ANALYSIS OF ENERGY AND SPECTRAL EFFICIENCY USING ZERO-FORCING TECHNIQUE WITH DISCONTINUOUS TRANSMISSION

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Abstract

In any cellular system energy consumption plays an important role to decide the efficiency of cellular networks. This paper explains how Cell discontinuous transmission (DTX) technique has been used to mitigate the energy consumption of a cellular network. The main contribution of this paper is to analyse the effect of traffic load on the various network parameters such as SINR (signal to interference plus noise ratio), energy and spectral efficiency of cellular networks. The optimum traffic load is derived using binary search algorithm. This paper describes that how Zero-Forcing (Z-F) technique is effectively useful when it combines with DTX method when compared with conventional Z-F and Maximal-Ratio (M-R) techniques in improving the energy and spectral efficiency calculations of a cellular system. In this paper we proposed a new ZF method in which it uses the Zadoff-Chu sequence transmission
Which reduces the drawback of conventional ZF technique that is high Peak Average Power Ratio (PAPR).Finally this paper shows energy and spectral efficiency calculations by using DTX method with new ZF technique which is proposed. All these analytical results are further verified by numerical simulations.

Keywords: Cell discontinuous transmission (DTX), traffic load, Zero-Forcing (Z-F) technique, Maximal-Ratio (M-R) technique, energy and spectral efficiency.

I. INTRODUCTION

Due to increase in the usage of numerous smart devices and networks the impact of traffic load become an essential parameter in the cellular communication system hence global mobile traffic would increase. To handle this network densification has been used to increase the capacity. So here it is required to reuse the radio resources.

To balance the increment in the network traffic load more number of base stations need to be installed but they consumes more energy. Different techniques have been proposed to reduce the energy consumption.

Depends on time scale there exist two types of traffic variations one is long term another is short term traffic variation. Base stations can have two levels of sleep mode, 1) long term sleep mode,2) short term sleep mode. Deep sleep is used for long term traffic variation where base station switches their modes according to traffic variation. Previously DTX method is adopted for short term traffic variation.

II. BACKGROUND AND MOTIVATION

Many techniques have been proposed in understanding the base station (BS) operations. The network densification has been proposed to increase capacity [2]. In a cellular network BSs consumes more energy and was discussed in [3]. The traffic level variations were proposed in [4] and [5]. The DTX method was discussed in [6], [7], and [8]. The design of efficient cellular networks was studied by authors in [9]. Cell DTX has been long applied in GSM network and it was proposed as a suitable technique to mitigate the influence of interference by improving the energy efficiency and it was discussed in [6], and [10].

DTX is also an important technique to save energy in LTE networks [11]. The tools of stochastic geometry [12] were used in this paper to analyze the performance of cellular networks.

The throughput, energy efficiency, impact of traffic density was investigated by authors in [13] and [14]. In this paper mainly we investigated the performance of cellular network while considering the impact of traffic load.

III.METHODOLOGY

In this paper we analysed the relation between traffic load and performance parameters of cellular network such as SINR, energy efficiency and spectral efficiency.

Steps involved:

1) Derive the network SINR distribution while considering network traffic load. Then we further derive network spectral and energy efficiency.

2) Present a sufficient condition for a cellular network to be interference-limited.

3) Analyse the impact of network traffic load on network spectral and energy efficiency.

4) Proposed Zero Forcing technique introduce and combine with DTX to improve energy efficiency and spectral efficiency.

5) Run numerical simulations to further confirm the analytic results.

IV.SYSTEM MODEL AND PERFORMANCE METRICS

1) NETWORK MODEL

Here we consider homogeneous network and the distribution of BSs is modelled with an ergodic PPP (point poisson process) with density λ_B . The relation between BS and user is modelled as

$$Pr = PtCKr^{-\alpha}h = Per^{-\alpha}h$$

where Pr, Pt, C, K, r, and α denote the receive power, the transmit power, the antenna gain, the path loss constant at unit distance, the distance between the BS and the user and the path loss exponent respectively. The random variable h models Rayleigh fading, i.g. h∼ exp.

2) TRAFFIC LOAD MODEL

The relationship between the density of active BSs λa, the density of deployed BSs λB and the network load ρ can be expressed as

$$\lambda_a = \rho\lambda_B$$

where λ_a is the total active base station density and ρ is the network traffic load and λ_B is the total base station density.

3) POWER CONSUMPTION MODEL

The BS power consumption model proposed in [6] is adopted in this work. In the active mode, the BS power consumption is modelled as below:

$$Pa = \xi Pt + Pc$$

where Pt and Pc are the transmit power and the circuit power respectively, and ξ is the inverse of the power amplifier efficiency. In the sleep mode, the BS turns off some components and consumes a smaller amount of power Ps. Define θ as the ratio between the sleep-mode power consumption and the active-mode power consumption and we have

$$Ps = \theta Pa.$$

For a traffic load ρ, the average power consumption in unit area is

$$E[Pu] = \lambda_a Pa + (\lambda_B - \lambda_a)Ps = \lambda_B Pa(\rho + (1 - \rho)\theta).$$

4) PERFORMANCE METRICS

The focus of this paper is to analyze the impact of traffic load on network performance. The ergodic average network spectral and energy efficiency are used as metrics to evaluate network performance. Here the ergodic average is the spatial average in an infinite plan and it accounts for both the random Rayleigh fading and the random distribution of BSs and users. According to Shannon-Hartley theorem, the achievable spectral efficiency ηSE of a given link with SINR γ is defined as

$$\eta_{SE} = log_2(1 + \gamma).$$

Therefore the ergodic average link spectral efficiency is given as

$$E[\eta_{SE}] = E[log_2(1 + \gamma)],$$

where E[x] is the expectation of a random variable x. For a given traffic ρ, assume there exist N active BSs in a unit area.

The ergodic average network spectral efficiency $E[\eta_{ASE}]$ can

be derived as

$$E[\eta_{ASE}] = E[\textstyle\sum_{i=1}^{N} log_2(1 + \gamma_i)$$

$$= E[N]\ E[log_2(1 + \gamma)] \text{ ----------(a)}$$

$$= \lambda_a E[\eta_{SE}] \text{ ------------------------(b)}$$

$$= \rho\lambda_B\ E[\eta_{SE}] \text{ ---------------------(c)}$$

where (a) follows from the approximation that the average area throughput is the product of average number of links per area and the average link throughput and this approximation will be validated by the simulation results in Section V;(b) follows from the fact that the average number of active BSs in unit area is λa and (c) is derived with (4). The unit of the network spectral efficiency is bps/Hz/m2. The ergodic average energy efficiency $E[\eta_{EE}]$ is defined as the average number of bits that can be successfully transmitted with unit energy. For a given traffic load ρ, the average network throughput in unit area is E[Tu] = W $E[\eta_{ASE}]$.

Considering the power consumption model described, the average energy efficiency $E[\eta_{EE}]$ is given as

$$E[\eta_{EE}] = E[Tu]/E[Pu] = (\rho W\ E[\eta_{SE}])/(Pa(\rho + (1 - \rho)\theta))$$

The unit of the average energy efficiency is bits / joule

V. PROPOSED METHODOLOGY AND PROBLEM FORMULATION

ZERO FORCING TECHNIQUE WITH DTX METHOD:

Zero-forcing (or null-steering) precoding is a method of spatial signal processing by which the multiple antenna transmitter can null multiuser interference signals in wireless communications. Regularized **zero-forcing precoding** is enhanced processing to consider the impact on a background noise and unknown user interference, where the background noise and the unknown user interference can be emphasized in the result of (known) interference signal nulling. Here conventional ZF technique has the drawback of high PAPR. In this paper it is overcome by using Zadoff-Chu sequence technique.

ZADOFF-CHU SEQUENCE TRANSMISSION:

A **Zadoff–Chu (ZC) sequence**, also referred to as **Chu sequence** or **Frank–Zadoff–Chu (FZC) sequence**,is a complex-valued mathematical sequence which, when applied to radio signals, gives rise to an electromagnetic signal of constant amplitude, whereby cyclically shifted versions of the sequence imposed on a signal result in zero correlation with one another at the receiver. A generated Zadoff–Chu sequence that has not been shifted is known as a "root sequence". These sequences exhibit the useful property that cyclically shifted versions of themselves are orthogonal to one another, provided, that is, that each cyclic shift, when viewed within the time domain of the signal, is greater than the combined propagation delay and multi-path delay-spread of that signal between the transmitter and receiver.

Zadoff–Chu sequences are used in the 3GPP LTE(Long Term Evolution) air interface in the Primary Synchronization Signal (PSS), random access preamble (PRACH), uplink control channel (PUCCH), uplink traffic channel (PUSCH) and sounding reference signals (SRS). By assigning orthogonal Zadoff–Chu sequences to each LTE eNodeB and multiplying their transmissions by their respective codes, the cross-correlation of simultaneous eNodeB transmissions is reduced, thus reducing inter-cell interference and uniquely identifying eNodeB transmissions. Zadoff–Chu sequences are an improvement over the Walsh–Hadamard codes used in UMTS because they result in a constant-amplitude output signal, reducing the cost and complexity of the radio's power amplifier.

ZERO FORCING TECHNIQUE:

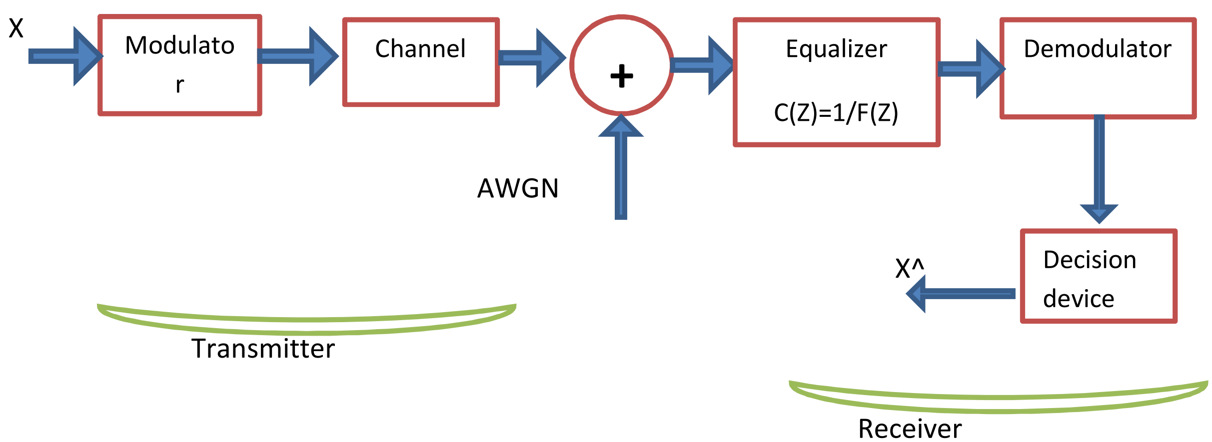

Figure: Block diagram of ZERO FORCING equalizer

Linear signal detection only treats the desired stream from the target antenna as the signals and all other transmitted signals would be treated as interferences. Interference signals from other transmitting antennas are minimized when detecting the signal from desired antenna. It is a low complexity detection algorithm that forces the interference to zero. The drawback of this method is retarded BER performance due to noise enhancement.

With a zero-forcing (ZF) equalizer, the tap coefficients w are chosen to minimize the peak distortion of the equalized channel, defined as

$$D_p = (1/\,|q_d|)\sum_{n=0,n\neq d}^{N+L-1}(|q_n - \hat{q}_n|)$$

where $\hat{q} = (\hat{q}_0, \ldots, \hat{q}_{N+L-1})^T$ is the desired equalized channel and the delay d is a positive integer chosen to have the value d = d1 + d2.

It showed that if the initial distortion without equalization is less than unity, i.e.

$D = (1/|P_{d1}|)\sum_{n=0}^{L}(|p_n|) < 1$, then D_p is minimized by those N tap values which simultaneously cause $q_j = \hat{q}_j$ for $d - d2 \leq j \leq d + d2$. However, if the initial distortion before equalization is greater than unity, the ZF criterion is not guaranteed to minimize the peak distortion.

VI. SIMULATION RESULTS

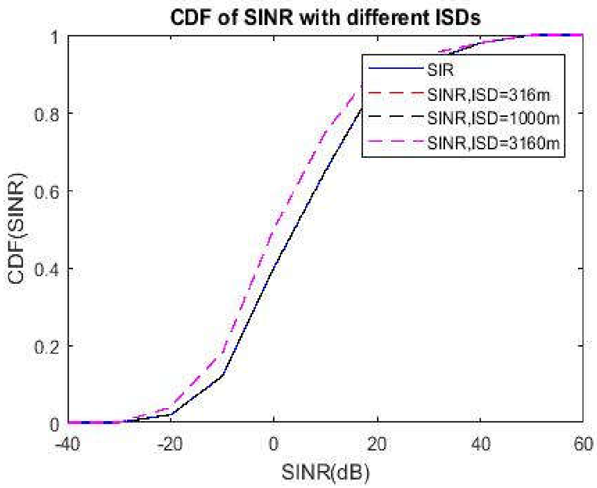

Figure1. CDF of SINR with different ISDs

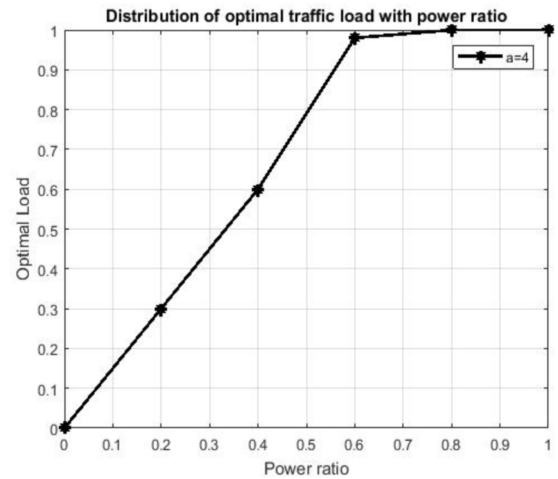

Figure2. Distribution of optimal traffic load with power ratio t = 4

Figure1 shows the distribution of SINR as a function of different ISDs (Inter site distances).The average ISD of cellular network is indirectly proportional to the square root of base station density. In figure2 it was shown that optimum traffic load variation as a function of power ratio theta(t).

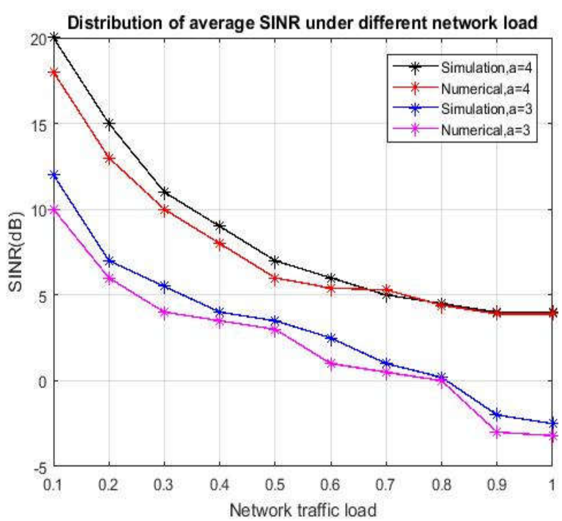

Figure3. Distribution of average SINR under different network load

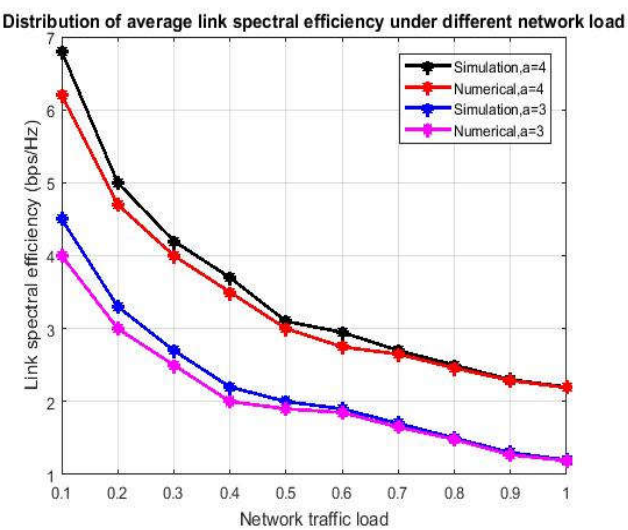

Figure4. Distribution of average link spectral efficiency under different network load

Fig.3 shows how the average SINR changes as the traffic load increases. Firstly, it is also shown that the simulation results and the numerical calculation results follow the same trend, although there is a minor gap between them. The results tell that the higher the traffic load is, the lower the average SINR is. This is due to the fact as the traffic load increases, there will be more active BSs in the network, which brings in stronger interference. Therefore the average SINR deteriorates. Comparing the results with different path loss exponents, we can find that the higher the exponent is, the better the SINR distribution is. Fig.4 is shown that As the link spectral efficiency is a monotonically increasing function of SINR, the similar results can be found for the link spectral efficiency. Fig.5 shows the impact of traffic load on network spectral efficiency. The vertical axis is normalized with the BS densityλ_B. Unlike SINR and link spectral efficiency, the network spectral efficiency increases as the network traffic load increases. The maximum network spectral efficiency can be achieved when the network is fully loaded. This is resulted from the fact that as the traffic load increases, in spite of the deterioration of single link quality, the frequency reuse factor increases.

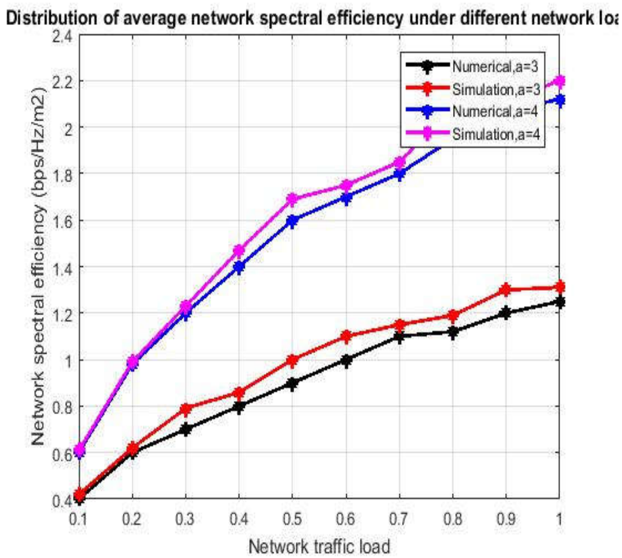

Figure5. Distribution of average network spectral Efficiency under different network load

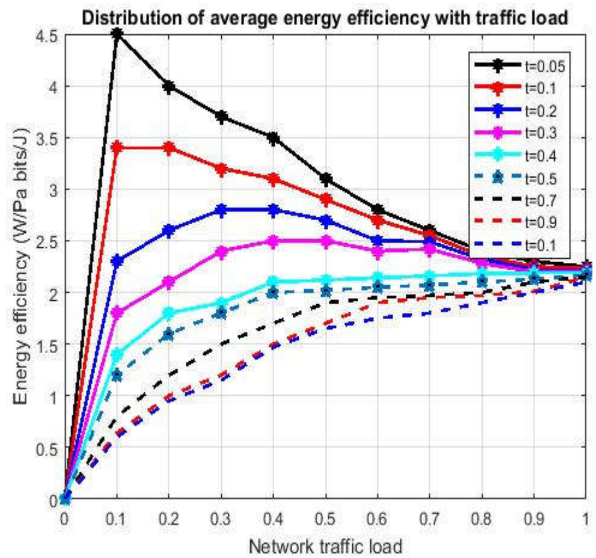

Figure6. Distribution of average energy efficiency with traffic load (simulation result, a=4)

Fig. 9 illustrates the change of average energy efficiency as the traffic load increases. The vertical axis is normalized with the system bandwidth W and the power consumption Pa of active BSs. The relationship between the average energy efficiency and the network traffic load is highly influenced by the ratio 't' of the sleep-mode power to the active-mode power. For small ratios, the energy efficiency would first increase and then decrease as the traffic load increases.

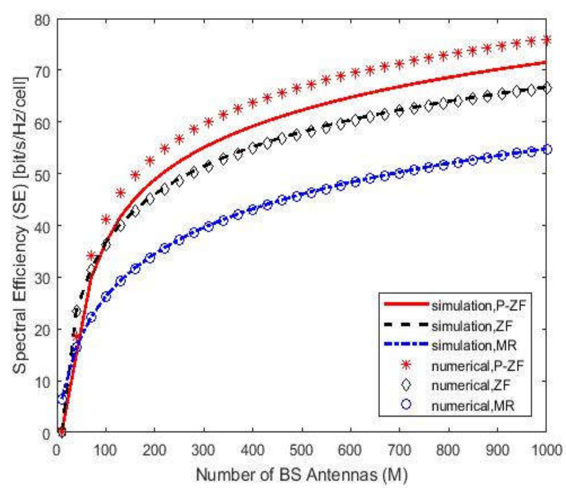

Figure7. Distribution of average network spectral Efficiency under different network load using ZF and MR techniques.

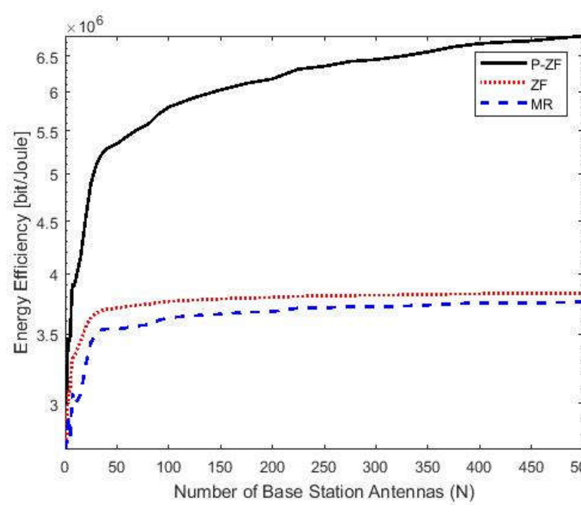

Figure8. Distribution of average energy efficiency with traffic load using ZF and MR techniques.

From the figures 7 and 8, it is clearly shown that the P-ZF technique gives better performance than conventional ZF and MR techniques where it is clear that energy and spectral efficiencies are increases as the network traffic load increases that is what the final result of this paper. Here we should identify that P-ZF technique is the combination of conventional ZF and DTX techniques.

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VII. CONCLUSION

In this paper we analysed the effect of traffic load on the various network performance parameters such as SINR, energy efficiency, link spectral efficiency. Here first we derived SINR distribution so that interference can be reduced. It is shown that SINR and link spectral efficiency decreases as traffic load increases but whereas the network spectral efficiency increases with respect to network traffic load. Here we observed that energy efficiency first increases and then decreases and as the network traffic load increases. Finally it was observed that the ZF technique works efficiently when it combines with DTX method than MR technique by improving the energy and spectral efficiency. In this paper it is shown that the new ZF technique in which the Zadoff-Chu sequence process is used hence we observed that it reduces PAPR of conventional ZF method .Finally it is shown that energy and spectral efficiencies increases as the network traffic load increases with new proposed ZF method.

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