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Network Simulation and Implementation of 5G NR Network in Tripoli City

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Abstract: Recent tremendous rise in mobile communications is transforming the globe into a completely linked civilization. Current 4G networks account for about half of global mobile traffic, and overall mobile data traffic is likely to skyrocket in the coming years. The fourth generation (4G) mobile communication system is incapable of meeting some unique needs such as high traffic density, high traffic volume density, a large number of connections, and high mobility. This research is aimed to examine the deployment of 5G NR in various situations utilising the expert radio-planning tool Atoll in order to improve 5G NR Co-exists 4G in the neighbourhood of Tripoli City by building a 5G NR network. It is intended to cover the area with a 4G/5G network.

Keywords: Mmwaves, Link budget, SS-RSRP, SS-SINR, 5G topology, NRand Coverage

Introduction

Users have grown accustomed to wireless network connections in a variety of devices, including smartphones and smart watches, during the previous few decades. Mobile communications have progressed from a comparable first generation (1G) that employed circuit switched technology, through a third generation (3G) that featured packet switching, and lastly to the most current fifth generation (5G). Mobile communication users have growing wants and expectations, which pushes technology progress to meet those demands. Many never-before-seen services and applications, such as self-driving cars, remote surgery, and artificial intelligence, are now available. Wireless carriers must be prepared to handle a three-order-of-magnitude increase in data traffic in order to serve the new services. Researchers have to locate more capacity in additional new wireless spectrum to do this[1]

Since the new wireless spectrum needs a larger quantity of capacity, millimeter-wave frequencies will be taken into consideration for the 5G New Radio (5G NR) technology's spectrum. For 5G NR , the Third-Generation Partnership Project (3GPP) defines two categories of frequency range: Frequency Range 1 (FR1), which covers 450 MHz to 6000 MHz in the sub-6 GHz range, and Frequency spectrum 2 (FR2), which covers 24250 MHz to 52600 MHz in the millimeter wave spectrum Channel bandwidths for the FR1 range form 5 MHz to 100MHz, while those for the FR2 range from 50MHz to 100MHz . Massive MIMO, mmWave beam steering, configurable time and frequency intervals, bandwidth sections, and mmWave propagation are just a few of the technical advances that will be available in future 5G networks. Prior to implementing any communications system, careful planning is required. For wireless network operators, the planning and optimization of the network is essential[1]. This report was developed for the 5G New Radio (NR) planning process using Atoll planning software. The findings of this study should help with the development of the 5GNR network as well as the monitoring of the Secondary Synchronisation Reference Signal Received Power (SS-RSRP) and Secondary Synchronisation Signal-to-Noise and Interference Ratio (SS-SINR) parameters in Tripoli, Libya.

Research Method

For the sake of the 5G NR coverage estimates in Atoll, each pixel on the map is treated as a non-interfering user with a defined service, mobility type, and terminal. This analysis provides information on effective signal levels, signal quality, and throughput.

An accurate user distribution at a certain moment is the foundation of a simulation. A snapshot is the representation of the user distribution at a specific time. Based on this snapshot, Atoll estimates a number of network characteristics, including user throughputs, uplink noise increase, downlink and uplink traffic loads, and more. Iterative calculations are used to calculate simulations.

A simulation, as opposed to a forecast, refers to a specific distribution of 5G users. Figure 1 depicts the network planning in Tripoli town using 5G technology.

This study concentrated on 5G NR planning at a frequency of 26 and 3.5 GHz based on coverage area, i.e. Planning in terms of the capacity and coverage they are served at sites in the covered area. Calculating the route loss and signal level as part of coverage planning tries to determine the signal strength and attenuation between UE and base station. The downlink and uplink data rates as well as cell capacities are calculated during capacity planning.

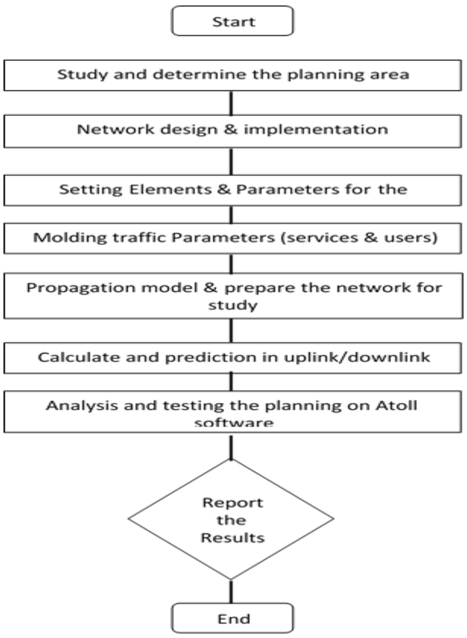

Fig 1: Flowchart of the paper

The number of sites needed to cover the target location was established by the study's findings. In the subsequent step, the parameters derived from the planning outputs were investigated. In reality, the first step in this study was to locate the area and create a digital map of Tripoli, Libya, where 5G New Radio (NR) network planning will take place. The area and geographic location of Tripoli were the data that were needed for this investigation. the taxonomy of services should also be determined. The analysis and execution of a planning simulation based on the data collected and the findings of the calculations served as the paper's concluding stage. Version 4.3 of the Atoll planning program was used to process the data.

A. *Coverage area*

The area that will be covered by a network serves as the basis for the computation used in the coverage planning. In reality, a number of variables, including transmit power, route loss, device sensitivity, radio link budget computation, and cell radius, might have an impact on this planning.

In this study, the network design tried to determine the ideal number of sites for the Tripoli region by estimating the coverage area for each site based on the propagation model to be used in the simulation.

TABLE 1: RSRP Value Category

Kategori	*Range*
Good	-70 dBm s/d -90 dBm
Normal	-91 dBm s/d -110 dBm
sBad	-110 dBm s/d -130 dBm

B. *Secondary Synchronisation- Reference Signal Received Power Parameter (SS-RSRP)*

The term "SS reference signal received power" (SS-RSRP) refers to the average power (Watts) measured on User Equipment (UE) from the cell transmitter's secondary synchronisation signal (SS).

The Secondary Synchronisation - Physical Broadcast Channel (SS-PBCH) window duration constrains the measurement time resource for SS-RSRP[11].

C. *SS reference signal received quality (SS-RSRQ) parameter*

The phrase refers to the NSS-RSRP/NR carrier RSSI ratio (also known as secondary synchronisation signal reference signal received quality, or SS-RSRQ), where N is the number of resource blocks in the NR carrier RSSI measurement bandwidth. Both the numerator and denominator measurements must use the same set of resource blocks [11].

D. *The signal-to-noise and interference ratio (SS-SINR) of a system.*

The SS signal-to-noise and interference ratio (SS-SINR) is defined as the linear average of the power contribution (in [Watt]) of the secondary synchronisation signal-carrying resource elements divided by the linear average of the noise and interference power contribution (in [Watt]) of the secondary synchronisation signal-carrying resource elements within the same frequency bandwidth [11].

E. *The rate of data*

Data rate, which is defined in bits per second, is the number of bits of data that may be delivered during a transmission process in one unit of time. The maximum DL and UL data rates supported are computed using the combination supported by the EU.

RESULT AND ANALYSIS

A. *Model of 3GPP 38.900 propagation*

The Atoll GPP 38.900 is a propagation model that can handle frequencies up to 100 GHz. The technical report 3GPP TR 38.900 backs this up.

The 3GPP TR 38.900 as implemented in ATOLL is a semi-deterministic propagation model in that it uses empirical formulas to calculate path loss along transmitter-receiver profiles and determines LoS/NLoS status based on actual geo data (rather than the 3GPP TR 38.900's suggested LoS/NLoS probabilities) [10]. Our propagation scenarios, which include Rural Macro, Urban Macro, Urban Micro, and Indoor Hotspot, are defined by ATOLL 3GPP 38.900. Established sets of empirical formulae are used for both line-of-sight (LoS) and non-line-of-sight (NLoS) propagation under each propagation scenario, known as a configuration in Atoll. These formulae allow for the user-defined and automatic calibration of the route loss terms' coefficients using measurement data.

B. *Standard Propagation Model (SPM)*

The Standard Propagation Model (SPM) is based on the Hata formulas and is suited for scenarios in the 150 to 3500 MHz band over long distances.

This paper applied 5G mmwave a 24-100 GHz frequency range, which is a 3GPP 38901 propagation model used. Also 3.5 GHz that belong to new bands below 6 GHz, which Standard Propagation Model (SPM) used.

C. *Simulation Results*

This research have couple simulation scenarios, the first will be establishment of the 5G NR network In a certain area in the city of Tripoli. The second will be an upgrade from the fourth generation network to the fifth generation, 4G / 5G network will be deployed, there will be large macro cells and 5G small cells to cover the area in addition to the scenario of a crowded party or event.

The locations of the sites were determined using the Site Placement feature of the Atoll programme. The simulation results showed the parameters' values for SS-RSRP and SS-SINR, the average data rate achieved throughout, and the number of gNodeBs necessary to fully cover the selected region of Tripoli.

TABLE 2: THE ESSENTIAL SYSTEM PARAMETERS [4] [6] [7].

Parameters	**Settings**	
	Scenario1 ***5G***	*Scenario2* ***5G/4G***
Frequency band	n78 3.5)/n256 (26) GHz	*5G* (3.5 / 26 GHz) *4G* (900 MHz)
Carrier BW (MHz)	100/200/400	*5G* (100/200/400) *4G* (20/15/10)
Duplex Mode	TDD	TDD
Propagation Model	3GGP / SPM	3GGP / SPM/Cost_Hata
Max power (dBm)	50	50/43 for both
SSS EPRE (dBm)	15	15
Antenna H (m)	30	30
Layer	*5G* Macro cell / small cell	*LTE* Macro cell /*5G* small cell
The type of cell	P-Cell	P-Cell
Minimum SS-RSRP	-140	-140
SS/PBCH numerology	(15 KHz)/ (120 kHz)	(15 kHz)/ (120 kHz)
Number of	6 Sites * 3	12 Sites * 1 sectors

gNodeB	sectors	
Planning Area	25.11 km²	1.31 km²
Traffic numerology	2 (60 /120 kHz) Normal CP	2 (60 /120 kHz) Normal CP
Radio equipment	5G NR Radio Device	5G NR and LTE Radio Device
Scheduler	Proportional Fair	Proportional Fair
Diversity support (DL)	Transmit Diversity; SU-MIMO; MU-MIMO	Transmit Diversity; SU-MIMO; MU-MIMO
Diversity support (UL)	Receive Diversity; SU-MIMO; MU-MIMO	Receive Diversity; SU-MIMO; MU-MIMO

1. *Scenario 1 5G NR network Downlink*

A. *SS-RSRP*

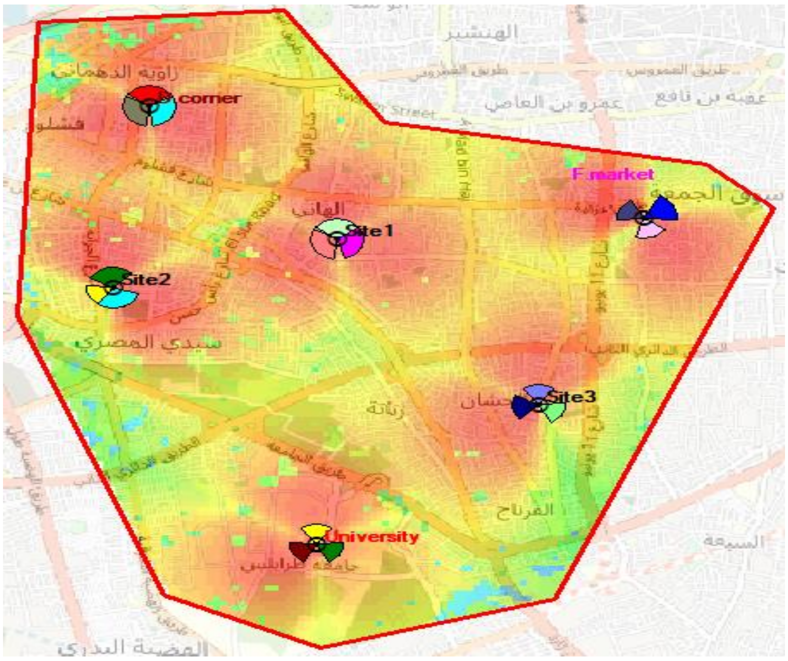

Fig 2: Scenario 1 SS-RSRP Parameter

TABLE 3: Statistical Calculation Scenario 1 SS-RSRP Parameters

Raster Statistic	**Value (dBm)**
Minimum	-140
Maximum	-70
Mean	-95

Results of the SS-RSRP simulation on coverage area can be seen at Table below.

TABLE 4: The Results of SS-RSRP Scenario 1

SS-RSRP Value	Percentage %	Area km2)	Color
-70 to 80 dBm	44.054	13.406	
-80 to 90 dBm	41.2	11.144	
-90 to 100 dBm	11.6	3.041	
-100 to 110 dBm	1.7	0.24	
-120 to 140 dBm	0.88	0.142	

The forecast utilising 6 sites, each with 3 gNodeB, yielded an average SS-RSRP of -82.02 dBm. This indicates that the preceding technology (5G) has excellent signal strength. SS-RSRP, on the other hand, was measured in this investigation with a minimum value of -140 dBm and a maximum value of -70 dBm.

B. Data Rate

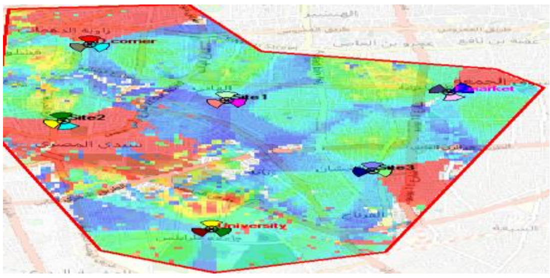

Fig 3: Scenario 1 Data Rate

TABLE 5: STATISTICAL CALCULATION SCENARIO DATA RATE PARAMETERS

Raster Statistic	**Value (Mbps)**
Minimum	20
Maximum	250
Mean	120

As shown in Table VI the results of the data rate based on coverage area.

TABLE 6: The RESULTS OF SS-RSRP SCENARIO 1

Data Rate Value	Percentage %	Color
250_200 Mbps	28.79	
200_150 Mbps	7.28	
150_100 Mbps	18.38	
100_50 Mbps	25.82	
50_20 Mbps	19.7	

The data rate average that obtained from the prediction using 6 sites each with 3 of gNodeB was 140 Mbps . This means that the data rate is good in the previous technology (5G). Meanwhile, this research showed SS-RSRP with a low value of 20 Mbps and a high value of 250 Mbps.C. SNR

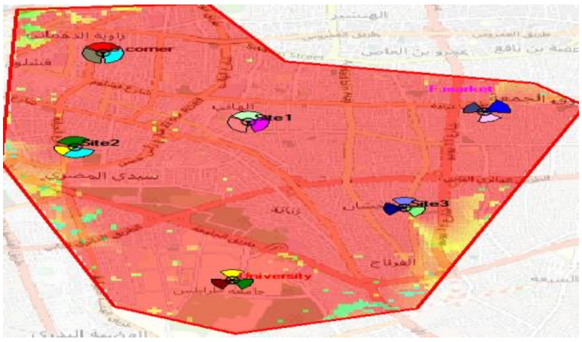

Fig4: gNodeB mapping scenario 1 SS-SINR parameter

TABLE 7: Statistical Calculation Scenario 1 SS-SINR Parameters

Raster Statistic	Value by (dB)
Low	-20
High	30
Mean	10

Results of the SS-SINR simulation based on coverage area can be seen at Table below.

TABLE 8: SIMULATION RESULTS OF SS-SNR SCENARIO 1

SS-SNR Value	Percentage %	Area (km2)	Colo r
30 to 20 dB	96.93	24.18	
20 to 10 dB	1.86	0.48	
10 to 0 dB	0.81	0.2	
0 to -10 dB	0.36	0.1	
-10 to -20 dB	0	0	

The average SS-SNR obtained from the prediction using 6 sites each with 3 sectors of gNodeB was 25 dB. This means that the signal strength is very good in the technology of (5G). Meanwhile, this study showed SS-RSRP with a minimum value of -20 dB and a maximum value of 30 dB

2. *Scenario 2 upgrade from the fourth generation to the fifth generation network, 4G& 5G NR network.*

In this case study, the scenario is proposed 4G & 5G network work together, and a party or festival is supposed to be covered in a certain square in Tripoli. As well as the advent of mmWave bands for 5G NR Small cells, collaboration between 5G, 4G macro cells, and 5G Small cells alone will be necessary in this situation. (i.e. creating the 4G network, as if the present network and then upgrading and developing it to the 5G network on top of the 4G network).

The locations of the sites were chosen to cover as much of the region as feasible in order to have a uniform distribution of users across all cells. The total size of the selected area is 1.31 km² it is a different area than the one in the first scenario 1.

As indicated in the graphic below, six separate transmitters dispersed across several sites will provide LTE coverage for the whole region.

Fig5: Distribution of the LTE Sites and Transmitters.

As indicated in the graphic below, 4 separate transmitters dispersed across several sites will provide 5G NR coverage for the whole region. The 4 5G sites will be radiating as macro cells

Fig6: Distribution of the 5G NR Sites and Transmitters.

5G NR limited cell deployment Because the event or festival will take place in a very limited area, small cell deployment at higher frequencies, notably millimeter range frequencies, has been chosen as the means to cover it.

Small cells are pieces of radio equipment that may be mounted on buildings, traffic signals, or other objects.

It is first necessary to choose the Martyrs Square where the ceremony would take place. Martyrs' Square will be used as the location for the festival simulation because it is where the Tripoli City Festival and performances are held. Then, as indicated in the image below, the traffic map is constructed as precisely as possible to make it as realistic as feasible.

Fig 7: The festival area, Martyrs Square

The following figure shows the creation and orientation of the small cells in the festival area (Martyrs Square) in Tripoli.

Fig 8: 5G NR Small cells.

Finally, the "Default Beamformer" is used by all transmitters in both LTE and 5G NR. However, 5G NR need 128 for both transmission and reception antennas, compared to 4 transmission and 4 reception antennas for LTE transmitters

Each transmitter also uses its mechanical azimuth value to direct its beam towards a particular spot.

A. Coverage by SS-RSRP and Transmitters

Using Atoll's prediction, the area that each transmitter will cover in a 4G/5G network can be determined as shown in the following figures.

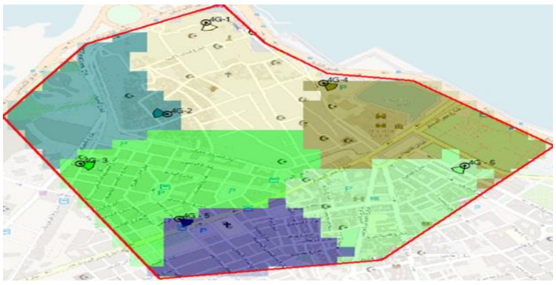

Fig 9: Area Covered by LTE Transmitters

The prediction chosen depends on the received reference signal strength (SS_RSRP), a common indicator of coverage quality.

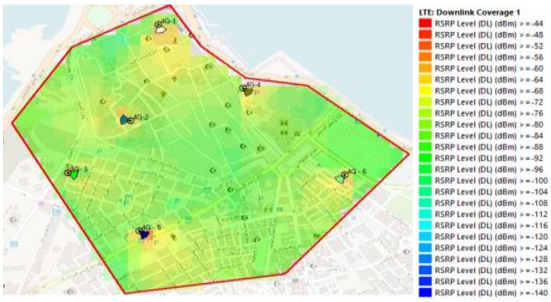

Fig 10: LTE Coverage by SS-RSRP

TABLE 9: LTE SS -RSRP Statistical Calculation PARAMETERS

Raster Statistic	Value (dBm)
Minimum	-140
Maximum	-44
Mean	-96

The forecast made using 6 sites of gNodeB yielded an average SS-RSRP of -79.72 dBm. The bulk of the region seems to be covered by a pretty strong reception signal for the older technology (4G). A minimum value of -140 dBm and a maximum value of -44 dBm were found for SS-RSRP in this investigation.

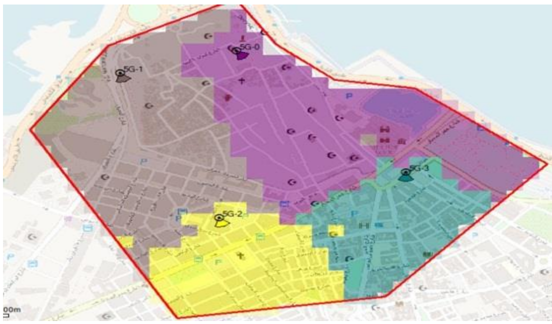

Fig 11: Area Covered by 5G NR Transmitters

The prediction chosen depends on the received reference signal strength (SS_RSRP), to indicate the coverage quality of 5G gNodeB Transmitters.

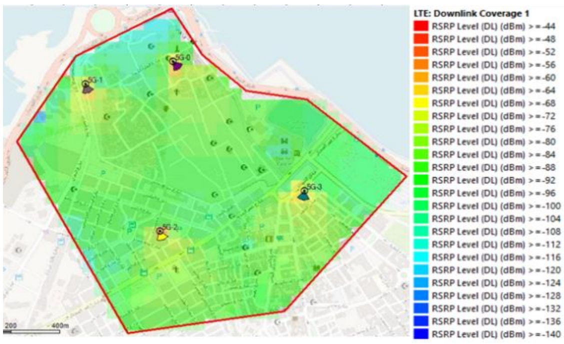

Fig 12: 5G NR Coverage by SS-RSRP

TABLE 10: 5G SS -RSRP Statistical Calculation PARAMETERS

Raster Statistic	Value (dBm)
Minimum	-140
Maximum	-44
Mean	-96

The forecast made using 6 sites of gNodeB yielded an average SS-RSRP of -88.72 dBm. In the previous technology (5G), the vast majority of the region is covered by a pretty strong reception signal. A minimum value of -140 dBm and a maximum value of -44 dBm were found for SS-RSRP in this investigation. A forecast of 5G NR Downlink footprint was developed and is provided as shown below in order to see if the full party or festival can be covered by just two 5G small cells.

Fig 13: 5G Small Cells Coverage by SS-RSRP

This graph demonstrates that a strong SS-RSRP signal level of roughly -90 dBm will cover the party area.

B. 3D Simulator

The simulations will assist in determining weather the deployment was effective or whether the small and macro cells distribution is insufficient to simultaneously cover a concert and this computation zone.

The results of the final simulation, which was run using the two traffic maps of the 5G/4G network's macro and small cells, are depicted in the following image.

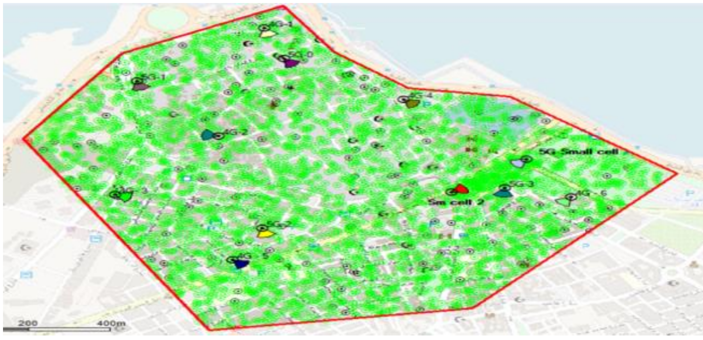

Fig 14: 5G/4G Network Simulation Result.

3,565 people are included in this simulation shows that the bulk of them are connected (green dots). with only a small proportion having no coverage or service. The specifics of these percentages are depicted in the image below.

Total number of users not connected (rejected): 7 (0.2%)
No Coverage: 7
No Service: 0
Scheduler Saturation: 0
Resource Saturation: 0
Backhaul Saturation: 0

Fig 15: Breakdown of the Rejected Users

Out of 3,565 users, 7 have been denied in total, giving the rejection rate a 0.9% value. It can be observed that 0 have no service and 7 have no coverage in the figure below.

For the concert users, a zoomed image will be presented below because the data above do not depict whether the concert users were accepted by the network or not.

Fig 16: Simulated Concert Users

It appears to be a decent proportion, however in order to do a more thorough research, no concert attendees were turned away from the network owing to any issues. The tables below provide comparisons.The lowest and maximum demand for each service will be compared in the table with the outcomes.

TABLE 11: COMPARISON OF DEMAND AND ACHIEVED SIMULATION RESULTS

Service	Demand connected users	obtained connected users	Min Throughput Demand (UL) Mbps	Max Throughput Demand (UL)Mbps	obtained Throughput (UL) Mbps	Min Throughput Demand (DL) Mbps	Max Throughput Demand (DL)Mbps	obtained Throughput (DL) Mbps
Broadband	2,859	2,853	899.9	8,999	5,437.45	1,055.8	20,888	7,883.94
Internet	245	245	1.1	11	11	44.6	446	265.13
Video	71	71	384	900	900	0	0	0
Voice	357	356	1.49	1.49	1.49	1.51	1.51	1.51
Concert service	33	33	0	1,700	1,700	0	800	800

The table demonstrates that each throughput value obtained falls between the lowest and maximum demand for each service.

Conclusion

This work designed and improved 5G NR networks, models and parameters NR planning was studied and the main objective was to develop a study allowing to implement the dimensions of 5G networks, and then implement the 5G NR network planning for some areas in Tripoli using the simulation program Atoll.for tthis paper Atoll was used to implement coverage predictions, quality predictions, amplitude predictions, and realistic simulations in order to study signal propagation using different propagation models and the benefits of using beamforming and massive MIMO. As a consequence of the 5G NR network design based on coverage area by watching SS-RSRP and SS-SINR parameters, has satisfactory and normal network performance. The average data rate of downlink 140 Mbps. The second case study, on the other hand, similarly offered coverage in a different location via a 4G/5G network, but this time it also addressed the difficulty of handling a scenario in which several individuals are crammed into a small region, the outcomes in terms of rejected users in this case were successful because the network displayed a 0.2% offline user percentage with no coverage on the map's edges. The majority of service consumers were then pleased with the network's throughput performance.

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