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Enhanced LTE-A Model for Improving Energy Efficiency in LTE-A Relay Networks

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***Abstract:* -- In future wireless communication, the networks will face the dual challenge to support large traffic volumes by providing reliable service for delay-sensitive traffic. To get this challenge, the relay network is introduced here as a new network design for the fourth generation (4G) LTE-Advanced (LTE-A) network. The resource allocation is investigated including subcarrier and power allocation, under statistical quality of service (QoS) constraints for 4G LTE-A relay networks. Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation (FBMC/OQAM) is recognized as an appropriate modulation scheme for 4G/5G wireless technologies. In this paper, we investigate an enhanced LTE-A model for improving energy efficiency in relay network with an extremely low Adjacent Channel Leakage Ratio (ACLR). Our result suggests that the improvement of energy efficiency with extremely low ACLR, when compared with schemes A, B, C & D. With an extremely low ACLR, FBMC/OQAM scheme is a suitable candidate for cognitive radio (CR) applications.**

***Keywords:*-- Relay network, Adjacent Channel Leakage Ratio (ACLR), Energy Efficiency, Wireless Communication.**

I. INTRODUCTION

Over the past two decades, the mobile wireless services have grown from niche market applications to globally available components of daily life. In February 2015, Cisco for global mobile data traffic from 2014 to 2019, indicating an order of magnitude growth in data traffic by year 2019. In future wireless networks will face the dual challenge to support large traffics by providing good service for delay-sensitive traffic. Furthermore, future mobile data networks will carry delay-sensitive traffic types including video, web/data, online gaming, voice-over-IP (VoIP), etc. In 2019, nearly three-fourths of the global mobile data traffic will be video. Since a significant portion of the video traffic is delay-sensitive with stringent quality of service (QoS) constraints, the predictions clearly suggest that the future mobile data networks will face the dual challenge of supporting large traffic volumes and also providing reliable service for applications of the heterogeneous service constraints.

In LTE-A relay networks, base stations and relay nodes share the same spectrum resource to serve mobile stations (MSs). The relay networks with a deployment of both high power base stations (BSs) and low power relay nodes (RNs) sharing the same spectrum resources have been recently adopted in the 4G mobile broadband system-3GPP LTE-A networks. The introduction of low power relay nodes changes the traditional homogeneous cellular mobile network to a heterogeneous one where nodes with different transmission power levels are overlaid with each other, and creates both opportunities and challenges. The report is divided into following sections : section 1 discuss the objective of Relaying. section 2 presents the structure of LTE-A relay network and its queueing. section 3 presents the simulation results. section 4 the last section summarizes the conclusion.

1. Objective

The objective of the present work is to get better efficiency in relay networks and analyze the relaying, by using Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation (FBMC/OQAM) with an extremely low Adjacent Channel Leakage Ratio (ACLR).

2. System Model for LTE-A Relay Networks

Figure 1. shows the LTE-A relay network. Relaying is one of the features being proposed for 4G LTE-A system. The aim of LTE relay network is to enhance both coverage and capacity to the users. The idea of relay nework is not new, but LTE relays and LTE relaying is being considered to ensure that the optimum performance is achieved to enable

the expectations of the users to be met while still keeping OPEX (Operational Expense) within the budgeted bounds.

In LTE-A systems, where orthogonal frequency division multiplexing access (OFDMA) is used subcarriers need to be optimally allocated for the access (RN-MS) link and the backhaul (BS-RN) link respectively. By using dual decomposition, the optimal subcarrier and power allocation strategies are derived to maximize the effective capacity (EC) of LTE-A relay systems.

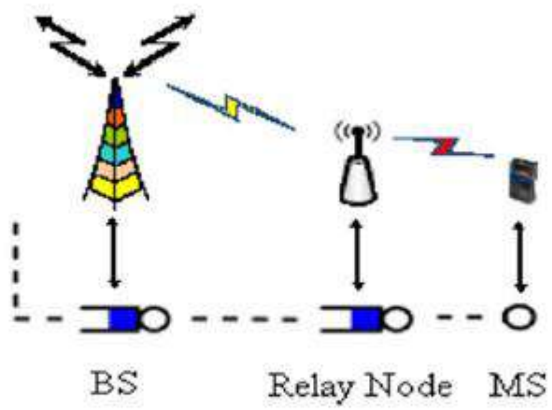

Fig. 1. LTE-A relay network with its queueing abstraction

The optimal sub-carrier and power allocation strategies mainly depend on QoS constraint.

To address, the QoS requirements of delay-sensitive traffic, a metric is adopted to capture the asymptotic decay-rate of buffer capacity :

$$\theta = -\lim_{x\to\infty} \frac{\log \Pr\{L > x\}}{x}$$

Where „ L " is the equilibrium queue length distribution of the buffer which present at the transmitter.
The main contributions are the following :

[1] The effective capacity of a LTE-A relay network based on large deviation principle, is a function of the subcarrier allocation scheme as well as the power allocation scheme for both the access link as well as the backhaul link of the underlying OFDMA relay network.

[2] The optimal resource allocation strategy by dual decomposition, which has low computational complexity compared to the exhaustive search method. The closed-form expressions of the optimal power and subcarrier allocation strategy are derived given the underlying quality of service (QoS) constraint under the assumption of the rayleigh fading channel in the low SINR regime.

[3] The characteristics of the effective capacity of the LTE-A relay network are identified and the properties of the optimal resource allocation strategies are characterized. The optimal subcarrier allocation strategy behaves to equate the effective capacity of the access link with that of the backhaul link while the optimal power allocation strategy follows a water-filling strategy. The water level depends on mainly underlying QoS constraint $\theta 0$.

[4] By decomposing the original resource allocation problem into two sub-problems: subcarrier allocation and power allocation, we introduce a low-complexity suboptimal resource allocation strategy. Furthermore, the optimal power allocation strategy as a function of the underlying quality of service (QoS) constraint is investigated in the low and high SINR regime respectively, which is unexplored in the literature as large. It is verified that the introduced resource allocation strategy performs close to the optimal one with less complexity via numerical simulation results.

[5] Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation (FBMC/OQAM) Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation (FBMC/OQAM) is recognized as an appropriate modulation scheme for 5G wireless technologies. With an extremely low Adjacent Channel Leakage Ratio (ACLR), FBMC/OQAM scheme is a suitable candidate for cognitive radio (CR) applications.

III. SIMULATED RESULTS

In this section, all the results after simulation is explained and presented for improving the energy efficiency in relay networks. The key system level simulation parameters are summarized in Table 1.

Table 1

Key system level simulation parameters

System Parameters	Values
System bandwidth	2.5 MHz
Subcarrier bandwidth	15 kHz
Resource block group (RBG) size	24 subcarriers
Resource block group (RBG) bandwidth	360 kHz
Number of RBG in the system	6
Average transmit power at the base station	43 dBm
Average transmit power at the relay node	30 dBm
Distance between BS and RN	450 meters
Distance between RN and MS	15 meters
Channel model (penetration and path loss)	3GPP Relay networks [25, A.2]

We consider a LTE-A system of total bandwidth of 2.5 MHz which consists of 6 physical resource block groups (RBGs) to be shared between a base station and a relay node. The effective capacities of the proposed resource allocation (subcarrier and power allocation) strategies are compared to that of all schemes A, B, C & D along with an extremely low ACLR in Fig. 2.

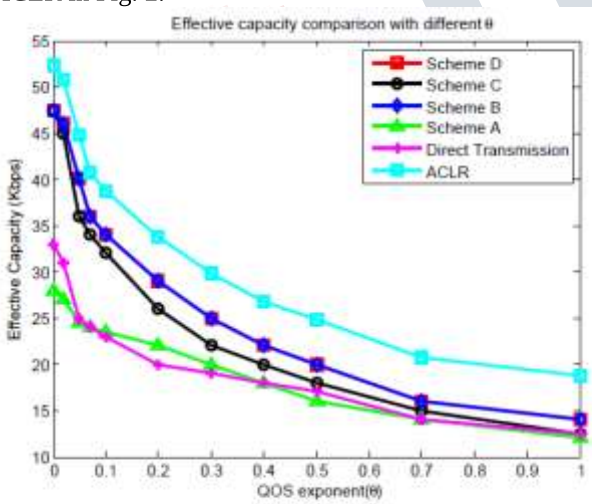

Fig. 2. Effective capacity comparison with an extremely low ACLR

In "scheme A", the subcarrier allocation strategy is based on the algorithm introduced in suboptimal subcarrier allocation with equal power allocation. In "scheme B", the resource allocation strategy is based on the optimal subcarrier and power allocation algorithm through dual decomposition method introduced in optimal subcarrier and power allocation. The "scheme C" is achieved using the subcarrier allocation strategy introduced in suboptimal subcarrier allocation and the power allocation for a fixed subcarrier allocation, while "scheme D" is the optimal resource allocation strategy obtained through optimal power allocation over all possible subcarrier allocation schemes.

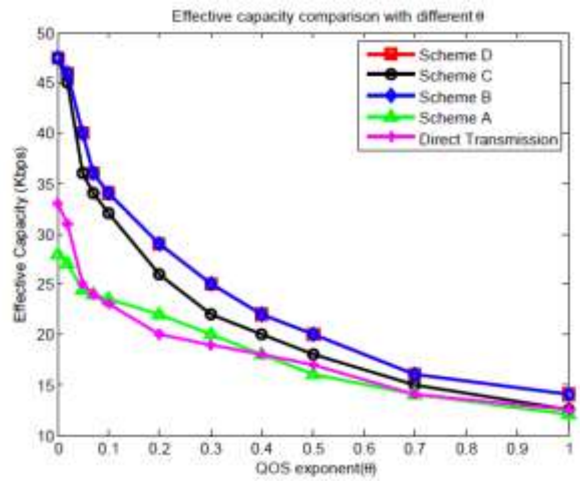

Fig. 3. Effective capacity comparison with different θ

From Fig. 3, both "scheme B" and "scheme D" have same performance across all QoS range of interests in the low SINR regime and also the performance of "scheme C" approaches to both "scheme B" and "scheme D" in both small and large QoS regime. But, in moderate QoS regimes, the "scheme C" performs worse than the optimal strategy strictly.

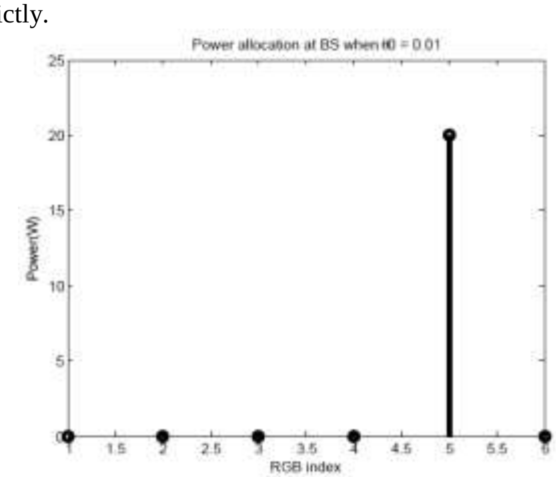

Fig. 4. Power allocation at base station when θ0 = 0.01.

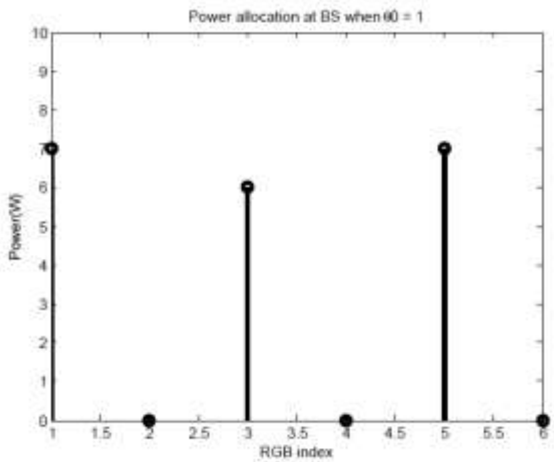

Fig. 5. Power allocation at base station when $\theta 0 = 1$.

The resource allocation strategy ("scheme C") at the BS is shown in Fig. 4 for the case of $\theta 0 = 0.01$ and in Fig. 5 for the case of $\theta 0 = 1$. When $\theta 0 = 0.01$, RBG 5 is the best RBG available at the base station so that the base station will allocate all the transmit power to RBG 5 as shown in Fig. 4. When the traffic is delay-sensitive ($\theta 0 = 1$) as seen in Fig. 5, the base station distributed transmit power equally among RBGs 1, 3 and 5.

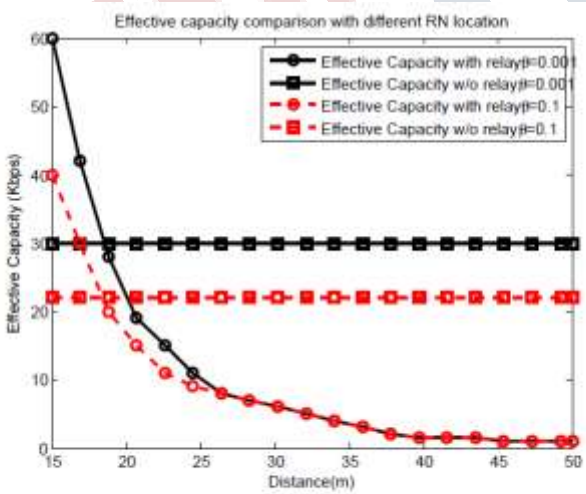

Fig. 6. Effective capacity comparison with different RN location

In Fig. 6, the effective capacity of the LTE-A relay network with different relay node location is investigated. It is assumed that the base station is 450m away from the mobile station while the distance from the relay node to the mobile station varies from 15 m to 50 m.

We derive the maximum effective capacity using the method introduced in section iii. It can be seen that when the distance between the RN and the MS is small, e.g., less than 20 m, the higher effective capacity can be achieved compared to that of the direct transmission, which is due to the less from the MS, the access link will becomes the bottleneck, which leads to the lower effective capacity of the underlying LTE-A relay system.

IV. CONCLUSION

This paper studied enhanced LTE-A model for improving energy efficiency in relay network with an extremely low ACLR and optimal resource allocation strategies in LTE-A relay networks under statistical quality of service (QoS) constraints. Filter Bank Multicarrier with offset Quadrature Amplitude modulation (FBMC/OQAM) is recognized as an appropriate modulation scheme for 5G wireless technologies. With an extremely low Adjacent Channel Leakage Ratio (ACLR), FBMC/OQAM scheme is a suitable candidate for cognitive radio (CR) applications.
Like all multicarrier systems, FBMC/OQAM suffers from the high Peak to Average Power Ratio (PAPR). Because of its overlapping signal structure, the direct application of the PAPR reduction schemes proposed for the Orthogonal Frequency Division Multiplexing (OFDM) signal to FBMC/OQAM one is not effective. In this investigation, the main contribution is a novel PAPR reduction scheme based on the extension of the current Tone Reservation (TR) scheme as used in OFDM to FBMC OQAM. of optimal re source allocation strategies are identified. It is shown that the optimal power allocation scheme is in the form of "water-filling" where the water level depends heavily on the underlying QoS constraint. It is also observed that in the high SINR regime, both the base station and relay node will distribute their power equally to all the available subcarriers regardless of the QoS constraint $\theta 0$. In the low SINR regime, as the QoS constraint $\theta 0$ becomes more stringent, the transmit tends to spread its transmit power over available frequency resources.

By relaxing the subcarrier allocation constraints and adopting the dual decomposition, we obtained the optimal resource allocation strategy to maximize the effective capacity of the LTE-A relay system. Based on optimal power allocation strategy, suboptimal low-complexity resource allocation strategies are introduced. The effective capacity performance of the these strategies are compared to that of the optimal resource allocation scheme based on exhaustive search. Based on simulation results, the proposed scheme shows almost the same PAPR reduction performance when compared with that of the conventional TR method originally proposed for OFDM. Furthermore, the loss of the effective capacity of the suboptimal strategy in minimal at stringent QoS constraints (large θ0)

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