Challenges in 5G Network Planning: Design and Optimization using Atoll

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A Thesis Submitted to the Academic Faculty in Partial Fulfillment of the Requirements for the Degree of

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Challenging 5G Network Planning, Designing and Optimization using ATOLL Radio Planning Tool

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Abstract

This thesis paper consists of some 5G technology features such as 3D Beamforming, Massive MIMO, mm wave transmission usage [1]. With the introduction to a new period of time the 5G technology of mobile communication helps us to have massive scale communication by connecting innumerable devices giving new alternatives to different sectors which ensures a reliable and services with very low latency to the users. To support all these features, these 5G noteworthy features are acknowledged using a network planning software, Atoll.

Atoll is a multi-technology wireless network design and optimization system that guides wireless operators through the entire network design process, from initial planning to densification and optimization. For the design and deployment of 5G networks, it supports the latest technological developments such as massive MIMO, 3D beamforming, and mm - wave propagation. This paper also contains network planning and optimization of a sample area of Uttara using Atoll. The number of base stations required for an optimal communication was observed and set accordingly.

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Abbreviations & Acronyms

5G	Fifth Generation
DL	Downlink
DTM	Digital Terrain Model
eMBB	Enhanced Mobile Broadband
EPRE	Energy Per Resource Element
FDD	Frequency Division Duplex
GSM	Global System for Mobile communications
IMT-2020	International Mobile Telecommunications 2020
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union-Radio Communications Sector
LTE	Long-Term Evolution
MAC	Medium Access Control
MIMO	Multiple-Input Multiple-Output
mMTC	Massive Machine Type Communication
MU-MIMO	Multi-User MIMO
NB-IoT	Narrow-Band Internet-of-Things
NR	New Radio
OFDM	Orthogonal Frequency-Division Multiplexing
PBCH	Physical Broadcast Channel
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PDSCH	Physical Downlink Shared Channel
PHY	Physical Layer
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RB	Resource Block
RLC	Radio Link Control
SISO	Single-Input Single-Output
SNR	Signal to Noise Ratio
SPM	Standard Propagation Model
SS	Synchronization Signal
SS-RSRP	SS Reference Signal Received Power
SU-MIMO	Single-User MIMO
TDD	Time Division Duplex
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication System
URLLC	Ultra-Reliable Low-Latency Communication

Chapter 1

1. Introduction

Mobile networking technology has been evolving over the last decades as the needs of consumers continue to evolve and new use scenarios are uncovered. Mobile network communication has started its journey with the introduction of first generation of mobile communications in 1980s [2] with analog voice then to over digital voice signals in the 1990s with second generation of mobile technology. 3G came in the early 2000s with new mobile broadband, which allowed easy cellular internet connectivity and made voice communications lesser of a priority. 4G came along with LTE [3][4] and opened doors for improvement in mobile broadband.

Now that we are facing the start of a new period of time, the fifth generation of mobile communications (5G) is promising in various fields including the immense demand for mobile networks with data speeds of multiple gigabits per second, allowing new instances, like vast communications linking innumerable computers, cameras, which offering technological advances in different sectors such as business, transportation and communication, ascertaining ultra-reliable services with low-latency for utilizing in sectors of public safety, vehicle communication, remote surgery and many more.

To ensure the maximization of all these plots, 5g technology has some noteworthy features such as Massive MIMO, 3D beamforming, use of mmWave [5] that can increase the area of coverage and user capacity of the network and also make it more reliable.

However, prior to the operational implementation of any new technology, there is a preparation process in which facets of radio engineering, for example deciding the position transmitters and of base stations, calculating its capacity and fixing the size of cells in terms of reach and capacity, assigning different frequencies and analyzing radio transmission and environmental interference, are analyzed then simulated.

For this sort of network plan and optimization, providers use simulating software. Atoll [6] is a network planning and optimizing tool that is provided by the company Forsk, for working with a large number of radio network technologies to design and optimization.

1.1 The advancement of cellular technologies

1.1.1 1G

The first generation of wireless cellular technology is referred as 1G. These were introduced in 1980. Only voice calls were possible using this technology. This continued till it was replaced by 2G digital telecommunications later.

1.1.2 2G

2G stands for the second generation of cellular technology. The radio signals used in this technology are digital whereas 1G used analog signals. The power requirements of digital transmission are smaller. 2G introduced SMS, image messages, and MMS (Multimedia Message Service) [7]. 2G was launched on GSM technology and FDMA or TDMA multiplexing techniques are used in it. This also supports more frequency band. Before the introduction of 3G, there are two intermediate levels of 2G: 2.5G and 2.75G, which use GPRS and EDGE technologies, respectively.

1.1.3 3G

With the introduction of 3G [8], the communication sector got a huge gift as video transmission was possible for the very first time. 3G technology uses CDMA technology which has a data rate of 144 kbps and can be up to 1.92 Mbps. Some applications of 3G can be mobile internet access, wireless voice calls, fixed wireless internet access, video calls. Later 3G also introduced some upgraded versions [9], 3.5G and 3.75G which has higher data rates.

1.1.4 4G

Next on the list is fourth generation [10] of mobile wireless network technology. 3G is incompatible for modern technologies such as full-motion video, teleconferencing in wireless media, multi-media [11]. Multiple 3G standards render roaming and operating across networks more difficult, so a scheme with a higher data rate was created. 4G [10] is an all-IP, with OFDMA-based infrastructure capable of about hundred megabits per second for higher mobility and around Gigabit speed for low mobility, with high security and end-to-end quality of service. It can handle a larger number of user equipment (UEs) with less lag. It has a 100 MHz maximum bandwidth. Some of the applications of 4G can be high-definition mobile TV, IP telephony, 3D television, mobile web access video conferencing, gaming facilities.

1.1.5 5G

The fifth-generation technology for mobile communication network [12] is known to be 5G, which the cellular companies started implementing globally in the late 21st decade. It came to compensate the drawbacks 4G had, which offer access to the majority of existing cellphones. 5G will use a completely new band of radio signals. It will use “mm Wave” to broadcast at frequencies between 30-300 GHz. There are about three major field applications for the 5G network technology. They are Ultra Reliable Low Latency Communications (URLLC), Massive Machine Type Communications (mMTC), and Enhanced Mobile Broadband (eMBB).

1.2 Objectives

This research work aims the usage of Atoll to work with some noteworthy features of 5G network technology and come up with a suitable network plan for a certain area and to optimize it. To do so, some objectives were determined.

- Identifying some important features of 5G network technology like 3D Beamforming [13], Massive MIMO [14].
- To understand how Atoll uses different geographical parameters to model the area.
- Identifying the network requirement of the area based on population, clutter class, clutter heights.
- Finding a suitable way to optimize the network plan to minimize the cost.

Chapter 2

2. 5G technology

To meet the new and modern requirements of the modern world, 5G came in place. This overcomes the lacking which 4G had earlier. It started its journey at around 2019.

5G networks have far greater connectivity and coverage rates than previous networks. The Wireless World Wide Web (WWWW) should be the focus of 5G. Various wireless and broadband technologies such as UMTS, LTE, Wi-Fi, Wi-max are being developed for the development of the Dynamic Ad-Hoc Wireless Networks (DAWN) alongside World Wide Wireless Web (WWWW) and Real Wireless World. Under the latest smartphone operating system, 5G technology offers unprecedented network capabilities as well as the capacity to connect an infinite number of calls and transmit an unlimited amount of data. It has a promising future because it can handle the new technology and offer luxury handsets to its customers.

2.1 Basic features of 5G

- Higher frequency bands are being used to accommodate extremely large transmission bandwidths and high data rates. In theory, 4G networks can reach average download speeds of one gigabit per second, although this has never been achieved in reality. For 5G, this will increase to 10Gbps.
- To improve network energy efficiency and reduce interference, an ultra-lean design is used to prevent always-on transmissions.
- The mobile IP address of the guests is determined by their location or related network in Internet protocol version 6 (IPv6).
- Many subcarriers can be supported at the same time.
- 5 G can also make the best of any existing piece of spectrum across a large variety of regulatory spectrum paradigms and frequencies, including small bands under 1 GHz, mid bands between 1 to 6 GHz, and millimeter wave medium bands.
- Low latency
- Beam-centric architecture allows for extensive beamforming and a large range of antenna elements for both transmission of data and control-plane procedures.
- More Personalized Access

2.2 5G key challenges

- Higher-frequency bands are expected to play a role in 5G [15]. There is more bandwidth available in these airwaves, but signals cannot travel almost as fast at these high frequencies as they do at the frequencies used by 4 G, resulting in a poor communication.
- One of the most significant issues facing 5G is standardization. Several committees are now focused on interoperability requirements, historical compatibility of older systems (4G, 3G, 2G), and future-proofing the network.
- There is no unique infrastructure for linking various engineering operations. A regulatory body that offers a shared forum for all engineering activities to manage interconnectivity challenges and information sharing is needed.
- Interference may be caused by a variety of factors, like buildings, trees, and even poor weather. Operators must build more base stations to ensure greater coverage and to use antenna technology such as massive MIMO to combat this.

2.3 Advantages of 5G over 4G

5G is a unified platform that is more capable than 4G.

5G wireless network technology chooses to be more compatible and a capable network which gives improved and very fast mobile broadband experiences alongside different services like critical networking and vast IoT. This technology supports all sorts of spectrum forms (licensed, unlicensed and sharing) with variation of high, low and mid quality. It also provides modern linked connection methods like multi hope mesh network, device-device connections and a number of deployment models (from large macro level cells to micro cells, hotspot).

Better Spectrum

5G has better spectrum quality than any other previous versions. It can make the best use of any available bandwidth (MHz) to a versatile spectrum of regulatory bands. With range starting from 1GHz of the lower bands to around 1 GHz and 6 GHz of the mid bands, to mmWave known to be of higher bands.

Faster Data Rate

5G very fast than the previous version of mobile network technology, 4G. It has an average data speed over 100 Mbps with peaks at about 20 Gigabits per second (Gbps).

More Capacity

5G is planned to accommodate a 100-fold improvement in network capacity and performance.

Lower Latency

5G has a dramatically lower latency, allowing for more instantaneous, real-time access: the end-to-end latency has been reduced by tenfold to only 1ms.

2.4 Applications

5G has three major field applications, which are the massive Internet of Things alongside mission-critical communications, and enhanced mobile broadband. The capacity to flexibly support future systems, forward compatibility that are not known in today's world is one of the distinguishing features of 5G.

Enhanced mobile broadband (eMBB)

5G mobile network technology will provide us with new immersive experiences like more uniform data speeds, VR and AR with quicker speed, lower cost-per-bit and lower latency, alongside making our cellular phones smarter and better.

Ultra Reliable Low Latency Communications (URLLC)

5G would allow new services like remote control of different equipments, mission-critical infrastructure, and medical procedures, which can transform industries with lower latency, ultra-reliable and accessible, connections.

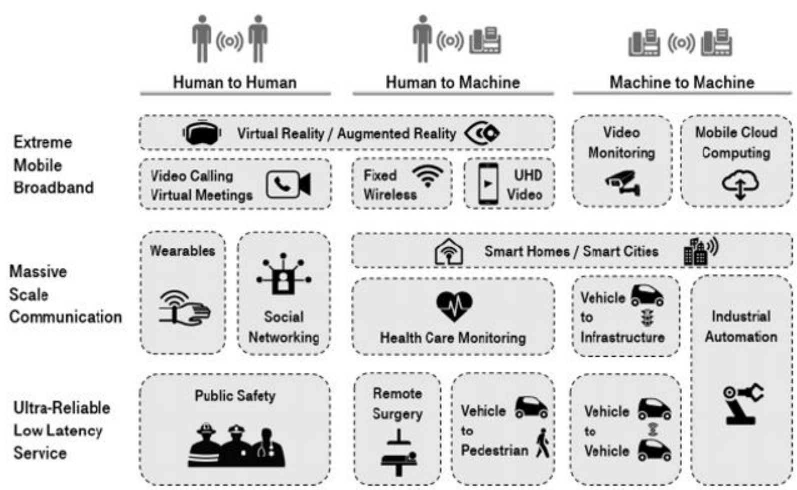


Figure 2. 1 5G uses cases

Massive Machine Type Communications (mMTC)

5G is designed to link a large number of embedded sensors in practically all by allowing data speeds, power, and mobility to be scaled down, resulting in incredibly lean and low-cost networking solutions.

2.5 Frequency bands and technical specifications

The radio communication sector of the International Telecommunication Union (ITU), ITU-R which is are held accountable for the making optimal usage of the radio frequency spectrum, published the International Mobile Telecommunications-2020 (IMT-2020), which contains some standards of 5G network to use.

The set of standards for technical performance published is summarized in the table below.

Table 2. 1 Minimum Technical Requirements for IMT-2020

Parameter	Minimum Technical Performance Requirement
Peak data rate	Downlink: 20 Gbps Uplink: 10 Gbps
Peak spectral efficiency	Downlink: 30 bit/s/Hz Uplink: 15 bit/s/Hz
User-experienced data rate	Downlink: 100 Mbps Uplink: 50 Mbps
Area traffic capacity	10 Mbps/m2 (indoor hotspot for eMBB)
User plane latency	4 ms for eMBB 1 ms for URLLC
Control plane latency	20 ms
Connection density	1,000,000 devices per km2
Energy efficiency	Efficient data transmission in a loaded case Low energy consumption when there is no data High sleep ratio Long sleep duration
Reliability	1-10-5 success probability of transmitting a layer 2 PDU of 32 bytes within 1 ms, at coverage edge in Urban Macro for URLLC
Mobility	1.5 bit/s/Hz at 10 km/h for indoor hotspot eMBB 1.12 bit/s/Hz at 30 km/h for dense urban eMBB 0.8 bit/s/Hz at 120 km/h for rural eMBB 0.45 bit/s/Hz at 500 km/h for rural eMBB
Mobility interruption time	0 ms
Bandwidth	At least 100 MHz and up to 1 GHz in higher frequency bands. Scalable bandwidth shall be supported

These are divided into frequency ranges of two separate bands due to different radio frequency (RF) specifications (e.g. maximum transmitting power):

- All existing and new bands below 6 GHz are included in **Frequency range 1 (FR1)**
- Newer bands in the range of 24.25 – 52.6 GHz are included in **Frequency range 2 (FR2)**

In our thesis FR1 has been used. The operating bands for the FR1 has been shown below:

Table 2. 2 New Radio Operating Bands

NR Operating Band	Uplink Range (MHz)	Downlink Range (MHz)	Duplex Mode
Frequency Range 1 (FR1)			
n1	1920 – 1980	2110 – 2170	FDD
n2	1850 – 1910	1930 – 1990	FDD
n3	1710 – 1785	1805 – 1880	FDD
n5	824 – 849	869 – 894	FDD
n7	2500 – 2570	2620 – 2690	FDD
n8	880 – 915	925 – 960	FDD
n12	699 – 716	729 – 746	FDD
n20	832 – 862	791 – 821	FDD
n25	1850 – 1915	1930 – 1995	FDD
n28	703 – 748	758 – 803	FDD
n34	2010 – 2025	2010 – 2025	TDD
n38	2570 – 2620	2570 – 2620	TDD
n39	1880 – 1920	1880 – 1920	TDD
n40	2300 – 2400	2300 – 2400	TDD
n41	2496 – 2690	2496 – 2690	TDD
n50	1432 – 1517	1432 – 1517	TDD
n51	1427 – 1432	1427 – 1432	TDD
n66	1710 – 1780	2110 – 2200	FDD
n70	1695 – 1710	1995 – 2020	FDD
n71	663 – 698	617 – 652	FDD
n74	1427 – 1470	1475 – 1518	FDD
n75	N/A	1432 – 1517	SDL
n76	N/A	1427 – 1432	SDL
n77	3300 – 4200	3300 – 4200	TDD
n78	3300 – 3800	3300 – 3800	TDD
n79	4400 – 5000	4400 – 5000	TDD
n80	1710 – 1785	N/A	SUL
n81	880 – 915	N/A	SUL
n82	832 – 862	N/A	SUL
n83	703 – 748	N/A	SUL
n84	1920 – 1980	N/A	SUL
n86	1710 – 1780	N/A	SUL

Chapter 3

3. Atoll for 5G networks:

Forsk's Atoll is a platform for wireless network which supports a wide range of technologies like 5G New Radio, Long Term Evolution, NB-Internet of Things, UMTS, GSM, and MIMO, 3D Beamforming, and millimeter-wave propagation, as well as the latest technological advances such as MIMO, millimeter-wave propagation and 3D Beamforming.

This can give operators and vendors a framework to design, optimize, and plan their networks. Users are expecting more and better facilities as technology advances.

This clarification is important that most of the information are taken from Atoll User Manual [16], and from Atoll Technical Reference Guide [17].

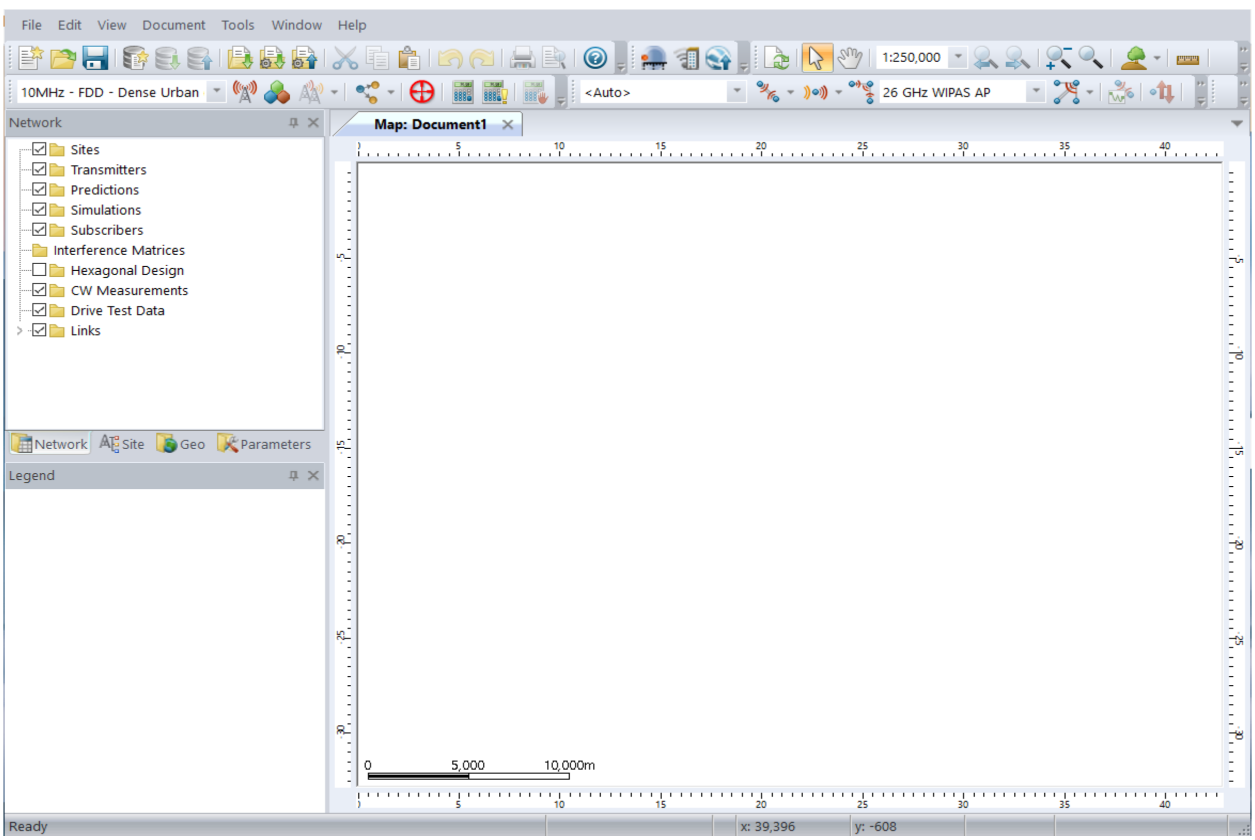


Figure 3. 1 Working environment of Atoll

3.1 Atolls reconfigurable parameters:

Atoll aids in the modelling of different pieces of equipment and parameters used to create a network, such as the cell tower, cell parameters, and transmitter. The location of the base station and transmitters is referred to as the site. The device used to produce radio waves for sending or receiving data through an antenna is referred to as a transmitter. Finally, a cell is a transmitter's RF tube.

The downlink and uplink losses are calculated using the properties of three components that make up the base station subsystem:

- **TMA:** This is used to lower the base station's composite noise number. Known as Tower Mounted Amplifier.
- **Feeder cable:** links the antenna to the TMA
- **Transmitter equipment**

The parameters for the base station subsystem are mentioned in the table below.

Table 3. 1 Base station sub-system equipment

TMA	Default TMA Equipment
Feeder	Default ½' Feeder
Transmitter	Default eNode-B Equipment

Table 3. 2 Transmitter total loss

	Transmission	**Reception**
Total Losses (dB)	**0.5**	**0.5**

The following are the cell parameters that Atoll helps to customize:

• **Carrier:** In the frequency range, the transmitter is the cell's carrier. The carrier bandwidth was indicated.

• **Maximum transmission capacity in dBm:** The maximum power which can be transmitted by the cell.

• **Layer:** The cell's network layer. It may either be a macro (for macro cells) or a nano (for small/micro cells) plate.

• **SS/Physical Broadcast Channel numerology:** The kind of numerology used by the cell.

• **SS/ Physical Broadcast Channel periodicity:** The SS/ Physical Broadcast Channel bursts' frequency.

• **Radio equipment:** radio equipment used for mobile phones.

• **Scheduler:** Bearer selection and resource allocation are handled by the cell's scheduler.

• **Diversity service (DL):** The antenna diversity approach that the cell supports in the downlink.

Table 3. 3 5G Network Radio Bearer

Radio Bearer Index	Modulation	Channel Coding Rate	Bearer Efficiency (bits/symbol)
19	QPSK	0.117188	0.2344
20	QPSK	0.188477	0.377
21	QPSK	0.300781	0.6016
22	QPSK	0.438477	0.877
23	QPSK	0.587891	1.1758
24	16QAM	0.369141	1.4766
25	16QAM	0.423828	1.6953
26	16QAM	0.478516	1.9141
27	16QAM	0.540039	2.1602
28	16QAM	0.601563	2.4063
29	16QAM	0.642578	2.5703
30	64QAM	0.455078	2.7305
31	64QAM	0.504883	3.0293
32	64QAM	0.553711	3.3223
33	64QAM	0.601563	3.6094
34	64QAM	0.650391	3.9023

35	64QAM	0.702148	4.2129
36	64QAM	0.753906	4.5234
37	64QAM	0.802734	4.8164
38	64QAM	0.852539	5.1152
39	256QAM	0.666504	5.332
40	256QAM	0.694336	5.5547
41	256QAM	0.736328	5.8906
42	256QAM	0.77832	6.2266
43	256QAM	0.821289	6.5703
44	256QAM	0.864258	6.9141
45	256QAM	0.89502	7.1602
46	256QAM	0.925781	7.4063

- **Uplink diversity support (UL):** This refers to the kind of antenna diversity strategy that the cell supports.
- **Number of Multi User MIMO users for downlink:** On the downlink, this is the total number of MU-MIMO users sharing the same services.
- **Number of Multi User MIMO users for uplink:** The total number of MU-MIMO users who have access to the same uplink facilities.
- **Traffic load for downlink in %:** The percentage of downlink traffic load.
- **Traffic load for uplink in %:** The percentage of uplink traffic load.
- **Downlink traffic load maximum (DL) in percentage:** This should not be surpassed.
- **Maximum traffic load in uplink in %:** The uplink's maximum traffic load should not be surpassed.
- **UL noise rise in dB:** the dB increases in uplink noise.
- **Maximum no. of neighbours:** The cell's maximum number of 5G New Radio neighbours.
- **Maximum no. of inter-technology neighbours:** Depends on cell.

Bearer	C/(I+N) Thresholds (dB)
19	-4
20	-2.8
21	-1.2
22	0.8
23	2.4
24	3.2
25	4.8
26	5.6
27	6.8
28	7.6
29	9.4
30	10.4
31	11.8
32	13.8
33	15.4
34	16.6
35	18
36	18.8
37	20.2
38	21.8
39	23.6
40	24.6
41	25.6
42	27.2
43	29
44	29.8
45	31.8
46	33.8

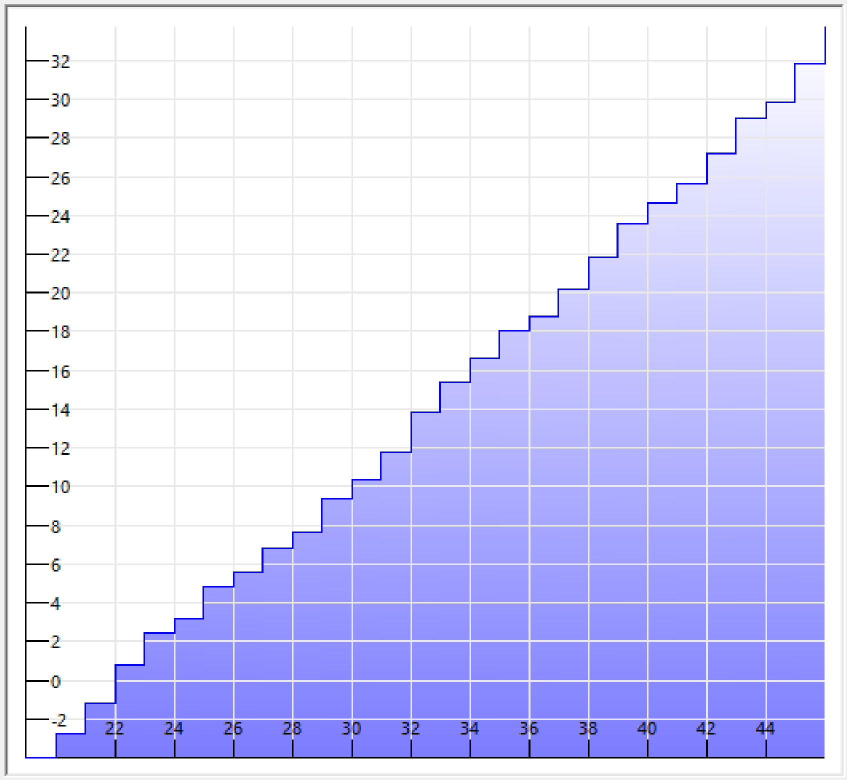


Figure 3. 2 The C/(I+N) bearer selection criterion

3.2 Traffic Parameters:

The traffic parameters in Atoll are common to all radio communication systems and specify the services that users need, their mobility, the devices they use, the user profile, and the area in which they are located based on user intensity.

Subscribers in Atoll have access to some services. For example: voice, internet, and broadband. However, since future 5G networks can accommodate massive amounts of high-bandwidth data, Web browsing was the type of service used by 5G New Radio subscribers.

The pedestrian accessibility category was used for 5G NR subscribers and a speed of 3 km/h.

The UE is a cell phone here.

For the experiment, we used a 5G smart phone. Specifications are:

Noise figure is 8 dB, losses as 0 dB, min power taken as -40 dBm whereas we took max power as 23 dBm. It supports MIMO and antenna gain is 0 dB and the number of transmitting antennas and number of reception antennas both are 4.

The company user was the user profile that was considered, and it had the following characteristics:

Table 3. 4 User profile

User Profile	Service	Terminal	Calls/hours	UL Volume (Kbytes)	DL Volume (Kbytes)
Business User	Web Browsing	5G Smartphone	0.1	700	4500

Finally, mobility type, and density, the atmosphere class defines the regions. The city was set up as a compact urban environment, with 800 enterprise usage users/square kilometre.

3.3 Beamforming features:

One of Atoll's main features is 3D beamforming, it allows to form beam in both horizontal planes and vertical planes.

3D beamforming in Atoll refers to uniform planar array antennas with horizontal and vertical antenna components aligned around a two-dimensional axis. The frequency range at which it can operate, number of antenna components, inter-element spacing, polarization, port number and radiation patterns characterize each 3 dimensional beamforming antenna.

Atoll models can be used to achieve 3D beamforming by discriminating between the antenna model and the beam pattern.

• Physical beamforming antenna equipment creates a lot of antenna patterns. Which are represented by the beamforming antenna.

• Beamforming pattern creates a lot of different types of beam patterns. And these beam patterns represent the 3D beamforming patterns.

The physical characteristics which we will reconfigure to figure out the the 3D beamforming antenna panel can be defined by the following parameters:

• **Frequency range:** The 3D beamforming antenna is built to run within a great range of frequencies. It is considered in MHz range.

• **Vertical spacing:** the difference in wavelength multiples between two vertical antenna components.

• **Horizontal spacing:** the difference in wavelength multiples between two horizontal antenna components.

• **Columns:** It is denoted by N. How many component exists in the panel is known as column.

• **Number of rows:** It is denoted by M. M represent the number of rows on which the antenna components are arranged inside the column.

• **Number of transmission ports:** Total number of ports can be used in the transmission process.

• Number of reception ports: Total number of ports can be used in operation at a given time.

Each 3D beamforming pattern represented by the given parameters:

• Beam type: It can be a control channel, it can also be a traffic channel, even it can be both. The SS/Physical Broadcast Channel block in 5G New Radio uses control channel beams, while the Physical Downlink Control Channel and Physical Downlink Shared Channel use traffic channel beams.

• Beam index: determines the 3D beamforming model's special index for the beam pattern.

• Electrical azimuth: It is represented in degree. It indicates a direction that points the pattern of the beam.

• **Electrical tilt:** It is also represented in degree. It indicates the tilt direction of the beam pattern.

• **Horizontal elements:** It is denoted by m. The horizontal elements specify the amount of horizontal antenna elements used to form the beam pattern.

• Vertical elements (n): indicates how many elements of vertical antenna were used.

• Boresight gain (dB): indicates how far the beam gains in the direction specified by its tilt. And it’s also specified by its azimuth.

• Half-power beamwidth: It is represented in degree. It shows the horizontal template aperture equivalent to a 3 dB pattern attenuation.

Antenna produces different beam pattern, which can be graphically seen using Atoll, as shown in Figure 3.3

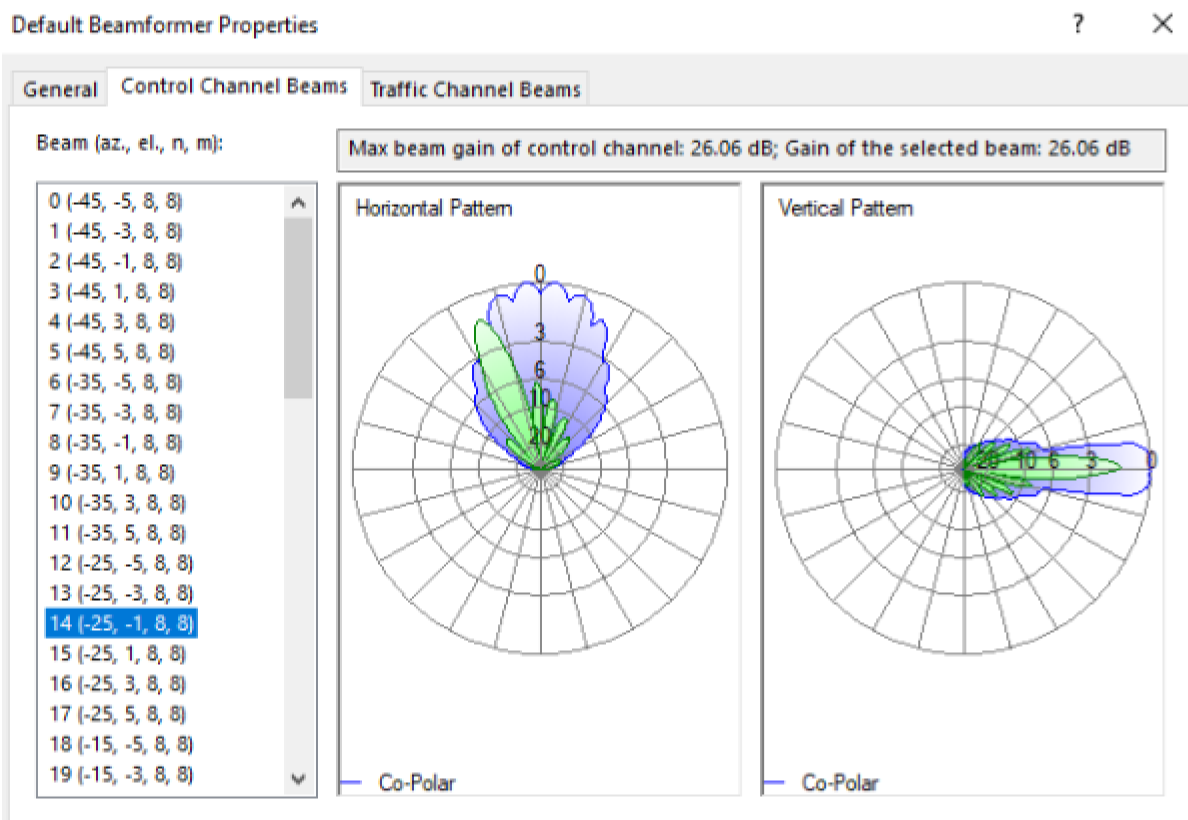


Figure 3. 3 Beam patterns

3.4 MIMO features:

Spatial multiplexing represents the transmit diversity, receive diversity, SU-MIMO. And interactive MIMO represents the MU-MIMO are all supported by Atoll the radio network planning tool

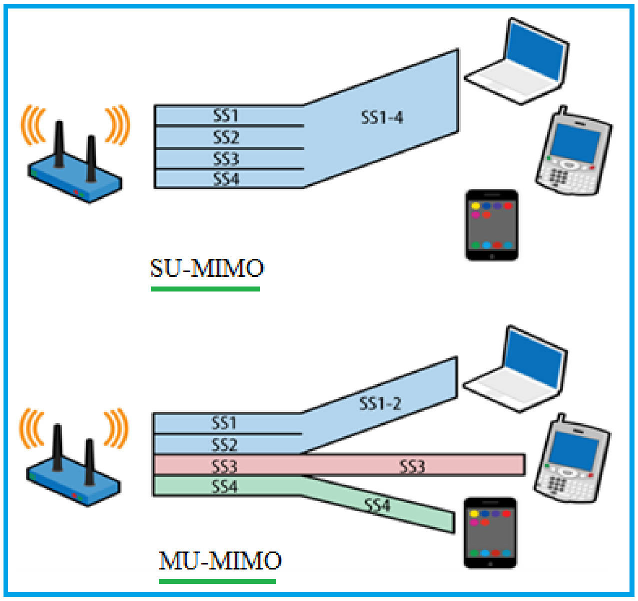
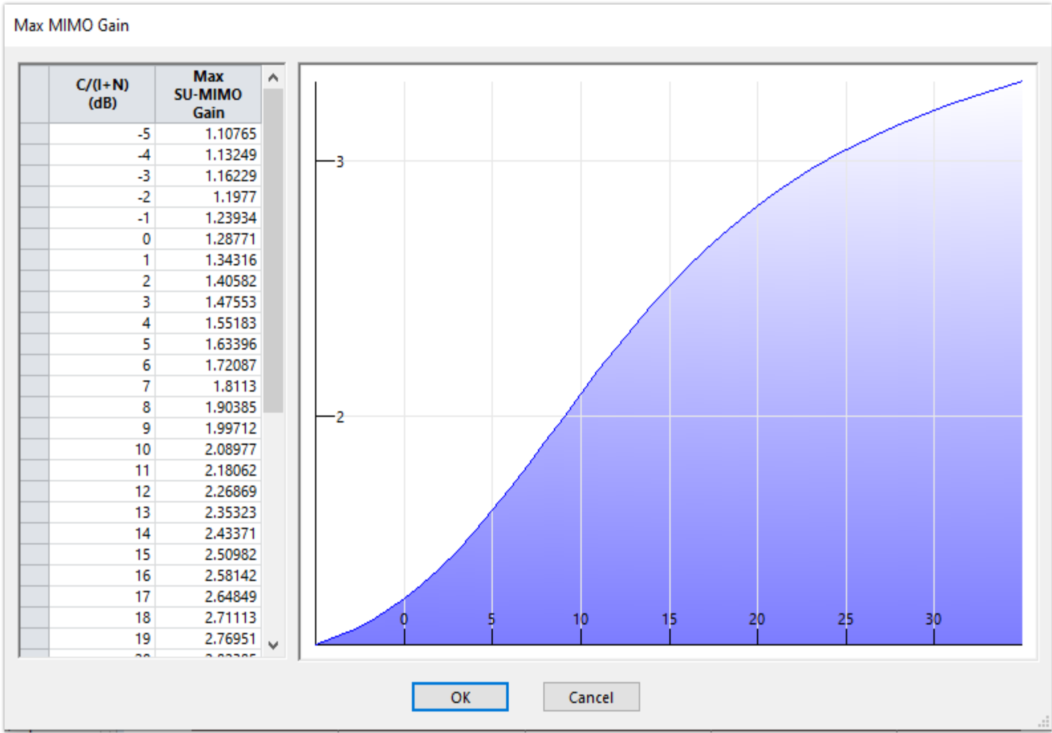


Figure 3. 4 SU-MIMO & MU-MIMO

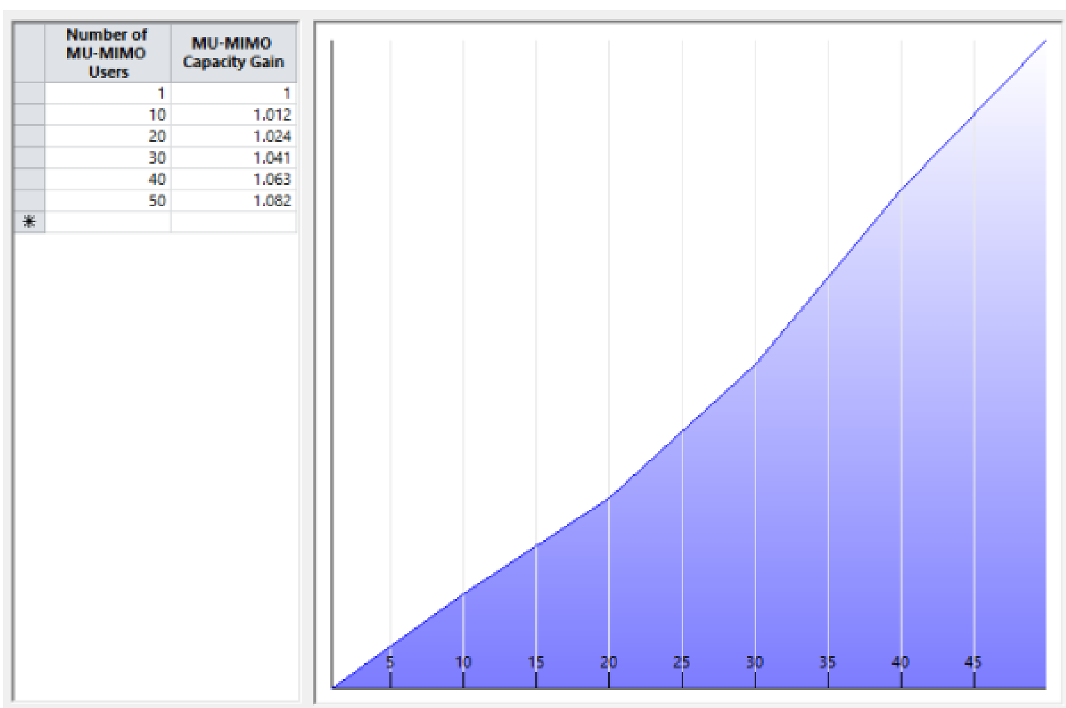
If Physical Downlink Shared Channel or Physical Uplink Shared Channel of Carrier to Interference Ratio at a certain place where the UE is higher or almost same to the threshold in 5G New Radio equipment then only the UE will be benefited by the MIMO gain. Atoll sets this standard to 14 decibels by law. But if the UE doesn't reach to this threshold then it will not be benefited by the gain. It means that SU-MIMO as well as the MU-MIMO will only be used above this threshold.

SU-MIMO gain can vary. Which depends on the number of transmission and reception end and carrier to noise and interference ratio amount, which can be called a power gain specified to increase data rate. Figure 3.5 shows the benefits for a 16 antennas transmitter and 8 antennas receiver.



C/(I+N) (dB)	Max SU-MIMO Gain
-5	1.10765
-4	1.13249
-3	1.16229
-2	1.1977
-1	1.23934
0	1.28771
1	1.34316
2	1.40582
3	1.47553
4	1.55183
5	1.63396
6	1.72087
7	1.8113
8	1.90385
9	1.99712
10	2.08977
11	2.18062
12	2.26869
13	2.35323
14	2.43371
15	2.50982
16	2.58142
17	2.64849
18	2.71113
19	2.76951

Figure 3. 5 Single User MIMO capacity gains with respect to C/(I+N) level for 16x8 antenna



Number of MU-MIMO Users	MU-MIMO Capacity Gain
1	1
10	1.012
20	1.024
30	1.041
40	1.063
50	1.082

Figure 3. 6 MU-MIMO Capacity Gain with respect to number of user

Table 3. 5 MU-MIMO Diversity Gain According to Number of Antennas

Transmission Antennas	Reception Antennas	Diversity Gain (dB)	Transmission Antennas	Reception Antennas	Diversity Gain (dB)
128	1	9.0309	1	32	9.0309
128	2	6.0206	2	32	6.0206
128	4	3.0103	4	32	3.0103
128	8	0	8	32	0
64	1	9.0309	1	16	9.0309
64	2	6.0206	2	16	6.0206
64	4	3.0103	4	16	3.0103
64	8	0	8	16	0
32	1	9.0309	2	1	3.0103
32	2	6.0206	4	1	6.0206
32	4	3.0103	8	1	9.0309
32	8	0	1	2	3.0103
16	1	9.0309	2	2	0
16	2	6.0206	4	2	3.0103
16	4	3.0103	8	2	6.0206
16	8	0	1	4	9.0309
1	128	9.0309	2	4	3.0103
2	128	6.0206	4	4	0
4	128	3.0103	8	4	3.0103
8	128	0	1	8	6.0206
1	64	9.0309	2	8	9.0309
2	64	6.0206	4	8	3.0103
4	64	3.0103	8	8	0
8	64	0			

Chapter 4

4. Selection of deployment area and network planning:

The first part of this chapter is consist of two things. First one is the geographical area. And second one is the geographic data. Which was used in network planning software Atoll to carry out different calculations.

The second part is consist of network planning in that specific area considering best signal level along with coverage by transmitter.

4.1 Necessary data and study area:

Our selected area was 64.53 km^2 of Uttara, Dhaka (Bangladesh).

Here used coordinate system we took was WGS 84 / UTM zone 44N and the bounding region coordinates are:

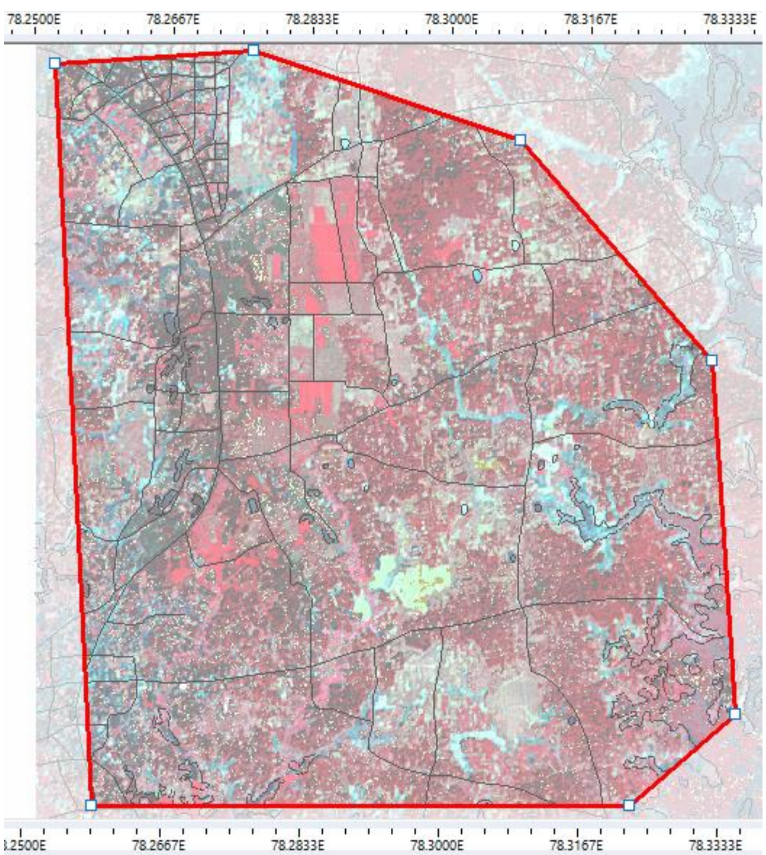


Figure 4. 1 Uttara coordinates

For performing various calculations in Atoll we imported 4 geographic data types, those are:

- Digital Terrain Model (DTM)
- Clutter Classes
- Clutter Heights
- Vector Layers

4.1.1 DTM

The elevation of the ground over sea level is described by the term DTM (Digital Terrain Model). Propagation models automatically take these values and do the calculations.

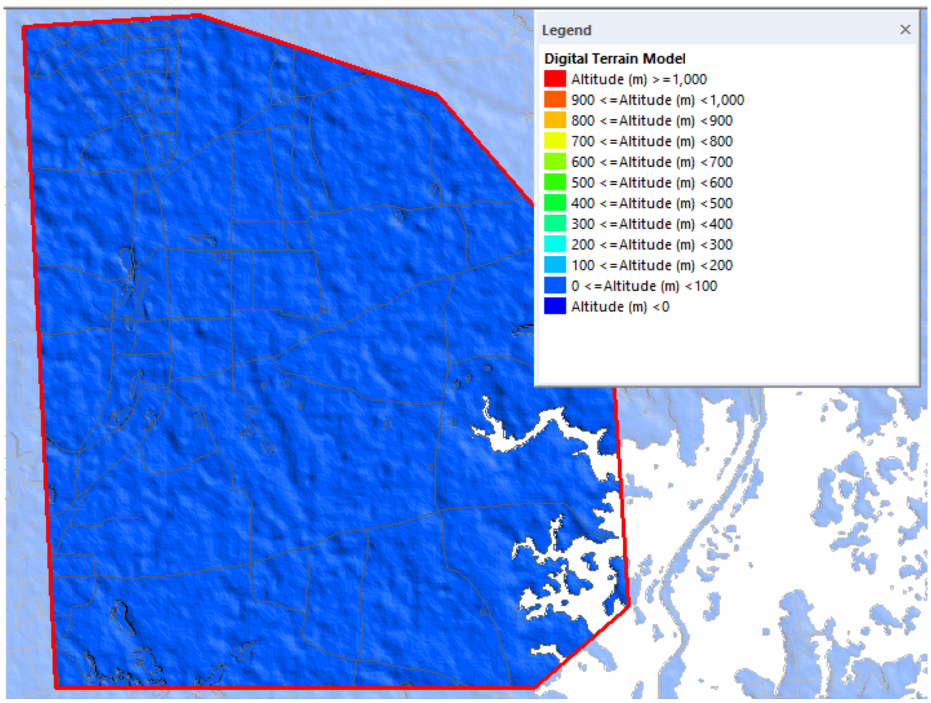


Figure 4. 2 Digital Terrain Model

4.1.2 Clutter Classes

The amount of land covered or land used is described by the clutter class data file. The propagation model takes clutter groups into account while computing.

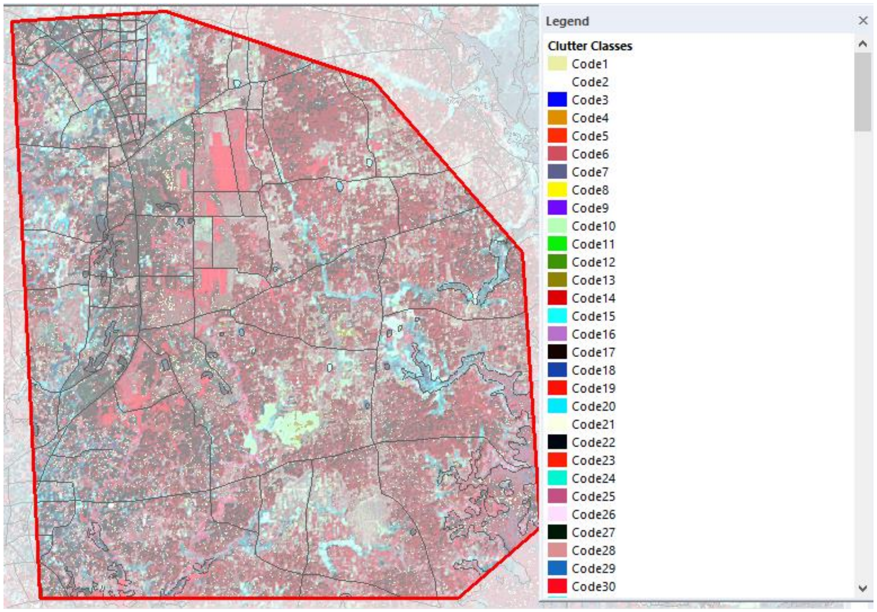


Figure 4. 3 Clutter Classes

Each color code defines a specific class name. A list of code, class name and the class description is given below:

Table 4. 1 Clutter Class

	Code	Class Name	Class Description
	1	Open	Open space outside the town without vegetation.
	2	Forest	Forested lands with closed tree canopy. No distinction is made between deciduous and coniferous.
	3	Sea	Sea and ocean.
	4	Inland water	Rivers, canals of more than 10 m width, lakes, reservoirs.
	5	Residential	Houses in suburban environment. Suburban dwellings. Lots may be as small as 30m by 30m, but are usually larger and include vegetation cover. Individual houses are frequently visible. Average height is below 15m.
	6	Mean urban	Areas within urban perimeter. The mean urban should have mean street density with no pattern, the major streets are visible, the built-up features appear distinct from each other. Some small vegetation could be included. Height is 15-30m.
	7	Dense urban	Areas within urban perimeter. This includes dense urban areas with dense development where built-up features do not appear distinct

			from each other. It also includes built-up features of the downtown district with heights 15-30m .
	8	Block buildings	Groups of buildings, either parallel or not, that may be separated by large green space. Height is above 30 m..
	9	Industrial	Areas including buildings with large footprints separated by streets (factories, shopping malls, storehouses etc.).
	10	Villages	Small built-up area in rural surrounding.
	11	Open in urban	Open spaces inside the town: streets, avenues, vacant lots, squares.
	12	Parks in urban	Park of less than 20m height trees.
	13	Airport	Territory of airport without buildings and runways.
	14	Wetland	Swampland.
	15	Dense residential	Groups of houses or collective residential buildings in suburban environment. Suburban density typically involves laid out street patterns in which streets are visible. There is no open space between constructions. Average height is below 15m.
	16	Dense urban high	Financial District. Heights are over 40 m.
	17	Buildings	Isolated cluster of high towers or skyscrapers higher than 40 m.
	18	Sparse forest	Forested lands with a low density of trees and without canopy tree.

Here we have 209 possible classes and a code is embedded in each pixel of the clutter class.. This code represent used grounds [18].

4.1.3 Clutter Heights

The elevation of a clutter over a DTM with one altitude specified by pixel is referred to as clutter height. This file includes various altitudes from the same clutter class.

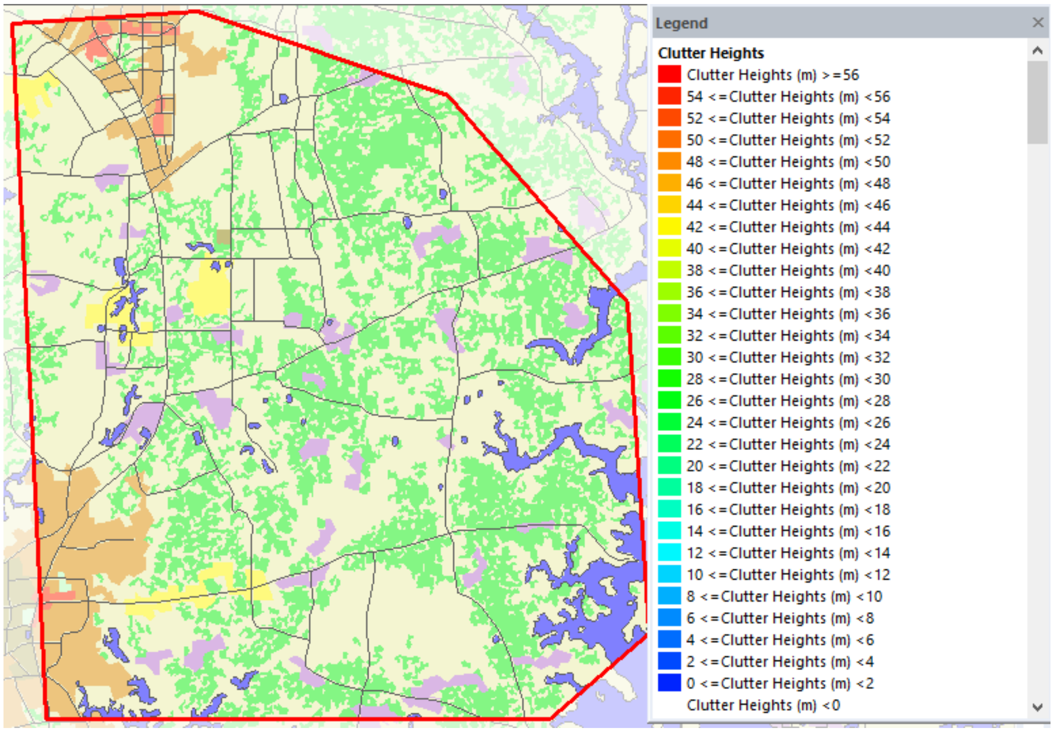


Figure 4. 4 Clutter Heights

4.1.4 Vector Layers

To describe polygons Atoll recognizes some factors such as contours and points. For examples areas, paths, and costlines.

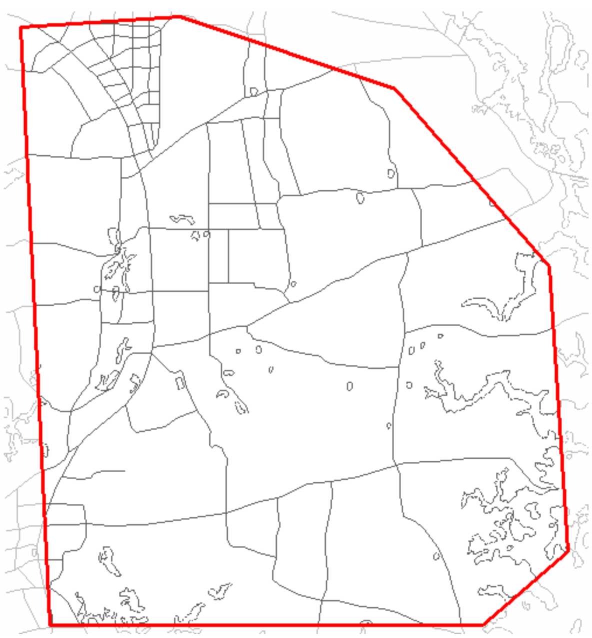


Figure 4. 5 Vector Layers

4.2 Network planning

Uttara is one of the most developed residential area of Dhaka city. Efficient 5G radio network planning is a great challenge here. If we want to do so with the optimal utilization of limited resources then it will be a big challenge.

4.2.1 Steps of network planning:

The radio network planning process is divided into five main stages, with the first four being prelaunch and the fifth being post-launch. Preplanning, preparation, comprehensive planning, acceptance, and optimization are the five main phases. A flowchart is given below:

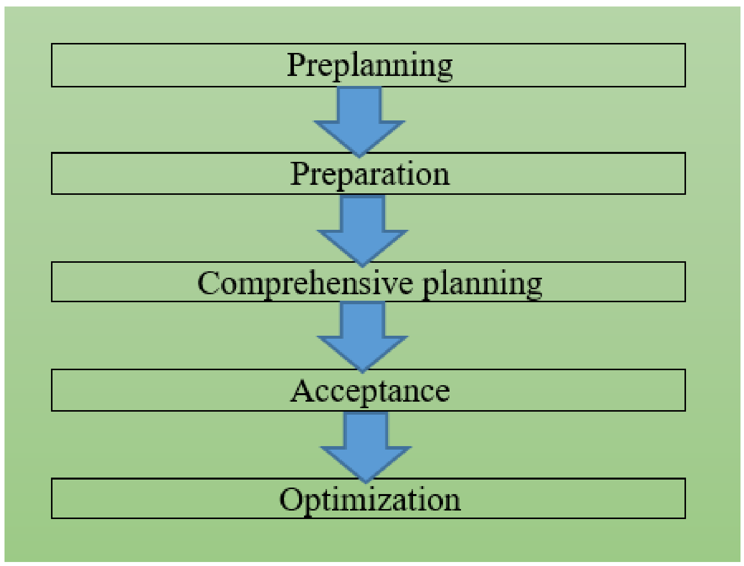


Figure 4. 6 Network Planning Steps

Preplanning: Before the actual network planning begins, the preplanning process includes the tasks and training. It is advantageous to be aware of the current market situation and competitors, just as it is in any other industry. The customer approves the network preparation requirements.

Preparation: The dimensioning and initial network configuration provide feedback to the planning process. This is the foundation for nominal preparation, which relates to the coverage of radio networks. Using a planning tool to manage capacity. The basic strategy does not commit to exact site locations but offers an initial estimate a rough idea of the positions as well as the distances between the sites.

Comprehensive planning: Detail preparation will begin after the planning process is completed and the location and configurations of the site are known. Frequency, adjacency, and parameter preparation are all part of the comprehensive planning process.

Acceptance: In addition to fine-tuning, a review is performed for any defects that could have occurred during the installation process. Prelaunch optimization is a high-level technique that does not dig into details. After the launch, network optimization continues at a more comprehensive stage.

Optimization: As we all know, optimization is a never-ending operation. The optimization includes all details about the network and its current state as input. Some important elements, such as statistical data, alarms, and traffic, must be closely controlled.

In this thesis, simulation result, budget calculations, coverage analysis as well as capacity analysis have been performed. For design and analysis purpose we have used here Atoll radio network planning tool.

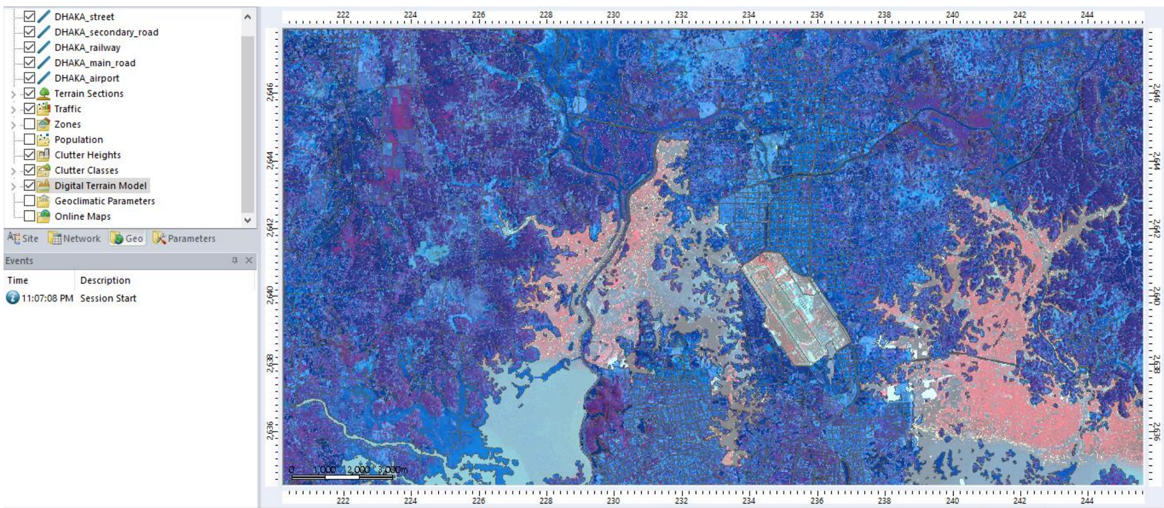


Figure 4. 7 Import Dhaka city map in Atoll

Selected statistical zone:

- Selected focus zone: 64.53 km^2
- Selected computation zone: 64.53 km^2
- Population (total): 345097
- Density: 9350/km
- Hexagon radius, X= 350 m
-

Planning parameters:

- Propagation model: Okumura-hata
- Antenna: 65deg 18dBi 0Tilt 2100MHz
- Antenna height: 30 m
- Hexagon area: 2.6 X

All these above mentioned parameters are described in Hata model and used for urban areas.

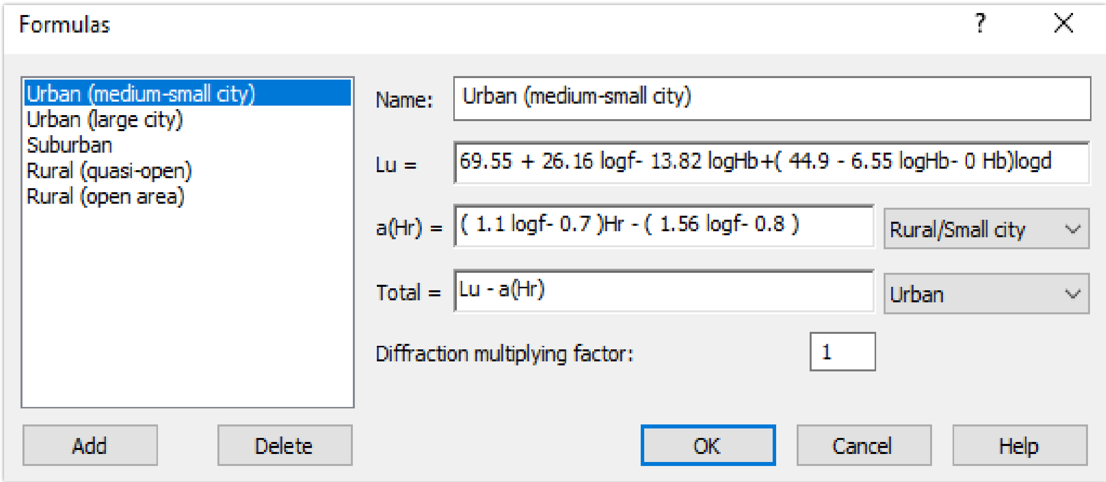


Figure 4. 8 Formulas of Okumara-Hata model

Here, Lu is the median path loss and its unit is decibel. Frequency of transmission is denoted by f. Hb is the effective height of e-NodeB and its unit is meter (m). Link distance is denoted by d with kilometer (km) unit. The antenna height of a base terminal is its operational height is represented by Hr and the unit is meter (m). And a(Hr) is known as correction factor of height of the antenna.

4.2.2 Basic predictions:

We have performed basic predictions of coverage by transmitter, coverage by signal level and coverage by overlapping zone.

Initially implemented number of sites are 33.

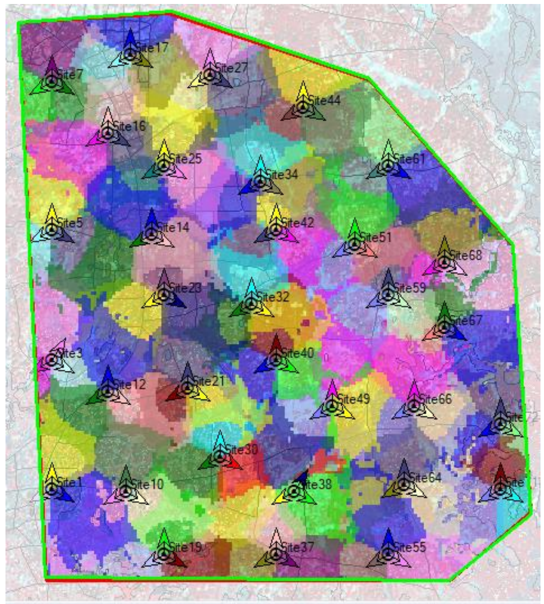


Figure 4. 9 Predictions of coverage by transmitter

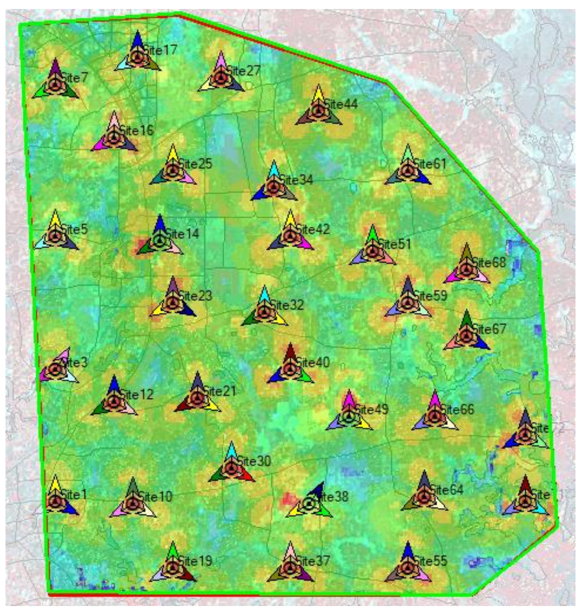


Figure 4. 10 Predictions of coverage by signal level

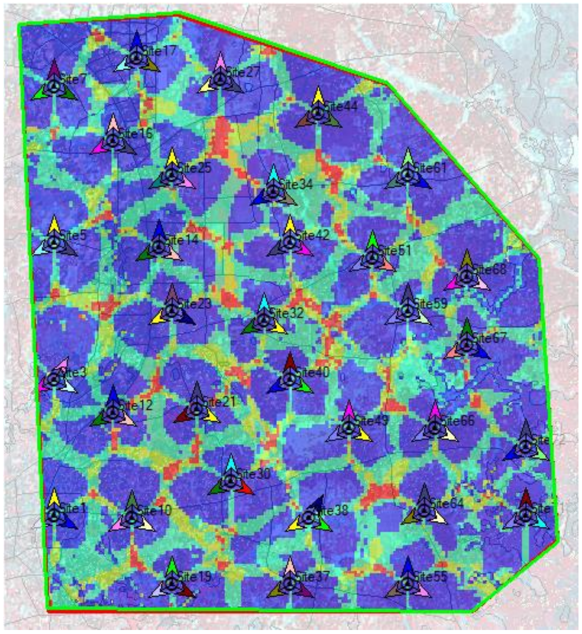


Figure 4. 11 Predictions of coverage by overlapping zone

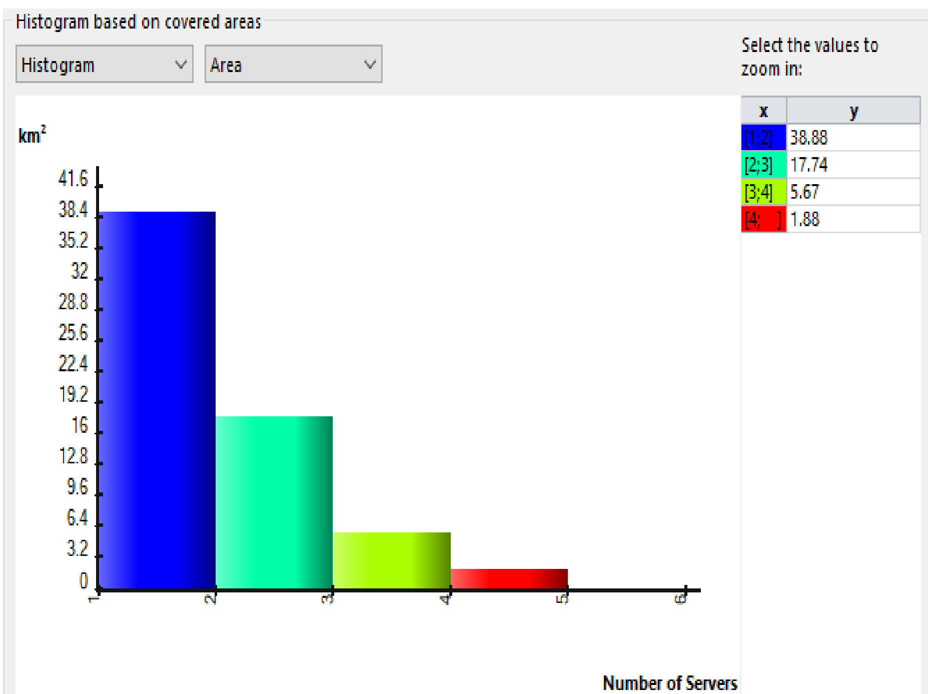


Figure 4. 12 Number of servers based on coverage areas

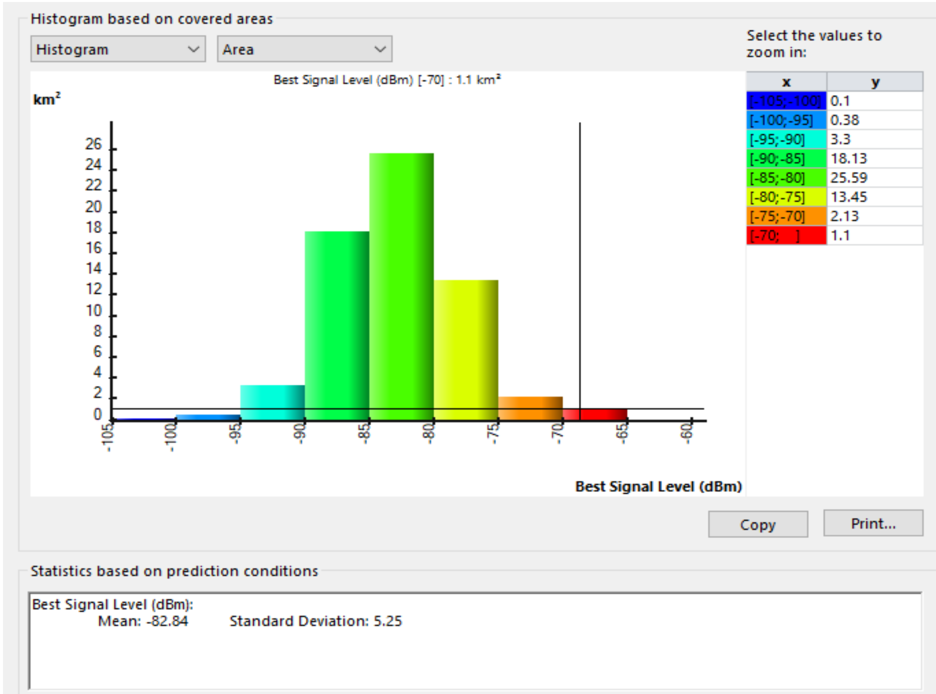


Figure 4. 13 Best signal level based on covered areas

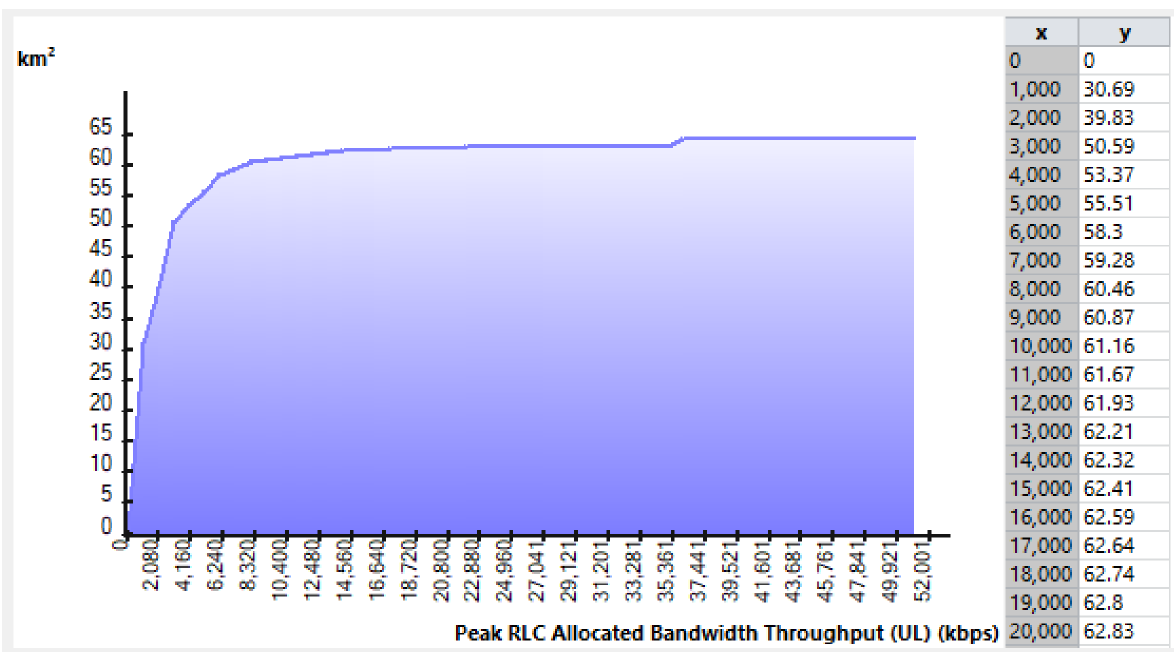
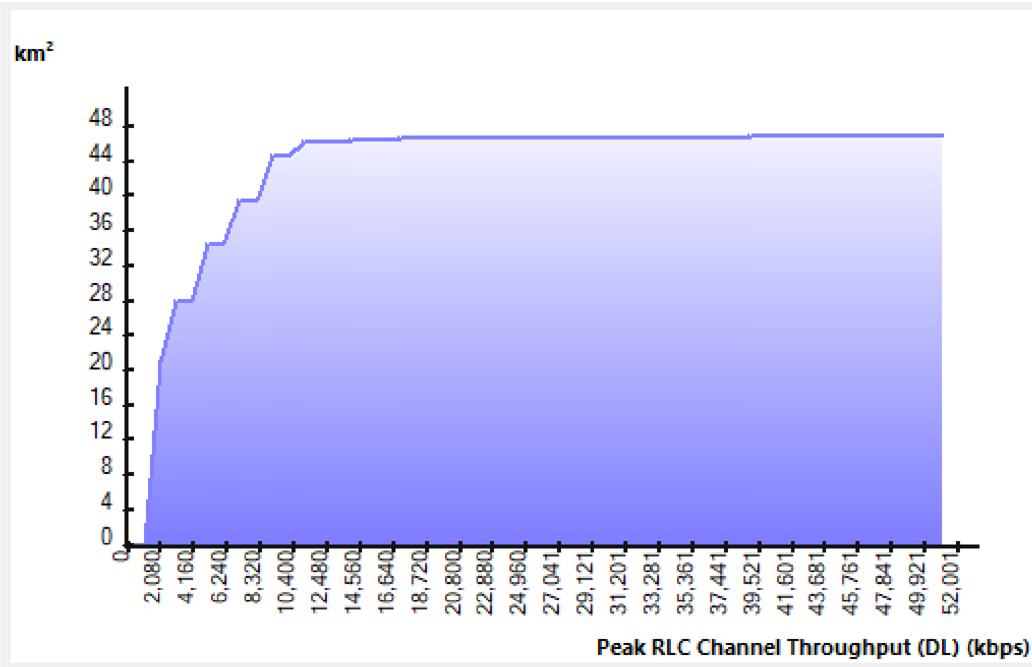


Figure 4. 14 Coverage by peak RLC throughput (UL)



x	y
0	0
1,000	0
2,000	20.97
3,000	27.89
4,000	27.89
5,000	34.48
6,000	34.48
7,000	39.51
8,000	39.51
9,000	44.53
10,000	44.53
11,000	46.21
12,000	46.21
13,000	46.21
14,000	46.49
15,000	46.49
16,000	46.49
17,000	46.53
18,000	46.53
19,000	46.65
20,000	46.65

Figure 4. 15 Coverage by peak RLC throughput (DL)

Figure 4. 16 Geographical Profile of site 34_1

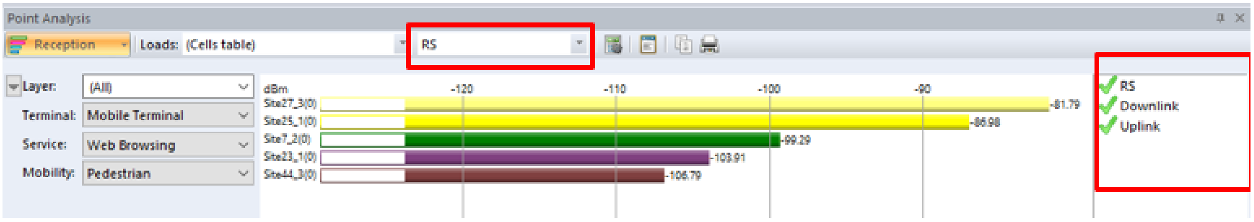


Figure 4. 17 The point analysis of RS of site 27_3

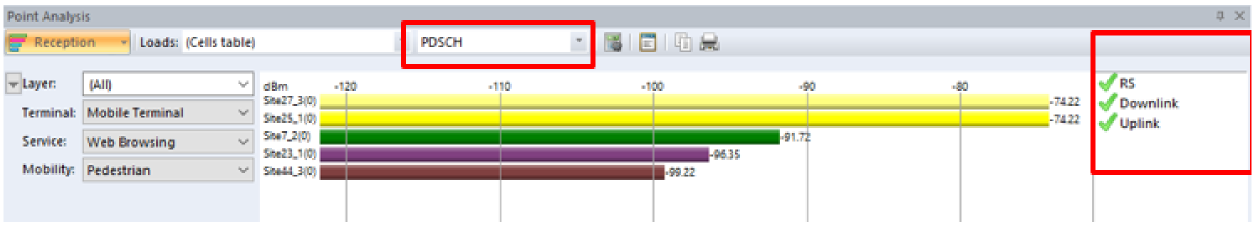


Figure 4. 18 The point analysis of PDSCH of site 27_3

When looking at the coverage prediction data, it's clear that the proposed network will have sufficient coverage [19]. Again, post-simulation review of the traffic map shows that subscribers are largely connected at both Uplink and Downlink. Which means it is a very good sign for the expected network. Performance analysis using a point analysis method strengthens the basis for a successful planned network.

4.2.3 ACP (Automatic Cell Planning):

Preferences:

Optimization calculation settings: High precision

Low quality improvement changes: 50%

Prediction transparency: 50%

Multi-storey: Enabled

EMF exposure: Enabled

Template Setup:

Propagation model: SPM

No. of iteration: 240

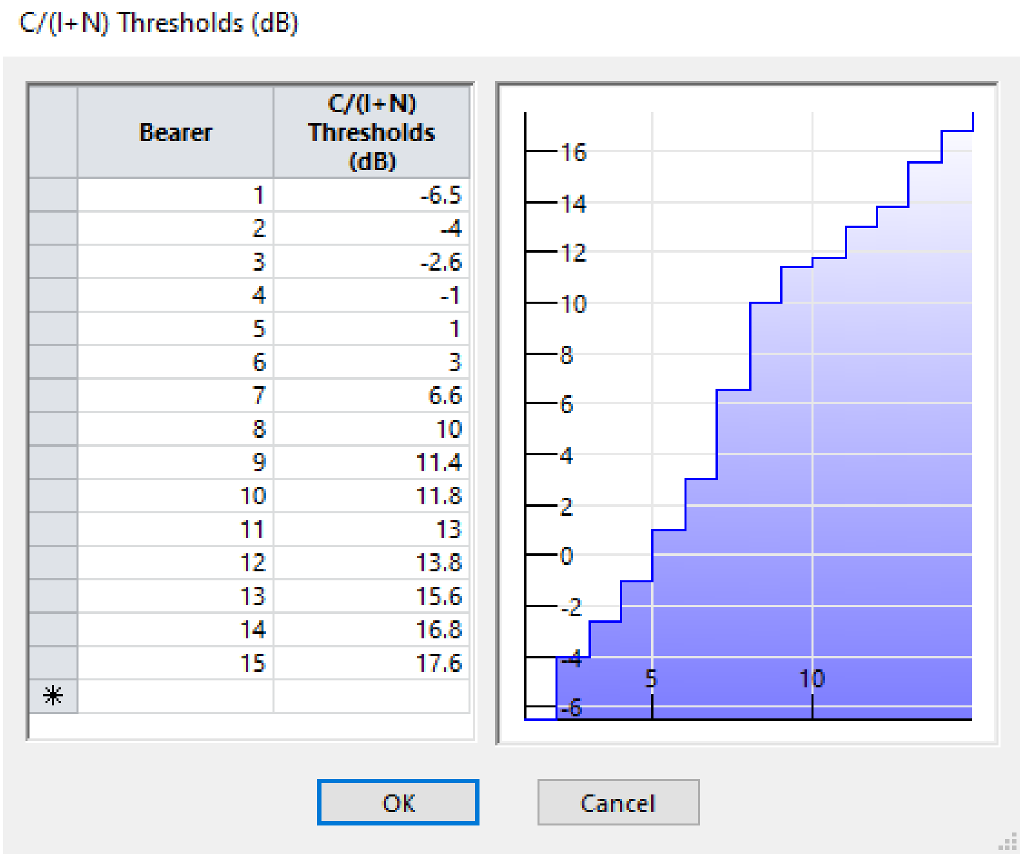
Resolution: 50 m

Cost weighting: Normal

4.3 Predictions & Optimizations Reports:

For a coverage-limited scenario or an interference-limited scenario, coverage or cell range is calculated. The fading margin, cell edge target signal level, average load, and other factors all play a role.

The following figure illustrate that C/(I+N) thresholds depend on user mobility.



Bearer	C/(I+N) Thresholds (dB)
1	-6.5
2	-4
3	-2.6
4	-1
5	1
6	3
7	6.6
8	10
9	11.4
10	11.8
11	13
12	13.8
13	15.6
14	16.8
15	17.6

Figure 4. 19 C/(I+N) thresholds in decibel

Table 4. 2 Surface area coverage

Name	**Surface (km^2)**	**% of Covered Area**	**%Focus Zone**
Overlapping Zones (DL) 0	**64.168**	**100**	**99.4**
No. of servers >=4	1.88	2.93	2.9
No. of servers >=3	7.545	11.758	11.7
No. of servers >=2	25.288	39.409	39.2
No. of servers >=1	64.168	100	99.4

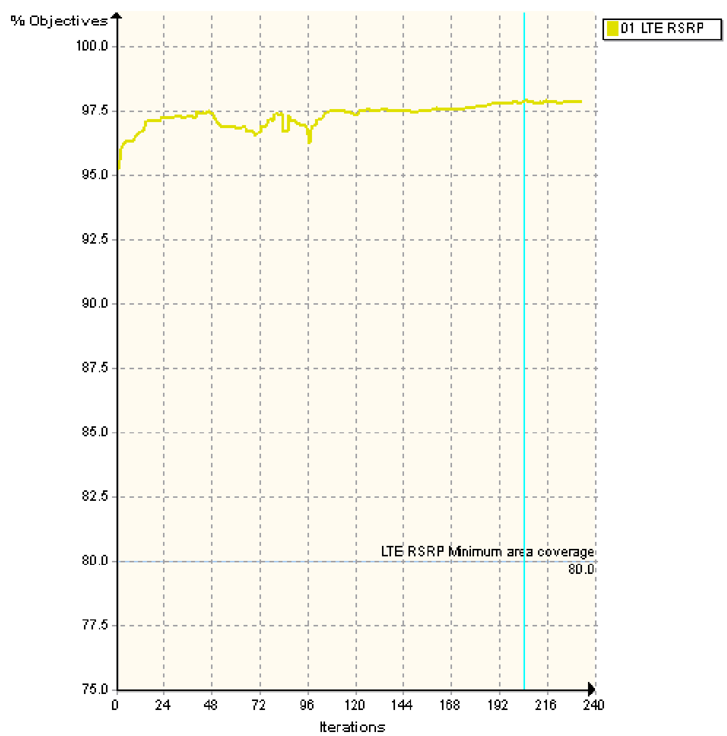


Figure 4. 20 %RSRP

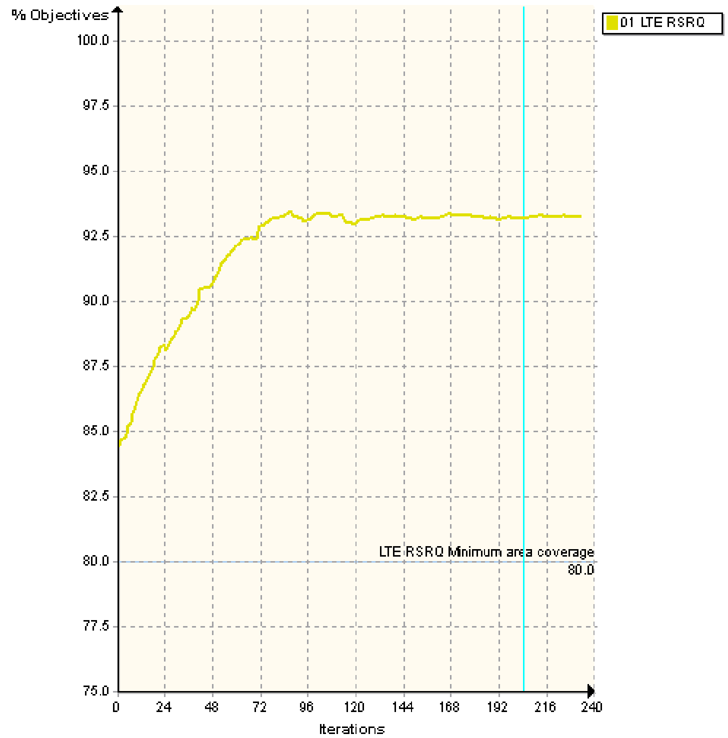


Figure 4. 21 %RSRQ

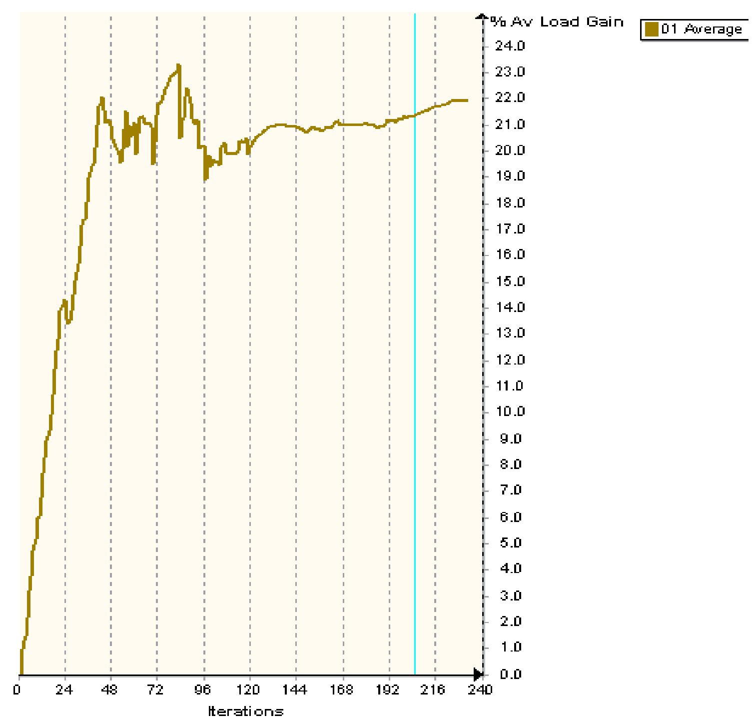


Figure 4. 22 Average Load Improvement

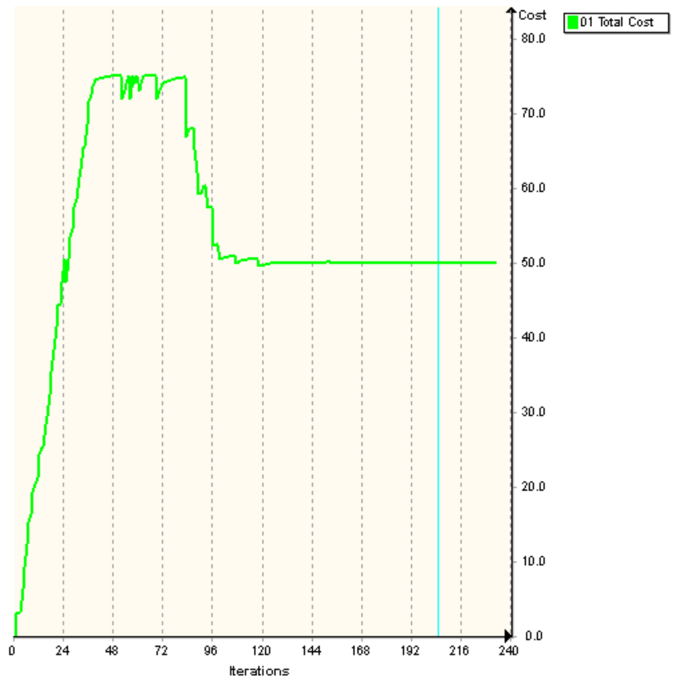


Figure 4. 23 Total Fixed Cost

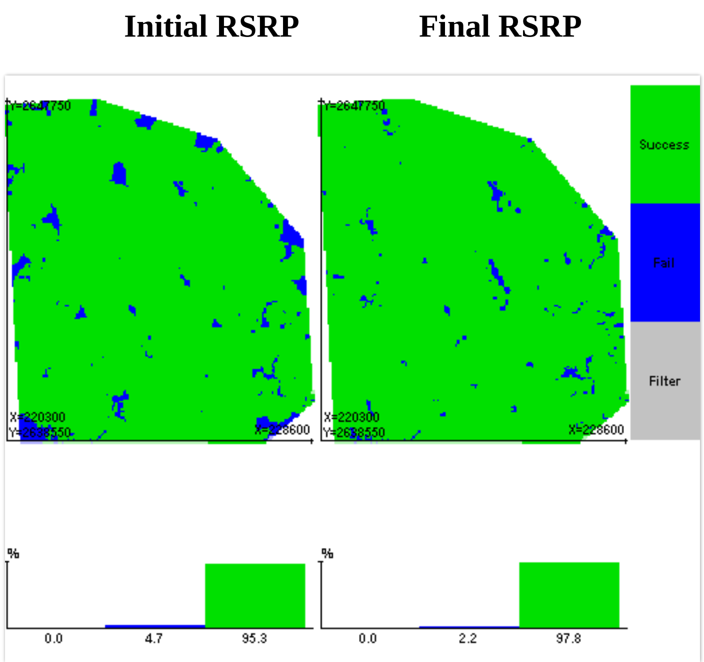


Figure 4. 24 Improvement in RSRP

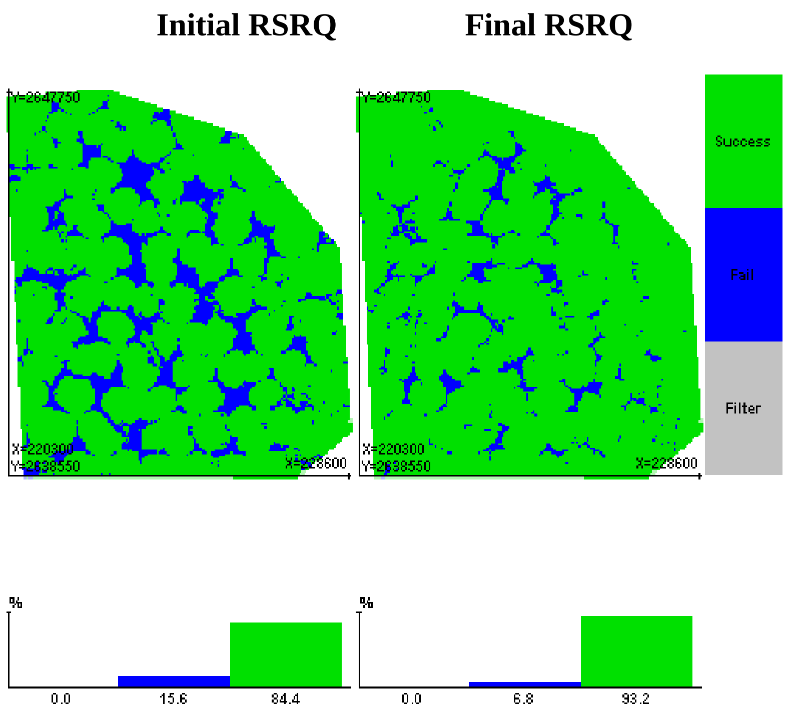


Figure 4. 25 Improvement in RSRQ

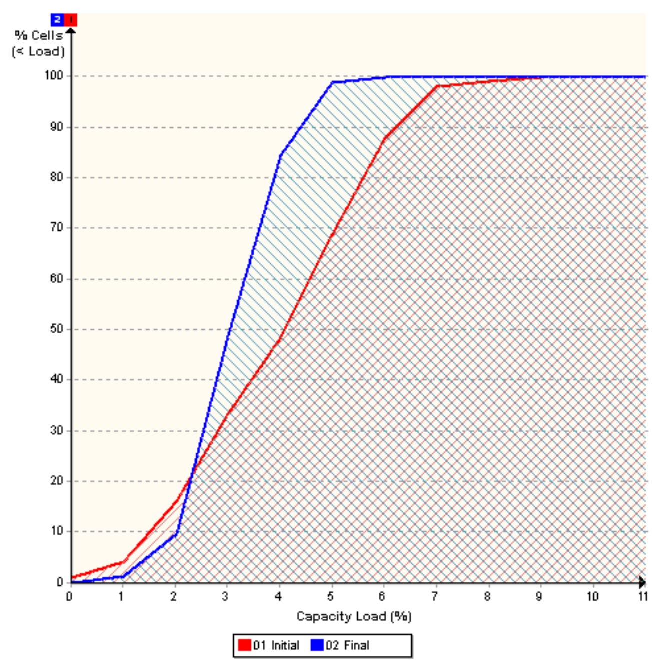


Figure 4. 26 Improvement in Capacity

Table 4. 3 Capacity Stats

Capacity stats		
	Initial	Final
Number of cells	99	84
Min	0.88	0.00
Max	9.49	6.10
Load balance	70.60	84.00
Average	4.99	4.09
Standard deviation	1.83	0.82

It is visible that the RSRP and RSRQ both improved as well as the capacity. After 240 number of iterations %RSRP increased from 95.3% to 97.8% and %RSRQ increased from 84.4% to 93.2%. Undoubtedly it is a good improvement but main drawback here is cost.

To reduce this cost we manually reduced the number of sites. Initially it was 33 then we reduced it to only 19. Then again we have calculated the basic predictions and observed the signal coverage and quality.

4.4 Manual Optimization:

Basic predictions:

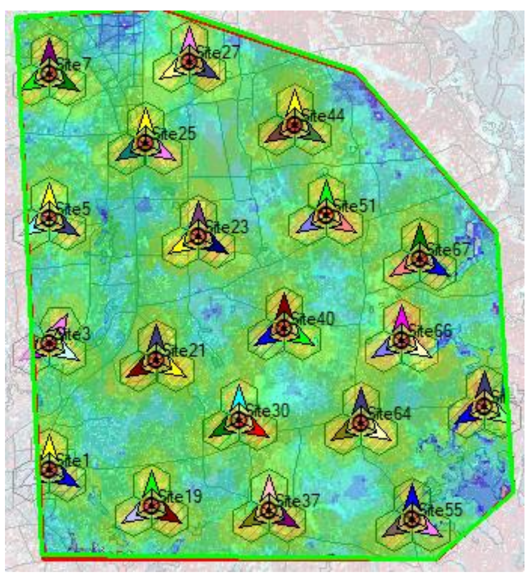


Figure 4. 27 Coverage by downlink signal level

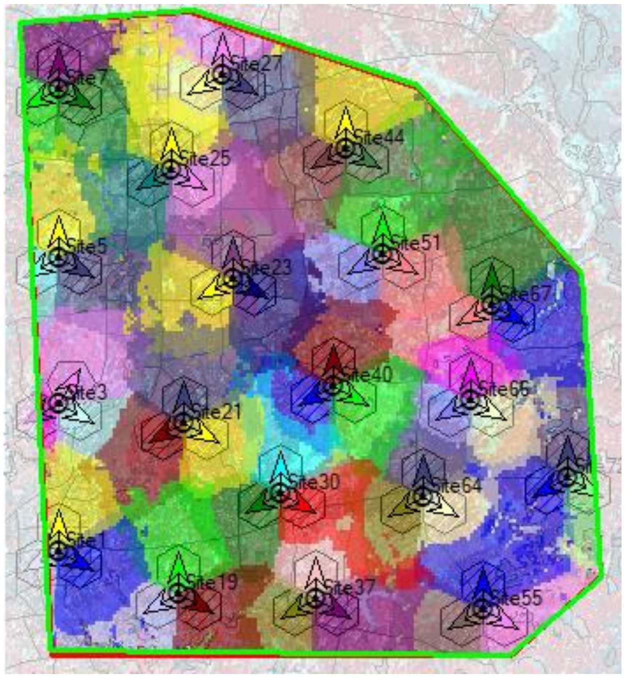


Figure 4. 28 Coverage by downlink transmitter

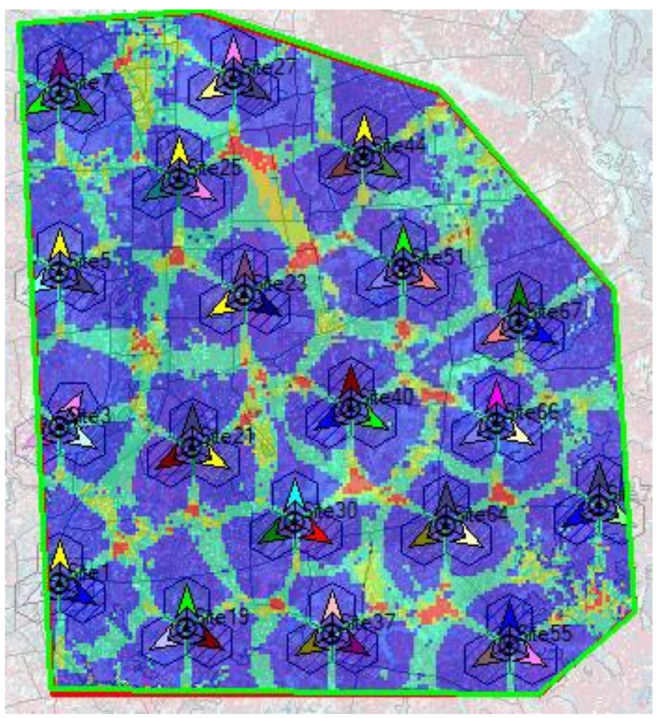


Figure 4. 29 Overlapping zone (DL)

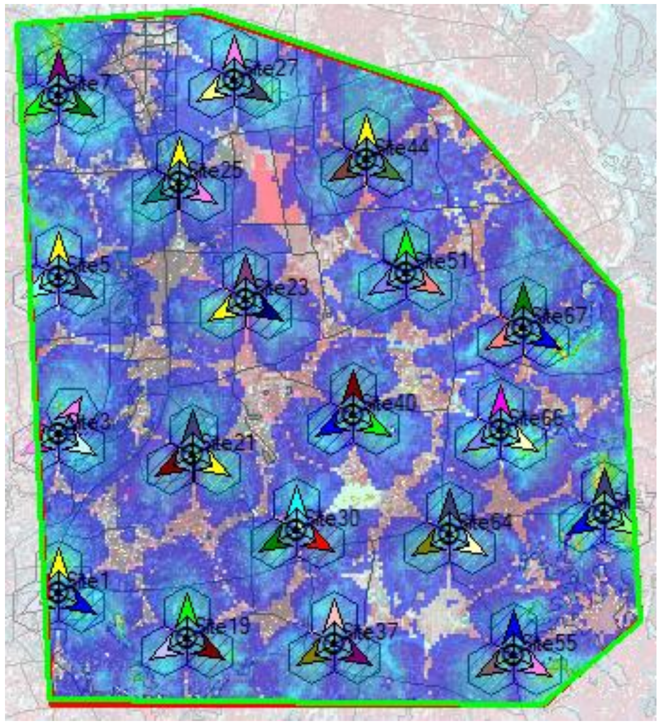


Figure 4. 30 Coverage by throughput (DL)

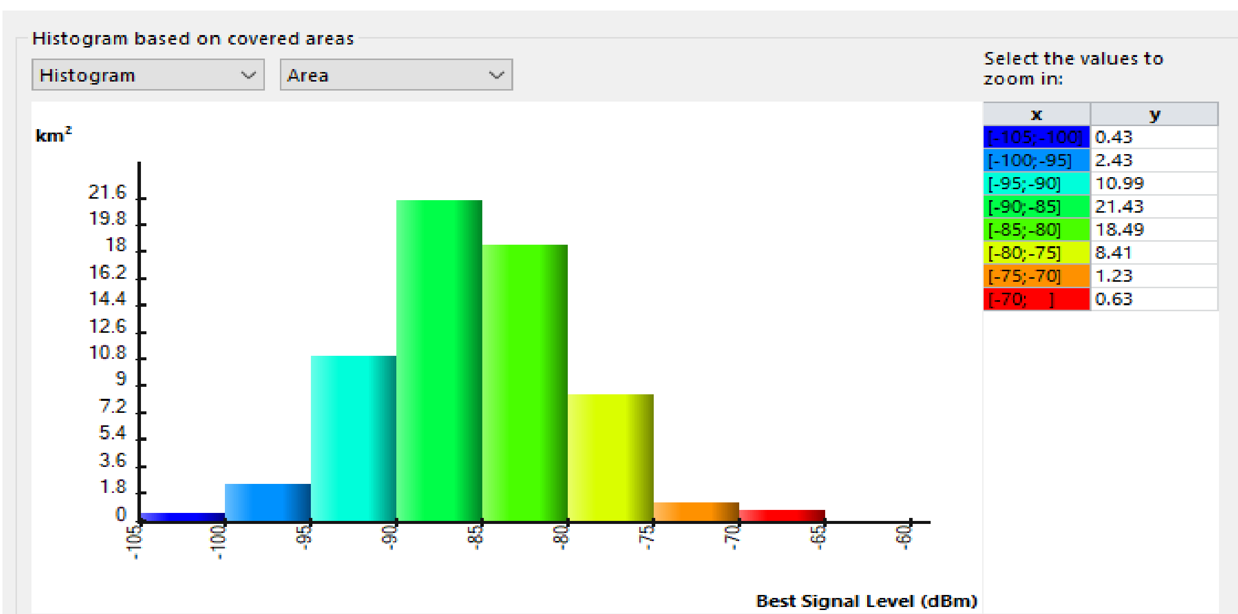


Figure 4. 31 Best signal level based on covered areas

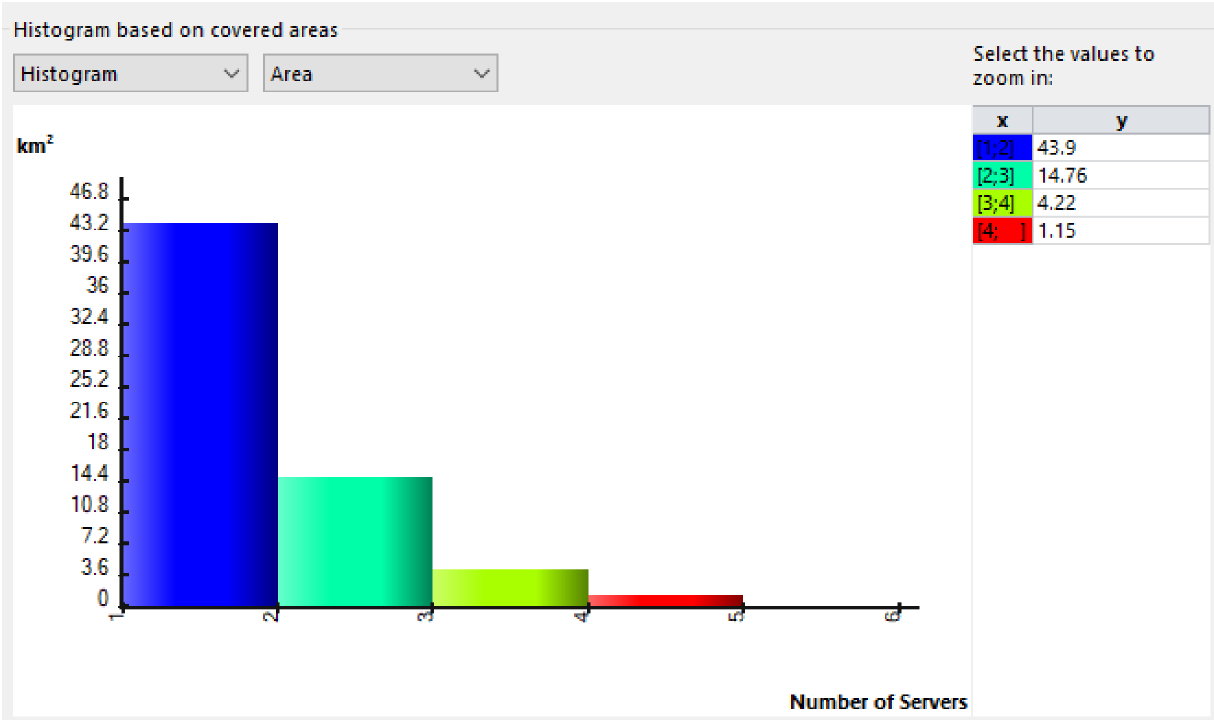


Figure 4. 32 Number of servers based on covered areas

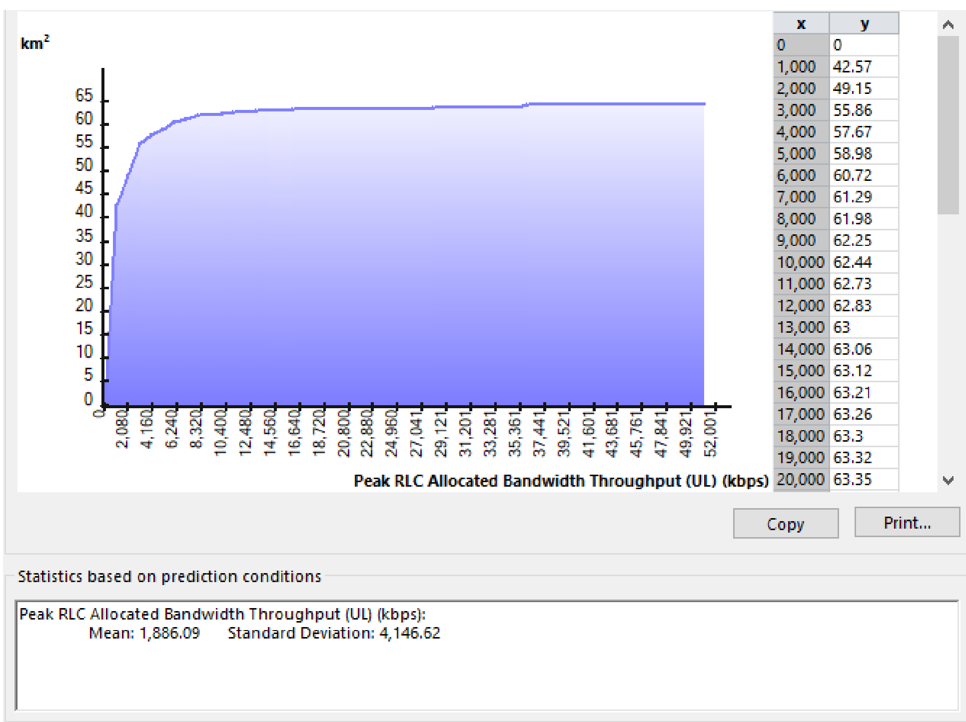


Figure 4. 33 Uplink Peak RLC throughput

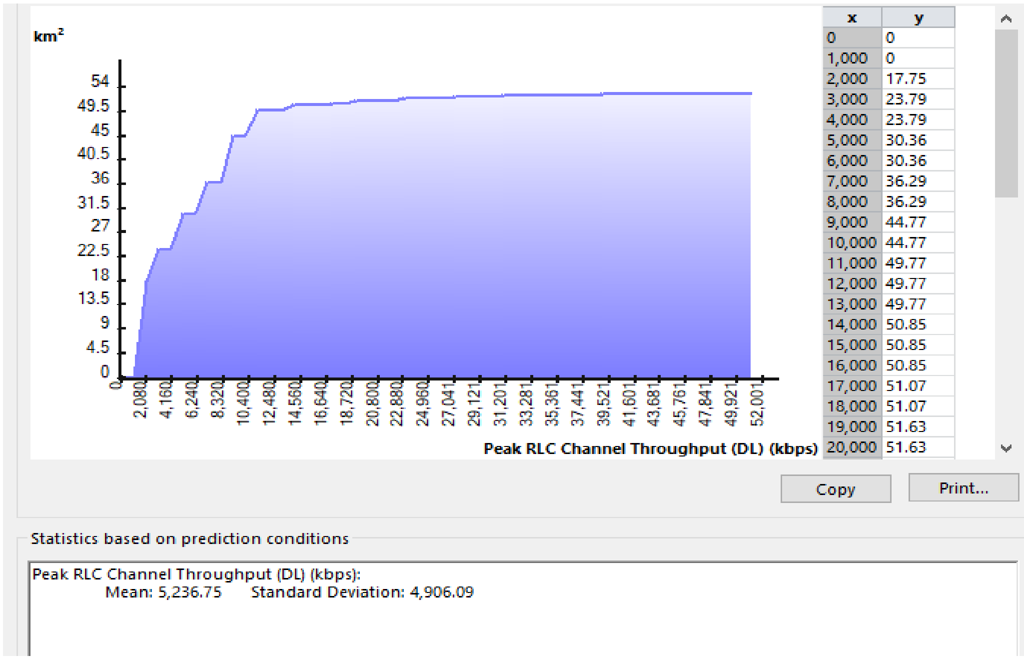


Figure 4. 34 Downlink Peak RLC throughput

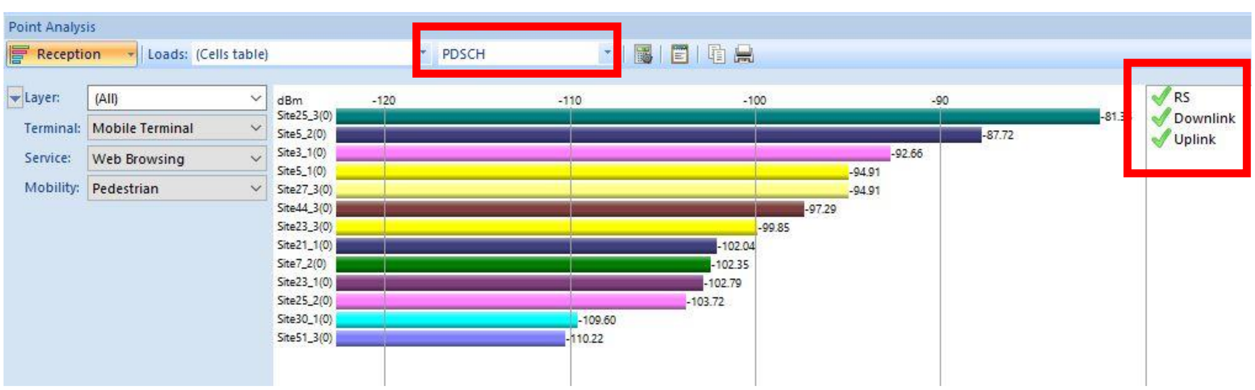


Figure 4. 35 PDSCH observation using point analysis tool

Figure 4. 36 Geographical Profile of site 7_2

We can see that subscribers mostly connected through PDSCH at both Uplink and Downlink [20]. And also Reference Signal (RS) is giving positive sign [21]. The figure (4.36) shows the geographic profile of site 7_2.

4.5 Results & Discussions:

Initial RSRP Final RSRP

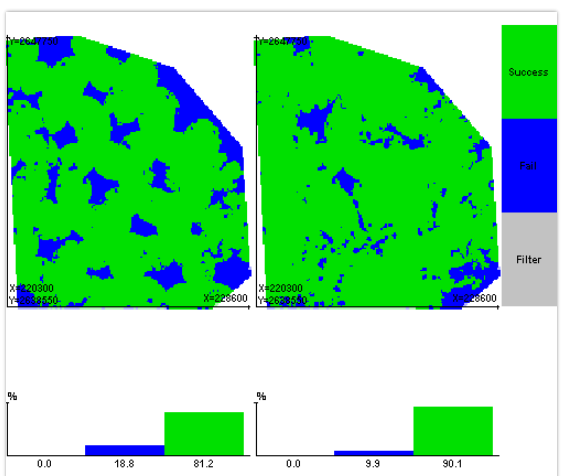


Figure 4. 37 %RSRP

Initial RSRQ Final RSRQ

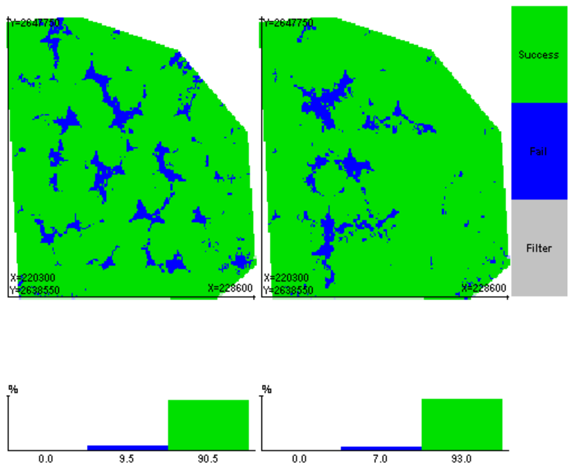


Figure 4. 38 %RSRQ

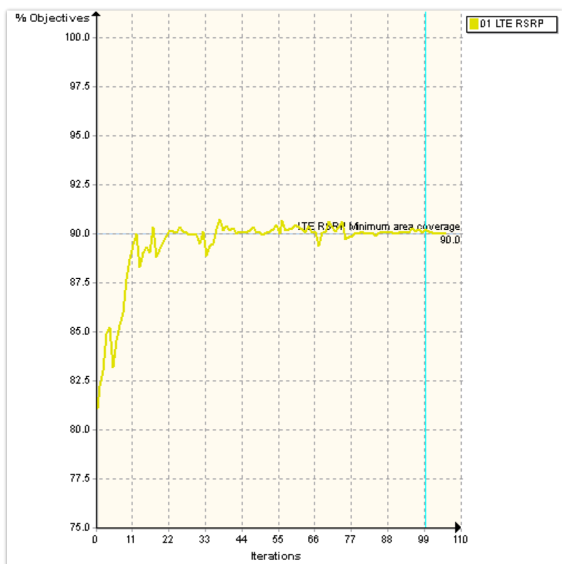


Figure 4. 39 Improvement in RSRP objectives

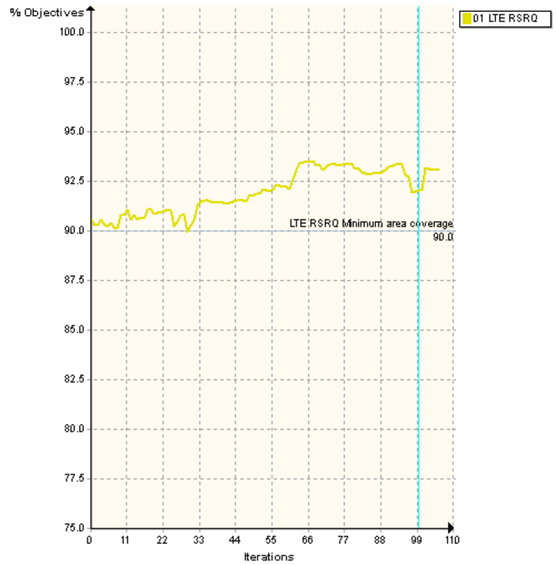


Figure 4. 40 Improvement in RSRQ objectives

Table 4. 4 RSRP and RSRQ objectives

Objective: RSRP		
Zone	Initial (%)	Final (%)
Focus	81.16	90.09
Computations	81.05	90.00
Objective: RSRQ		
Zone	Initial (%)	Final (%)
Focus	90.49	93.05
Computation	90.51	93.05

We have achieved desired coverage with an improvement of 8.96% in RSRP and 2.54% in RSRQ. In both cases our requested coverage was 90.00%. And this time we have achieved our expected result using only 19 sites.

Objective *LTE RSRP* (Coverage >= 90.0%)

	Evaluation Zone
Initial	81.05%
Final	90.00%
Improvement	***8.96%***
Objective	**ACHIEVED**

Objective *LTE RSRQ* (Coverage >= 90.0%)

	Evaluation Zone
Initial	90.51%
Final	93.05%
Improvement	***2.54%***
Objective	**ACHIEVED**

Figure 4. 41 Improvement statistics

Chapter 5

5. Conclusion and Future Prospects:

As broadband service is increasing drastically and in the field of cellular, extensive coverage, high capacity and QoS (Quality of Service) have become key factors to the users. The main purpose of this work was to study the Reference Signal Received Power (RSRP) & Reference Signal Received Quality (RSRQ). Also capacity level was performed.

In this thesis, Atoll was used to study and predict the coverage, quality and capacity. First we imported the map of "Dhaka City" then we selected our area of study. After that we implemented sites according to our necessity. Then we have seen the prediction results. To be more realistic, we again optimized the previous design to get a better coverage and signal quality by reducing the number of sites and modifying the antennas.

Our expected coverage was 85% and we have successfully achieved it. Network success rate depends on 3 factors. These are coverage, capacity & quality. Reducing dropped calls rate and optimization increased the capacity. Elimination of interference from both external & internal sources increases the quality of network.

Taking general parameters, traffic parameters, beamforming features and MIMO features into account the work was done. By modifying these parameters and taking necessary steps we have reduced the overlapping zones.

As for future work, we would like to compare between different propagation models and to sort out the best propagation model for 5G network in terms of signal quality, user throughput and coverage. These parameters can also be efficiently updated by combining different MIMO configurations and beamforming capable antennas.

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