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Resource allocations for Delay-sensitive traffic over LTE-Advanced relay networks

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Abstract: *New trends are more essential in the area of wireless communication for different applications. Wireless communication is one of the important aspects of life. The growth of wireless communication technology has demand for the high speed, efficient, reliable voice and data communication. In future wireless networks will face a problem on supporting large traffic volumes for delay-sensitive traffic. To recover that problem relay network has been used in architecture for the fourth generation (4G) LTE-Advanced (LTE-A) networks. Here we investigate resource allocation and subcarrier and also power allocation for LTE-A relay network. The optimal subcarrier and power allocation strategies are derived for maximize the effective capacity (EC) of the LTE-A relay systems. If identified the characteristics of resource allocation strategies, and low complexity sub optimal scheme is developed by the optimal subcarrier and power allocations. Then results suggest that optimal subcarrier and power allocation strategies are heavily depend on the QoS constraint. When low signal-to-interference-pulse-noise (SINR) regime and less QoS constraint, then both base and relay stations are allocate all the power to the best sub carriers. When QoS constraint becomes more stringent, both base and relay stations will spread their power over available subcarriers. In high SINR, regardless of QoS constraints, base stations and relay stations are equally allocate power to the available subcarriers. The main contribution is a novel Peak Average Power Ratio reduction scheme based on the extension of the current Tone Reservation (TR) scheme as used in OFDM to FBMC/OQAM. 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.*

Keywords: *Effective capacity, LTE-Advanced, Quality of service, Relay node, Tone reservation.*

I. INTRODUCTION

In the past three decades, mobile and wireless communication grown from market applications to globally available components of daily life. Past 25 years companies are unknown but now a day each and every company economy, product and households will depend on wireless communication (Dr. Houman Zarrinkoub, 2014). The growth in mobile services, web browsing, social networking and audio and video streaming is developed by wireless communication. In one word the wireless communications randomly changes the life of persons. In February 2015, Cisco predicted a 57% compound annual growth rate (CAGR) for global mobile data traffic from 2016 – 2019, indicating an order of magnitude growth in data traffic by year 2019 (Cisco, San Jose, et al., 2015). For 2020 nearly 75% of the global mobile data traffic will be video. To overcome this problem data demand, mobile operators can take different approach to boost network capacity. The delay-sensitive traffic depends on QoS.

Meanwhile, 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 (Y.Li, Y.Yi, M.Baker et al., 2012-13). The introduction of low power relay nodes changes the traditional homogeneous cellular network to a heterogeneous one where nodes with different transmission power levels are overlaid with each other, and creates both opportunities and challenges (L.Lui, Y.Yi, H.Li et al., 2012). LTE-A relay network having base station and relay nodes these are used to serve mobile station with their same spectrum resources. “Cell-Splitting” concept is used in LTE-A relay networks. The overall information-theoretic capacity of a heterogeneous network can be significantly increased due to “cell-splitting” gain (T. Cover and A. E. Gamal et al., 1979). If we are using low power relay nodes that will provide excess problems to the network. The resource allocation between access link (RN-MS) and backhaul link (BS-RN) should be optimized due to maximum utilization of the system resource. In LTE-A systems where orthogonal frequency division multiplexing access (OFDMA) is used subcarriers need to be allocated for the access link and the backhaul link optimally.

Quality of service (QoS) is the overall performance of a system like telephony or computer network. In the field of telephony, quality of service was defined by the ITU in 199 (J. Tang and X. Zhang et al., 2007). Quality of service comprises requirements on all the aspects of a connection, such as service response time, loss, signal-to-noise ratio, crosstalk, echo, interrupts, frequency response, loudness levels, and so on. A subset of telephony QoS is grade of service (GoS) requirements, which comprises aspects of a connection relating to capacity and coverage of a network (F. P. Kelly et al., 1991). The QoS requirement for the delay-sensitive traffic, in this paper, a metric is adopted to capture the asymptotic decay-rate of buffer occupancy (D.Wu,L. Liu, P. Parag et al., 2003, 2007):

$$\theta = -\lim_{x\to\infty} \frac{\log \Pr\{L>x\}}{x} \qquad (1)$$

Where, L is equilibrium queue-length of the buffer present at the transmitter. Here θ reflects the quality of wireless link. Large θ gives better performance or tighter service. This metric is closely tied to the concept of effective bandwidth, which has been studied extensively in the context of wired networks (C.-S. Chang 2000). In wired connections service rates are constant; in wireless channels service rates are time-varying. Where the relay node has no buffer then power allocation will be maximize the effective capacity of relay networks. In (J. Tang and X. Zhang et al., 2007) impact of QoS constraint on the optimal power allocation is investigated in single carrier point to point system. The optimal power allocation strategy heavily depends on the QoS. In this paper we consider that maximizing the effective capacity of LTE-A relay networks under channel statistical QoS. Relay networks have been heavily investigated in the information theory society (T. Cover and A. E. Gamal et al.,1979). Here investigated that all the subcarriers used at the base station (BS) are fully reused at the relay node (RN). The total power allocation of both BS and RN is assumed that of individual power constraint at BS and RN are same. However, in this paper, we will characterize the optimal power allocation strategy for delay-sensitive traffic based on QoS metric θ which can be related to the delay-violation probability.

This work is improved by the understanding of delay-sensitive traffic over relay networks. Specifically the effective capacity for OFDMA-based LTE-A relay network is maximize by the optimal/suboptimal resource allocation strategies.

Our main contributions of the paper:

First we characterize the effective capacity of LTE-A relay network based on large deviation principle (A. Dembo, O. Zeitouni, 1998). Second an optimal resource allocation strategy has low computational complexity compared to the exhaustive search method. Third identifying the effective capacity of LTE-A relay network and characterize the properties of optimal resource allocation strategies. The effective capacity of access link and backhaul link depends on the power allocation strategy follows a water-filling strategy (Yan Li, Lingjia Liu et al., 2015). The water level depends on QoS constraint θ_0. Fourth investigate the main contribution is a novel PAPR reduction scheme based on extension of the current Tone reservation (TR) scheme used in OFDM to FBMC/OQAM. Conventional TR method originally proposed for OFDM. Finally decomposing the original resource allocation problem into two sub-problems: sub carrier and power allocation. Further optimal power allocation strategy as a function of QoS constraint is investigated in low and high SINR regime.

It is important to note that optimal/suboptimal resource allocation strategies considering both access link as well as backhaul link for effective capacity of LTE-A relay networks are largely unexplored.

II. SYSTEM MODEL OF THE LTE-ADVANCED RELAY NETWORKS

LTE (Long Term Evaluation) Advanced is a mobile communication 4G standard approved by International Telecommunications Union (ITU) in Jan 2012 (Dr Houman Zarrinkoub 2014). The name suggests a more advanced set of standards and technologies that will be able to deliver bigger and speedier wireless-data. LTE-A promises to deliver true 4G speeds, it‘s to be two to three times faster than LTE. True 4G is also known as IMT-Advanced, LTE-A was standardized by the 3rd Generation Partnership Project (3GPP) in March 2011 as 3GPP (P. Bhat *et al.*, 2012). LTE-A shall be capable of interworking with LTE and 3GPP systems. LTE-A serves multiple mobile users with different channel condition. Advantages of LTE-A provide low latency, higher network throughput, increase data rate, cost effectiveness and improvement over 4G network (M. Baker et al., 2012).

Consider a LTE-A relay network from fig.1. In LTE-A relay networks, the main contribution of relay node used to extends coverage places where reception is poor (Y. Li, L. Liu, H. Li et al., 2013). They will increase the coverage range with good speed, even if you are on the outskirts of network. Relay node receive the signal, amplify that signal and then retransmit same signal. LTE-A supports more advanced relay nodes those will first decode the transmission information and then forward to destination that means mobile station, each relay is serving for MS. Relay node reduces the interference. The relay node is in between MS and BS send information by multi communication. If mobile station directly connects with base station, it cannot receive signals from relay node. If the mobile station is associated with relay node, it cannot receive signals from base station directly. It will happen in practical situation.

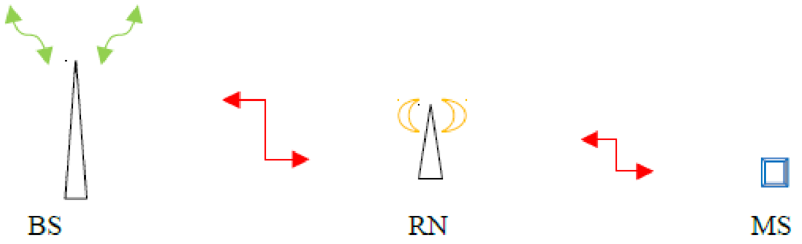

Fig1. LTE-A relay network

Once resource allocation is used the mobile station connected to the relay node, information before sending to the relay node it comes from base station. Each subcarrier of the system is assigned to either backhaul link that or access link. Where the dedicated backhaul is challenging there relay node will provide solution. This paper mainly focuses on the simple network architecture with single relay node and mobile station. By results from this paper generalized that network architecture consisting of multiple relay nodes and mobile stations. In research relay node is half-duplex, while full-duplex relays are investigated in practical systems considering half-duplex relay operation occurs (Yan Li, Lingjia Liu et al., 2015).

Once the resource allocation is used then base station forward the information to relay through downlink channel which will sent by error control and higher transmit power to the relay node and mobile station can correctly decode that information. Decoded information and sends to the destination. This procedure is done by current LTE-Advanced system.

III. ADJACENT CHANNEL LEAKAGE RATIO (ACLR)

The LTE-A transmitter meet the power for required specification those situations unwanted emission of power leaks in to adjacent channel as defined by ACLR. The adjacent channel leakage ratio (ACLR) of any general purpose RF device, whether a mixer, amplifier, isolator or other device is frequently dominated by the 3^{rd} order inter modulation distortion (IM3) of device. The relationship between the performance and output intercept point (OIP3) parameter of the device can be derived. Each of the individual subcarriers would carry fraction of total carrier power. From the above fig.2 RF carrier is modelled by four individual subcarriers, each one has one-quarter of the power by the total bandwidth of subcarriers is distributed by equal intervals across the carrier bandwidth. The green lines in fig.2 called subcarriers 1,2,3,4 from left to right. First red distortion product to the left two green subcarriers results that IMD3 distortion from those two subcarriers.

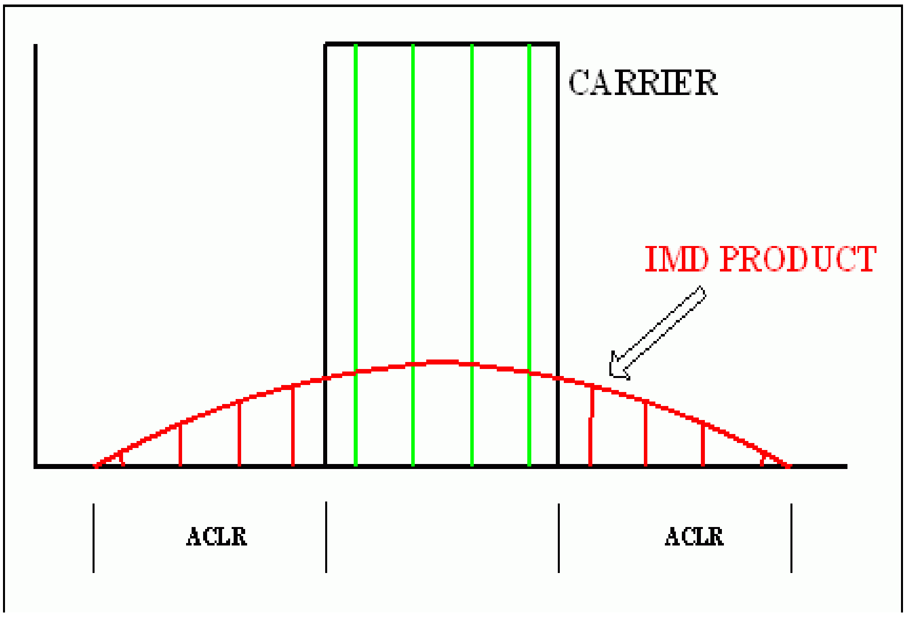

Fig.2 subcarrier model of a broadband carrier signal

Subcarriers 2 and 4 produce IM3 products directly fall on top of the IMD product subcarrier 1 and 2. This summation effect forces the IMD products closer to the edge of the RF carrier to be higher in magnitude than those IMD products farther away from the edge of the RF carrier, producing the characteristic "shoulders" that appear in an ACLR distortion spectrum. The ACLR performance of multiple wideband carriers look much like the ACLR from this model, where each individual wideband carrier occupies a fraction of the total wideband carrier bandwidth. The ACLR for a carrier adjacent to the last carrier in the contiguous collection of wideband carriers rides on the high shoulders of the IMD3-induced distortion response. This causes the ACLR for a multicarrier case to be considerably worse than that for a single-carrier system. The relationship between 3^{rd} order IM products of a device and 3^{rd} order intercept point of that device is:

$$IMD3 = (3 \times P_m) - (2 \times OIP3) \quad (2)$$

Where,

P_m = power per tone in a two-tone test case

IMD3 = 3^{rd} order IM3 in dBm, in absolute power

OIP3 = 3^{rd} order intercept point in absolute power

For convenience this formula rewritten

$$IMD3 = 2 \times (P_m - OIP3) \quad (3)$$

Where,

P_m = power tone in a two-tone test case

IMD3 = 3^{rd} order IM3 in dBc in relative power

OIP3 = 3^{rd} order intercept point in absolute power

The ACLR of a wideband carrier can be related to the two-tone IMD3 performance by a correction factor. This correction is due to the fact that the ACLR performance is degraded by the IMD3 performance. This degradation is itself due to the effects of the various inter modulation products that form from the spectral density of the spread-spectrum carrier. A useful relationship for ACLR to IMD3 is as follows:

$$ACLR_n = IMD3 + C_n \quad (4)$$

Where, C_n is form of following:

No.of carrier	1	2
Correction C_n (dB)	+3	+9

Now combine the above relationships for IMD3 and ACLRn into one unified expression to derive the ACLR for a number of spread-spectrum carriers from the basic performance parameters of the RF device.

$$ACLR_n = (2 \times [(P - 3) - (OIP3)]) + (C_n) \quad (5)$$

Where,

P =total output power for all carriers in dBm

OIP3 = OIP3 of the device in dBm

C_n = value from the above table

$ACLR_n$ = ACLR for n carriers in dBc

IV. SIMULATION RESULTS

In this section simulation is done by MATLAB R2010a. MATLAB is a widely used programming language for algorithm development, data analysis, visualization and numerical computation. MATLAB has a long history in communication system design and used by both academic and practitioners. Many of its features and capabilities are perfect for modelling wireless systems (D. Tse and P. Viswanath, 2005): (1) it has interactive program and environment that matches the exploratory nature of science; (2) it provides seamless access to data and algorithms; and (3) it has tools for visualization, algorithm development, and data analysis.

From fig.3 it can seen that Scheme B and Scheme D have same performance across all the QoS range of low SINR regime Scheme A is subcarrier allocation strategy, Scheme B is equal power allocation. The performance of Scheme C approaches to the Scheme B and Scheme D in both small QoS regime and large QoS regime. Scheme C achieved by subcarrier allocation strategy with power allocation scheme, Scheme D achieved by optimal power allocation (Yan Li, Lingjia Liu et al., 2015). Scheme C performs worse than optimal strategy.

The performance of Scheme A is worse than all other schemes. ACLR means Adjacent Channel Leakage Ratio is used to controls inter modulation distortion. The performance of the four schemes is almost same in large QoS regime. At the small QoS The "water-filling" power allocation strategy will generate effective capacity.

In the small QoS regime "water-filling" power allocation will result that total available power will transmit to the best subcarrier. By ACLR transmission is best for remaining all the schemes and direct penetration is worse compared with scheme C and also scheme B. in direct penetration no allocation strategies are used.

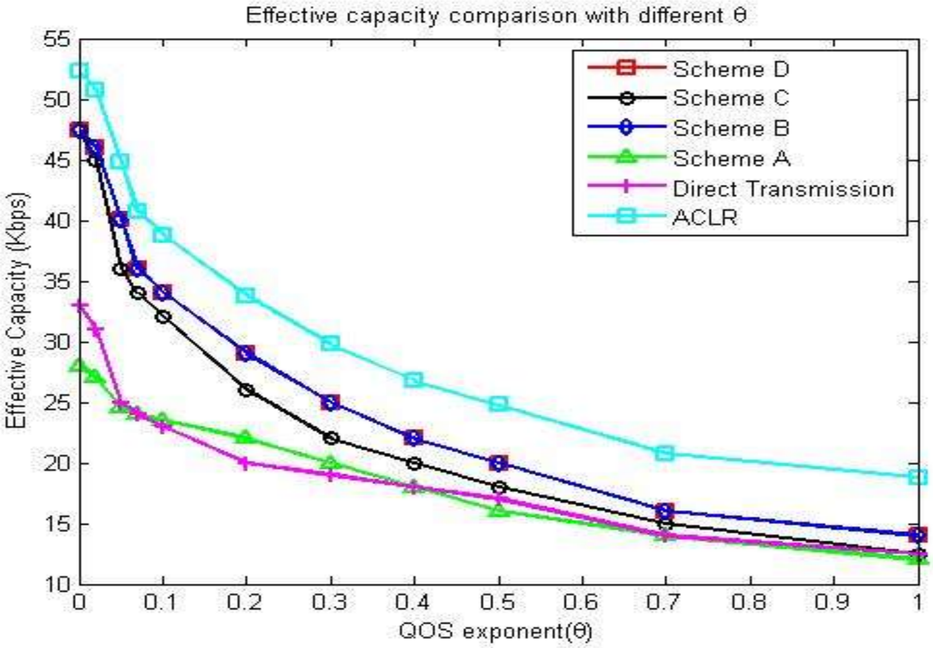

Fig.3 Effective capacity comparison with different □

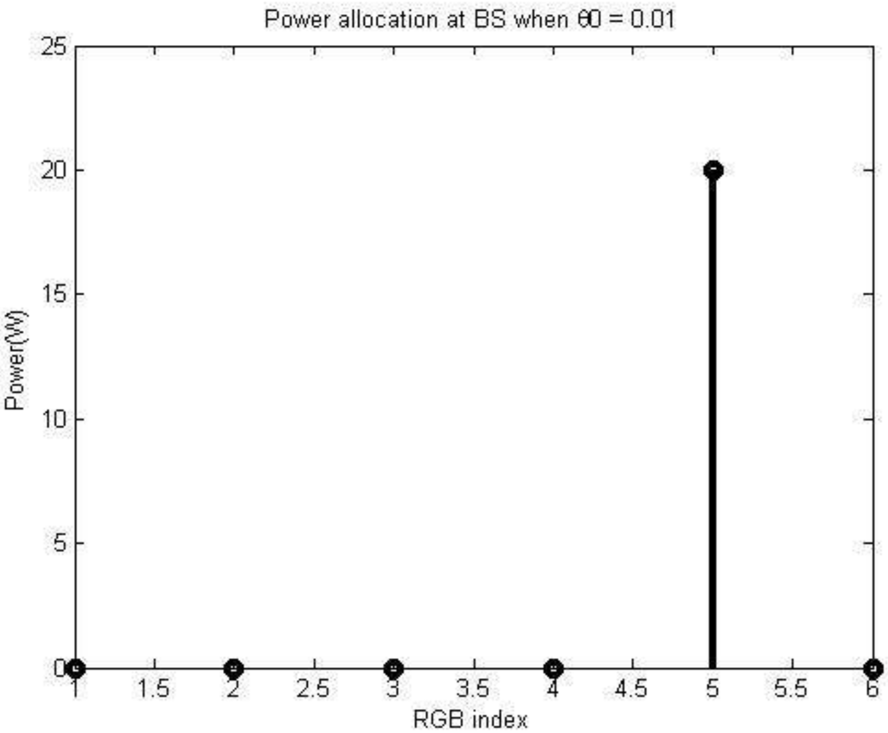

Fig.4 Power allocation BS at □$_0$ = 0.01

Consider a LTE-A system of total bandwidth of 2.5MHz which consists of 6 physical resource block groups (RBGs) (L. Liu *et al.*, 2012) to be shared between a base station and a relay node. The power allocation strategy at the base station shown in below fig.4 for the case of θ_0 = 0.01 and in fig.5 θ_0 =1.When RGB 5 θ_0 = 0.01 is the best RGB available at the base station.

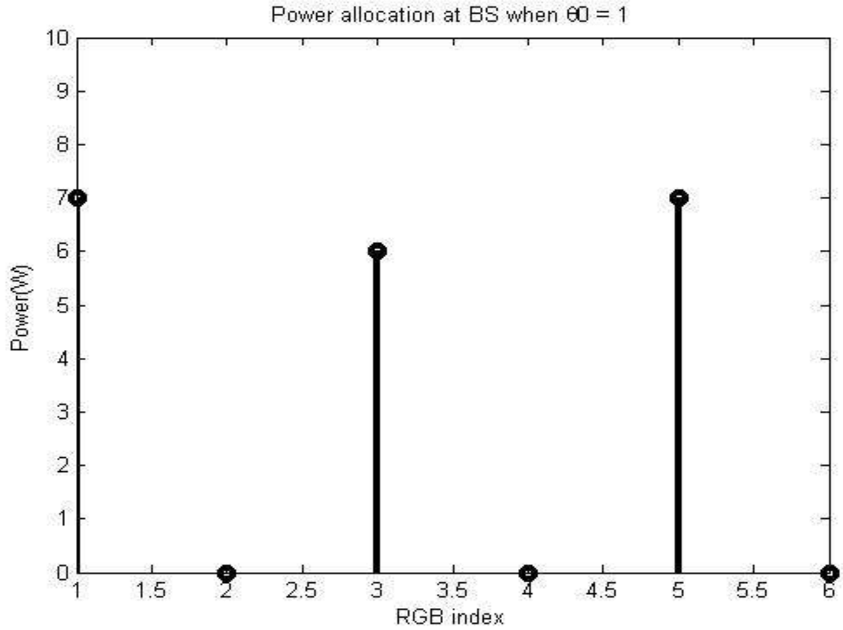

Fig.5 Power allocation BS at θ_0 =1

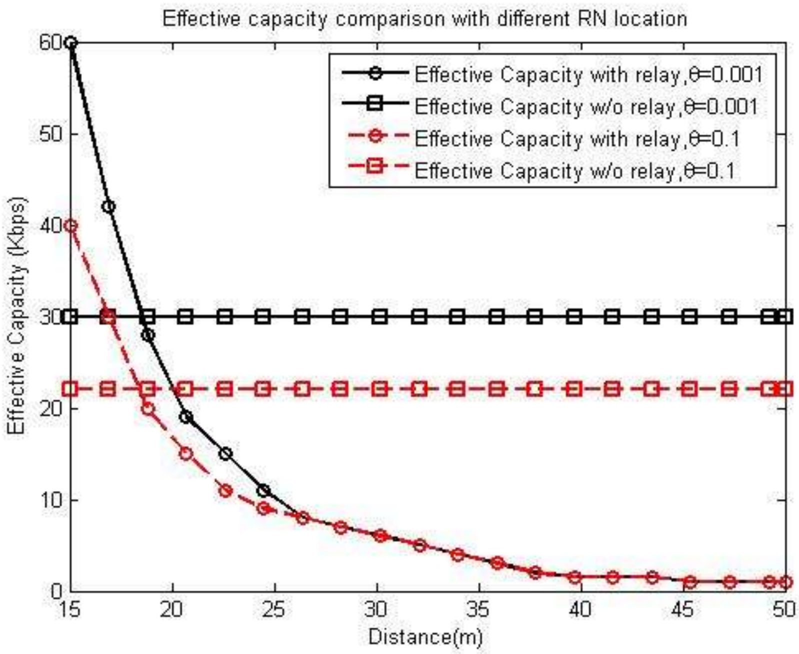

Fig.6 EC comparison with relay node and without relay node

Fig.5 the base station distributed transmits power equally among RGBs 1, 3 and 5. In fig.5, effective capacity of LTE-A relay network with different relay node investigated. It can be seen that the distance between the RN and MS is small. The higher effective capacity can be achieved by ACLR, which is due to less penetration and less path loss. When RN is longer from MS the access link will becomes the bottleneck, which leads to the lower effective capacity under LTE-A relay system (Yan Li, Lingjia Liu,Yang Li, 2015).From figure6 we observe the performance of effective capacity related with relay node. When we are using relay node then effective capacity is varying, without relay effective capacity is same for different locations.

V. CONCLUSIONS

This paper studied optimal resource allocation strategies in LTE-A relay network under statistical quality of service. Optimal power allocation scheme is in the form of "water-filling" where the water level depends heavily on the underlying QoS. Tone reservation is used to decrease the complexity and minimize the PAPR.

The main advantage of TR is no side information and performance is better it shown in ACLR. In high SINR regime both base and relay node will distribute their power equally to available subcarriers of the QoS constraint θ_0. In low SINR the QoS constraint θ_0 becomes more stringent the transmit power over available frequency resource. The optimal resource allocation strategy is used to maximize the effective capacity of LTE-A relay system. Based on optimal power allocation strategy, suboptimal low-complexity resource allocation strategies are introduced. Simulation result suggests that our introduced optimal resource allocation strategy achieve exactly the same performance as the one based on exhaustive search.

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