

5G Wireless Channel Test Scenarios Including Simulations of Swarm Intelligence Optimization Algorithms on Massive MIMO Simulation Network

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Abstract

5G Wireless Communication technology hardware trials, testbed and deployments are happening throughout the world in a faster pace since 2018. When this standard rolled out by IMT 2020, ITU and 3GPP, the deployment and market usage is expected by the year 2020. Various universities and telecom companies already deployed trials and implemented test trials. The principle document for any testbed or hardware trials or deployments need to cater the understanding of 3GPP release document as of now LTE release 17 – M.2412 document. This paper concentrates on the various channel propagation test environment scenarios adopted in this LTE release M2412 document. This paper shows the basic simulation that completes estimation of received power versus transmitter-receiver distance in urban macro and Rural Macro, LMLC test model environment. This research paper also aims for a second part which is also an extension of the author work published in one of the similar work in applying swarm intelligence optimization on a Massive MIMO simulation work. This work utilizes two swarm intelligence optimization algorithms, Chameleon swarm intelligence optimization (CSIO) and Capuchin search optimization (CSO) algorithms applied on Massive MIMO network. The constraint parameters of spectral efficiency estimation of uplink scenario identified are bandwidth, B, transmission power P and coherence time, Tau_C by taking a Massive MIMO network simulation framework. Lower bound and upper bound values are fixed for these constraint parameters and found out the best global values. These global values of constraint parameters are feed back to the Massive MIMO network simulator and observe the spectral efficiency considering Number of base station antennas, M = 10, number of user antennas, K=1 considering M-MMSE receiver combining scheme. This paper leads to a new research insight of developing mathematical structure of swarm intelligence to ensure the entire network which the author consider as a future scope of study.

Keywords: 5G Communication, Massive MIMO, 5G Test scenarios, Channel Models, SINR, 3GPP release 17, LMLC

1. Introduction

5G Communication technology aims to offers remarkable improvement in data rate and spectral efficiency, along with, low power consumption and latency compared to 4G standards [1]. This generation standard is proposed by ITU, 3GPP, IMT-2020 and various partner telecom companies. The entire 5G implementation, test trials and deployments taking care of core network and channel modeling is based on the timely releases of LTE. LTE release 14 onwards is for developing 5G standard and timely restructuring and advancements is shown in further releases as the years progressed since 2015. However, the proposed implementation of 5G is expected in

year 2020. However, it is now in release 17 document and the trials and technology deployments are reached based on this document. In this paper, authors are focusing on LTE release 17 standard documents M.2412 [5]. However, the details of various channel models such as Indoor Hotspot (InH), Urban Micro (UMi), Urban Macro (Uma), Rural Micro (RMi) and Rural Maro (RMA) and LMLC (Low Mobility Large Cell) and the related specifications and pathloss model scenarios are re-visited and interpreted for the better understanding of research developments..

2. 5g Standard Deployment Scenarios

This section focus on various research challenges and current updates on deployment of 5G. Some of the areas addressed in this section include current updates on 5G testbed, channel measurement scenarios implemented in test trials by various universities and from industry perspectives and influencing parameters of spectral efficiency in Massive MIMO testbed. T H Lohet. al (2020) [1], developed a research testbed of 5G based on Massive MIMO in an indoor environment in University of Surrey. It consists of 128 channels with SDR environment, 64 active transmit antennas, 8 beam forming scenarios with single user and multi user downlink scenario. The testbed scenario is in Fig. 1.



Fig 1. Massive MIMO Testbed, University Surrey [1]

This paper involves detailed analysis from the basics of 5G test environments, segments of 5G and channel models updates on various simulators. 5G Segments of various applications are fitted into three as shown in Fig 2. The paper captures various channel model scenarios to develop hardware trials or testbeds as in Table 1.

Table 1. Channel Model Scario 5G Test Environments [2]

Type Name	Description	Scenario
Indoor Hotspot - eMBB	Offices or shopping malls	Environment: floor with an area of 120 m x 50 m Users: stationary or

		pedestrian Deployment: 12 sites which are placed in 20 m spacing
Dense urban - eMBB	City with high user density	Environment: urban environment with 19 sites (Inter Site Distance (ISD) = 200m) Users: pedestrian and vehicular Deployment: Composed of two layers, macro and micro. The macro layer follows a regular grid with three Transmission Reception Points (TRxPs) per site and the micro layer is composed of 3 micro sites randomly dropped in each macro TRxP area
Rural eMBB	Rural area with larger and continuous coverage	Scenario: rural environment with 19 sites (ISD = 1732 M or 6000 m) Users: pedestrian, vehicular and high speed vehicular Deployment: regular grid as in the dense urban - eMBB

		environment
Urban macro-mMTC	City with a high number of connected machine type devices	Scenario: urban environment with 19 sites (ISD = 500m) Deployment: regular grid as in the dense urban – eMBB environment
Urban macro-URLLC	City with services requiring URLLC communications	Deployment: regular grid as in the dense urban – eMBB environment

Chiraviglio L et. al (2017) [3], addressed the issue of not getting at least 2 billion people without wireless connectivity, those who are in the regions of low income regions and rural areas, where, telecom setup investments is difficult in this areas. The reduction in cost is estimated in low income regions and rural areas. Table 2 provides a chart taken from this paper that shows the 5G Deployment scenarios.

Table 2 Comparison - Urban, rural and low-income areas [3]

	5G Urban Scenario	5G Rural Scenario	5G Low-income scenario
Service Type	HD video, HD streaming, tactile internet, IoT	HD Video, emergency service, e-Health, e-Learning	Basic connectivity, emergency service, delay-tolerant, e-Health, e-Learning
Network Constraints	Maximize bandwidth, minimize delay, coverage	Coverage, guaranteed bandwidth	Coverage
Energy Sources	Power grid	Power grid,	Unreliable power

		renewable resources	grid and/or renewable sources
Monthly User Subscription fee	Pay per bandwidth	Same as standard Urban areas	Low
Business Model	Return on investment	Subsidized by the government	Subsidized by the government
Required network flexibility	High	High	High
User mobility	Pedestrian, vehicular, high speed vehicular	Pedestrian, vehicular	Pedestrian, low-speed vehicular

In this section, authors focused on bringing the attention of the researchers in the 5G current testbeds in development, link level 5G simulator and a brief idea of different channel models scenarios of 5G and the possible test environment.

3. Test Environment Scenarios

In this section, it is explained the ITU M.2412 – LTE release 17 document 5G Test environments for channel modeling scenarios. Also, discussed some important research papers and the key results obtained in the test propagation environment scenarios. As the detailed specifications and test environments are in this document, this paper picks only one case of scenario – Which is Rural Macro and Low Mobility Large Cell (LMLC). Table 3 shows the evaluation configurations for Rural – eMBB and a sub channel model case – LMLC. The other test cases are available in the M.2412 document [5].

Table 3 Evaluation configurations for Rural – eMBB test environments [5]

Parameters	Rural – eMBB	LMLC
Carrier frequency	700 MHz, 4GHz	700 MHz
BS antenna Height	35 m	35 m

Total Transmit power	49 dBm for 20 MHz and 46 dBm for 10 Mhz	49 dBm for 20 MHz and 46 dBm for 10 Mhz
UE power class	23 dBm	23 dBm
Inter-site distance	1732 m	6000 m
Number of antenna elements	Upto 64 Tx/Rx, Upto256 Tx/Rx	Upto 64 Tx/Rx
Device deployment	50 % indoor, 50 % outdoor (in car). Randomly and uniformly distributed over the area.	40 % indoor, 40 % outdoor (pedestrian), 20 % outdoor (in car). Randomly and uniformly distributed over the area
UE mobility model	Fixed and identical speed of all UEs, randomly and uniformly distributed direction	Fixed and identical speed of all UEs, randomly and uniformly distributed direction
UE speeds of interests	Indoor users: 3km/h; outdoor user (in car):120 km/h, 500 km/h for evaluation of mobility in high-speed case	Indoor users: 3km/h; outdoor user (pedestrian):3 km/h, outdoor users (in car):30 km/h
BS noise figure	5 dB	5 dB
UE noise figure	7 dB	7 dB
BS antenna element gain	8 dBi	8 dBi
UE antenna element gain	0 dBi	0 dBi
Thermal noise level	-174 dBm/Hz	-174 dBm/Hz
Simulation	20 MHz for	20 MHz for TDD,

bandwidth	TDD, 10 MHz+10 MHz for FDD	10 MHz+10 MHz for FDD
UE density	10 UEs per TRxP Randomly and uniformly distributed over the area	10 UEs per TRxP Randomly and uniformly distributed over the area
UE antenna height	1.5 m	1.5 m

In release 17 of 3GPP Document Rural Macro channel model, especially, on LMLC standard is provided. This standard is used to specifically considering rural areas in India scenario [11], [16]. It is discussed about the rural large cell of Inter sector distance of 6000 meter (6KM), where, one base station tower in Gramapanchayath can serve all the nearby rural areas of 6KM distance. The spectrum allocated is 700 MHz and in 3.5GHz. Other parameters of LMLC are, channel bandwidth of 10 MHz, transmission power of 46 dBm, antenna tilt angle of 6 degree, maximum of 3 Km/hr of speed or low mobility is expected in LMLC. A typical cellular deployment in rural setting is shown in Fig 2 [16]. The structure shows that the base stations are installed (installed in GramaPanchayat – Main Village point) far apart and one base station connects to other villages in the nearby rural areas. Therefore, an LMLC network can really set a channel model scenario, considering, 5G deployment in near future offering service availability to the rural areas.

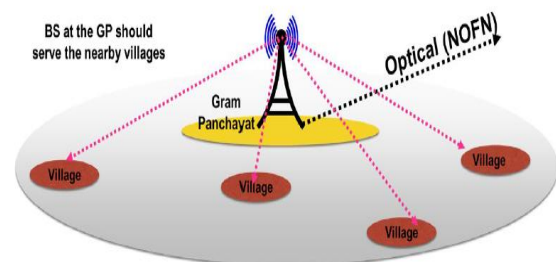


Fig 2. Typical cellular deployment in a rural Indian Scenario (Image courtesy [16])

4. Simulation Results And Discussions

The first simulation work is based on the rural test scenario-Urban Macro and Rural Macro. This paper also tried to develop SINR Vs CDF measurements of all channel model scenarios. However, the scope of attempt is done with receiver power, PrVs T-R distance (Distance) is plotted for Rural Macro, Urban Macro and InH. The simulation runs in basic Java platform mimicking the 3GPP M.2412 model. In Fig. 5 Received power versus Distance for Uma_A (Urban Macro-Configuration A) and in Fig. 3, Received power versus distance for UMa (Urban Macro) for both configuration. It is seen that the plot is for both LOS and NLOS cases using the pathloss expressions provided in the M.3214 document. In Urban Macro-transmission power of 49 dBm, 20 MHz of bandwidth and carrier frequency of 700 MHz and in Rural Macro scenario, parameters chosen are 44 dBm, 20 MHz of bandwidth and carrier frequency of 700 MHz. The simulation result shows the requirement of providing the parameters and pathloss expression provided in the document. This shows the transmission power is more in urban macro compared to rural macro. Also, the NLOS offers less received power as distance increases because of the multipath fading issues and the requirement of large and small scale fading parameter modeling is required.

In Fig. 4, Received power versus distance for UMa (Urban Macro) for both configurations, Rural Macro is plotted which shows both LOS and NLOS graph of received power Versus Transmitter-receiver distance in meters. This shows the transmission power is more in urban macro compared to rural macro. Also, the NLOS offers less received power as distance increases because of the multipath fading issues and the requirement of large and small scale fading parameter modeling is required. The corresponding expressions of LOS and NLOS is taken and simulated in Python Coding in Kaggle platform.

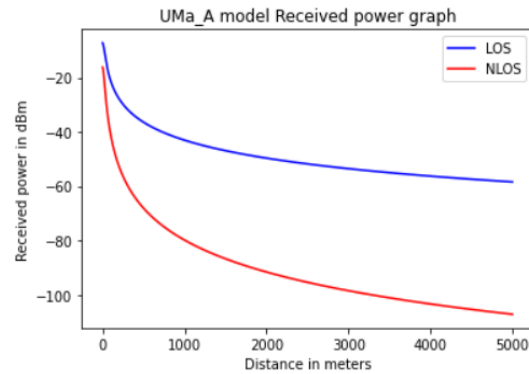


Fig 3.Simulation result of Urban Macro to estimate received power Versus Distance

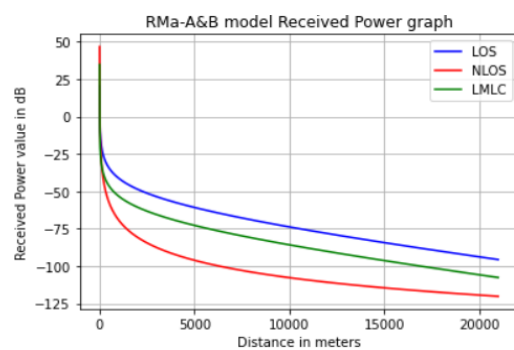


Fig 4.Simulation result of Rural Macro to estimate received power Versus Distance

The second simulation work is based on the two swarm intelligence optimization algorithms applied on the Massive MIMO network which the author published other optimization algorithms in one of the earlier work. Massive MIMO ensures significant improvement in spectral efficiency and data rate in 5G standard. A suitable Massive MIMO network simulator is taken from the literature [29]. This structure however, utilizes fixed values of base station antennas, M , number of user antennas, K , transmission power, P and bandwidth, B . The network structure and values could be found in the paper [29]. This research is an extension work of author work published in the article [28]. The same network and constraint parameters are chosen in this as well. In the previous paper, author took three optimization algorithms, initially with convex optimization solver and two meta-heuristic algorithms White shark optimization (WSO) and Particle swarm optimization algorithms (PSO). The requirement of investigating more meta-heuristic Swarm intelligence algorithms lands up in two more

optimizations algorithms in this paper, Capuchin search algorithm (CSO) and Chameleon swarm intelligence algorithm (CSIO) [30], [31].

The authors concentrate on the requirement of investigating optimization algorithms to run on Massive MIMO network. This also shows the optimization algorithm uses a single cell out of 16 cell network, with $M=10$, $K=1$ considering M-MMSE receiver combining algorithm. The convergence limitations of the algorithms not able to run on entire 16 cells. In this paper it showcases the results obtained by running different lower and upper bound on the constraint parameters and determines the global best values. The extension of the work leads to test the simulator in two more swarm intelligence algorithms, Chameleon swarm intelligence optimization algorithm (CSIO) and Capuchin swarm intelligence algorithm (CSO). The results and discussion provided in this section IN Table 4.

Table 4 CSIO and CSO influence on Spectral efficiency

Case 1: $K=1$, $M=10$ (M-MMSE) with CSIO

Iteration 1: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	200
gbest (Global Best Value)	B= 12.4627, P = 87.2509, Tau_C = 199.6359	
Iteration 2: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	30
Transmission Power, P	50	150
Coherence Time, Tau_C	100	250
gbest (Global Best Value)	B= 10, P = 149.2903, Tau_C = 239.6851	
Iteration 3: Parameters Under Test	Lower bound Value	Upper bound value

Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	300
gbest (Global Best Value)	B= 16.1774, P = 90.0262, Tau_C = 225.6761	
Iteration 4: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	20	100
Transmission Power, P	50	100
Coherence Time, Tau_C	200	400
gbest (Global Best Value)	B= 22.2989, P = 98.5282, Tau_C = 327.0740	

Case 2: $K=1$, $M=10$ (M-MMSE) with CSO

Iteration 5: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	200
gbest (Global Best Value)	B= 13.4151, P = 99.9951, Tau_C = 172.4300	
Iteration 6: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	30
Transmission Power, P	50	150
Coherence Time, Tau_C	100	250
gbest (Global Best Value)	B= 15.9987, P = 126.5411, Tau_C = 143.4516	
Iteration 7: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	300

gbest (Global Best Value)	B= 10.7491, P = 80.2389, Tau_C = 292.3028	
Iteration 8: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	20	100
Transmission Power, P	50	100
Coherence Time, Tau_C	200	400
gbest (Global Best Value)	B= 20.0969, P = 96.3101, Tau_C = 215.5324	

Spectral efficiency values running the selected global parameters using cases 1 and 2

Case 1: K=1, M=10 (M-MMSE) with CSIO		
Iteration No.	gbest (Global Best Value)	Spectral Efficiency (bits/s/Hz)
Iteration 1	B= 10, P = 76.8076, Tau_C = 180.4117	3.9036
Iteration 2	B= 10, P = 149.2903, Tau_C = 239.6851	2.0261
Iteration 3	B= 16.1774, P = 90.0262, Tau_C = 225.6761	4.4893
Iteration 4	B= 22.2989, P = 98.5282, Tau_C = 327.0740	4.1924
Case 2: K=1, M=10 (M-MMSE) with CSO		
Iteration 5	B= 13.4151, P = 99.9951, Tau_C = 172.4300	5.0945
Iteration 6	B= 15.9987, P = 126.5411, Tau_C = 143.4516	4.5534
Iteration 7	B= 10.7491, P = 80.2389, Tau_C = 292.3028	4.0190
Iteration 8	B= 20.0969, P = 96.3101, Tau_C = 215.5324	4.4787

Spectral efficiency using gbest values from CSO and CSIO through iterations 1 to 8 is shown in Fig. 5.

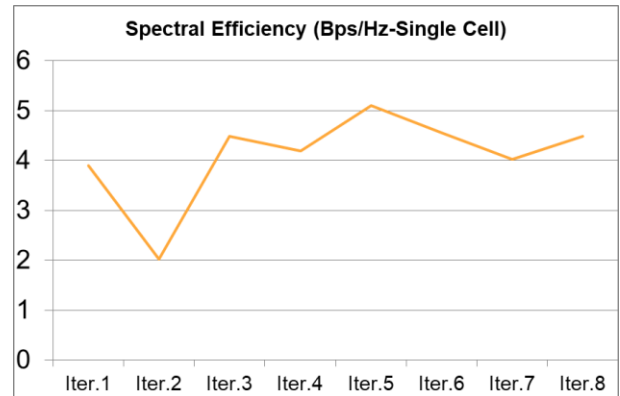


Fig 5. Spectral efficiency in between 1 to 6 bps/Hz for different Test Iterations

In both CSIO and CSO, spectral efficiency improvement is observed in the case where used best Tau_C values, then second choice is increase of transmission power, P and finally on Bandwidth, B. Tau_C is one of the design parameter provides best lower bound value, when compared with B and P.

5. Conclusion

This research article shows the importance of choosing relevant test environment scenarios in 5G standardization and for testbed development and further real deployment scenarios. The article introduces to some of the current research testbed of 5G, the segments and test environments and simulator development currently in progress. The motivation for any 5G research and development of trials need to focus on the 3GPP document and basic simulation of received power in channel models also done as starting stage of the research and open a huge scope of future work on the development of all other simulation channel level parameters such as data rate, spectral efficiency, throughput, CDF and SINR estimations by choosing the pathloss models and scenarios provided in the LTE releases of 5G standardization. The second part of the work is to highlight the importance of reaching 5G technology connectivity to the rural area in India. However, data rate, spectral efficiency estimation on this model can be taken as a future scope of research work. This 5G technology is a key communication standard aims to reach to all larger cell coverage rural areas of developing countries. The standard is put forth by Indian Telecommunication departments; C-DoT, TSDSI

and government regulatory TRAI. This standard is approved by ITU in February 2020 and is included as a sub-channel model under Rural Macro as Low mobility Large Cell LMLC Channel modeling so as to reach 5G technology service to reach rural areas in developing countries. Second level simulation study is an extension of swarm intelligence on the Massive MIMO Network simulator published in IJECS Journal IN Nov 2022. There, we have used WSO and PSO Swarm intelligence algorithms to optimize the constraint parameters such as bandwidth, transmission power and coherence time. In this paper, additional two swarm intelligence algorithms are used such as CSO and CSIO. The findings concluded that the spectral efficiency parameter improvement is strongly depended on the selected constraint parameters and also different optimization algorithms can be used to further maximize the parameter in Massive MIMO testbed based on 5G.

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