Energy Efficiency Maximization in 5G

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Abstract:* The Energy and Spectral efficiencies are two of the important challenges to be met in fifth generation (5G) cellular networks. A proposal is made to establish relation between Long-Term Evolution (LTE) and 5G networks. The spectral efficiency is maximized by optimizing the energy efficiency using the artificial intelligence mechanism of Particle Swarm Optimization algorithm. When the mobile user is linked to the base station with low power, the effect on spectral and energy efficiencies are calculated through the MATLAB simulation. A network performance improvement in both the spectral and the energy efficiencies are observed when the base station serves the mobile user. The optimized results using PSO algorithm are shown and compared for different modulation systems.

Keywords: **Optimization algorithm, Spectral efficiency, Energy efficiency, Long Term Evolution (LTE), Artificial Intelligence, Particle Swarm.**

1. Introduction

This study establishes co-operation between LTE and future generation networks. In view of wireless network in 5G domain that aims to compensate the tradeoff between Energy Efficiency(EE) and the performance of wireless network. This is done through switching ON/OFF mechanism in 5G base-stations alternatively based upon traffic load at that instant of time. It also assures the coverage of the wireless network for the mobile subscribers by activating the other left out LTE BS's. Considering particle swam optimization(PSO) algorithm that results in maximum coverage in 5G base station which covers the entire area while user is in switch-OFF session.

In this section, the paper demonstrates the introduction of the 5G and cellular communication which describes the approach to balance between the LTE and 5G.The second section discusses the previous works done in 5G for energy optimization, where different kinds of algorithms have been used. The third section deals with the design methodology through which PSO algorithm is introduced and being used in the next section. Further mathematical model is discussed for PSO which is useful for our approach. Then in section IV simulated results are discussed followed by Conclusions.

2. Literature Survey

Several studies have been conducted on reducing the power consumption using various base station techniques. In paper [1], Dynamic planning was introduced through which the usage of number of active devices were reduced during the low traffic conditions, thus saving the power consumed. Here we consider 3 UTMS schemes, which further describe the 3 classes of services: 1. Quality of service (QOS) 2.Electronic Magnetic and propagation exposure 3.Link budget. By using these schemes the power consumption is reduced by 50 percent. The paper [2] focuses on the UTMS Networks as the active devices are the main reason for the energy consumption. Here, a novel approach is proposed for UTMS energy management. During night, when some devices of the base station are in switched OFF mode, the service and coverage of the network is provided by the remaining active devices. The paper[3]is the extension work of paper[2],in which an optimization technique is proposed, which assumes that a fraction of the cells are to be in turned off state, and then further refers to the constraints which results from the cell layout. In paper[4],the issue of energy consumption is reduced using 2 techniques:

1.Centralized algorithm 2.De-centralized algorithm. The centralized algorithm works on the mechanism in which, each base station determines, depending on the traffic conditions, which base station is to be switched. The De-centralized algorithm works on the mechanism in which, decision of ON/OFF switching will be taken based on the estimation of traffic load of the network. Both the algorithms are tested and simulated, and the simulation results give the energy efficiency of the proposed algorithm and tradeoff between cell coverage and the energy savings.

In Base station (BS) switching algorithm, the energy efficiency can be improved by hardware implementatio**n**, but this implantation results in high costs. Thus, one must consider both operational and economical dimensions before initiating the replacement in the hardware. ON/OFF mechanisms in BS switching schemes are more suitable and can be executed in ease with the use of present topological network, without the necessity of replacement in hardware. These BSs are responsible for 57% of the total energy consumption. The Base station algorithm is a system level approach which is very much easy to handle. The key contributions are to design a methodology to provide relation between the LTE and 5G networks. For this methodology the mathematical modeling is done and is discussed in the next section.

3. Mathematical Modeling

Propagation channel model:

$$Pr = Ptx + G - P_{loss} - sigma \qquad (1)$$

Where,Pr indicates received power, Ptx indicates transmitted power,Sigma indicates shadow fading margin, G indicates total antenna gain, and P_{loss} indicates path loss.

LTE path loss model:

In the equation 2, P_L indicates LTE path loss model, ‘f’ indicates frequency, h_{BS} indicatesBase Station antenna height, h_{UE} indicates UE antenna height, h_{bl}indicates mean of building height,Wst indicates width of the street, ‘R’ indicates radius in meters.

$$P_L = 161.04 - 7.1 * log10(Wst) + 7.5 * log10(hbl) - \left(24.37 - -23.7 * \left(\frac{h}{h_{bs}}\right)^2\right) * log10(h_{bs}) + \left(43.42 - 3.1 * log10(h - bs)\right) * (log10(R) - 3) + 20 * log10(f) - (3.2(log10(11.75 * h_{UE}))^2 - 4.97) \qquad (2)$$

5G path loss model:

$$L5G(i) = alpha\_s * (PL\_SUI(d) - PL\_SUI(d0)\ ) + PL(d0) + Xsig \qquad (3)$$

$$PL_{SUI_{d(i)}} = PL(d0) + 10 * log10\left(\frac{d(i)}{d0}\right) + Xfc + Xrx + Xsigma \qquad (4)$$

$$PL_{d0} = 20 * log10\left(\frac{4\pi d0}{lambda}\right)n \qquad (5)$$

$$PL_{d0} = a - (b * hTX) + \left(\frac{c}{hTX}\right); \qquad (6)$$

$$Xfc = 6 * log10\left(\frac{F}{2000}\right); \qquad (7)$$

$$Xrx = -10.8 * log10\left(\frac{hRX}{2}\right); \qquad (8)$$

a = 4.6,b = 0.0075,C= 12.6.Where,$alpha\_s$ indicates slope correction factor,PL_SUI_d indicates original SUI model at distance d,PL_d0 indicates Free space path loss(db) at distance d0,$Xsigma$ indicates typical log normal random shadowing with variable Mean of 0 dB,Xfc indicates Correction factor for frequency,Xrx indicates Correction factor for receiver,F indicates carrier frequency,hTX indicates Transmitter height in meters,hRX indicates Receiver height in meters.

Minimum Power:

$$P_{min} = (N0 * BW) + Nf + SINR + IM \tag{9}$$

Where, for Noise Band Width specified the thermal noise assigned is indicated by $NO * BW$indicates,Nfindicates Receiver,Noise figure,IM indicates Implementation margin.

Cell Coverage:

$$a = \frac{Pmin-Prx}{sigma_{si}} \tag{10}$$

$$b = \frac{alpha*0.434}{sigma_{si}} \tag{11}$$

$$CC = qfunc(a\_MHz) + exp(((2 - (2 * a\_MHz * b)))/b\text{^}2).* qfunc((2 - (a\_MHz * b))/b) \tag{12}$$

Data Rate:

$$DR(x\_RB) = (x\_RB * N\_RBSC * N\_SCsym * CR * m\_symbits)/T\_slot\,; \tag{13}$$

Where, N_{RB}= 50 is Number of recourse blocks; N_{RBSC}=12 is Number of subcarriers per resource block; N_{SCsym}=7 is Number of modulation symbols; CR=0.125 is Code rate; $m_{symbits}$=2 is Number of bits per modulation; T_{slot}= $0.5*10^{-3}$ is Slot time

Energy Efficiency:

$$P\_BStot = N\_TRX * [(P\_PA + P\_RF + P\_BB)/(((1 - sigma\_DC) * (1 - sigma\_MS) * (1 - sigma\_cool)))] \tag{14}$$

$$N\_TRX = N\_carr * N\_sect * N\_ant; \tag{15}$$

Where, N_carr indicates number of carriers; N_sect indicates number of sectors; N_ant indicates number of antennas; Sigma_DC indicates losses by DC-DC power supply; Sigma MS indicates losses incurred by main supply; Sigma loss means losses incurred by cooling; P_BB means base band power; P_rf indicates radio frequency.

4. Mathematical modeling of PSO algorithm:

$$V\_new = w * v\_old + c1 * r1(p\_in - x\_in) + c2 * r2(p\_gn - x\_in) \tag{16}$$

$$w = wmax - (wmax - wmin) * iter/itermax \tag{17}$$

PSO algorithm:

- Initialize the parameters Ptxmin=10,Ptxmax=46,Gmin=5,Gmax=10,BWmin=1.4,BWmax=20, SINR_MIN=-5.1, SINR_min=4, SIGMA_max=8, m=5, N=20,maxrun = 10, itermax =50.
- Xi=(Ptx,G,BW,SINR,SIGMA)
- By the comparison of each position of the particle with constraints,
- if(Xi> maximum constraints) then
- Xi= maximum constraints
- End if
- If(Xi< minimum constraints) then
- Xi=minimum constraints
- End if
- Evaluate f(Xi) of each particle as per the equation.
- Store Pi and Pg(The best initial fitness value).
- Start While loop with(i<itermax)
- Now calculate the w value, and update the Vi, Xi values
- Then repeat the steps 3 to 9.

- Evaluate novel fitness values f(Xi) for each particle as per the equation.
- Compare each particle's fitness value with the current particles fitness value to obtain the best individual position.
- Comparison of the fitness evaluation with populations.
- Now end the while loop.
- Provide the best global fitness and also best global position for the parameters Ptx,G,BW,SINR,SIGMA.

5. Simulation Results

First part of the discussion is about the performance evaluation of LTE coverage area, while BS is switched off, which is based on the 5 constraints of the PSO.

Experimental Setup:

Table 1: List of the Parameters:

	Type	**Variable**	**Value**	**Units**
Network parameters	Frequency	F	2.6	GHz
	Bandwidth	BW	1.4-20	MHz
	Cell radius	R	0.5	km
	Transmission power	Ptx_min-Ptx_max	40-46	dB
Base station parameters	Antenna height	hBS	20	m
	Antenna gain	Gmin-Gmax	5-10	db
	Number of antennas	N_Ant	2	
	Number of sectors	N_Sect	3	
	Number of carriers	N_carr	1	
Mobile station parameters	Thermal noise density	N0	174	Db/Hz
	Noise figure	Nf	9	db
	Implementation margin	IM	3	db
	Antenna height	h_UE	1.5	M
	Morphology	Uurban		
	Propagation model	3Gpp UMa-NLOS		
	Average building height	hbl	20	m
Propagation losses	Street width	Wst	20	m
	SINR	SINR_min	-5.1	db
		SINR_max	18.6	
	Shadow fading margin	sigma	4-8	db
	Exponent path loss	alpha	3.2	

LTE:

Secondly, the discussion concentrates on data rate when 5G base station is switched off. Final part of the discussion is about Energy Evaluation based on the implemented base station switching ON/OFF mode.

The algorithm starts with the particle position (pi) and zero velocities. The LTE cell coverage obtained is 82%, with P_{tx}=43.08db, Gain (G) =7.97, SINR=1.49db and sigma=5.5db.

Furthermore when SINR decreases, Transmitted power P_{tx} and Gain G increases in order to handle the maximum cell coverage. From the below graph, when the cell radius is 500 m, which is known as the edge of the LTE cell experiences low traffic.

When the radius deceases the data rate increases. The above graph indicates data rate vs cell radius, with P_{tx} =43.08dB and B.W=10MHz.

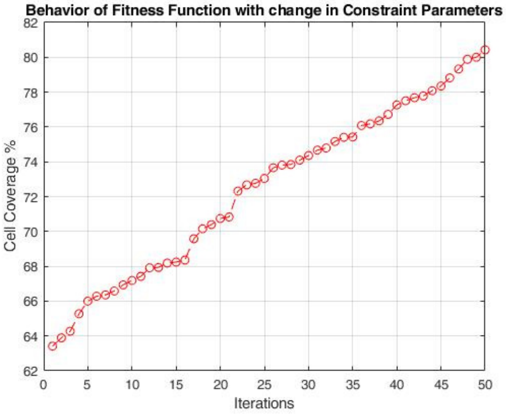

Figure 1: Cell coverage in LTE

5G:

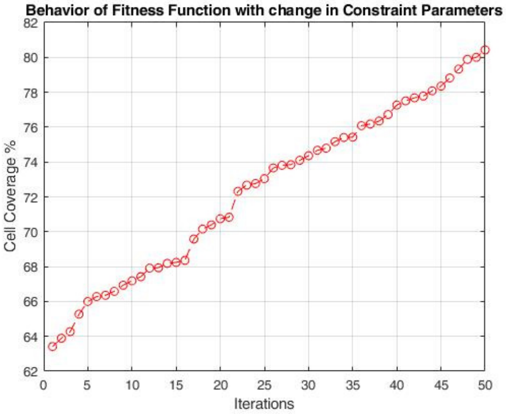

Figure 2: Cell coverage in 5G

In the figure 4, the relationship between the cell radii and P_{min} are observed. The received power level is in its peak level when the radius is in its minimum value. When the Pmin reduces the noise and the interference increase.

From the tables 2 and 3, the energy efficiency is calculated by dividing the Total number of bits transmitted(R) to the transmitted power for different modulations corresponding to their band widths.

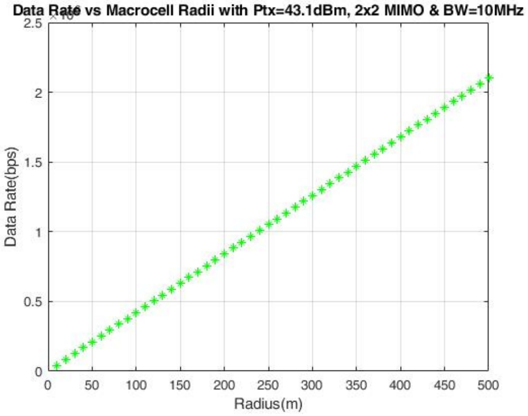

Figure 3: Data Rate with respect to Radius

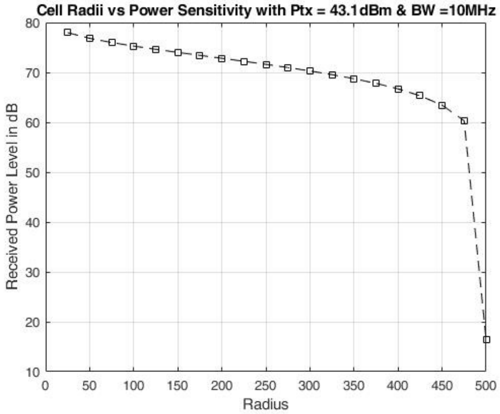

Figure 4: Received power

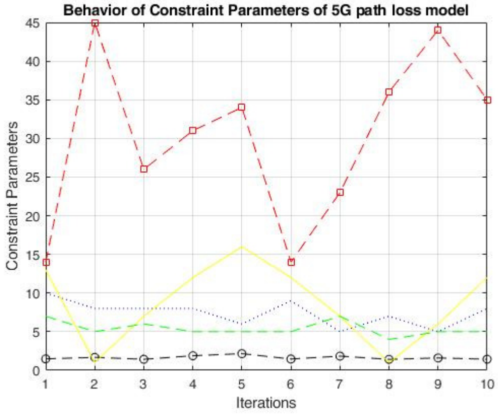

Figure 5: Constraint Parameters in 5G

The large bandwidth may improve the EE compared to the small bandwidth in the same size coverage area, provided that the large bandwidth can support more resource blocks, which ultimately leads to a higher data rate.

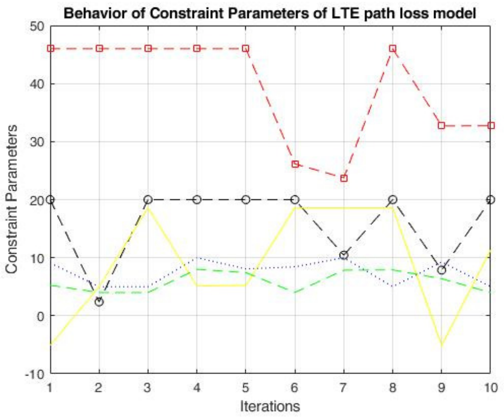

Figure 6: Constraint Parameters in LTE

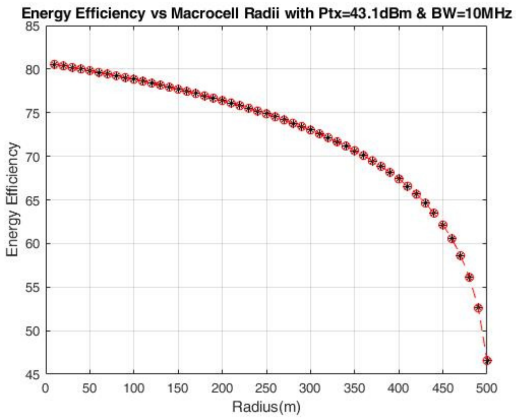

Figure 7: Energy efficiency w.r.t radii

Table 2: Energy Efficiency of 2x2 MIMO

Modulation	1.4MHz	3MHz	5MHz	10MHz	15MHz	20MHz
QPSK	86.86	217.58	371.97	741.71	1098.09	1470.07
16QAM	167.05	425.42	717.95	1416.61	2127.14	2837.68
64QAM	556.51	1026.82	1701.71	3405.66	5109.60	8387.56
256QAM	556.10	1363.15	4541.62	6995.45	6995.45	9085.47

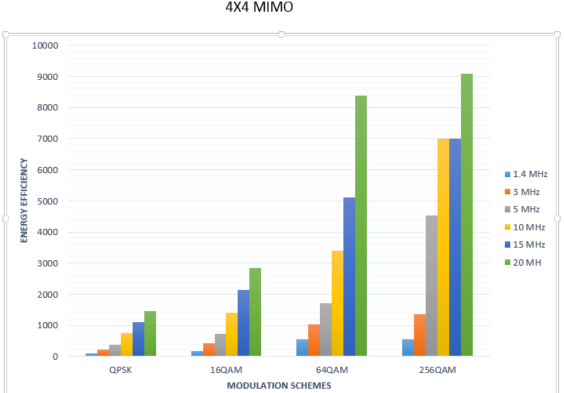

Figure 9: Energy efficiency w.r.t 4x4 MIMO

The above bar charts which are shown in figure numbers 8 and 9 represent different modulations i.e., QPSK, 16QAM, 64QAM, 256QAM along with their corresponding band widths i.e.1.4 MHz,3 MHz,5 MHz,10 MHz,15 MHz,20 MHz on x-axis and Energy efficiency on the Y-axis.

Table 3: Energy Efficiency of 4x4 MIMO

Modulation	1.4MHz	3MHz	5MHz	10MHz	15MHz	20MHz
QPSK	43.43	108.77	185.98	370.85	549.04	735.03
16QAM	83.52	212.71	358.97	708.30	1063.57	1418.84
64QAM	203.80	513.41	850.85	1702.83	2554.80	3497.72
256QAM	278.05	681.57	1136.70	2270.81	3497.72	4542.73

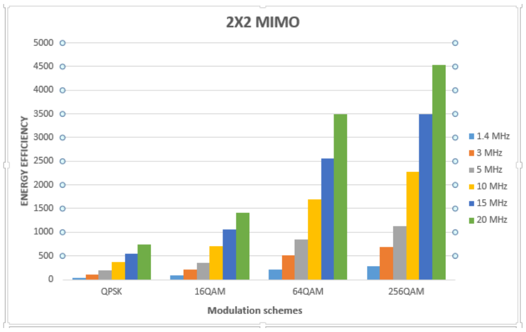

Figure 8: Energy efficiency w.r.t 2x2 MIMO

6. Conclusion

The proposed mechanism consumes very little energy by monitoring the network's traffic load and deciding to turn OFF / ON a base station. It also achieved balance between the LTE and 5G while guaranteeing service and maximum coverage. However, the energy savings and the trade-off through this mechanism depend on number of base stations that will be turned OFF. The proposed PSO algorithm provides the optimized parameters with which the system attains the optimized energy efficiency in different modulations using different MIMO.

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