Wireless Personal Communications
https://doi.org/10.1007/s11277-021-09049-z

Efficiency of Ultra-Dense Multi-Tier Future Cellular Networks for 5G: A Survey

Pankaj Shankar Shrivastava[1] · **Utsav Kumar Malviya**[2] · **Mekram Meshram**[2] · **Uma Shankar Dewangan**[2]

Accepted: 16 August 2021

Abstract
One of the important means by which 5G can be implemented is by Ultra-Dense Multi-Tier future cellular network. We have studied the effect of the densification of network, Signal to Noise plus Interference ratio (SINR), network load, channel and channel bandwidth on the spectral efficiency and energy efficiency of this system. The importance of the spectral efficiency is also discussed. It is observed that as network load increases, spectral efficiency and energy efficiency decreases for given network bandwidth. which can be improved with the help of SINR or the densification of network. We have found out the exact higher modulation method M-Quadrature Amplitude Modulation (M-QAM) used for the given system and how it can be improved. By using higher M-QAM method, we can transmit more bits simultaneously. The spectral efficiency and energy efficiency of the system increases. It was found that as network bandwidth increases, spectral efficiency got decreases. We have also found the optimum value of bandwidth to maximize the spectral efficiency of this system.

Keywords UDMT · 5G · Densification factor · Spectral-efficiency · Energy-efficiency

1 Introduction

The tremendous success of mobile cellular services that started with telephony is continuing with broadband data access with an incredible growth rate of traffic. Forecast on the telecommunication market states a continuous increase in the number of subscribers, and an exponential increase in generated data traffic [1]. The wireless communication had an explosive growth in last decade and had challenged to provide cost effective supporting a 1000 times increase in traffic demand for next ten years [2]. Authors in [3] considered CDMA to support multimedia services over TDMA and FDMA due to its higher capacity.

✉ Pankaj Shankar Shrivastava
pss1170@gmail.com

[1] Department of Electronics and Communication Engineering, School of Engineering and Technology, G.G.V, Bilaspur, Chhattisgarh, India

[2] Department of Electronics and Telecommunication Engineering, Government Engineering College, Bilaspur, Chhattisgarh, India

Published online: 02 November 2021

OFDM and OFDMA succeeded Code division multiple access (CDMA), are the modulation technology and multiple access strategies adopted in Long Term Evolution (LTE), fourth generation (4G) cellular network standard respectively. These methods succeeded CDMA which was very difficult to implement [4]. Now the focus is on small cells with Macro cell network (Heterogenous network) for higher spectral efficiency [5]. Macro-cells are connected to base stations and micro cells are served by Macro cell [6].

Fifth-generation (5G) cellular communication promises to provide the gigabits experience to mobile users [7]. Multi-input and Multi-output technology have been widely studied during the last two decades to improve the capacity and reliability of wireless systems [8]. One of the keys enabling technologies for 5G, UDMN provided high data rate connectivity and multi-tier network approach could provide access to a massive number of users and capacity gains [9].

Ekram Hossain et al. observation was that 5G systems would adopt a multi-tier architecture to serve users in an energy-efficient manner [10]. Also, a prime concern in the current scenario is the battery life of the mobile terminals. Pimmy Gandotra et al. gave a proposal for enhancing the battery life of the user terminals [11]. Cheng-Xiang Wang et al. proposed a cellular architecture that separates indoor and outdoor scenarios [12]. A. Gotsis et al. found that ultra-dense network (UDN) is a new paradigm in which network densification is taken to the next level [13]. Thurfjell et al. linked the system densification with an increase of the system throughput, energy efficiency of UDNs with stochastic geometry [14]. Xiaohu Ge et al. revealed that there exist densification limits for 5G ultra-dense cellular networks with backhaul network capacity and backhaul energy efficiency constraints [15]. Volker Jung nickel et al. focused on advanced techniques for higher spectral efficiency and improved coverage for cell-edge users [16]. Baha Uddin Kazi et al. made an in-depth survey of underlying novel ultra-dense heterogeneous networks, mm-Wave, and multicell cooperation [17]. Wei Yu et al. reviewed existing 5G research efforts toward addressing those challenges and presented future 5G avenues for research [18]. In this paper, authors [19] found out optimal BS densities to maximize the energy efficiency (EE) under the condition of satisfying the area spectral efficiency (ASE) requirement.

Authors in [20] analytically investigated the spectrum efficiency of densely deployed small cell networks in the downlink using tools from stochastic geometry and based on the network spectrum efficiency, results found out the optimal cell density and the corresponding optimal base station transmit power for achieving a high spectrum efficiency and/or energy efficiency. In this paper [21], authors introduced a sophisticated path loss model incorporating both line-off sight (LoS) and non-line-of-sight(NLoS) transmissions to study their impact on the performance of dense small cell networks (SCNs). Authors in paper [22] explored the realistic scenario of randomly distributed Femto cell Access Points (FAP) in heterogeneous networks and proposed a clustering approach combined with an active FAP selection algorithm to boost both spectral and energy efficiency without manual configuration. Authors in [23] found that PSR (Partial Spectrum Reuse) can improve both spectrum efficiency and energy efficiency. Authors in [24] studied the ASE in multiple association, and to investigate its relation to the main system parameters, namely: small cells density, users density, and multi cell size M. Authors in [25] explored network densification as the key mechanism for wireless evolution over the next decade. In paper [26], the user rate distribution obtained analytically, taking into account the effects of multiple access as well as the SIR outage.

In this paper [27], a novel approach for joint power control and user scheduling was proposed for optimizing energy efficiency (EE), in terms of bits per unit energy,in ultra-dense small cell networks (UDNs).However, Authors in [28] investigated existing researches on ultra-dense network mainly focus on system throughput while ignore energy efficiency(EE). Therefore, they analysed the UDN performance including not only system throughput but also EE in this paper.

Study in [29] showed that in a confined geographical area with a fixed number of users, the user bit rate always increases with network densification. Authors in [30] attempted to provide insights on fundamental issues related to UDN deployment, such as determining the infrastructure density required to support given traffic load requirements and the benefits of network wise coordination, demonstrating the potential of UDNs for 5G wireless networks. Analysis in [31] demonstrated that the network coverage probability first increased with the increase of the base station (BS) density, and then decreased as the small cell network (SCN) became denser. This decreased further made the ASE suffer from a slow growth or even a decreased with network densification. The ASE grew almost linearly as the BS density became ultra- dense.

Many other existing survey papers on different aspect related to UDMT network are presented in [32, 33, 34, 35, 36, 37]

In [33], a survey was presented based on Ultra dense network (UDN) introduction, modelling and performance metrics, and enabling technology for network densification. Yet, [33] did not cover topics on exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system.

In [34], a survey was presented based on Ultra dense network (UDN) development and issues related to 5G RAN. Yet, [34] did not cover topics on exact higher modulation method used and capacity enhancement, mitigate the effect of cell load of spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system.

In [35], an extensive survey of the current literature on 5G wireless communication focusing on UDN, mm Wave and multi cell cooperation such as coordinated multi point (CoMP cooperation) was presented.Yet, [35] did not cover topics on exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system.

In [36], an extensive survey of the current literature in the area of Energy Efficiency (EE) of Ultra-dense Het-Nets was presented focusing on peculiarities in network that made energy consumption serious, EE metrices used to gauge energy consumption rate, and future research direction. Yet, [36] did not cover topics on exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system.

In [37], an extensive survey of the current literature on recent advances and research challenges in intelligent management techniques and backhaul solutions for the combination of UDNs and other enabling technologies were presented that offers the visions of 5G focusing on mathematical tools widely exploited in solving these problems and the performance metrics used to evaluate the intelligent management algorithms, classify various management algorithms. Yet, [37] did not cover topics on exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system.

Authors in [39] provided an overview of Long Term Evolution (LTE) and WiMAX for mobile broadband communication.

Authors in [40] explored various physical layer research challenges in MIMO-OFDM system design. Authors in paper [41] discussed techniques that are required to competently design and fabricate mm-wave devices in silicon. Authors in [42] presented a mathematical technique for determining the optimum transmission rate and packet size in wireless system for OFDM modulation in downlink transmission. Authors in [43] found difficult to solve the optimization problem analytically related to ASE and EE of ultra dense HetNet. Hence, simulations are conducted to find optimal BS densities. Authors in [44] presented the detailed survey on the fifth generation (5G) cellular network architecture and emerging technologies to make system efficient. Authors in [45] proposed a cognitive radio -based spectrum sharing technique for 5G that efficiently assigned spectrum to unlicenced mobile users. Authors in [46] proposed an opportunistic power control algorithm that maximized system throughput.

Authors in [47] explored many questions related to densification of wireless network. Authors in [48] analysed spectral efficiency, area throughput, and network energy efficiency of Ultra dense network. Authors in [49] discussed load balance constraints, energy harvesting by base stations, user quality of service requirements, energy efficiency, and cross-tier interference limits of mm-Wave based UDN. Authors in [50] proposed a generalized orthogonal/non-orthogonal random access scheme to improve the network efficiency. Authors in [51] explored the effect of different factors related to densification on spectral efficiency.

Syed Waqas et al. primarily studied different factors affecting the UDMT system's capacity including the network densification, cell load, and multi-tier interference. The role of the ergodic channel capacity was also discussed Finally, the results show that the network densification and the cell load have a profound impact on system performance as well as spectral and energy efficiencies of the networks [9].

One important accomplishment of the present paper is that a number of analyses have been done for understanding channel spectral efficiency of the UDMT system.It was found that as network bandwidth increased, spectrum efficiency of the system decreased for fixed SINR and densification of network [9]. We have derived the expression for optimum bandwidth and found out the maximum spectral efficiency for the given system. In [9] number of analysis had been done for channel capacity of UDMT system but, spectral efficiency is not touched in details. In this paper, we have analysed SE vs other parameters of the system like SINR, cell load, network bandwidth and densification factor with additional effect of other. We have also found out how to improve SE of this system.

We have found out the effect of cell load on energy efficiency of this system with additional effect of other network parameters. It has observed that SE and EE of system have decreased as we increase cell load. They can be efficiently improved by increasing SINR and densification factor of network. In [9] it was only mentioned about higher modulation methods (16-QAM, 64- QAM etc.) may be used for the given system. As per the given data, a computer program is developed to find out which higher modulation method (M-QAM) is suitable and how we can improve the channel capacity of this system. The parameters spectral efficiency and energy efficiency are very important and directly related to the cost of transmission and environment. These are reasons for surveying spectral efficiency and its effect. We have tried to make this system efficient. As per the analysis we can choose different factors to make this system cost-effective so the majority of the population gets benefited from the facilities provided by 5G for mobile communication. As far as my knowledge is concerned, there does not exist any work related to the surveying of the spectral efficiency of the UDMT system. Table 1 shows mathematical notations used in this paper. Table 2 shows major work related to UDMT, SE and EE. Survey papers related to UDMT are shown in Table 3.

2 System Model

The possible system model of the UDMT system is shown in Fig. 1. There is a Macro Cell (MC) under which several micro base cells (mC) are operating. The MC operates at a low frequency while mC are operating at high frequencies. The coverage of the MC is larger as compared to the microcell. Users are randomly spread in the cell and can notice interference from Macro cell and microcells. The transmission channel is considered as Rayleigh fading [9].

3 Channel Capacity

According to Shannon's channel capacity, the maximum achievable capacity of a channel in a traditional cellular network when connected to cell i^{th} is

$$C_i = \frac{D.B}{a} log_2\left(1 + \frac{P_t}{N_o + I_u}\right) \quad (1)$$

where D = Densification factor of Network.

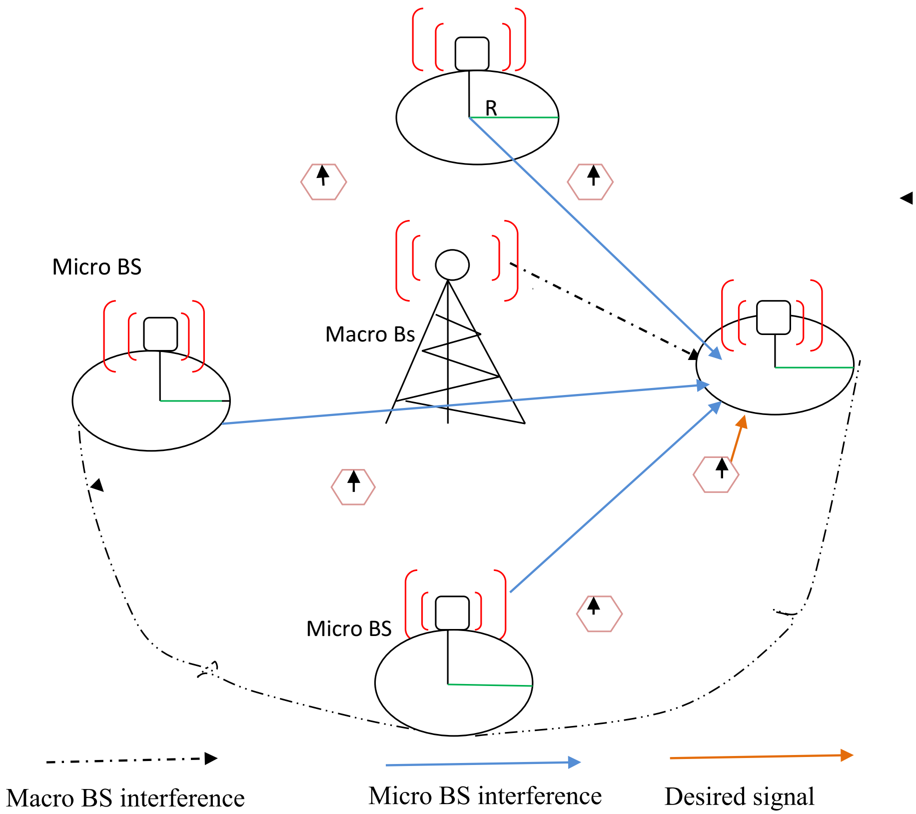


Fig. 1 The system model of a possible architecture for Ultra-dense multi-tier cellular network. The Macrocell has a large coverage area of radius D, While the Microcell has a radius R

B = Channel bandwidth.

P_t = Transmission power.

N_0 = Thermal Noise power.

I_u = Average power of the interfering Base stations.

a = Cell load of the network. [9]

The channel capacity of a system is defined as the maximum rate at which data can be transmitted over a given communication path or channel, under a given condition, it is referred to as channel capacity [38]. As the number of mobile users is increasing day by day,we increase the densification of the network (using small cells) to accommodate them. In this way, the capacity of the system increases by frequency reuse. In the case of mobile communication, signals from the base station to mobile reaches easily but the main problem is in communication between the mobile set to the base station, as the power of the mobile unit is not much powerful. Since the size of the cell is small so local interference is less compared to a big cell. If a small cell fails only the users in that cell get affected. To provide more advantages, we are covering a big cell into smaller cells. By increasing the number of small cells, we are increasing the cost of infrastructure and unwanted handoffs. Frequency planning is also required to avoid interference among users. These are some disadvantages of using small cells.

4 Spectral Efficiency

To cover a large area and to eliminate problems of the present Fourth generation system we have to use the Fifth generation of mobile communication (5G). One of the possible ways to implement 5G is the Ultra-Dense Multi-Tier (UDMT) cellular network. These networks are used to serve indoor mobile. All mobile phones present in a small area are connected to microcells. All mC present in a particular area are connected to MC as shown in Fig. 1. In this system, communication is possible with the help of the Macro station only. These types of networks provide high data rate connectivity. Ergodic channel capacity is the expected value of the instantaneous channel capacity.

Link spectral efficiency is a measure of how well the bandwidth resources are exploited in a communication system. It is measured in bits/s/Hz. The spectral efficiency of the UDMT cellular network is given by

$$\mu_s = \frac{D}{a} log_2\left(1 + \frac{Y}{B}\right) \tag{2}$$

where μ_s = Spectral efficiency.

Y = Signal to Noise plus interference ratio (SINR).

B = Channel Bandwidth.

a = Network load.

Spectral efficiency is calculated in bits/s/Hz, where bits/s is the unit of throughput and if throughput is quantified in terms of bandwidth, it becomes spectral efficiency with unit bits/s/Hz [9].

5 Network Densification

Nowadays the number of mobile users is increasing drastically. When number of users in a cell are close to the capacity of the system, cell is split into many small cells and capacity of the system increases. As the number of cells increases, the capacity of the system increases but interference among cells also increases. After a limit when we increase the number of cells, the capacity of the system decreases due to this interference. In densification, we are considering different techniques in the physical layer to enhance system capacity i.e., increase capacity by coordinated multi-point transmission, incorporating a new spectrum using Massive MIMO, enhancing bandwidth by using mm-Wave.

5.1 Cell Load

In any communication system, the number of active users connected at a given time to the Base station are termed as cell load of the system. The preference of any system is to connect more users efficiently. This decreases the transmission cost and the system becomes more spectral efficient. The mC decides the activation of this cloud-cell depending upon certain predefined parameters such as the number of active users, user throughput and delay demand, user priorities, and system performance level.

It was found that as the channel bandwidth increased for a given value of SINR, the spectrum efficiency of the system got decreased 9. We know there exists an optimum channel bandwidth which maximizes spectral efficiency. B_{opt} should satisfy the optimum bandwidth which maximizes spectral efficiency, and is computed by setting the derivative of Eq. (2) concerning B equal to zero.

Differentiating Eq. (1) w.r.t B we get,

$$\frac{d\mu_s}{dB} = \frac{D}{a}\left(1 + \frac{Y}{B}\right).\log 2$$

The optimum Bandwidth (B_{opt}) must satisfy

$$\frac{d\mu_s}{dB} = 0$$

$$\frac{D}{a}\left(1 + \frac{Y}{B_{opt}}\right).\log 2 = 0$$

$$1 + \frac{Y}{B_{opt}} = 0$$

From above equation We get.

$$\left|B_{opt}\right| = Y\,. \tag{3}$$

From the above equation, it is clear that optimum bandwidth depends only on the system parameter, Y i.e., SINR. In Fig. 2, we have plot optimum bandwidth vs SINR for the maximum value of spectral efficiency. It has been found that when the value of SINR is greater than 20 dB, B_{opt} increases gradually.

6 Energy Efficiency

Now-a-days energy efficiency is very important due to the environment and excess CO_2 emission. Even the government is very strict about this parameter. If any system is energy efficient it means that transmission cost is less which makes the system cheaper. It is one of the main parameters while choosing any system. If transmission cost is less, monthly bill is less and so availing that facility is easier and affordable. It is good for the environment and is economical. Transmission power of this system should be less to make this system energy efficient [9]. it is observed in Fig. 6 that as we increase network load, energy efficiency goes down. The energy efficiency of this system can be written as

$$\mu_E = \frac{Area\,spectral\,efficiency}{Average\,network\,power\,consumption}$$

$$\mu_E = \frac{\mu_S}{\frac{P_T}{\rho} + P_{BS}}.B \tag{4}$$

where area spectral efficiency (ASE) is $\mu_{S.}$ B.

P_T is the Base station transmit power. P_{BS} is the power consumed in other parts of the Base station.

7 Simulation Results and Discussion

It is observed that as Cell load increases, spectral efficiency and energy efficiency decreases. In this paper, a number of analyses have been done to find out how densification factor(D), Signal to Noise plus interference ratio (Y), Channel Bandwidth (B), and Cell

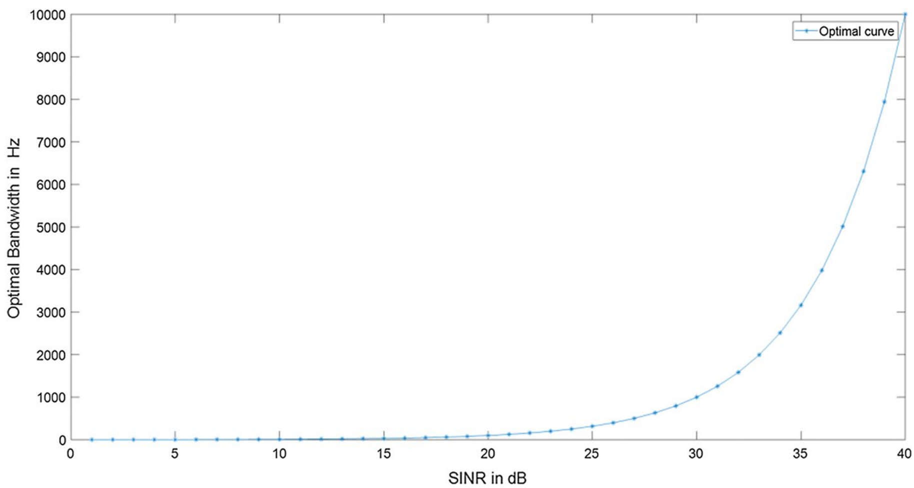


Fig. 2 Optimum bandwidth vs SINR

Load (a) affect the spectral efficiency and energy efficiency of this system. These analysis have done with an assumed system parameter Y = 1- 40 dB, B = 40–80 kHz, D = 1–16, a = 0.1 to 1. (10% to 100%) [9].

In Fig. 3, we have plotted the spectral efficiency of the system as a function of cell load. It has been found that there is an inverse relationship between the spectral efficiency of the system and cell load. As cell load increases, spectral efficiency of the system decreases for a given network bandwidth. Curves have been drawn for three different values of bandwidths. It can be verified that spectral efficiency can be improved by increasing the densification factor of the network. As shown spectral efficiency of denser is larger than the sparser network. The reason is that as we increase densification, cell load, and interference decreases, and channel capacity and spectral efficiency increase. It is also found that as Network bandwidth increases the spectral efficiency of this system decreases for a given network load. This observation is same as [9]

In Fig. 4, we have plotted the spectral efficiency of system vs SINR. It is observed that spectral efficiency is almost negligible for a given cell-load up to 10 dB. After 10 dB, it increases gradually. It is clear from the diagram that as the load increases for a given value of SINR, the spectral efficiency of the system decreases. Graphs are plotted for three different values of cell loads. It can be verified that the spectral efficiency of a given cell load can be improved by increasing the densification of the network. It is also observed that spectral efficiency for the denser network is larger than the sparser network for a given value of SINR.

In Fig. 5, we have plotted the spectral efficiency of the system vs densification of the network. There is a direct relationship between spectral efficiency and the densification of the network. It has been found that as densification at given cell load increases, spectral efficiency also increases. One can also see that as cell load increases for the given value of densification, spectral efficiency decreases. Three graphs are plotted for different values of cell loads. It is verified from the figure that the spectral efficiency of a given load can be improved by increasing the densification of the network. It is also found that as network bandwidth increases for given densification factor and cell load, spectral efficiency decreases. The spectral efficiency of the given bandwidth at a given cell load can be improved by increasing the densification of the network.

In Fig. 6, we have plotted the energy efficiency vs network load of this system with the additional effect of SINR and densification factors. There is an inverse relationship between energy efficiency and the network load of the system. Energy efficiency very much depends on SINR. Curves for three different values of SINR are shown in the diagram. It

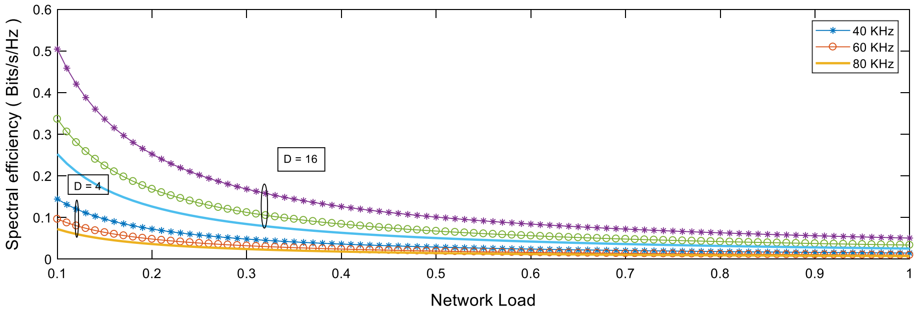


Fig. 3 Spectral efficiency vs cell load

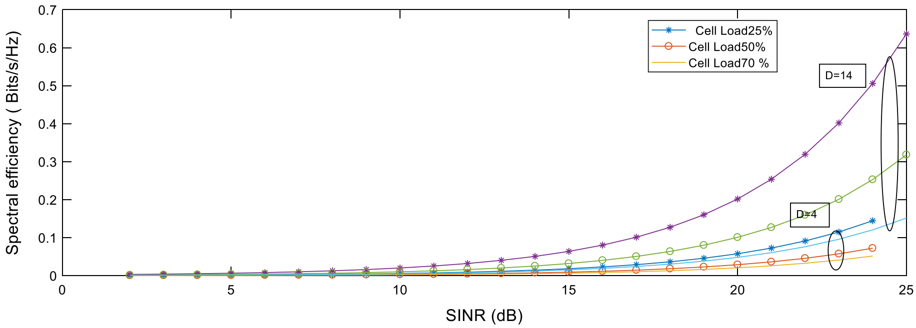


Fig. 4 Spectral efficiency of system vs SINR

is observed that with an increase in SINR, better energy efficiency of the system can be achieved for a given cell load. It is also verified that the energy efficiency of the higher denser network is more. The reason for this is that as SINR increases, noise and interference decreases. The channel capacity of the system increases, data rate increases, and hence the energy efficiency of this system increases.

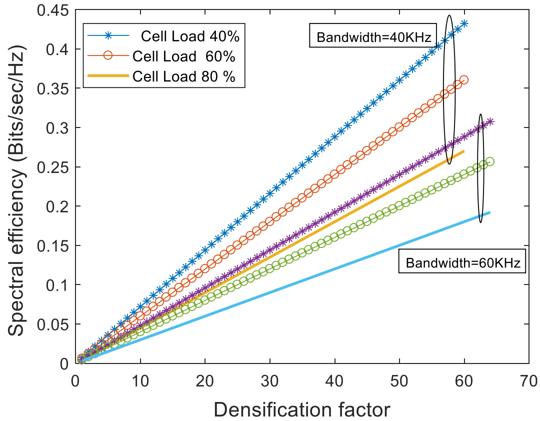
Next, a number of analysis have done to make any system energy efficient with the help of spectral efficiency. In Fig. 7, We have plotted SINR vs spectral efficiency of this system for different cell loads. It is observed that as the spectral efficiency of the system increases for a given load, the value of SINR increases. Three graphs are plotted for different values of cell loads. It is observed that SINR at given cell load and spectral efficiency can be improved by increasing the densification of the Network. The reason is that as densification increases, the cell load decreases. As interference among users decreases, SINR increases.

Now, the next analysis has been done to find out the exact suitable higher modulation method (M-QAM) used for given system. Enhancement of energy efficiency with the help of the spectral efficiency is also discussed.

The bit error rate (BER) plays a big role in deciding the capacity or data rate of a system. This BER depends on $E_b/N_{o,}$.i.e. Energy transmitted /Bit /Hz.

This ratio E_b/N_o is important because the BER for digital data is a decreasing function of this ratio [19]. Given a value of E_b/N_o needed to achieve the desired BER. In

Fig. 5 Spectral efficiency vs densification factor



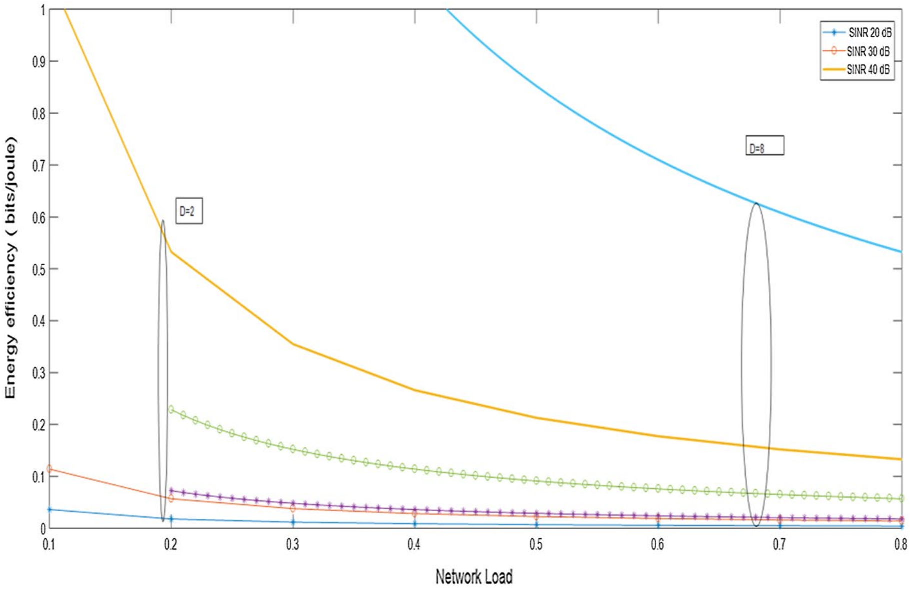
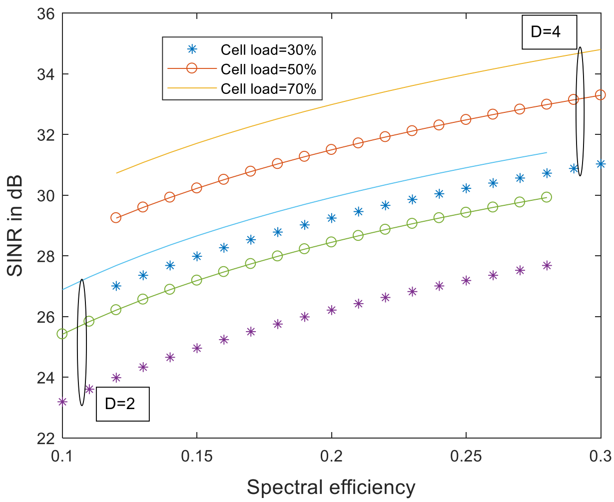


Fig. 6 Energy efficiency vs network Load

Figs. 8 and 9, we have plotted P_b (BER) vs E_b/N_o for 64-QAM and 128-QAM respectively. It can be observed to maintain a BER of 10^{-7}, with the required values of E_b/N_o for 64-QAM and 128-QAM are being 19.9 and 23.2 respectively. The complete list of the required values of E_b/N_o for higher modulation methods M-QAM is shown in Table no 4. Two conditions can be noticed from the above Fig. 9 when D = 4 and cell load = 50%:

Fig. 7 SINR v/s spectral efficiency



1. For SE = 0.14 Bits/s/Hz, the value of SINR = 30 dB. Hence $E_b/N_{01} = 20$.
2. For SE = 0.28 Bits/s/Hz, the value of SINR = 33 dB. Hence $E_b/N_{02} = 25$.

The above-said values of E_b/N_{01}, E_b/N_{02} are calculated from Eq. (5) given below

$$\frac{E_b}{N_O} = \frac{C}{I} \cdot \frac{B_T}{R} \tag{5}$$

where B_T = Network bandwidth = 60 kHz;

R = Data rate = 30 Mbps;

So, in case-1, since the value of E_b/N_{01} is greater than 19.9 (refer Table 4) we can transmit information by using 64-QAM i.e. 6 bits are transmitted simultaneously. In case-2, E_b/N_{o2} increases to 25 which is greater than 23.2 and sufficient to maintain a BER of 10^{-7} of 128- QAM. Now we can transmit information by using 128-QAM i.e.,7 bits are transmitted simultaneously. So, channel capacity becomes doubled as compared to the previous case. The reason for this is that as we increase spectral efficiency, SINR increases and interference decreases. In this way, by increasing the spectral efficiency, data rate and system capacity of this system increases. It means the energy efficiency of the system increases and the overall cost of transmission decreases.

Algorithm for selection of M-QAM method is shown in Fig. 10. The description of algorithm is as follows:

1. Input number of possible higher modulation methods (N) available as shown in Table 4. Here value of N = 8.
2. .Input required values of E_b/N_0 as per Table 4 for all given (N) eight methods i.e., 2-QAM, 4-QAM, 8-QAM, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM for BER = 10^{-7} expressed as X [1], X [2], X [3], X [4], X [5], X [6], X [7], X [8].
3. Input calculated value of E_b/N_0 from Eq. (5) and assign it as Y.
4. Compare Y with X [1] i.e., value of 2-QAM. If it is less then display output as "Higher modulation is not possible" and Exit.
5. Initialize N = 1. Check, if y is greater than X[N] i.e.,X [1]. If, yes then increment value of N by 1 i.e., N = 2 and repeat till Y less than X [N] otherwise display output "we can transmit information by using 2 N-QAM method".

Table 1 Mathematical notation

Notation	Description
D	Densification factor of network
B	Channel Bandwidth (Network Bandwidth)
P_t	Transmission power
N_o	Thermal Noise power
I_u	The average power of the interfering base stations
μ_s, SE	Spectral efficiency (bits/s/Hz)
a	Network load (Cell load)
Y	Signal to Noise plus interference ratio (SINR)
λ	Density of PPP

Table 2 Major work related to UDMT, spectrum efficiency and energy efficiency

References	Work area	Key points presented in the corresponding referred article
[13, 24, 26–29, 31, 35, 43]	Technical report	Interference management, dense small cell network,5G communication focuses on the effect of frequency reuse, mm-wave, Comp cooperation
[36, 41]	Architecture	The network architecture of UDHN
[20, 21, 26, 38, 39, 41]	Performance of UDN	Performance evaluation of Ultra-dense network, how much densification can be deployed for 5G ultra-dense cellular network
[23, 27, 36, 39, 43] [48, 50]	Enhancement of SE, EE	Optimality of SE and EE, SE enhancement with affordable complexity, increase SE and EE, Coverage probability and ASE,ASE and EE from the perspective of a typical base station

Table 3 Details of survey paper related to UDMT

Survey paper	Year	Topics covered	Topics not covered
[32]	2015	5G cellular network architecture, Multi input multi output, Device to Device communication, and some emerging technologies like Interference management, Spectrum sharing with cognitive radio, Ultra dense network, multi radio access technology, full duplex radios, mm wave solution for 5Gnetwork	Exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system
[33]	2016	Ultra-dense network (UDN) introduction, modelling and performance metrics, and enabling technology for network densification	Exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system
[34]	2017	Ultra-dense network (UDN) development and issues related to 5G RAN	Exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system
[35]	2018	UDN, mm Wave and multi cell cooperation such as coordinated multi point (CoMP cooperation)	Exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system
[36]	2020	Energy Efficiency (EE) of Ultra-dense HetNets focusing on peculiarities in network that make energy consumption serious, EE metrices used to gauge energy consumption rate, and future research direction	Exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system
[37]	2020	recent advances and research challenges in intelligentmanagement techniques and backhaul solutions for the combination of UDNs and other enabling technologies that offers the visions 5G focusing on mathematical tools widely exploited in solving these problems and the performance metrics used to evaluate the intelligent management algorithms, classify various management algorithms	Exact higher modulation method used and capacity enhancement, mitigate the effect of cell load on spectral efficiency and energy efficiency, optimize and calculate maximum value of spectrum efficiency of UDMT system

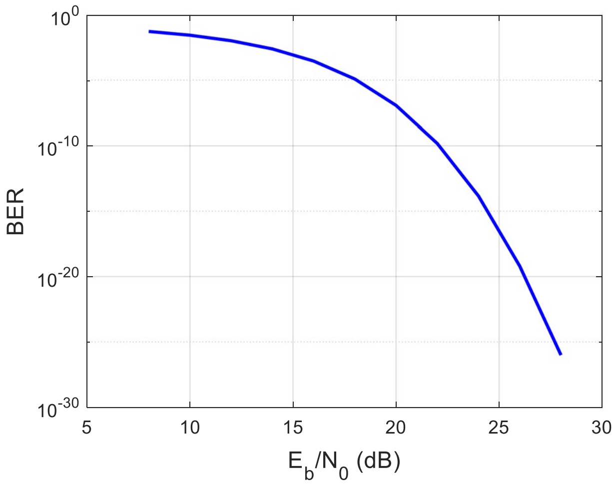


Fig. 8 BER vs E_b/N_o for 64-QAM

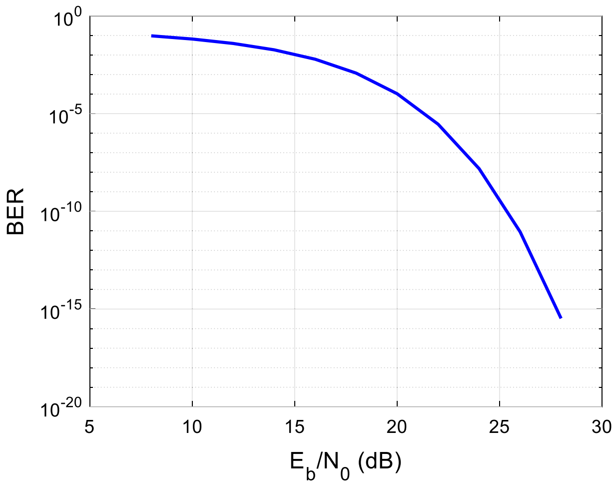


Fig. 9 BER vs E_b/N_o for 128-QAM

Table 4 Observed value of E_b/N_o for different BER (10^{-4} and 10^{-7}) by diversity analysis

S. No.	Higher modulation method	E_b/N_o for 10^{-4}	E_b/N_o for 10^{-7}
1	4-QAM	8	10
2	8-QAM	12	13
3	16-QAM	13	14.8
4	32-QAM	14.6	18.2
5	64-QAM	16.8	19.9
6	128-QAM	20	23.2
7	256-QAM	21.4	24.8
8	512-QAM	24.8	28.4

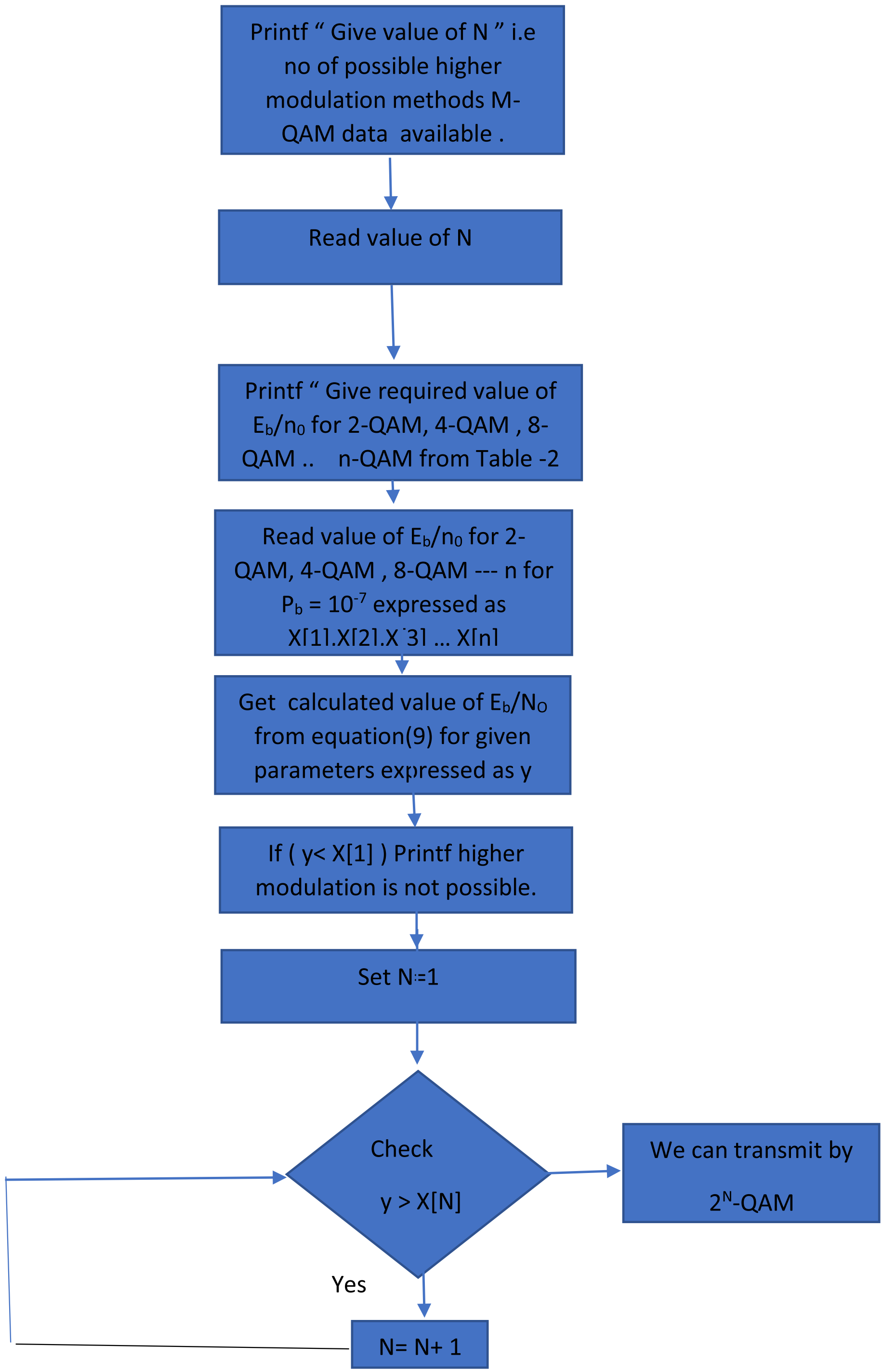


Fig. 10 Algorithm for selection of specific M-QAM method used

Now, The maximum spectral efficiency at optimum bandwidth for this system is calculated. One can verify from Fig. 11 that spectral efficiency at optimum bandwidth increases with an increase in densification.

Figure 11 is the plot of spectral efficiency vs SINR. It is found that as we increase network bandwidth, the spectral efficiency of the system decreases at a given value of SINR. This result is the same as given in [9]. Three graphs have plotted for three values of bandwidths i.e. optimum bandwidth, 20 kHz, and 10 kHz at network load of 60%. Spectral efficiency at optimum bandwidth for this system is maximum. One can verify from the figure that spectral efficiency at optimum bandwidth increases with an increase in densification.

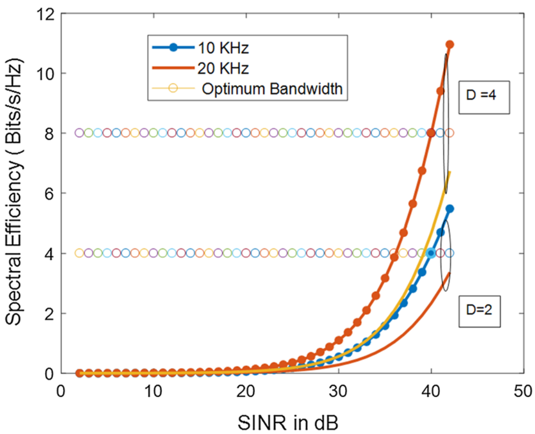
The relationship between the spectral efficiency of system vs SINR at the cell load of 60% is shown in Fig. 12. It is found that as we increase SINR, the spectral efficiency of the system increases. One can also verify that as we increase the densification of the Network for the given network load and SINR, the spectral efficiency of the system increases. So, for a given load, spectral efficiency can be effectively improved by increasing SINR and densification of the network as shown in Table 5.

The relationship between the energy efficiency of system vs SINR at cell load of 60% is shown in Fig. 13. It is found that as we increase SINR, the energy efficiency of the system increases. One can also verify that as we increase the densification of the network for a given cell load and SINR, the energy efficiency of the system increases. So, for a given load, energy efficiency can be effectively improved by increasing SINR and densification of the network as shown in Table 6.

From the computer simulations (Figs. 12 and 13) and Tables 5 and 6, we note that the for the given network load of 60%, the spectrum efficiency and energy efficiency of this system can be increased with increase in network densification and SINR.

In this paper, we have discussed the effect of different parameters like densification, cell load, network bandwidth on spectral efficiency, and energy efficiency with the additional effect of other parameters. It was found in [9] that as we increase network bandwidth, the spectral efficiency decreases for the given SINR. We have calculated the optimum Network bandwidth (B_{opt})for the given system. It has been found that B_{opt} depends only on SINR. The values of B_{opt} and maximum spectrum efficiency have also been calculated for the given system parameters as shown in Fig. 11. It was also found that as cell load increases

Fig. 11 Spectral efficiency vs SINR for network bandwidth



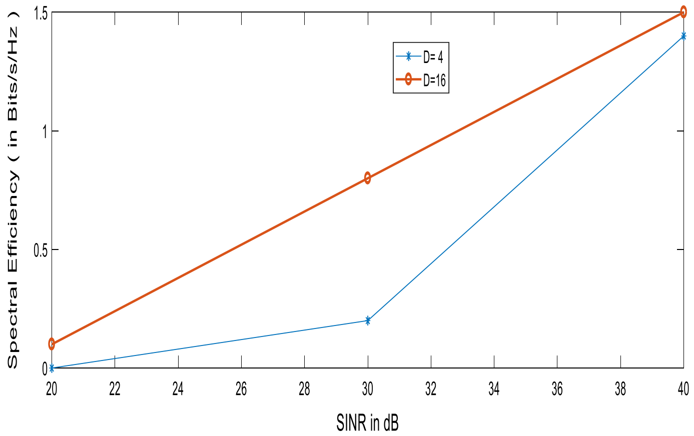


Fig. 12 Spectral efficiency vs SINR at network load of 60%

Table 5 Comparison of spectral efficiency at cell Load of 60%

S. No.	SINR in dB	Spectral efficiency at D=4	Spectral Efficiency at D=16
1	20	0	0.1
2	30	0.2	0.8
3	40	1.4	1.5

Table 6 Comparison of Energy efficiency at cell Load of 60%

S.no	SINR in dB	Energy efficiency at D=4	Energy efficiency at D=16
1	20	0.01	0.03
2	30	0.02	0.07
3	40	0.18	0.75

the spectral efficiency decreases. It has been found that increasing either the network densification, SINR, or both mitigates the effect of heavy cell load on the spectral efficiency and the energy efficiency as shown in Figs. 12 and 13. A computer code has been developed for computation of exact higher modulation method M-QAM used for given system parameters available in the literature [9]. It has also been found that if the spectral efficiency of this system increases, we may opt for the next M-QAM, and the number of bits transmitted increases. Hence data rate and channel capacity increase which supports energy efficiency.

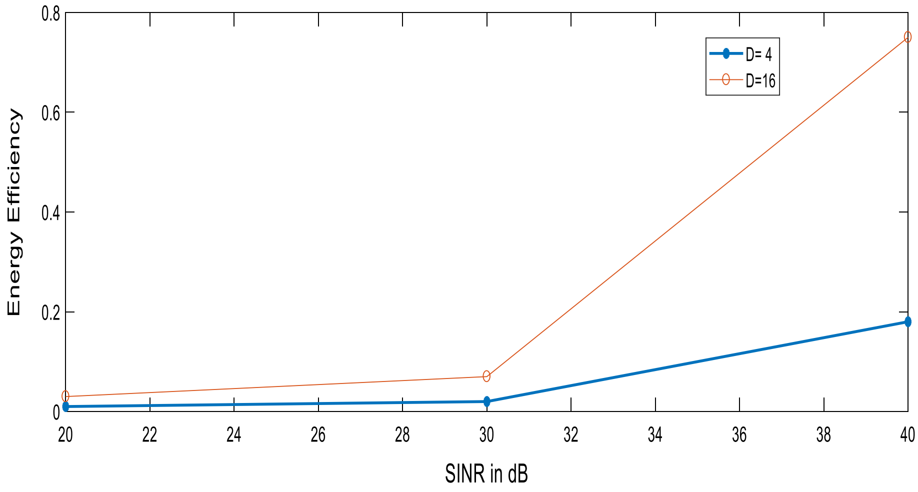


Fig. 13 Energy efficiency vs SINR at network load of 60%

8 Conclusion

Maximizing the spectral efficiency in a wireless channel is a very important issue for the quality of voice and data transmission. This system requires choosing the optimum value of bandwidth and cell load. These make it suitable to support high spectral efficiency and system capacity. In this paper, we have found that optimum bandwidth is a function of SINR. This equation can be used to find out optimum SINR that this system should be operated to achieve maximum spectral efficiency. We have found out the optimum bandwidth and maximum value of spectral efficiency for the given system as shown in Fig. 11. We have also discussed the effect of different parameters on the spectral efficiency and the energy efficiency of this system. Increasing SINR or the network densification factor mitigates the effect of heavy cell load. For the given system, 64-QAM is the higher modulation method we can use. it has been found that by increasing spectral efficiency, we go for the next higher modulation method like 128- QAM, etc. (7 bits are transmitted simultaneously instead of 6) so that channel capacity and data rate increase. The energy efficiency of the system also increases. Simulations are evident for the effectiveness of this. We can say that the UDMT network is going to be one of the most appropriate ways in the future for high-speed 5G mobile communication and which will be used within a few years or by 2021. In this paper, we have considered centralized densification based UDMT network. This work may be extended for distributed densification based same system in future.

Funding No.

Declaration

Conflict of interest The authors declare that they have no conflict of interest.

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Pankaj Shankar Shrivastava received his Ph.D. degree in Electronics and Telecommunication Engineering in 2015. He received his Master's and Bachelor's degree in Electronics and Communication Engineering from Birla Institute of Technology, Mesra , Ranchi (Jharkhand),India. He has published more than ten papers in conferences and journals. He has more than twenty years of teaching experience. His research area includes wireless and mobile communication.

Mr. Utsav Kumar Malviya In 2007 he received his B.Tech. degree in electronnics engineering from IETE, New Delhi, India, In 2010 he received M.Tech. degree in embedded system program from DAVV University, Indore, Indore, India. He is currently working as an ass-sistant professor in Government engineering college Bilaspur. He has 11 years of teaching experience and 1 year of industrial experience. His research interests include the design and verification methodology of SoCs, ASIC design, AI and Image processing.

Dr M.R Meshram was working as Associate Professor and Head of The Department of Electronics and Telecommunication Engineering at Government Engineering College Bilaspur. He has 35 years of teaching experience and his research interest include Development of Microwave Absorber, Microstrip Antenna, Computational Electromagnetics and Cellular Communication.

Mr. Umashankar Dewangan received his B.E. degree in Electronics & Telecommunication Engineering from SSCET, Bhilai in 2009.In 2012; he completed his Master degree in Communication system from the same institute. Currently he is working as an Assistant Professor in Electronics & Telecommunication Engineering Department of Government Engineering College, Bilaspur. His area of interest is secure communication, 4G/5G networks, biomedical signals and image processing.