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Power Consumption Reduction Technologies in LTE Networks

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Abstract- The present decade has witnessed a paradigm shift in the field of mobile communication, with an overwhelming increase in data usage. As more and more users are migrating to Smart phones, the amount of data being transmitted had increased manifold times. With enormous computing capabilities, these smart devices provide an advantage to their bulky counterparts like Computer, laptops regarding small size and ease of mobility. However, so much of data and signals proliferating the environment can be detrimental to the ecological balance. Thus, there is a need to have a cellular network, which can put a check on the carbon footprint of its signals. Long Term Evolution(LTE), due to its flexibility and backward compatibility has emerged as the network of choice for 4G and beyond. Third Generation Partnership Project(3GPP) has also taken the initiative in this direction by recommending Energy Efficient technologies to be incorporated in its release 12. In 3GPP Release 13 emphasizes the technologies such as Device to Device communication, enhanced carrier aggregation, opportunistic use of unlicensed Spectrum along with enhanced multi-user transmission techniques. In this article, the significance of key technologies for LTE network is highlighted, along with their inherent advantage of reducing the energy consumption of cellular network. An Energy Efficient model is proposed for LTE-Advanced which blends the technologies introduced by 3GPP such as adaptive OFDMA with that of MU-MIMO.

Keywords: Adaptive OFDMA, Carrier aggregation, Energy Efficient, LTE, MU-MIMO

I. INTRODUCTION

Concern for Green Energy: The interest for Green energy has attracted increasing attention, globally. The motivation for Green energy is the reduction of carbon footprint and minimizing greenhouse gas emissions. Information and Communication Technology(ICT) accounts for 2-4% of the total carbon emission globally[1]. With the phenomenal growth of ICT, this carbon emission is bound to increase. Mobile networks account for nearly 30% of the total ICT energy consumption. This figure is also bound to increase with the enhanced proliferation of wireless networks. Thus reducing energy consumption in wireless communications has attracted increasing attention recently. Network Energy Efficiency is a holistic approach, and various strategies at different layers have been proposed[2]:

1. Energy Efficient Architecture
2. Energy Efficient Resource Management
3. Energy Efficient Radio Technology

New network architectures such as heterogeneous networks, distributed antennas, multi-hop cellular, along with radio and network resource management schemes such as various cross-layer optimization algorithms, dynamic power saving, multiple radio access technologies coordination are being studied. At the physical layer, advanced techniques such as multiple-input-multiple-output (MIMO) and orthogonal frequency division multiplexing (OFDM), cognitive radio, network coding, cooperative communication, have been proposed[3]. Our focus is on the physical layer, and an energy efficient MIMO-OFDM model is proposed for Long Term Evolution Advanced(LTE-A). It is the dominant fourth generation(4G) standard, which meets as well as exceeds the criterion, laid down by International Mobile Telephony (IMT)-Advanced[4-5].

The LTE RoadMap: Third Generation Partnership Project(3GPP) has outlined the focus towards technologies such as machine-type communication(MTC), energy efficiency(EE), massive multiple input multiple output(massive MIMO), Heterogeneous Networks(Het-nets), Coordinated Multipoints(CoMP) in its release 12[6]. Fig. 1 depicts the technology areas for LTE-Advanced with concern towards ‘Green' communication. With an objective to reduce carbon footprint in the cellular network, 3GPP has initiated Network Energy Efficiency(EE) in release 12 which is the LTE-Advanced system. The various strategies to improve EE include Het-Nets, CoMP, self-organizing networks(SON), radio access technologies such as optimized orthogonal frequency division multiple access(OFDMA), Lean Carrier and massive MIMO. Our focus is energy efficient modeling of MIMO-OFDM for LTE-Advanced system. Table 1[7] succinctly highlights the technological milestones in each successive release(Rel 8 to 14).

II. THE METHODOLOGY

1. First, we model a conventional MIMO-OFDM system (Fig. 2)

2. Next, we model an energy efficient MIMO-OFDM system (Fig. 3) Instead of Single User MIMO(SU-MIMO), Multi-user MIMO(MU-MIMO) will be deployed to improve EE[8-10]. Utility-based adaptive OFDMA and link adaptation can significantly reduce the energy consumption[11-16].
3. Energy metrics to accurately quantify energy consumption.
4. Find out the Energy Efficiency(EE)η in bits/Joule
5. Find out the EE $\eta_{proposed}$ of the proposed model
6. Simulation to compare the Energy consumption of conventional model with the proposed model. The proposed model delivers promising results with reduced power consumption for LTE networks

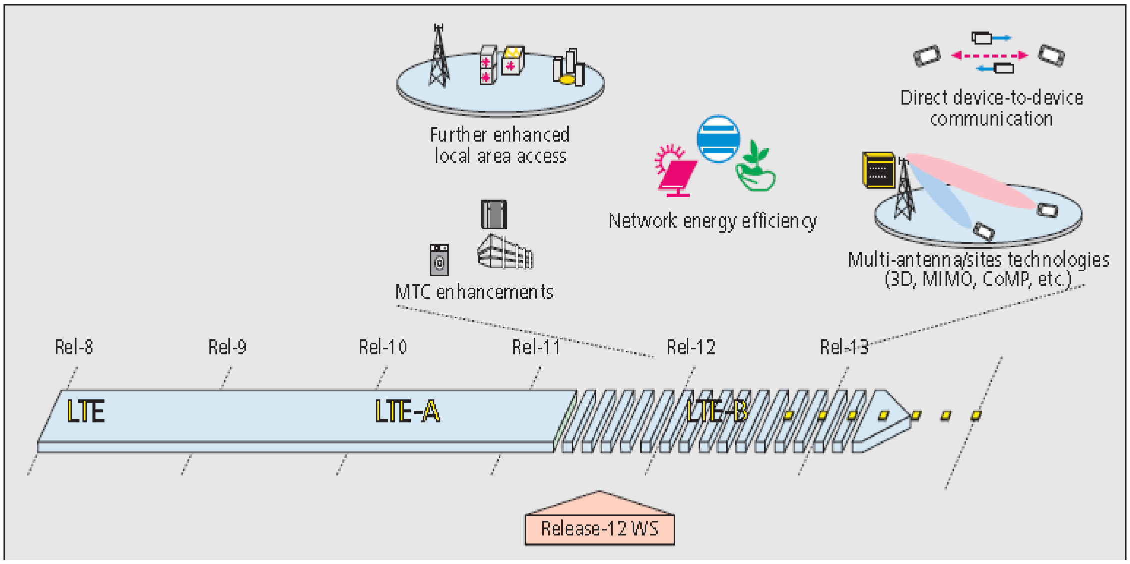

Figure 1.The LTE Technology Roadmap

Table 1 3gpp Release 8 To 14

3GPP Release	Rel Date	Technological Innovation	Standard
Release 8	March 2009	MIMO/OFDMA Flexible bandwidth	LTE
Release 9	March 2010	Evolved MBMS dual stream beam-forming	LTE
Release 10	June 2011	Carrier aggregation Enhanced MIMO	LTE-A
Release 11	March 2013	DL and UL CoMP In-device co-existence	LTE-A
Release 12	March 2015	Small cell enhancement Lean Carrier	LTE-A/B
Release 13	March 2016	Unlicensed Spectrum Elevation Beamforming Full Dimension MIMO	LTE-B
Release 14	June 2017	Multi-media Broadcast System Energy Efficiency and SON for AAS-based deployments	LTE-B

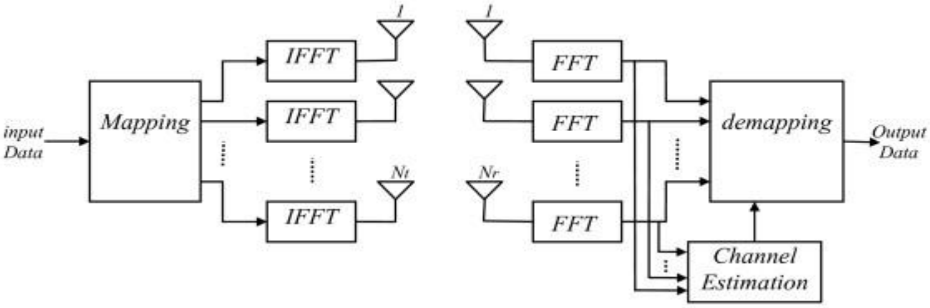

Figure 2 Conventional MIMO-OFDM Model (N_t transmit antennas and N_r receive antennas)

III. ENERGY EFFICIENT MODELING OF MIMO-OFDM FOR LTE-ADVANCED

MIMO-OFDM is the radio interface technology over the physical channel for LTE/LTE-Advanced. [*17*] analyzes the Energy Efficiency(EE) of cellular networks for the spatially distributed load. There exists a trade-off between EE and Spectral Efficiency(SE) in a cellular network[*18-21*]. Hence the modeling of Energy efficient radio interface has to be done without compromising the SE. In [*22*] an energy-efficiency optimized power allocation (EEOPA) algorithm is proposed to improve the energy efficiency of MIMO-OFDM mobile multimedia communication systems. Through simulation comparisons, the author(s) validate that the proposed EEOPA algorithm can guarantee the required Quality of Service(QoS) with high energy efficiency in MIMO-OFDM. In [*23*] comprehensive analysis of fundamental trade-off between SE and EE, deployment efficiency and EE is provided. In [*8*] it is shown that by transmitting and receiving information jointly, tremendous energy saving is possible for transmission distances larger than a given threshold. [*14*] demonstrates the improvement of energy efficiency by adapting both overall transmit power and its allocation, according to the channel states and the circuit power consumed. In [24] it is argued that conventional MIMO is not suitable for implementation to improve EE. Instead, virtual MIMO, also known as Multi-user MIMO(MU-MIMO) is proposed to improve EE. In MU-MIMO, multiple users co-operate for distributed transmission and information processing. Due to high Circuit power consumption in Single user MIMO(SU-MIMO), MU-MIMO is better suited for improving EE.

In Fig. 2, N_t and N_r form the antenna matrix, representing the number of transmit and receive antennas, M be the number of OFDM sub-carriers, S denotes the number of OFDM symbols, B is the system bandwidth, T_f is the frame duration. The received signal of the MIMO-OFDM communication system is expressed as[15]:

$$y_k(i) = x_k(i) + n \tag{1}$$

where y_k and x_k are the received signal vector and a transmitted signal at the k^{th} subcarrier, where k=(1,2,……………M) of the i^{th} OFDM symbol(i=1,2, ……..S). H_k is the frequency domain channel matrix at the k^{th} sub-carrier and n is the additive noise vector. Typically, the energy efficiency of MIMO-OFDM is defined as [24]:

$$\eta = C_{total}/E[\ P_{total}\ ] \tag{2}$$

where C represents the Capacity in bits/s/Hz, and E[.] is the expectation of total transmission power, measured in Joules. The Shannon capacity for single input single output(SISO) channel is given by

$$C = B\log_2 SNR \tag{3}$$

where B is the system bandwidth, SNR is signal-to-noise ratio. However the channel capacity of multiple antenna systems with N_t transmit, and N_r receive antennas can be increased by a factor of k where k=min(N_t, N_r). The capacity of a deterministic MIMO channel is given by[17]:

$$C = \sum i=1:k \log(1+P_i\lambda^2/N_o) \tag{4}$$

k=min(N_t, N_r), P_i =Water filling power algorithm, λ_i corresponds to an eigenmode of the H channel matrix. The capacity of the MIMO-OFDM system under an average transmit power constraint is given by [18]:

$$C_{MIMO\text{-}OFDM} = \frac{\max}{t_r(\Sigma)\le P}\frac{1}{M}\log_2\left[\det\left[I_{MN_t} + \frac{1}{{\sigma_n}^2}H\Sigma H^H\right]\right] \tag{5}$$

Where $\sum$ is the co-variance matrix of a Gaussian input vector, P is the maximum overall transmit power. I is the Identity matrix, σ_n^2 is the variance of the Gaussian random variable. To maximize Capacity, the channel matrix H, should be optimized.

$$C = \sum_{i=0}^{M}\log_2\left(1 + \frac{E_s\lambda_i}{MN_o}\right) \tag{6}$$

Here λ represents the channel power over the links. When the channel matrix is orthogonal, then the Capacity can be maximized as:

$$C = M\log_2\left(1+\frac{E_s}{N_o}\right) \tag{7}$$

(7) gives an important expression for Capacity in MIMO channel. The above result shows that the capacity in an orthogonal MIMO channel is M times the capacity of SISO channel. The capacity of a point-to-point MIMO channel is given as:

$$\hat{C} = \int_0^\infty \log_2(1+\gamma)\frac{\gamma^{n_r n_d - 1}\exp\left(\frac{-x}{\bar{\gamma}}\right)}{\bar{\gamma}^{n_r n_d}\Gamma(n_r n_d)}d\gamma \tag{8}$$

Where the PDF is given by [25]. By using (7) and (8), the Energy Efficiency is plotted in Fig. 4 and Fig 5. The results demonstrate the improvement of EE in MU-MIMO as compared to point-to-point MIMO because of precoding and orthogonal channels.

VI. CONCLUSION

In the current work, we have endeavored to envisage an energy-efficient model for the LTE-Advanced network which focuses on the physical layer. The proposed model deploys MU-MIMO and adaptive OFDMA to enhance EE. The simulation work is carried out using MATLAB. The results demonstrate that MU-MIMO enjoys an advantage over point to point MIMO because of reduced circuit power and precoding. Moreover, the use of OFDM modulation maintains the orthogonality between symbols and channels. The work can be further extended to incorporate large-scale antennas and cooperative relays.

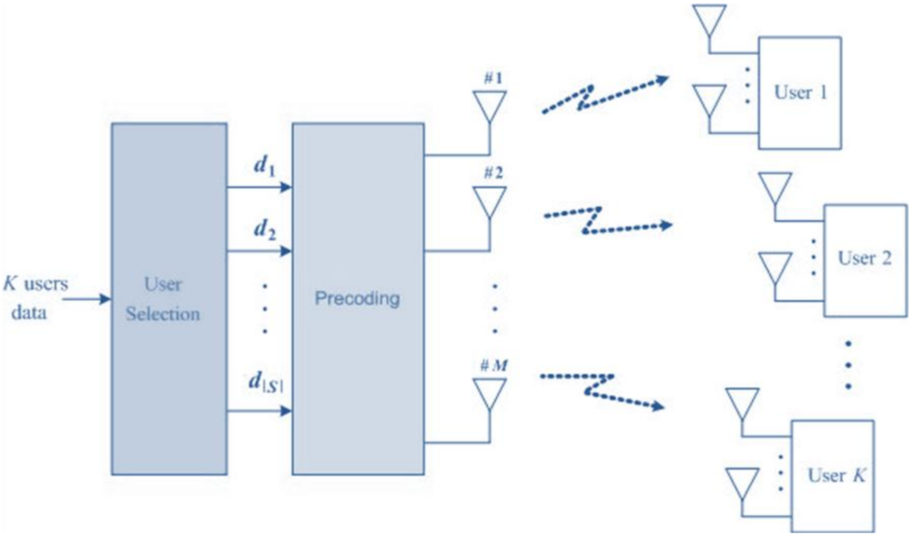

Fig. 3 MU-MIMO deployed to improve EE in the MIMO-OFDM model

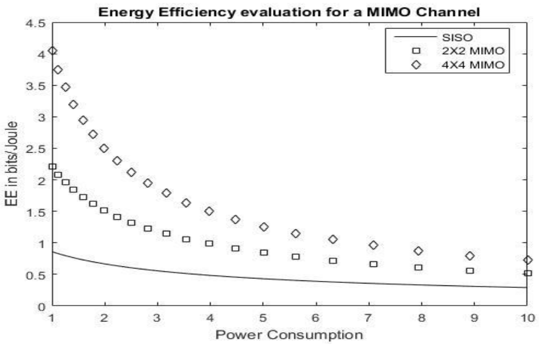

Fig. 4 EE in a Point to Point MIMO

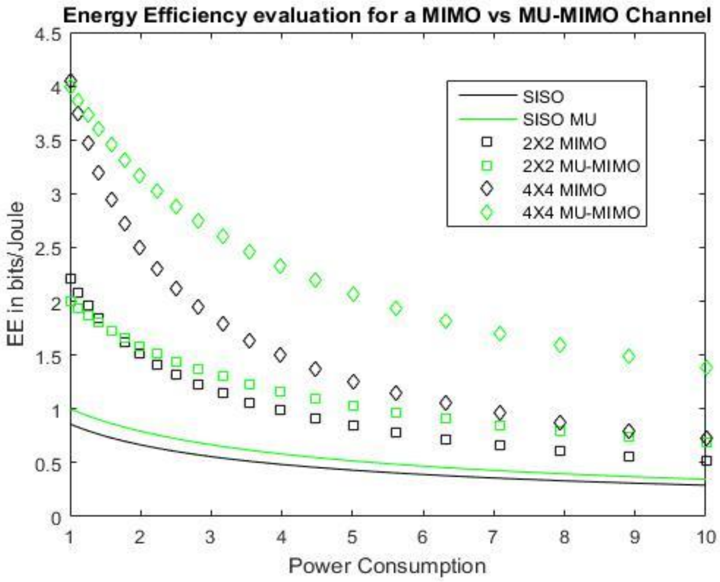

Fig. 5 MU-MIMO advantage over point to point MIMO

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