-sub frames.

There is another interference issue when deploying HetNets with CRE, since RE may cause low SINR from the pico cell users in the extended regions. This low SINR make decoding the Layer1/Layer2 control channels more complicated. To deal with L1/L2 control signaling, interference specific methods of frequency domain schemes are adopted. The interference cancellation of signaling channels is performed by separating control signaling in different component carriers (recall that carrier aggregation is supported by LTE Release 10) for the different cell layers where at least one component carrier in each cell layer is protected from interference from other cell layers by not sending control signaling (PDCCH, PCFICH, PHICH) on the component carrier in the other cell layers, as seen in figure 3.9 [10].

The macro cell sends control signaling on component carrier f1 but not on component carrier f2, while the situation is the reverted in the LPN (pico cell with RE) deployed within the macro cell [1]. Since Release10 introduces cross-carrier scheduling, resources on f2 can be utilized for data transmission, scheduled by control signaling received on f1. This approach will create frequency reuse for the control signaling while still permitting terminals to utilize the full bandwidth and accordingly enabling the highest data rates.

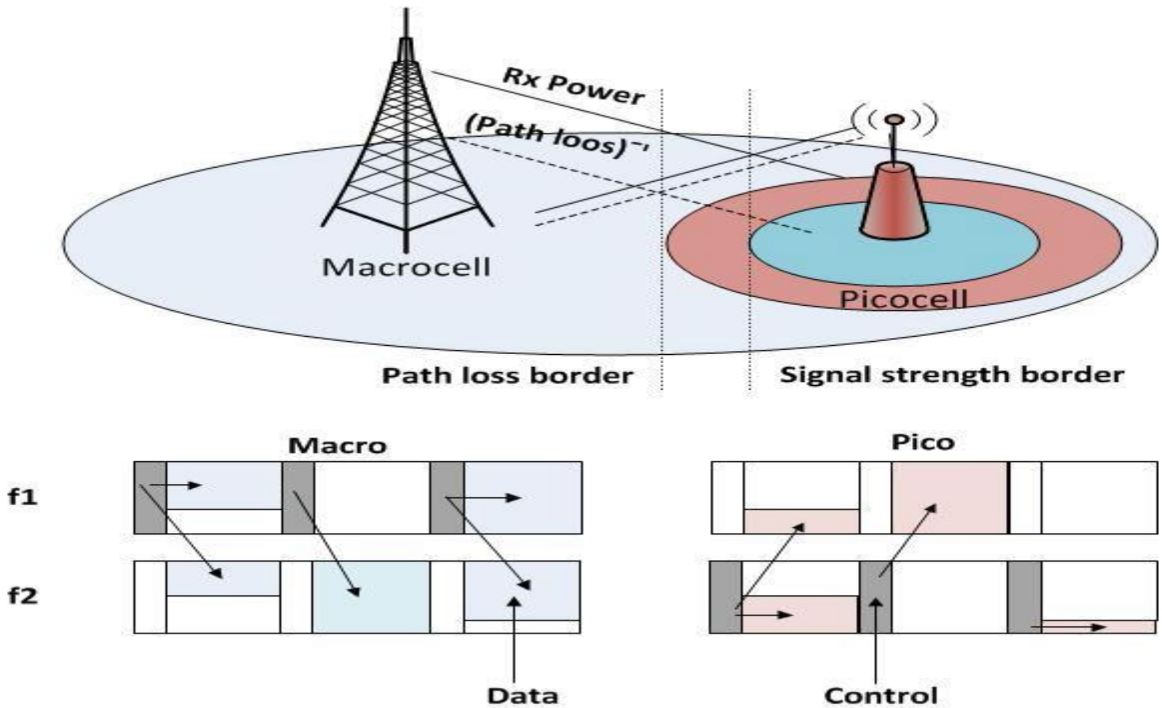


Fig 2.7: Interference Cancellation in HetNets.

2.5. Heterogeneous Networks Scenarios

According to the type of LPN (pico cell, femto cell) and deployment mode (indoor, outdoor), we can get a lot of HetNets scenarios to study and analyze but in this project, the assumed scenario is macro cells without outdoor deployment of pico cells or any other small cells in order to achieve the main objective of this thesis.

Chapter 3

Simulations and Results

3.1 Atoll

Atoll is a 64-bit multi-technology wireless network design and optimization platform that supports wireless operators throughout the network lifecycle, from initial design to densification and optimization. Further comprehension on Atoll is given in Appendix .

By means of the pre-planning information from the Link level Simulator and System level simulator the throughput analysis was achieved as thus.

3.1.2 Capacity calculation of Dhaka City

Taking the population of Dhaka to 15.4 million people

Overbooking factor to be 50

Let 0.75% of the total population be covered

i.e. 0.75% of 15400000 = 115500

Users to be supported simultaneously

115500/50 = 2310

No. of eNodeB for capacity = 2310/(3*15) = 51.1333 ≈ 51

3.1.3 Capacity calculation of Mumbai City

Taking the population of Dhaka to 12.4 million people

Overbooking factor to be 50

Let 0.75% of the total population be covered

i.e. 0.75% of 12,400,000 = 93000

Users to be supported simultaneously

93000/50 = 1860

No. of eNodeB for capacity = 1860/(3*15) = 41.3333 ≈ 41

These target capacities and coverage values were attempted in the simulations performed in Atoll

Coverage Predictions

DHAKA

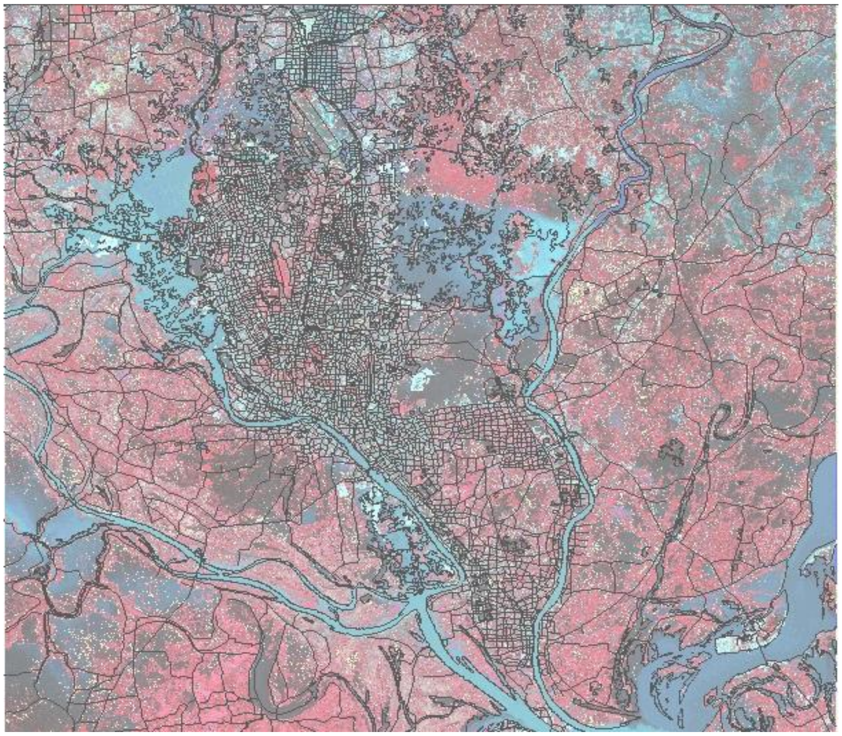


Figure 3.1: Dhaka Digital Map

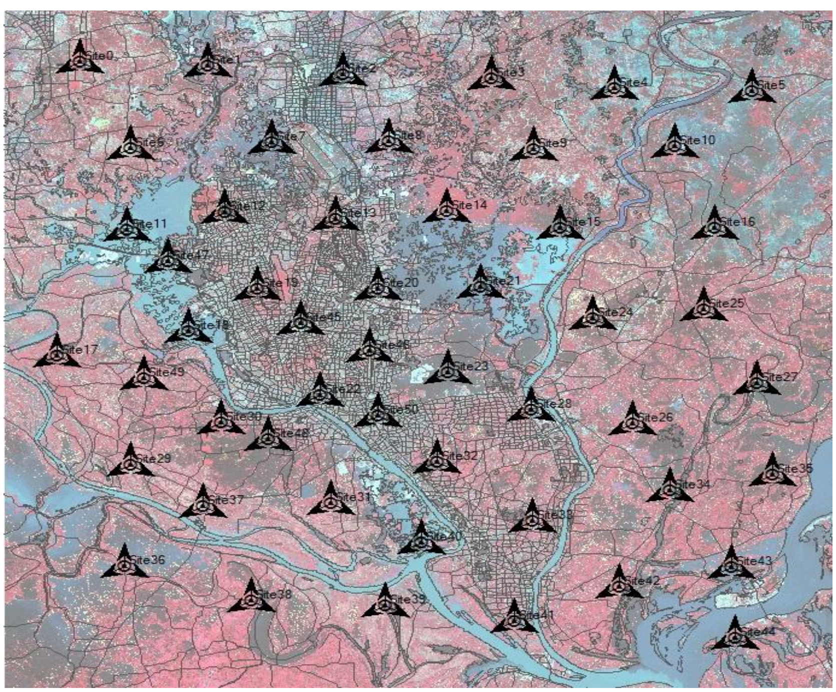


Figure 3.2: Dhaka Digital Map with transmitters

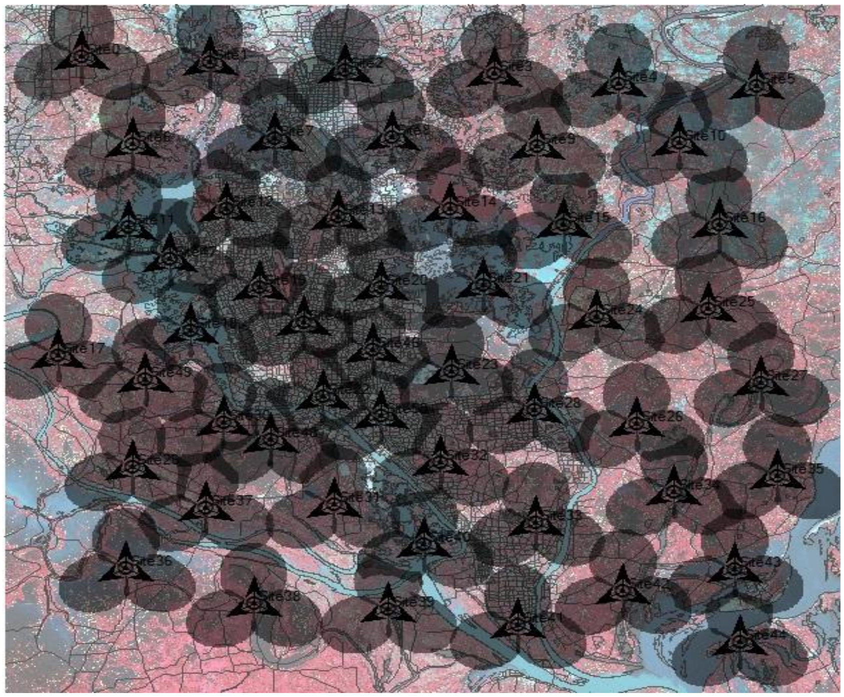


Fig 3.3: Coverage by Transmitters

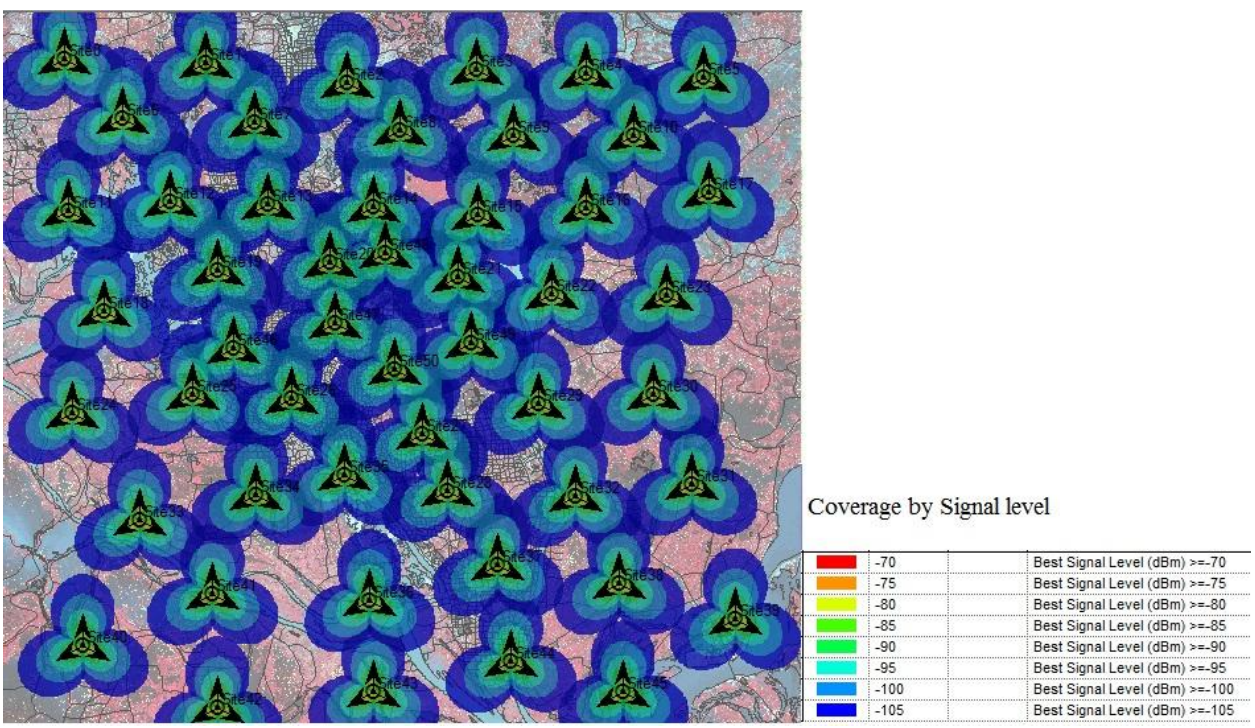


Fig 3.4 Coverage by signal level

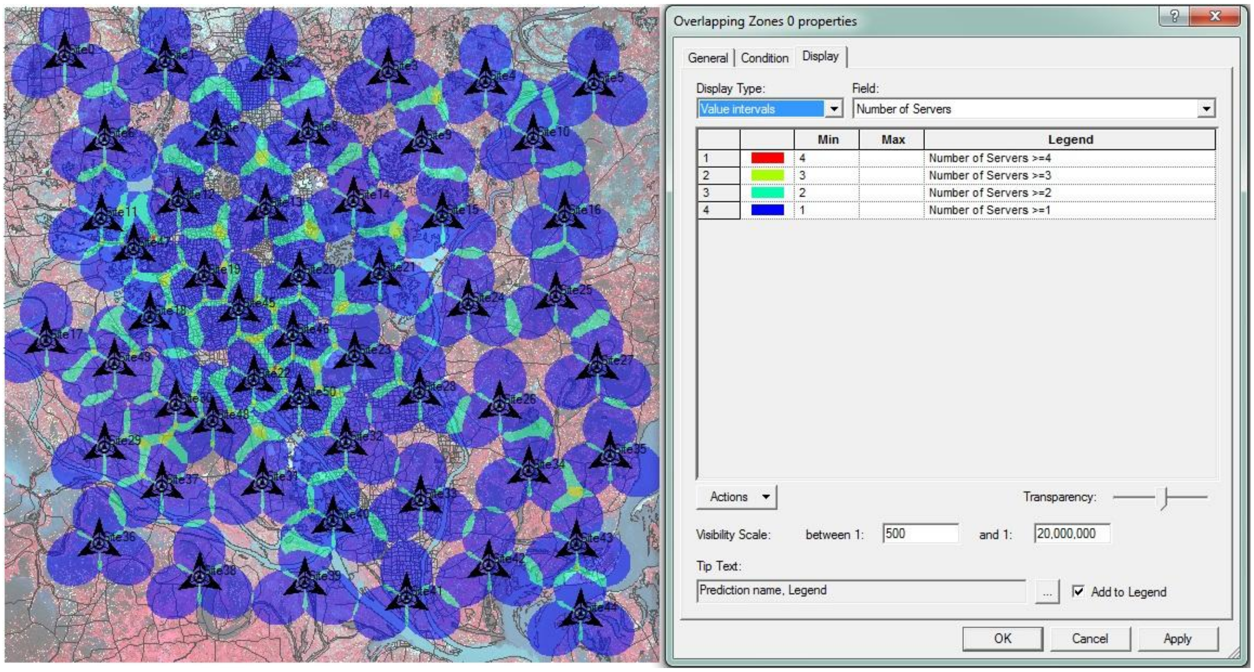


Figure 3.5: Coverage at overlapping zones

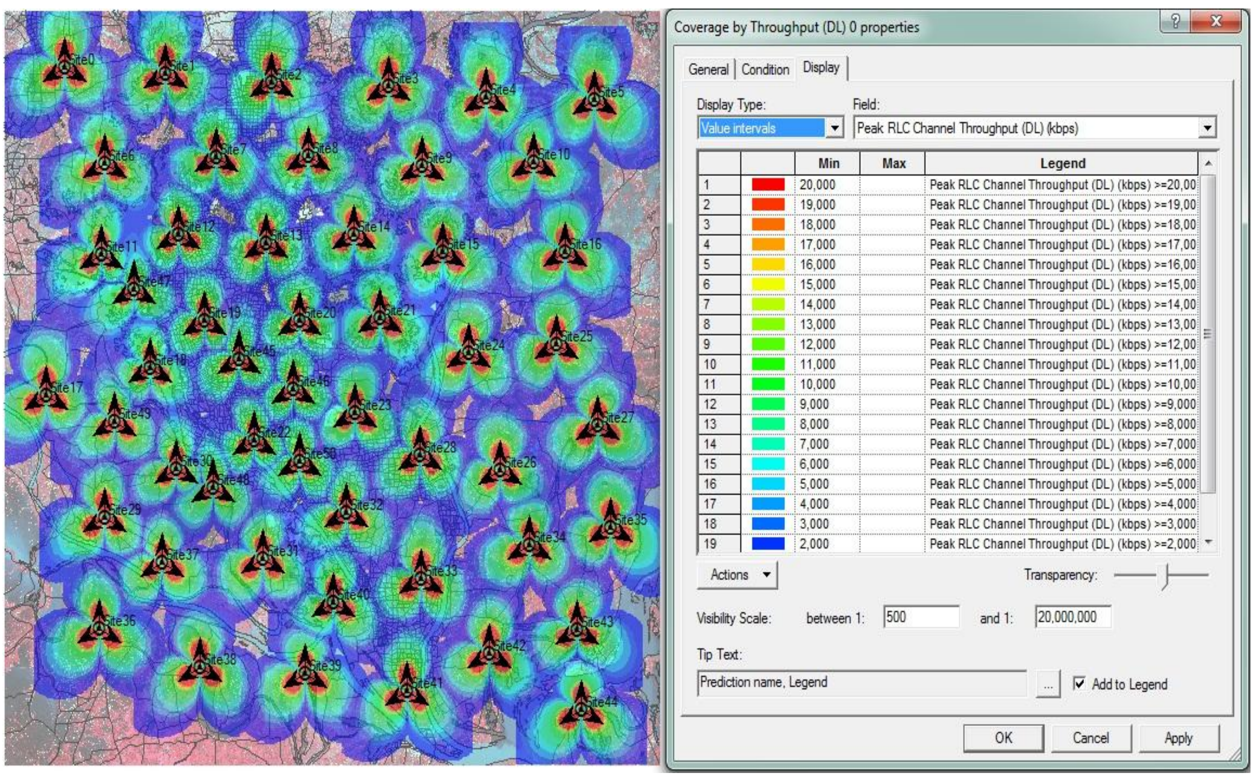


Fig 3.6: Coverage by Throughput DL

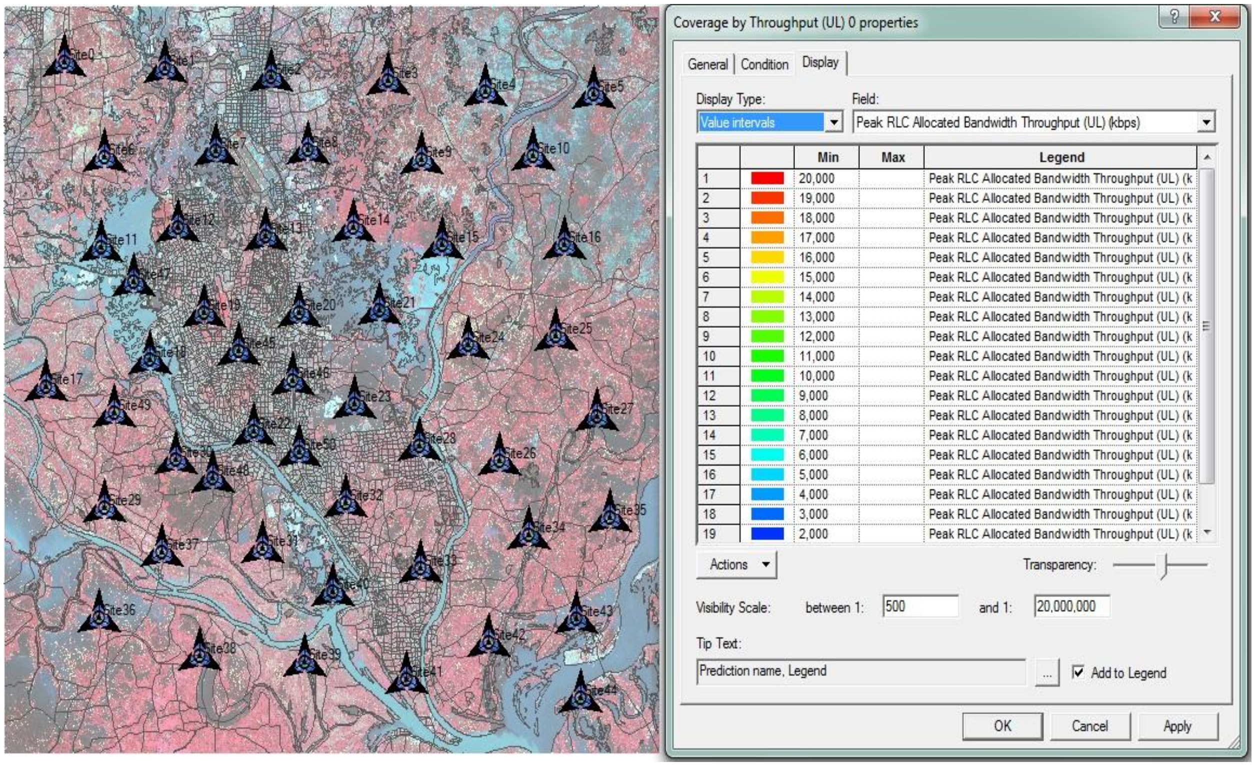


Fig 3.7: Coverage by Throughput UL

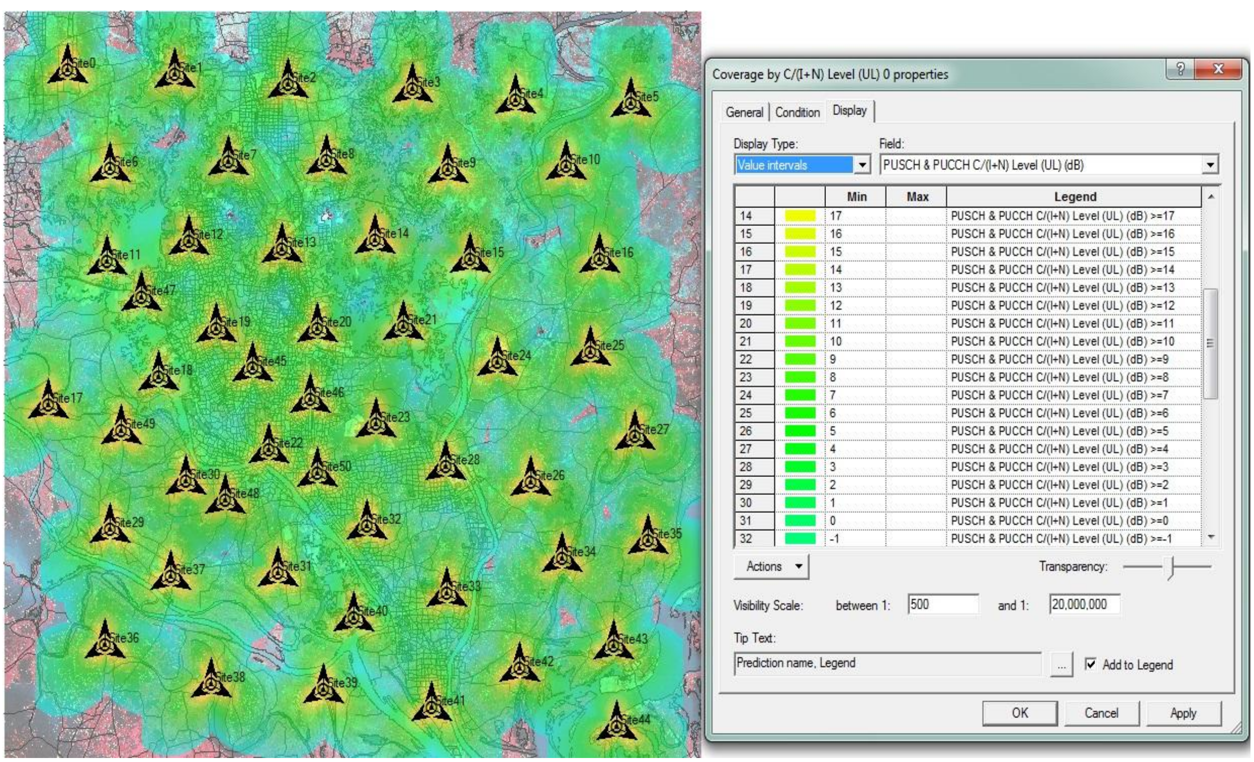


Fig 3.8: Coverage by Channel to Interference plus noise ratio UL

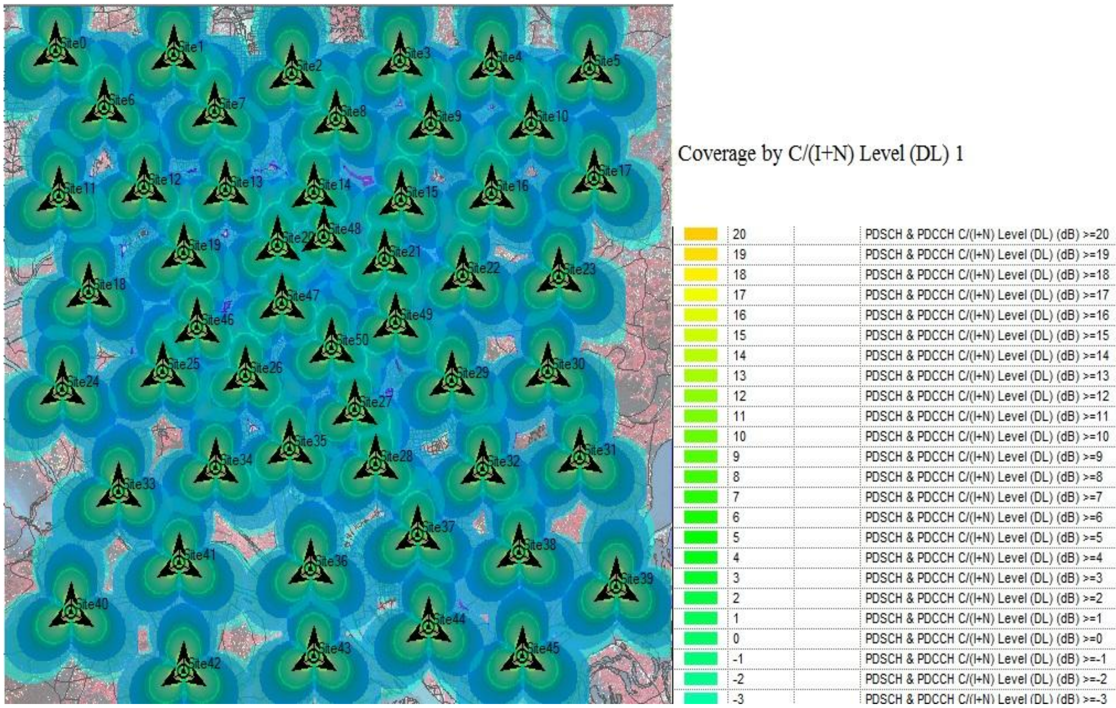


Fig 3.9: Coverage by Channel Over Interference Plus Noise Ratio (DL)

Dhaka Traffic Map simulations

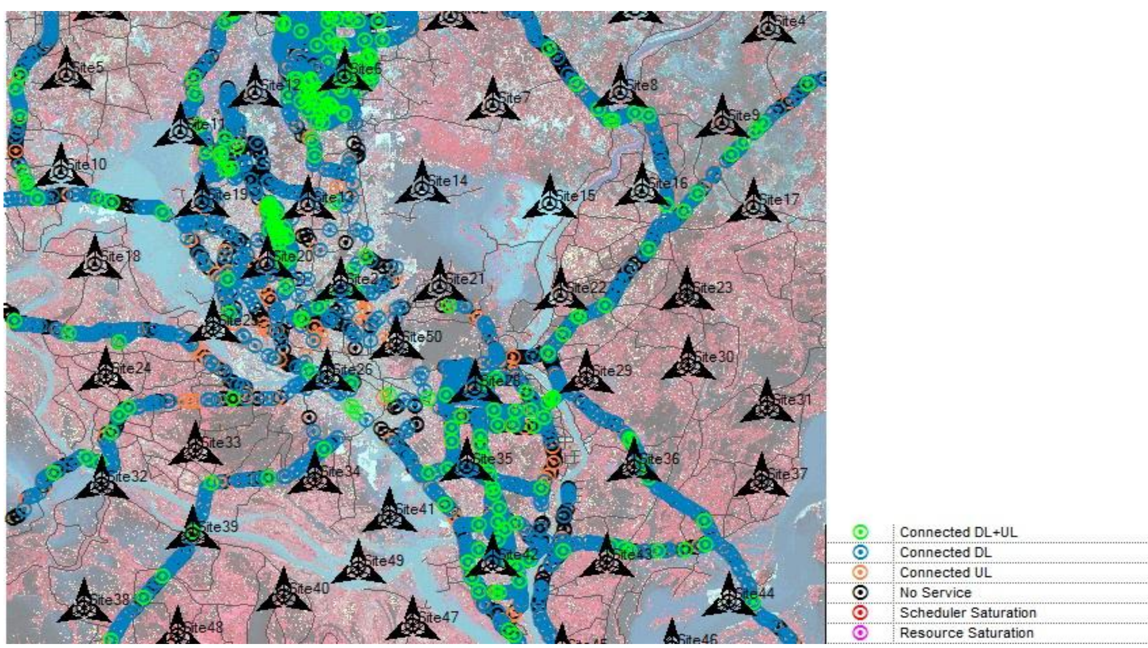


Fig 3.10: Dhaka Main road traffic Map after simulation

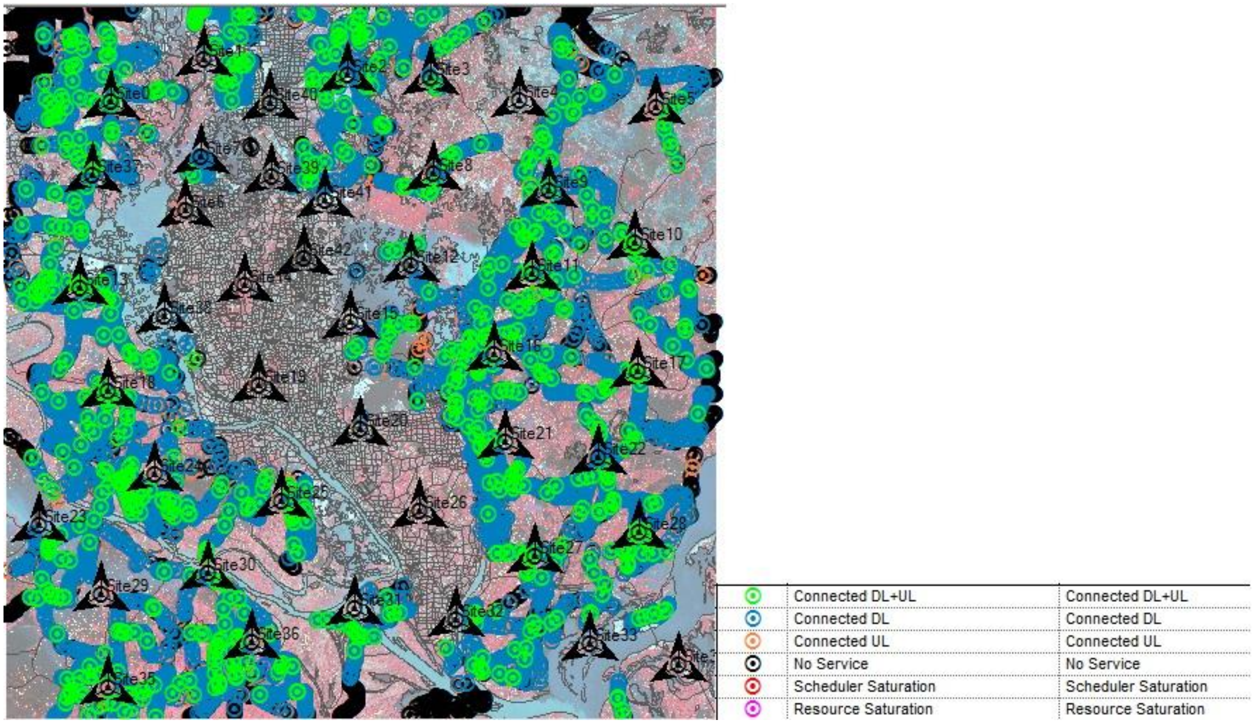


Fig 3.11: Dhaka secondary roads traffic Map after simulation

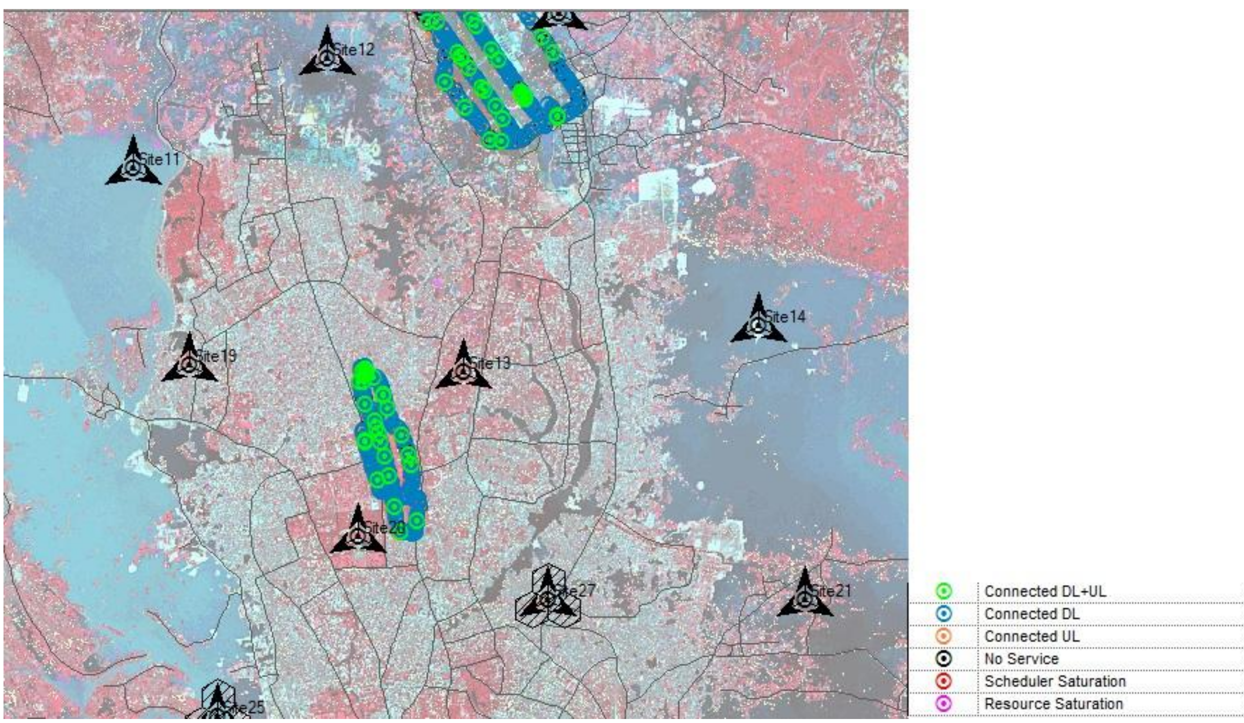


Fig 3.12: Dhaka Airport traffic Map after simulation

Point Analysis Tool

The Point Analysis Tool is used to find the signal received by a User Equipment (UE) at some position from the different Base station surrounding it.

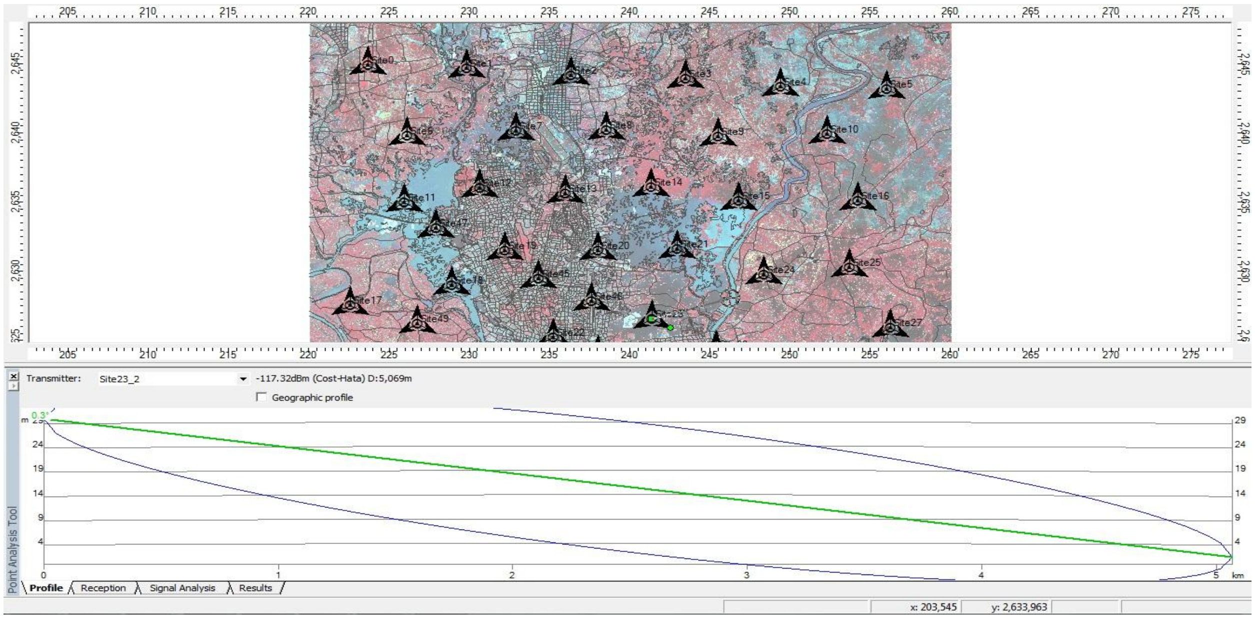


Fig 3.13: Point Analysis Tool position and Profile

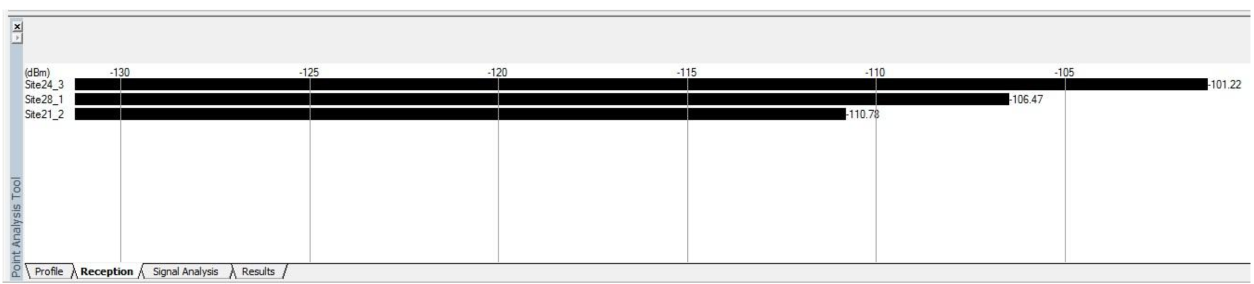
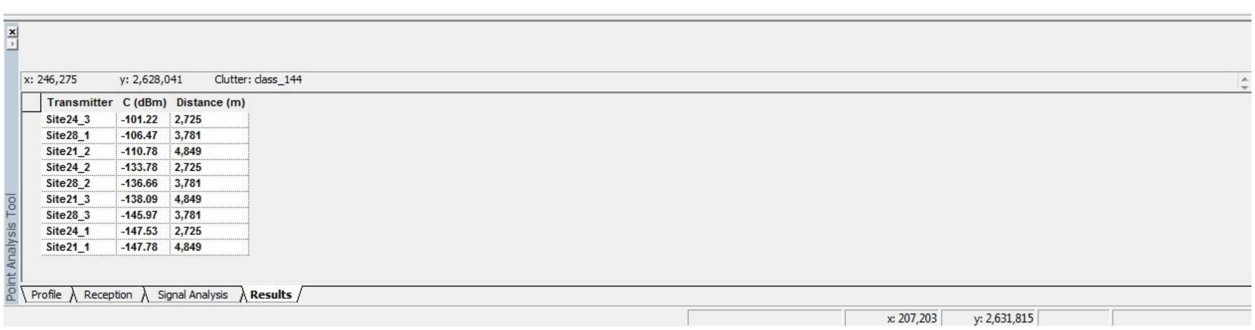


Fig 3.14: Point Analysis Tool received signal



Transmitter	C (dBm)	Distance (m)
Site24_3	-101.22	2,725
Site28_1	-106.47	3,781
Site21_2	-110.78	4,849
Site24_2	-133.78	2,725
Site28_2	-136.66	3,781
Site21_3	-138.09	4,849
Site28_3	-145.97	3,781
Site24_1	-147.53	2,725
Site21_1	-147.78	4,849

Fig 3.15: Point Analysis Tool results

Mumbai

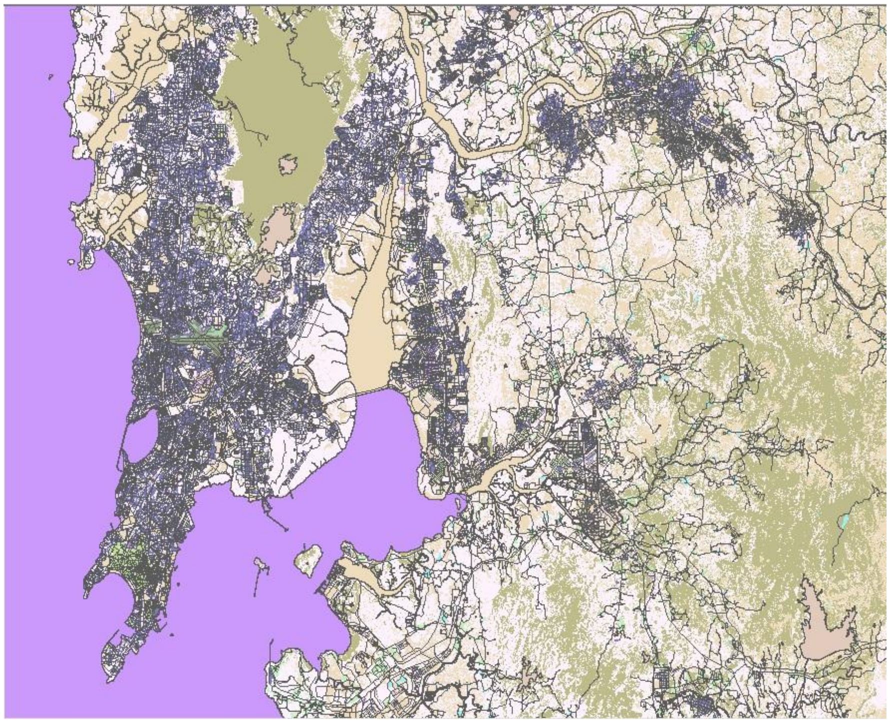


Fig 3.16: Mumbai Digital Map

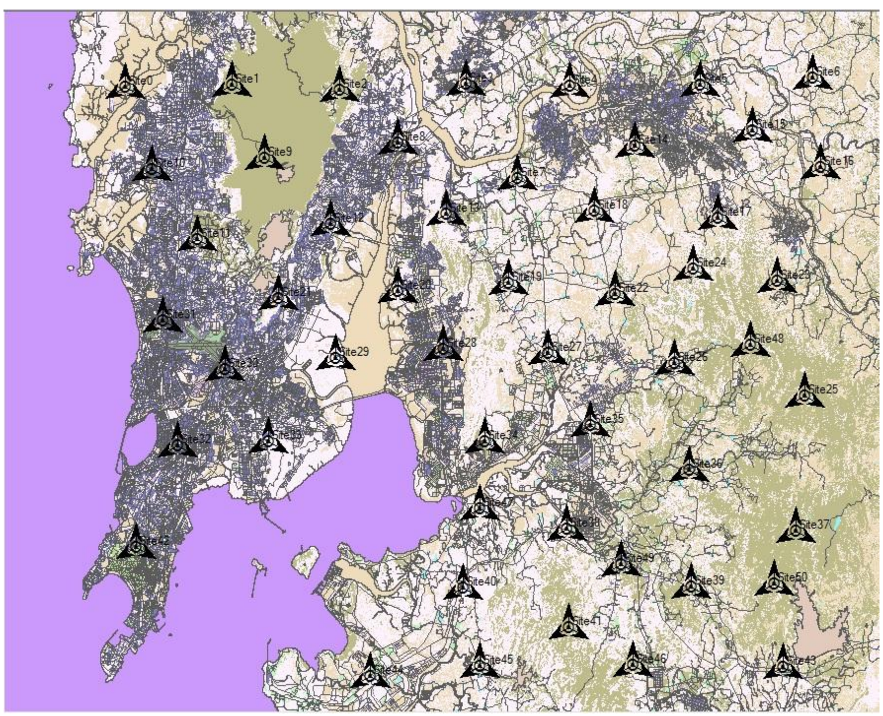


Fig 3.17: Transmitters placed on Mumbai map

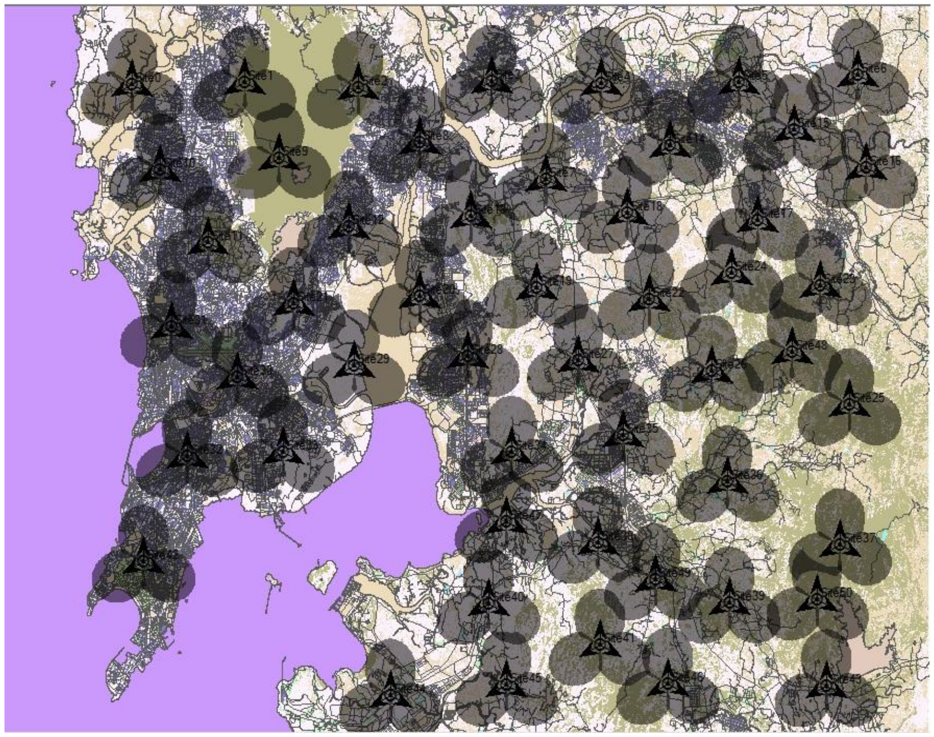


Fig 3.18: Coverage prediction by transmitters

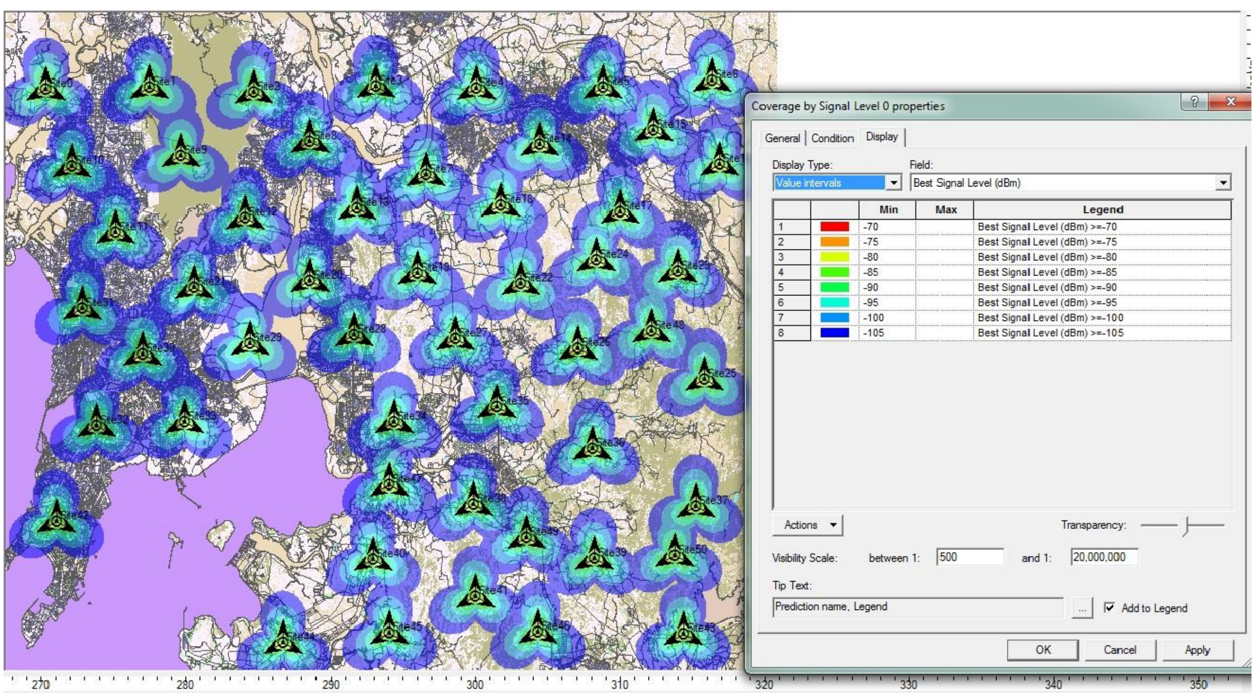


Fig 3.19: Coverage prediction by signal level

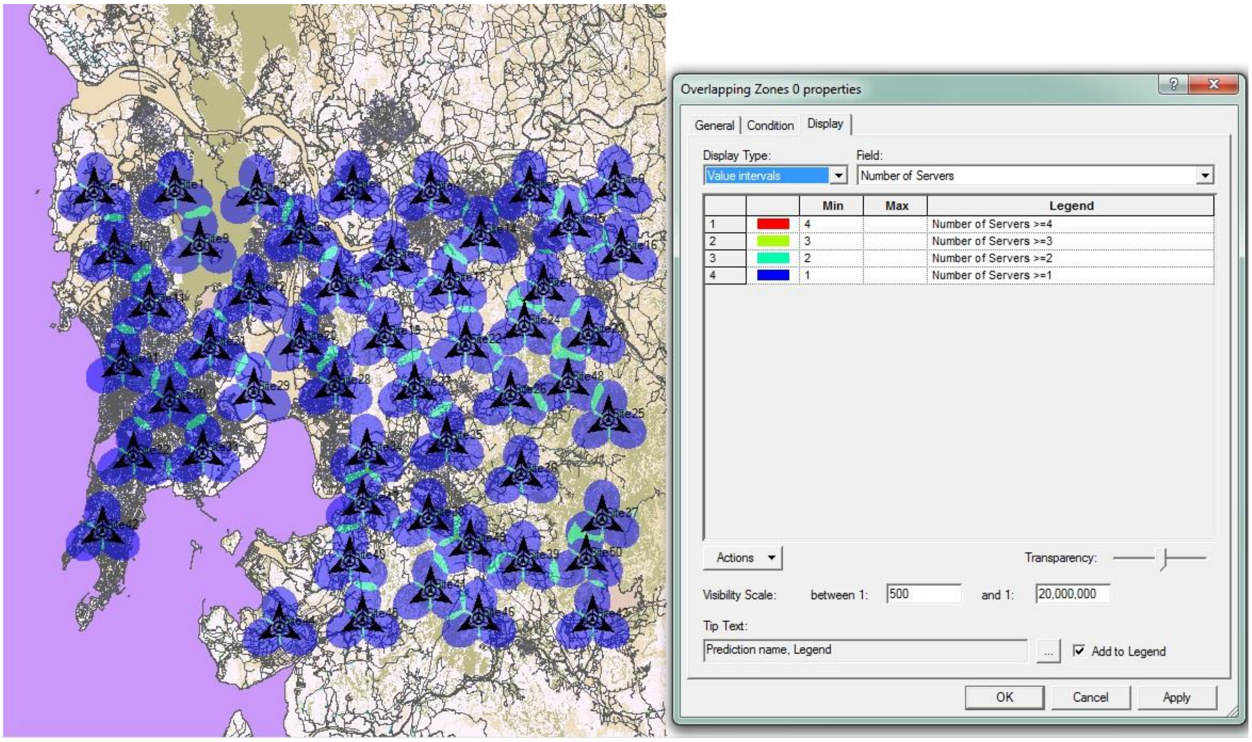


Fig 3.20: Coverage prediction by overlapping zones

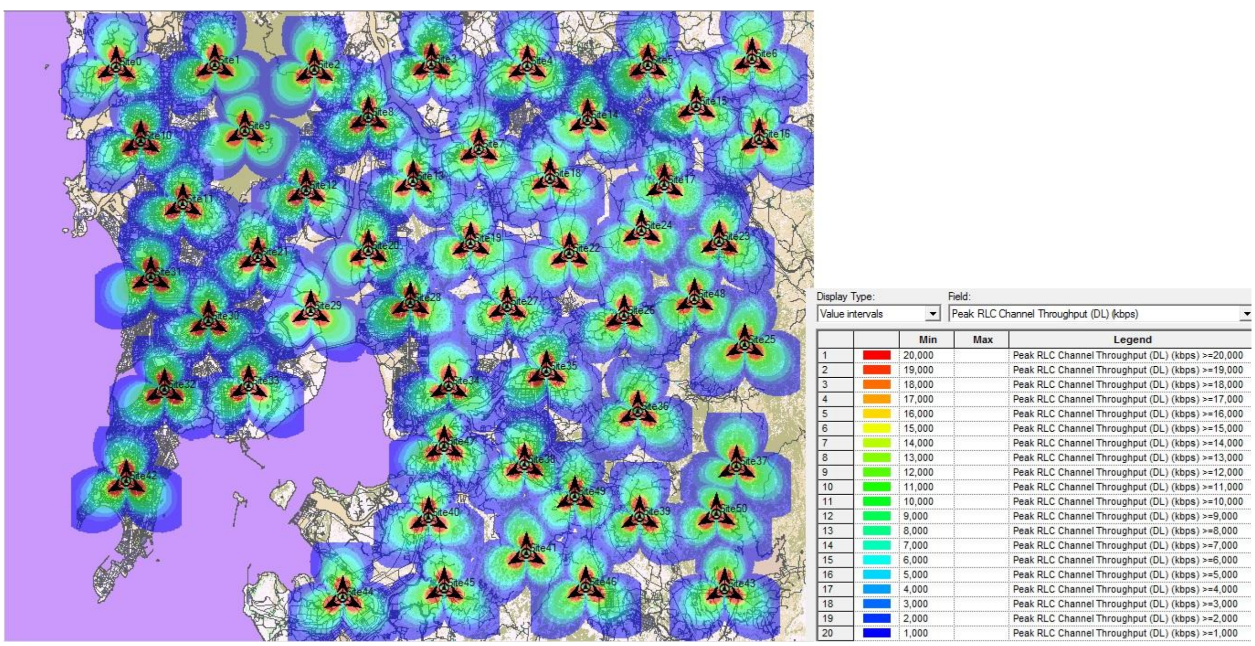


Fig 3.21: Coverage prediction by throughput DL

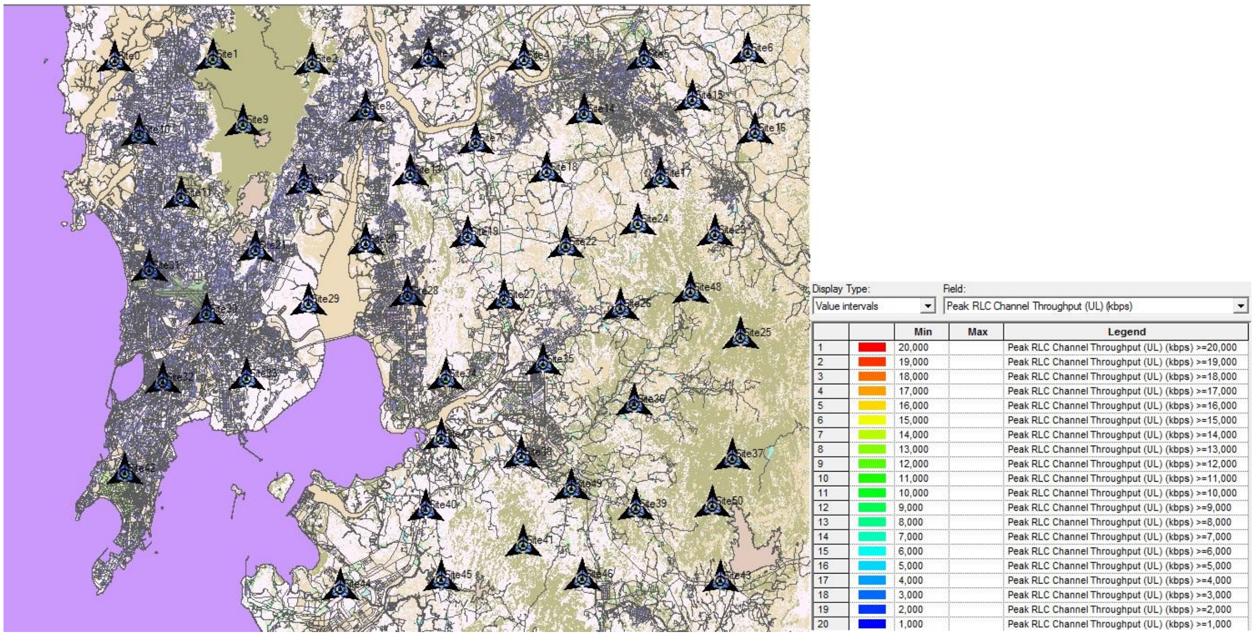


Fig 3.22: Coverage prediction by throughput UL

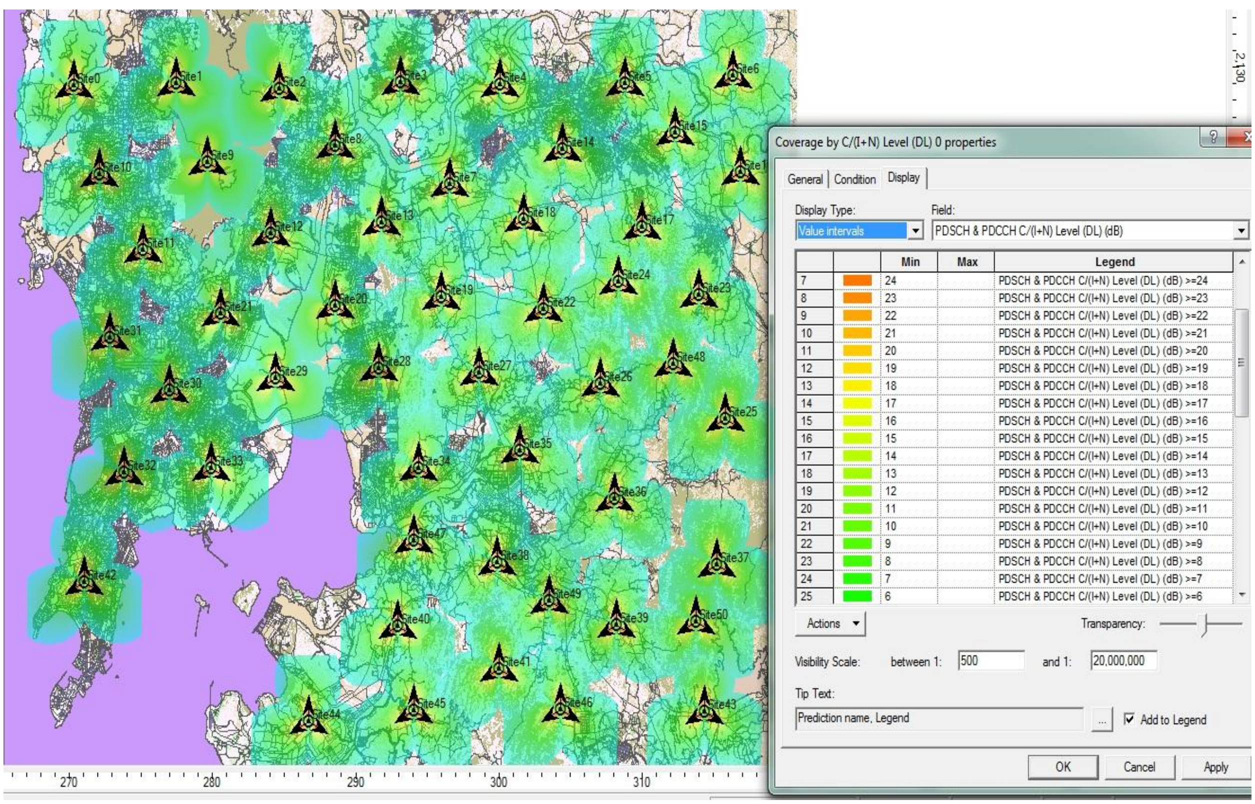


Fig 3.23: Coverage by channel over interference plus noise ratio (DL)

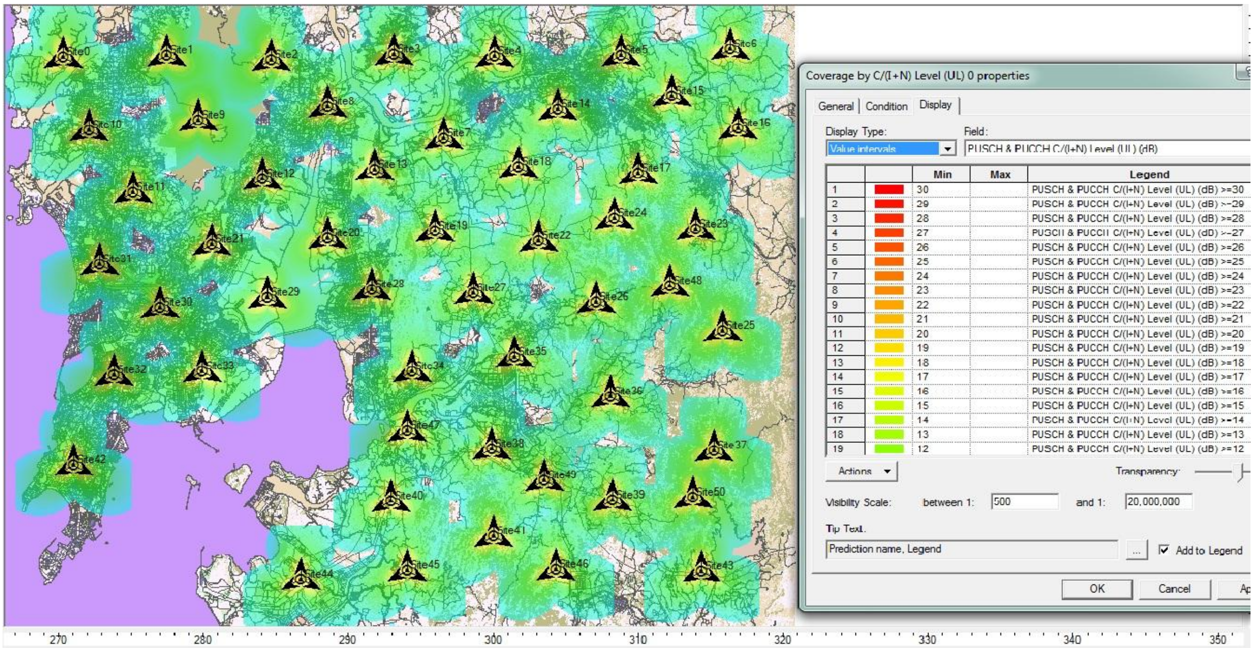


Fig 3.24: Coverage by channel over interference plus noise ratio (UL)

Mumbai traffic map simulations

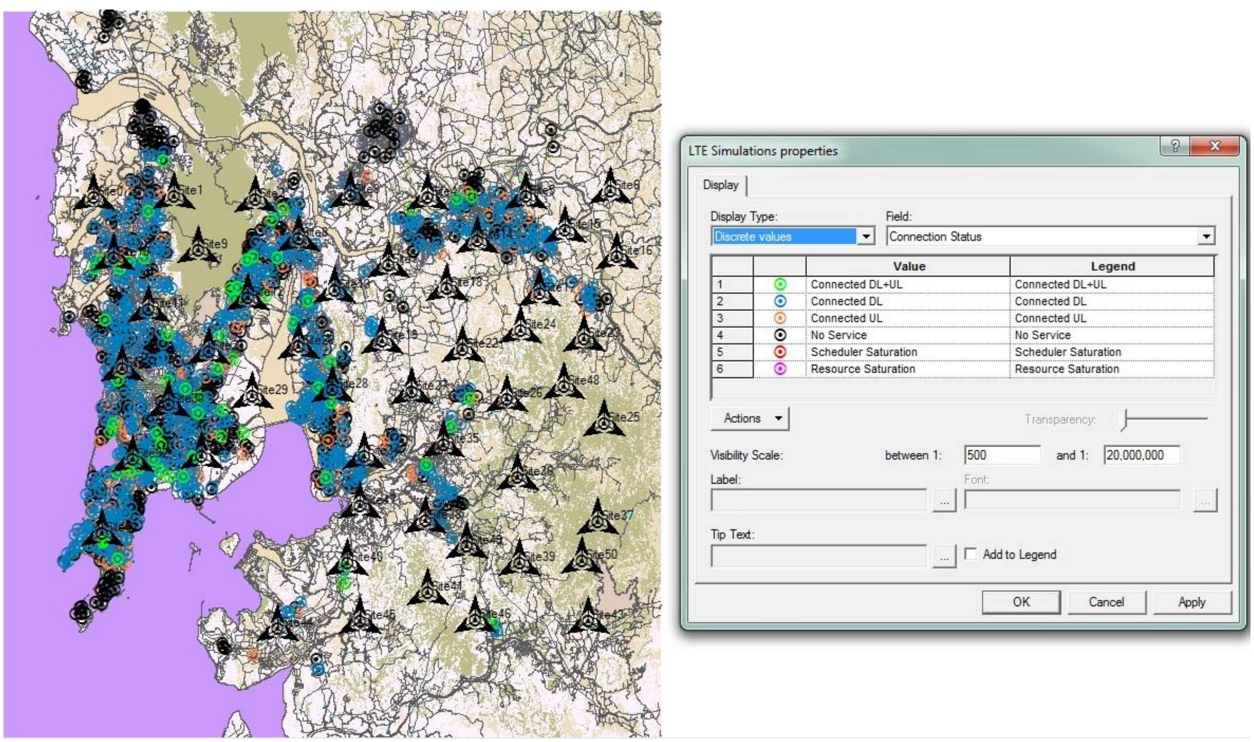


Fig 3.25: Mumbai streets after simulation

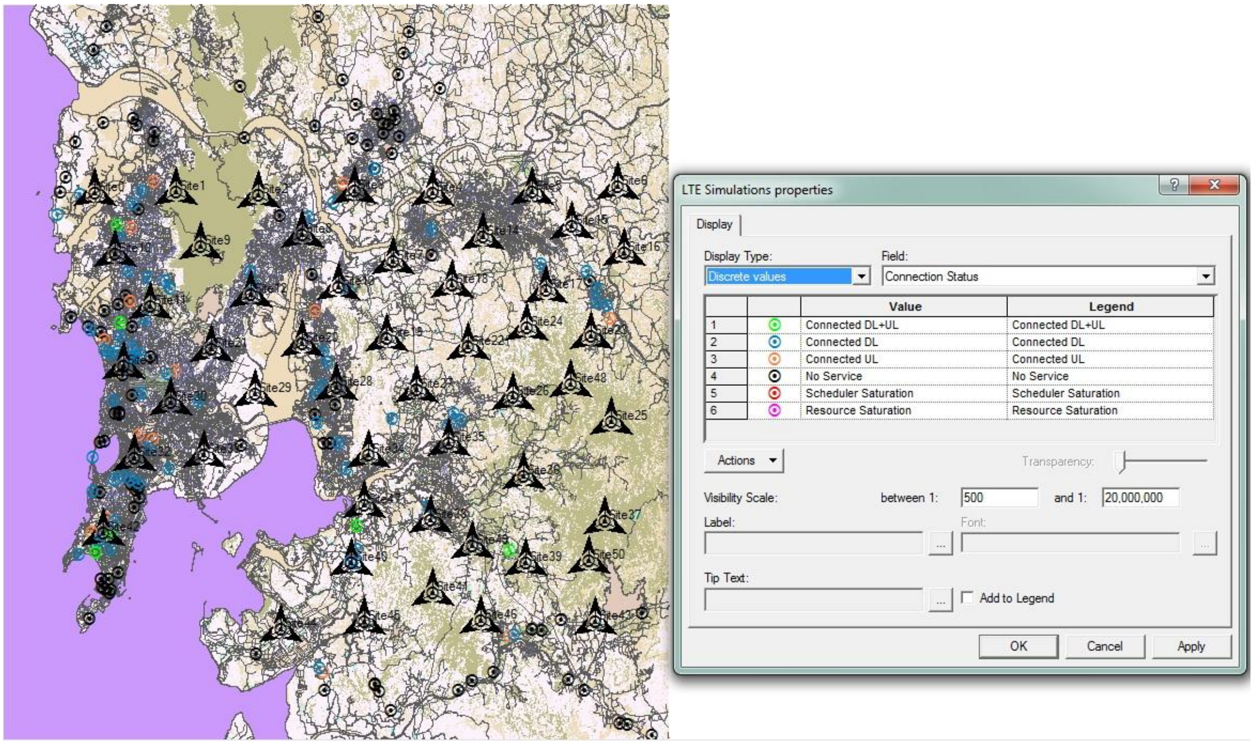


Fig 3.26: Mumbai main roads after simulation

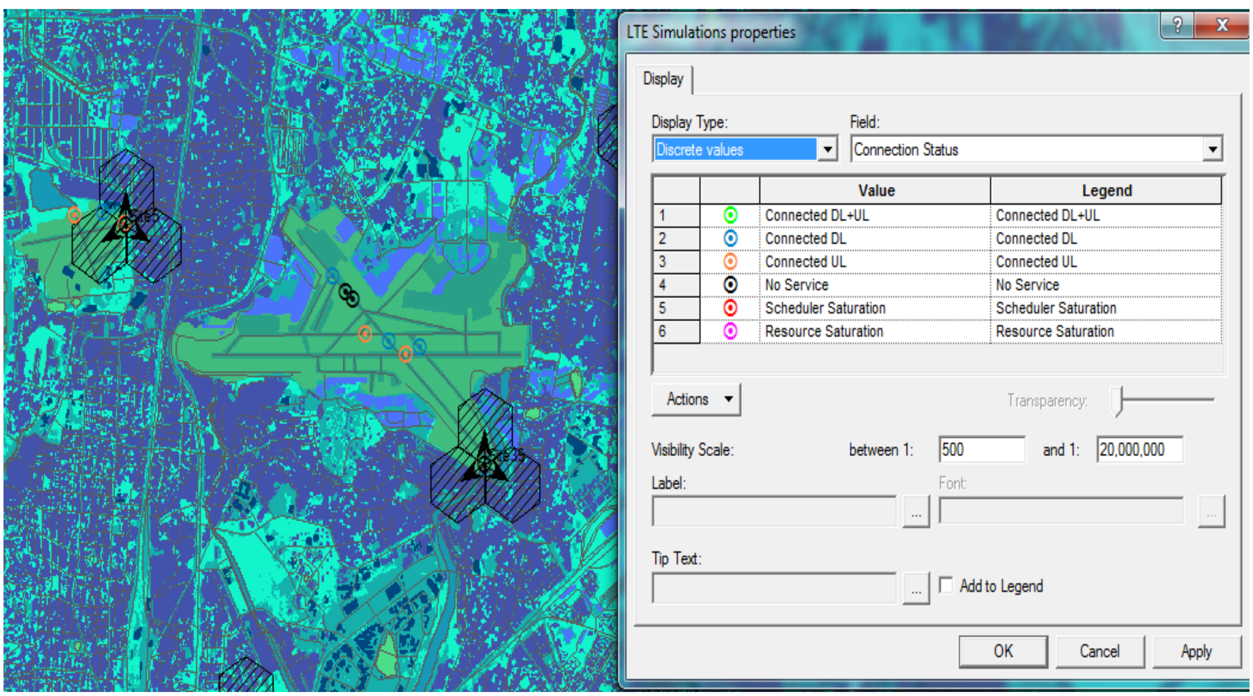


Fig 3.27: Mumbai airport after simulation

Point Analysis Tool

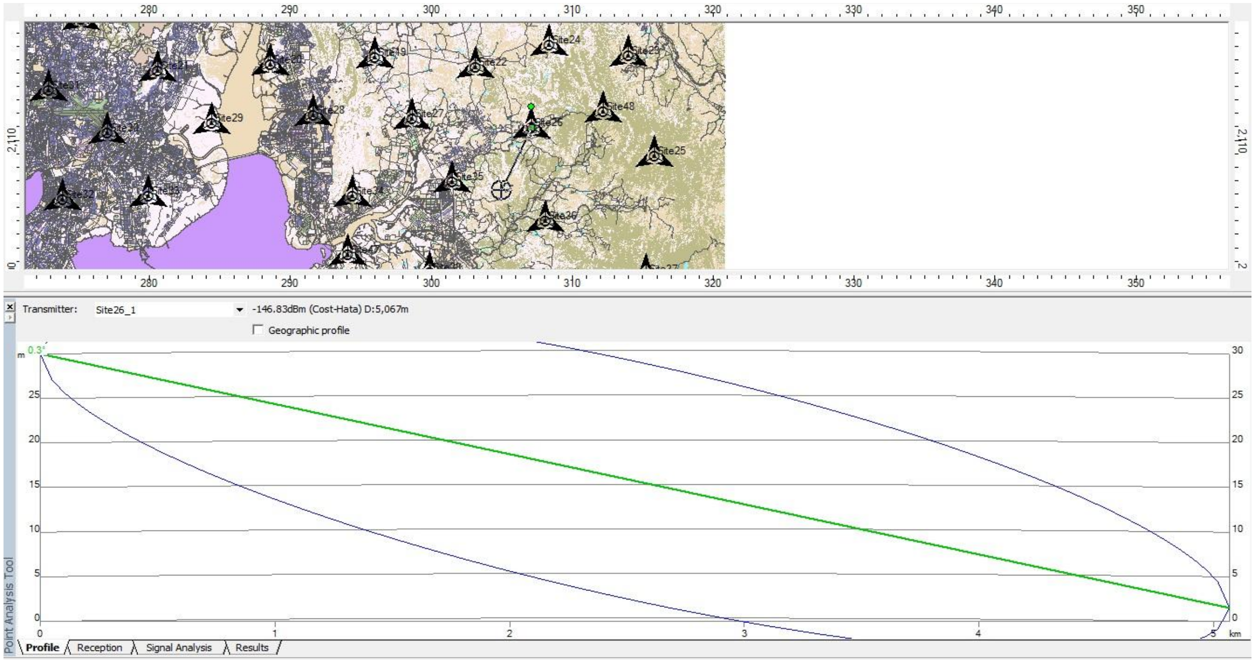


Fig 3.28: Point Analysis Tool position and Profile on Mumbai map

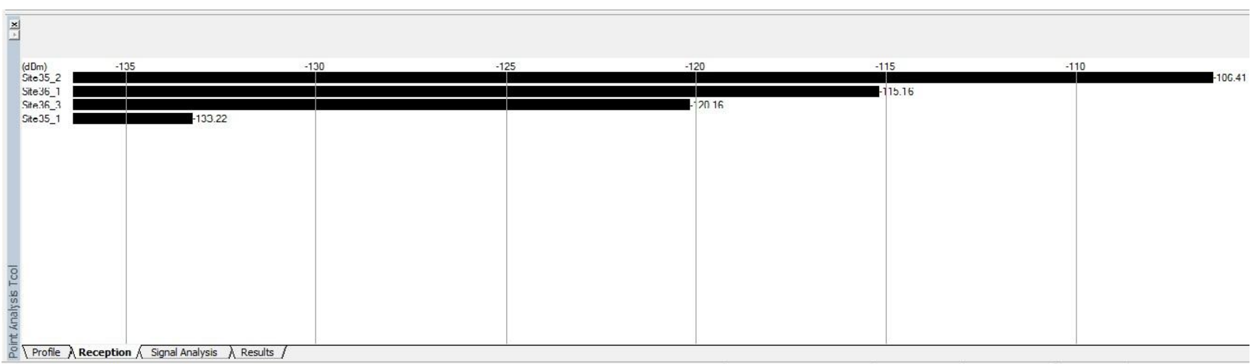


Fig 3.29: Point Analysis Tool received signal

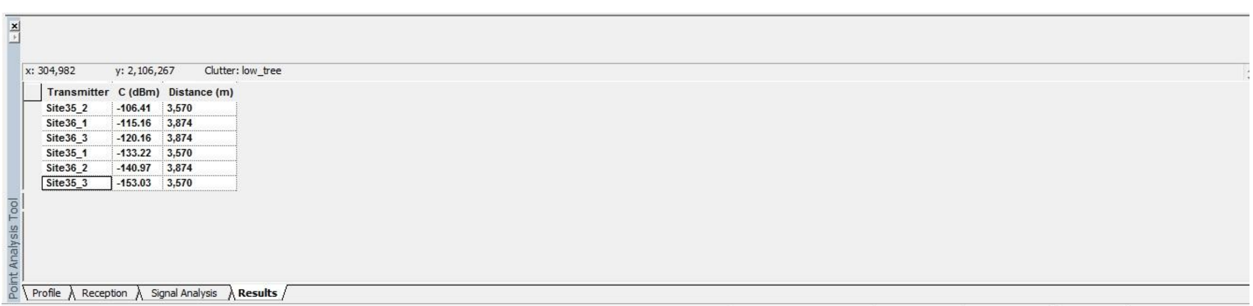
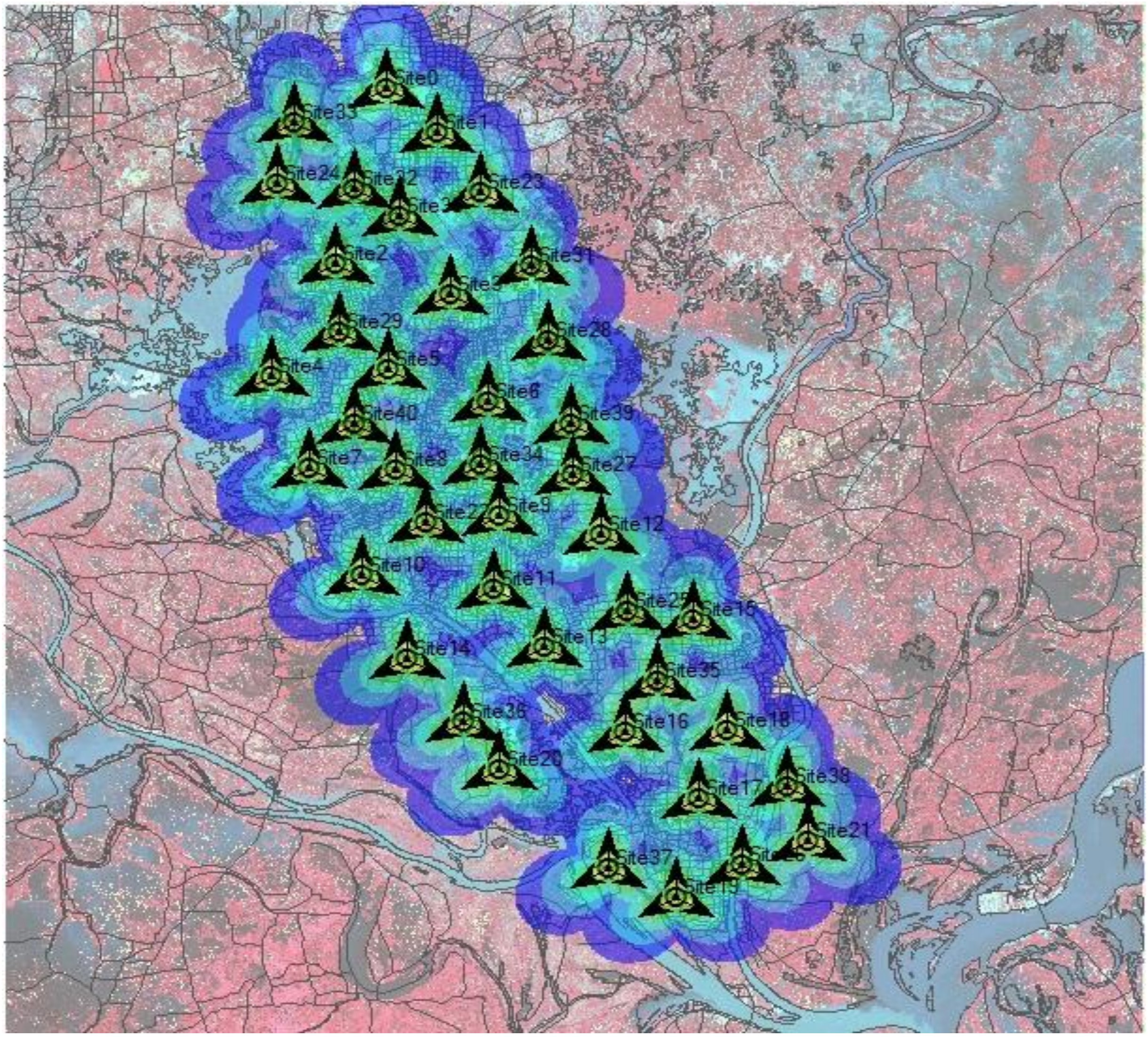


Fig 3.30: Point Analysis Tool results

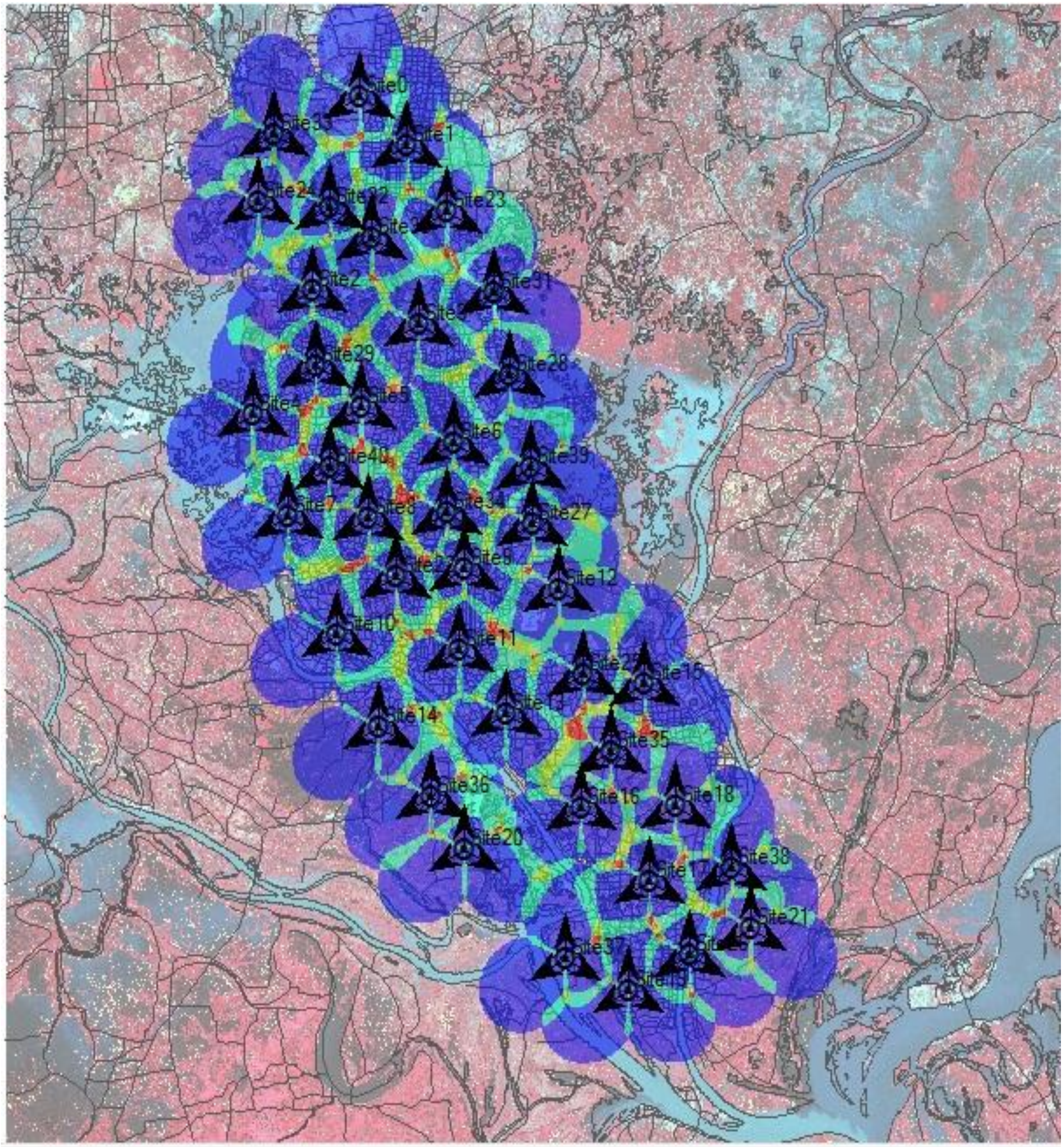
Furthermore we proceeded by reassigning the base stations new positions to cover densely populated areas, in so doing the homogeneity of cells are maintained. The simulation results are as follows.

DHAKA



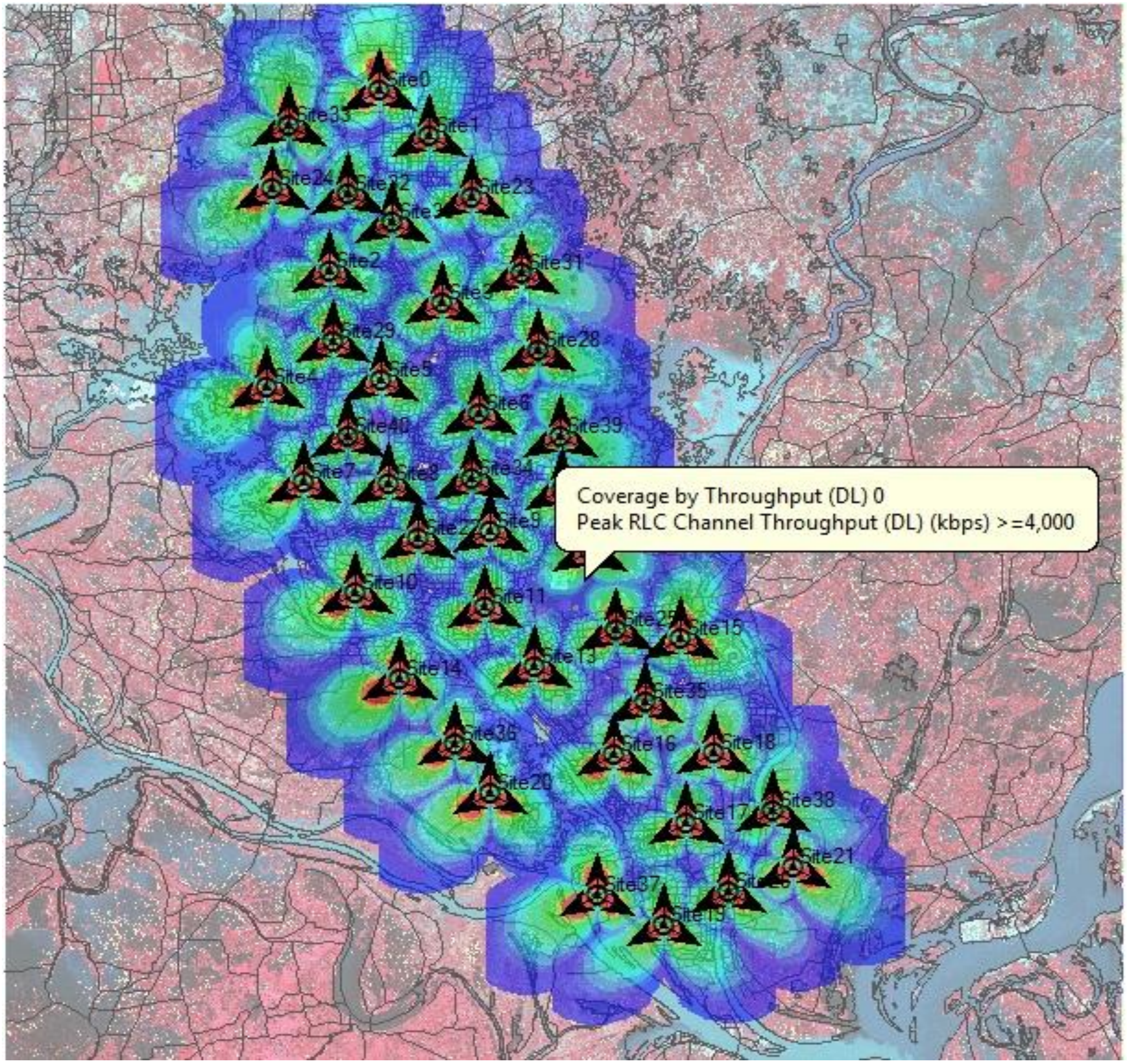
	-70		Best Signal Level (dBm) >=-70
	-75		Best Signal Level (dBm) >=-75
	-80		Best Signal Level (dBm) >=-80
	-85		Best Signal Level (dBm) >=-85
	-90		Best Signal Level (dBm) >=-90
	-95		Best Signal Level (dBm) >=-95
	-100		Best Signal Level (dBm) >=-100
	-105		Best Signal Level (dBm) >=-105

Fig 3.31: Coverage by signal level after new positioning of Base Station (BS)



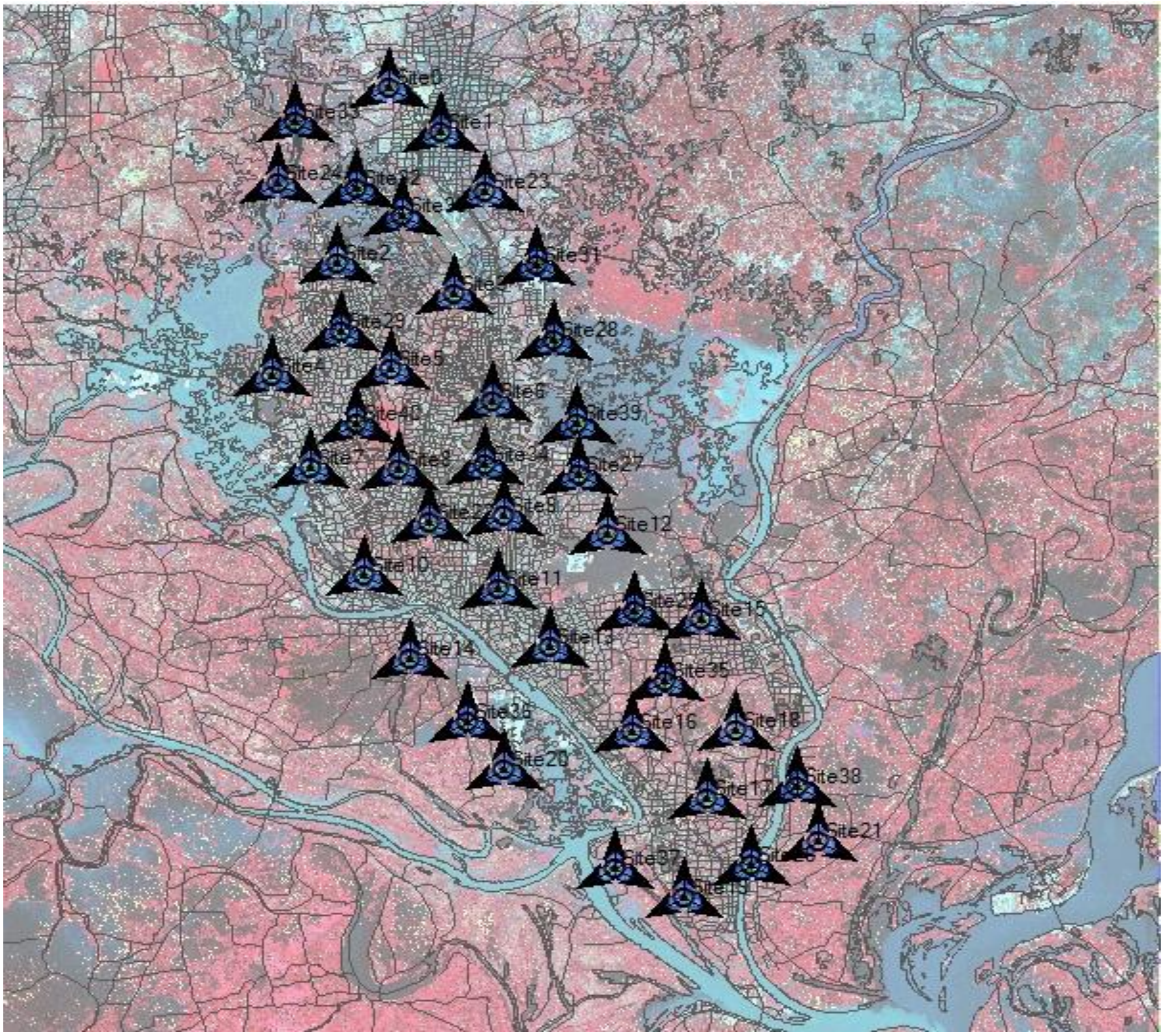
	4		Number of Servers >=4
	3		Number of Servers >=3
	2		Number of Servers >=2
	1		Number of Servers >=1

Fig 3.32: Coverage at overlapping zones after new positioning of BS



	20,000		Effective RLC Cell Capacity (DL) (kbps) >=20,000
	19,000		Effective RLC Cell Capacity (DL) (kbps) >=19,000
	18,000		Effective RLC Cell Capacity (DL) (kbps) >=18,000
	17,000		Effective RLC Cell Capacity (DL) (kbps) >=17,000
	16,000		Effective RLC Cell Capacity (DL) (kbps) >=16,000
	15,000		Effective RLC Cell Capacity (DL) (kbps) >=15,000
	14,000		Effective RLC Cell Capacity (DL) (kbps) >=14,000
	13,000		Effective RLC Cell Capacity (DL) (kbps) >=13,000
	12,000		Effective RLC Cell Capacity (DL) (kbps) >=12,000
	11,000		Effective RLC Cell Capacity (DL) (kbps) >=11,000
	10,000		Effective RLC Cell Capacity (DL) (kbps) >=10,000
	9,000		Effective RLC Cell Capacity (DL) (kbps) >=9,000
	8,000		Effective RLC Cell Capacity (DL) (kbps) >=8,000
	7,000		Effective RLC Cell Capacity (DL) (kbps) >=7,000
	6,000		Effective RLC Cell Capacity (DL) (kbps) >=6,000
	5,000		Effective RLC Cell Capacity (DL) (kbps) >=5,000
	4,000		Effective RLC Cell Capacity (DL) (kbps) >=4,000
	3,000		Effective RLC Cell Capacity (DL) (kbps) >=3,000
	2,000		Effective RLC Cell Capacity (DL) (kbps) >=2,000
	1,000		Effective RLC Cell Capacity (DL) (kbps) >=1,000

Fig 3.33: Coverage by throughput DL after new positioning of BS



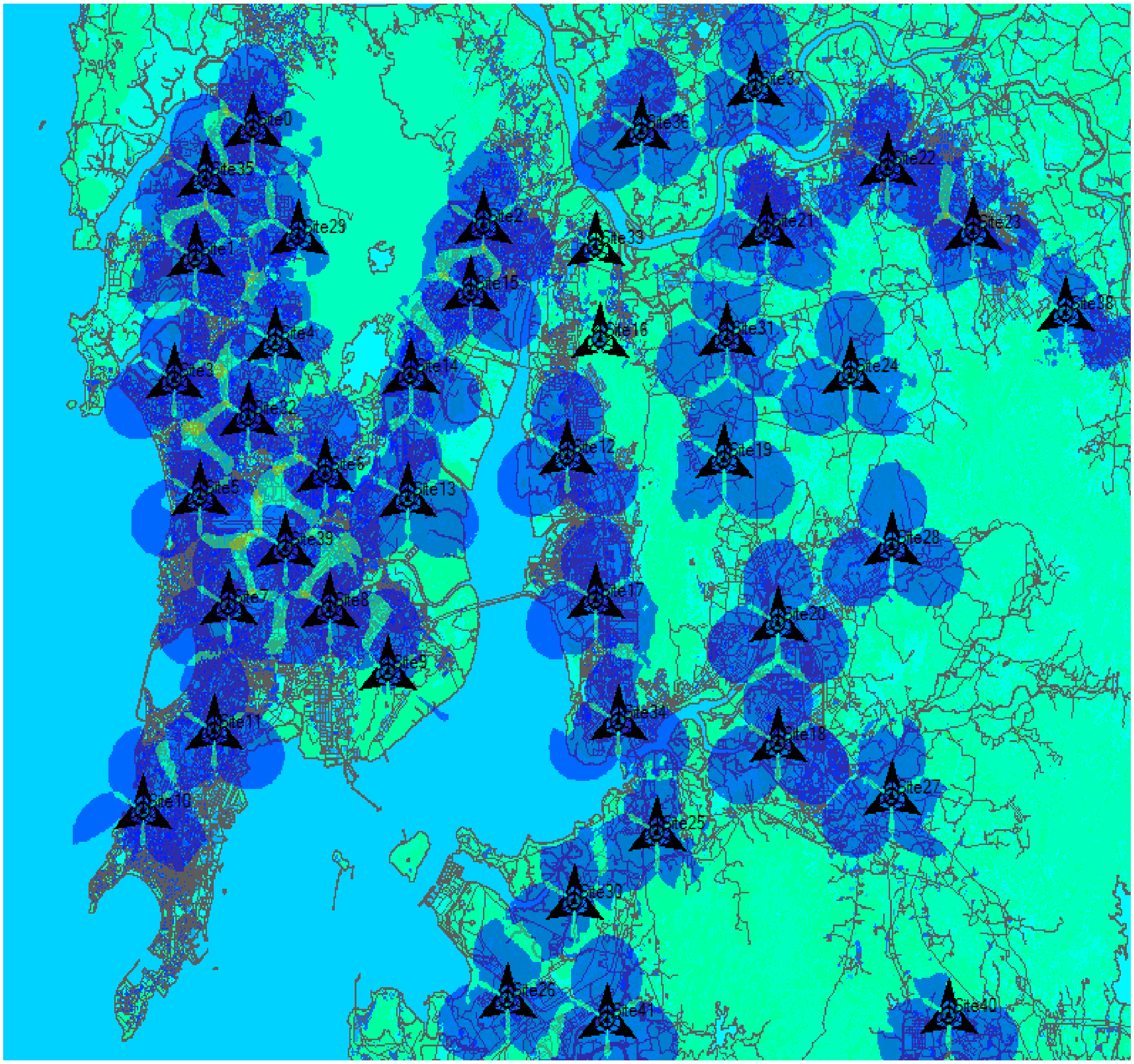
	20,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=20,000
	19,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=19,000
	18,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=18,000
	17,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=17,000
	16,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=16,000
	15,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=15,000
	14,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=14,000
	13,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=13,000
	12,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=12,000
	11,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=11,000
	10,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=10,000
	9,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=9,000
	8,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=8,000
	7,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=7,000
	6,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=6,000
	5,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=5,000
	4,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=4,000
	3,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=3,000
	2,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=2,000
	1,000		Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=1,000

Fig 3.34: Coverage by throughput UL after new positioning of BS

MUMBAI

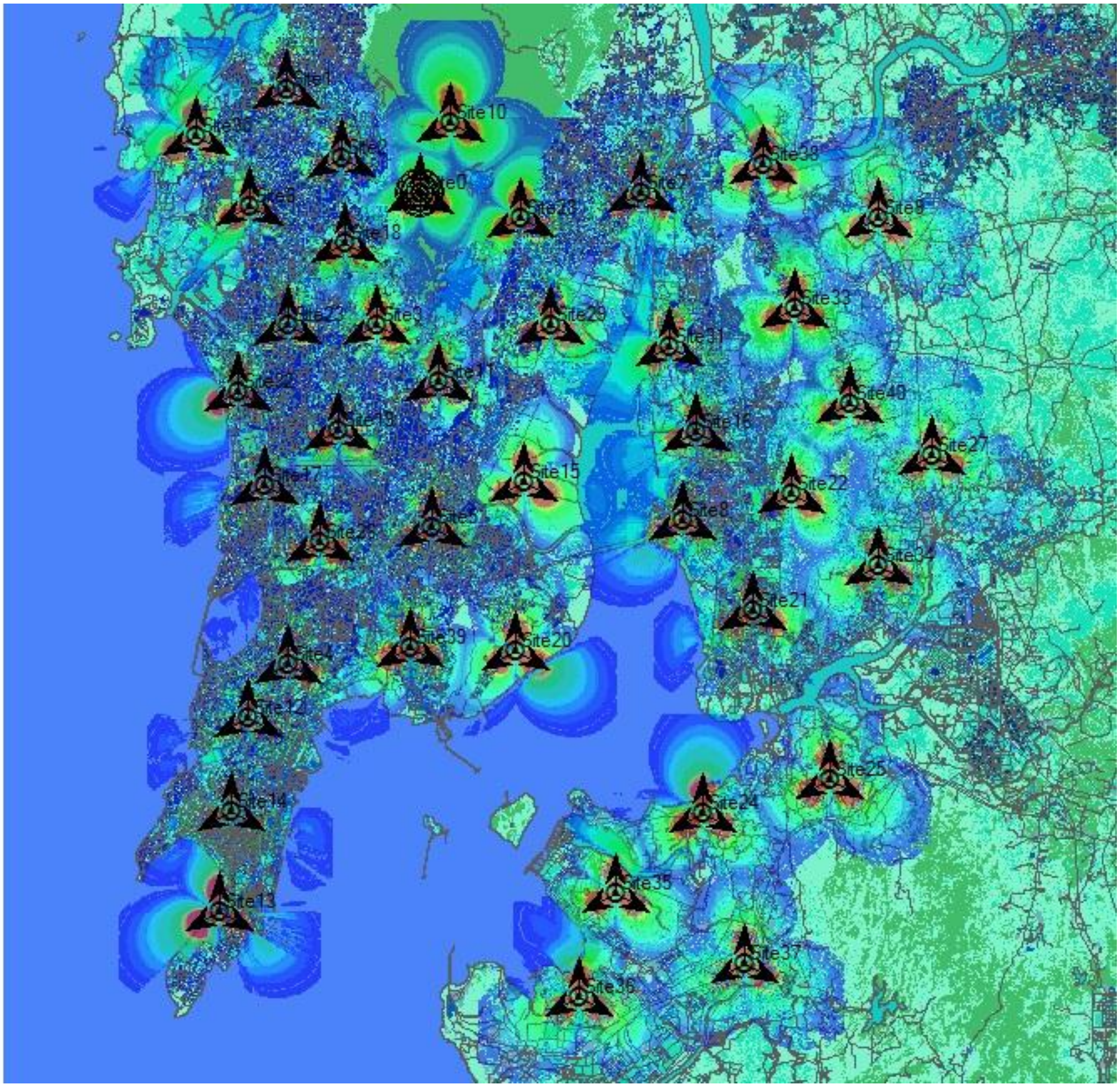
	-70		Best Signal Level (dBm) >=-70
	-75		Best Signal Level (dBm) >=-75
	-80		Best Signal Level (dBm) >=-80
	-85		Best Signal Level (dBm) >=-85
	-90		Best Signal Level (dBm) >=-90
	-95		Best Signal Level (dBm) >=-95
	-100		Best Signal Level (dBm) >=-100
	-105		Best Signal Level (dBm) >=-105

Fig 3.35: Coverage by signal level after new positioning of Base Station (BS)



	4		Number of Servers >=4
	3		Number of Servers >=3
	2		Number of Servers >=2
	1		Number of Servers >=1

Fig 3.36: Coverage at overlapping zones after new positioning of Base Station (BS)



	20,000	Effective RLC Cell Capacity (DL) (kbps) >=20,000
	19,000	Effective RLC Cell Capacity (DL) (kbps) >=19,000
	18,000	Effective RLC Cell Capacity (DL) (kbps) >=18,000
	17,000	Effective RLC Cell Capacity (DL) (kbps) >=17,000
	16,000	Effective RLC Cell Capacity (DL) (kbps) >=16,000
	15,000	Effective RLC Cell Capacity (DL) (kbps) >=15,000
	14,000	Effective RLC Cell Capacity (DL) (kbps) >=14,000
	13,000	Effective RLC Cell Capacity (DL) (kbps) >=13,000
	12,000	Effective RLC Cell Capacity (DL) (kbps) >=12,000
	11,000	Effective RLC Cell Capacity (DL) (kbps) >=11,000
	10,000	Effective RLC Cell Capacity (DL) (kbps) >=10,000
	9,000	Effective RLC Cell Capacity (DL) (kbps) >=9,000
	8,000	Effective RLC Cell Capacity (DL) (kbps) >=8,000
	7,000	Effective RLC Cell Capacity (DL) (kbps) >=7,000
	6,000	Effective RLC Cell Capacity (DL) (kbps) >=6,000
	5,000	Effective RLC Cell Capacity (DL) (kbps) >=5,000
	4,000	Effective RLC Cell Capacity (DL) (kbps) >=4,000
	3,000	Effective RLC Cell Capacity (DL) (kbps) >=3,000
	2,000	Effective RLC Cell Capacity (DL) (kbps) >=2,000
	1,000	Effective RLC Cell Capacity (DL) (kbps) >=1,000

Fig 3.37: Coverage by throughput DL after new positioning of Base Station (BS)

	20,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=20,000
	19,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=19,000
	18,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=18,000
	17,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=17,000
	16,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=16,000
	15,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=15,000
	14,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=14,000
	13,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=13,000
	12,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=12,000
	11,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=11,000
	10,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=10,000
	9,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=9,000
	8,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=8,000
	7,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=7,000
	6,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=6,000
	5,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=5,000
	4,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=4,000
	3,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=3,000
	2,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=2,000
	1,000	Peak RLC Allocated Bandwidth Throughput (UL) (kbps) >=1,000

Fig 3.38: Coverage by throughput UL after new positioning of Base Station (BS)

Chapter 4

Conclusion and Future Work

4.1 Conclusion

The main objective of thesis was to set up an LTE radio Network in Dhaka and Mumbai city and to analyze their performance as wireless networks. The target capacity and coverage values obtained were attempted in the simulations performed in the Atoll planning tool using Dhaka and Mumbai city as a case study for the LTE radio network planning.

In the results obtained the total path loss in dBm ranges from 140 to 174 gotten from Okumura model path loss which is more suitable in urban areas therefore being a good model in Mumbai simulation. Against each base station site on the legend is a numerical path loss value due to different to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas. Furthermore, the acceptable loss at every kilometer distanced travelled by the signal is 140-150 dbl which in our simulation there is a slight deviation on values but with a greater margin of amelioration.

In case of transmission power, 21dBm at 125mW Maximum output from a UMTS/3G mobile phone (Power class 4 mobiles) and 24dBm at 25mW Maximum output from a UMTS/3G mobile phone (Power class 3 mobiles).Now depending on the UE and comparatively to the appropriate level of dBm supplied by the designed base stations placed on Mumbai Map there is a constant power transmission supply.

4.2 Future work

This project opens several lines for further long-term investigation as for example, evaluating the current scenarios for special types of data like, voice and video.

Introduce system level simulator (SLS) and link level simulators (LLS)

SLS allows large scale network representation, a lot of macro cells and users, up to a hundred UEs attached per base stations, radio resource management algorithms, interference mitigation techniques, coverage estimation and more. This way it aims at evaluating the system performance in this large scale configuration through gathering various statistics for this purpose like throughput, interference, cell activity, outage probability, quality fairness among UEs and other traffic statistics.

LLS provides a means to test the performance of an LTE transmission on an uncorrelated PedB channel and flat Rayleigh channel for several transmission modes.

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APPENDIX

Atoll

Atoll is an open, scalable, and flexible multi-technology network design and Optimization platform that supports wireless operators throughout the network lifecycle, from initial design to densification and optimization. Atoll supports the following technologies

- GSM/GPRS/EDGE
- UMTS/HSPA
- CDMA2000 1xRTT/EV-DO
- LTE
- TD-SCDMA
- WiMAX 802.16d
- WiMAX 802.16e
- Microwave Radio links

ATOLL GENERAL FEATURES

- MULTI TECHNOLOGY TOOL
  1. Dedicated Project Templates & Propagation Models for all supported technology
- USER FRIENDLY GUI
  1. Windows based tools
  2. Easy to export/ import all required data
  3. Simply support copy/paste all data
- FLEXIBILITY IN DATA MANAGEMENT
  1. Display, Sorts & Filter
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