Subcarrier Analysis and Power Allocation for Cooperative Communication in LTE –Advanced Networks

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Abstract: ***The long term evolution (LTE-Advanced) is a standard introduced by 3rd Generation Partnership Project (3GPP). LTE-Advanced provides many benefits like high-speed data, bandwidth efficiency, latency, multimedia unicast and multimedia broadcast services to cellular networks.In cellular LTE-Advanced network**as**Base station or Enb (evolved nodeb) needs to perform resource allocation in changing environment, efficient joint resource allocation schemes for throughput maximization with low computational cost are preferred. Sincethe throughput maximization problem is mixed integer nonlinear problem (MINLP) optimal joint resource allocation scheme is implemented to solve this problem.. By implementing optimal joint resource allocation scheme higher achievable rate can be obtained when relay station operates in synchronous case than in asynchronous. However, synchronous case leads to high coding complexity that will increase the implementation costsignificantly. So for further enhancement of overall throughput is done when relay station operates in asynchronous mode by the use of multiple relays and proposed gradient power allocation method and is compared with optimal resource allocation scheme***

Keywords: LTE-Advanced, spectrum efficiency, relay channel,cooperative communication, resource allocation, user fairness.

1. Introduction

Due to increasing demand for high data rates and better quality of service (QOS) 3GPP has launched LTE-Advanced. Toenable high-speed data transmission for mobile phonesand data terminals at substantially reduced cost relays are preferred..Relays are low cost and low transmit power elements that receive and forward data from the base station to the users via wireless channels, and vice versa. Using fixed relays boosts coverage in cellular networks when carefully placed at the cell edge or in regions with significant shadowing. The cooperative communication with the help of relay stations is new technique to enhance the cell-edge throughput and to extend the coverage between the base stations and the relays. There are mainly two types of relays Type I and Type II.Type I relays are half-duplex relays type I relay creates its own physical cell the RS appears as base station (BS) to all UEs within its transmission range.A Type II relay is a full-duplex relay which does not create a new cell it is transparent to all UEs within its coverage area and the UEs with spatial separation, filtering the full-duplex relays require no specific resource partitioning . In this paper, focus is on Type II relays. Commonly used cooperative protocols are Amplify-and-Forward (AF) and Decode-and-Forward (DF). AF relays simply amplify the received signals and forward them to the destination. Whereas, DF relays can completely eliminate the noise since relays decode the received signal before forwarding it. With DF protocol, the source and the relay are able to transmit in the same frequency band (channel) to improve the spectral efficiency As in LTE-Advanced unique features of relays exist extensive research efforts have been done on various aspects including relay architectures, cooperative protocols, and cooperative gain.

Due to user demand of higher data rate communications, improving the network efficiency through resource allocation is a hot topic of research interest. Power allocation schemes to improve the achievable rate for various relay channels are investigated in. Study the joint OFDM sub channel and power allocation problem. However, in terms of the In-Band DF relay networks where the source and the relay occupy the same channel, very few works address the resource allocation issue. In this paper, we investigate the adaptive joint subcarrier and power allocation to improve the downlink transmission efficiency in LTE-Advanced relay systems. We focus on the In-Band Type II full-duplex relay stations with decode-and forward strategy, as it better exploit the broadcast nature of wireless signals while improving the utilization of existing allocated spectral resources. OFDM divides the frequency band into orthogonal narrowband subchannels (subcarriers), each subchannel can be viewed as a conventional relay channel where the Base station and the RS cooperate to transmit to the UE (destination). Firstly we investigate the power allocation on each subcarrier and propose optimal power dividing schemes between the eNB and RS to maximize the relay channel's achievable rate. Secondly, we jointly allocate subcarrier and power in the multiuser OFDM network. In the multi-user OFDM, a few resource allocation algorithms have been proposed processes where a uniform power distribution is assumed when allocating subcarriers. Section II introduces the system model, where the resource allocation problem is formulated as an optimization problem. The maximization problem of the relay channel's achievable rate on a single subcarrier is proposed .In Section III optimal power dividing scheme between eNB and RS is providedand optimal resource allocation method is proposed.Section IV aims at maximizing the overall throughput by gradient power allocation and Section V studies contains the simulation results and in Section VI, we provide some concluding remarks and possible future work.

2. System Model

The cellular network structure considered in this paper is shown in Fig. 1.

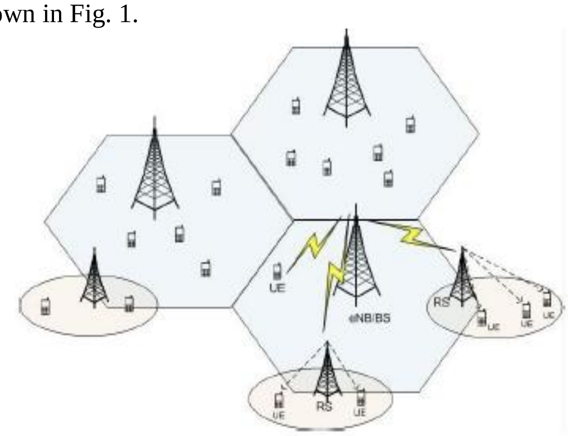

Figure 1: LTE-Advanced cellular network structure with the deployment of RSs

In each LTE-Advanced cell, an eNB is installed in the center to for serving several UEs. RSs that usually have smaller coverage area are employed near the cell edge to improve the cell-edge users' throughput or to extend the cellular radio coverage. We assume no cooperation exists among adjacent RSs, so any user can only be served by its affiliated eNB and RS if possible. In the downlink transmission, If a user is also located within the RS's coverage range, it can be reached by the eNB via two paths, the direct transmission link and the relay transmission link, like the three-node cooperative relay channel. The desired downlink transmission is from the eNB to the user, while the affiliated RS aids the communication by capturing the signals sent from the eNB and forwarding them to the user. Upon receiving the signals, the relay decodes the original message and retransmits it in its own codes during the subsequent transmission block.

LTE-Advanced cellular systems, the downlink frequency transmission technique is OFDM where bandwidth B is divided into n orthogonal subchannels operating at different subcarriers (tones). Each subchannel has a bandwidth of B/n. Let M = $\{1,...,m\}$ and N $=\{1,...,n\}$ denote the user set and the frequency-domain subchannel set, respectively. At the start of each transmission block, the subchannels are allocated by the eNB (Enhanced node-b) and the transmission power can be dynamically adjusted at both eNB and RS to improve the transmission efficiency.Assume all wireless channels are independent additive white Gaussian noise (AWGN) channels where the noise variances are normalized to 1. The channel gain coefficients for user k, $k\in$M on subchannel$l$, $l\in$N are denoted by $h_{sr}^{(k,l)}$,$h_{rd}^{(k,l)}$, and $h_{sd}^{(k,l)}$ representing the channel conditions of the eNB-RS, RS-UE and eNB-UE links, respectively. If a user is not within the RS coverage, there is only one direct transmission channel gain coefficient,.$h_{sd}^{(k,l)}$The channel state information is assumed to be known at both the transmitter and the receiver so that eNB can adaptively allocate the transmission power and subchannels according to the instantaneous channel state information. Throughput can be categorized as a mixed integer nonlinear problem (MINLP) which is generally difficult to solve. However, considering the unique feature of the system that orthogonality exists among subcarriers and users, we propose a two-layer resource allocation scheme to solve this We first focus on power dividing scheme between $P_S^{(k,l)}$, and $P_r^{(k,l)}$ to achieve the maximum rate. With the optimal dividing scheme on each single subcarrier, the problem can be transformed to the traditional multi-user OFDM resource allocation problem.

3. Power Division for A Single-User Relay Channel

Depending on which rate is the bottleneck, there are two power dividing strategies that the source node can select :

- If the destination decoding rate is the bottleneck, the source node can reduce$\beta^{(k,l)}$. Until the relay decoding rate equals the destination decoding rate.
- If the relay decoding rate is the bottleneck, the source node will set$\beta^{(k,l)}$ =1. Note that when $\beta^{(k,l)}$=1, the source node and the relay node will transmit independent codes. Therefore, the second case is also known as the "asynchronous case" while the first case is called the "synchronous case". The asynchronous case is more empirical to implement due to the reduction of coding complexity.

A. Synchronous Case

In synchronous case, the destination decoding rate is the bottleneck, and $\beta^{(k,l)} \neq 1$.Following the same argument in [21], we first divide the pwer between $\bar{\beta}^{(k,l)}P_s^{(k,l)}$ and $P_r^{(k,l)}$when the total power for the MAC channel is fixed. Then the relay decoding rate and the destination decoding rate are balanced when the total power is fixed. When $\left|h_{sr}^{(k,l)}\right| \geq \left|h_{sd}^{(k,l)}\right|$,the optimal power dividing scheme is given by

$$\begin{cases} \beta^{(k,l)}P_s^{(k,l)} = \dfrac{\left|h_{sd}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2}{\left|h_{sr}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2} P^{(k,l)}, \\ \bar{\beta}^{(k,l)}P_s^{(k,l)} = \dfrac{\left|h_{sd}^{(k,l)}\right|^2 + \left|h_{sr}^{(k,l)}\right|^2 + \left|h_{sd}^{(k,l)}\right|^2}{\left|h_{sd}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2 \left|h_{sr}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2} P^{(k,l)}, \\ P_r^{(k,l)} = \dfrac{\left|h_{rd}^{(k,l)}\right|^2 \left|h_{sr}^{(k,l)}\right|^2 - \left|h_{sd}^{(k,l)}\right|^2}{\left|h_{sd}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2 \left|h_{sr}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2} P^{(k,l)} \end{cases} \quad (1)$$

The largest achievable rate obtained in the synchronous case is given by

$$R^{(k,l)} = \frac{1}{n}\log\left(1 + \frac{\left|h_{sr}^{(k,l)}\right|^2 \left|h_{sd}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2}{\left|h_{sr}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2} \frac{P^{(k,l)}}{B/n}\right) \quad (2)$$

B. Asynchronous Case

In this case, the source and the relay employ independent codes, so $\beta^{(k,l)}$ =1. By the same argument, the maximum achievable rate is obtained when the relay decoding rate equals the destination decoding rate. When $\left[h_{sr}^{(k,l)}\right] \geq \left|h_{sd}^{(k,l)}\right|$, the following power dividing scheme is optimal:

$$\begin{cases} P_s^{(k,l)} = \dfrac{\left|h_{rd}^{(k,l)}\right|^2}{\left|h_{sr}^{(k,l)}\right|^2 - \left|h_{sd}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2} P^{(k,l)} \\ P_r^{(k,l)} = \dfrac{\left|h_{sr}^{(k,l)}\right|^2 - \left|h_{sd}^{(k,l)}\right|^2}{\left|h_{sr}^{(k,l)}\right|^2 - \left|h_{sd}^{(k,l)}\right|^2 + \left|h_{rd}^{(k,l)}\right|^2} P^{(k,l)} \end{cases} \quad (3)$$

The highest achievable rate in the asynchronous case is given by

$$R^{(k,l)} = \frac{1}{n}\log\left(1 + \frac{\left|h_{sr}^{(k,l)}\right|^2 \left|h_{rd}^{(k,l)}\right|^2}{\left|h_{sr}^{(k,l)}\right|^2 - \left|h_{sd}^{(k,l)}\right|^2 \left|h_{rd}^{(k,l)}\right|^2} \frac{P^{(k,l)}}{B/n}\right) \quad (4)$$

Algorithm of Optimal resource allocation algorithm for maximization of the overall throughput

1. For $l = 1, \ldots, n$, find a $k(l)$ satisfying $H^{(k(l),l)} \geq H^{(k',l)}$ for all $k' \in m$.Assign subchannel$l$ to user$k(l)$, i.e. $\rho^{(k(l),l)} = 1$

2. Allocate $P^{(k(l),l)} = \left(\lambda - \frac{1}{H^{(k(l),l)}}\right)^+$ as the transmitting power for user k (l) in sub channel l. λ is the water-filling level that is chosen to satisfy the total power constraint.

$$\sum_{(k(l),l)} P^{(k(l),l)} = P_{total}$$

4. Gradient Power Allocation

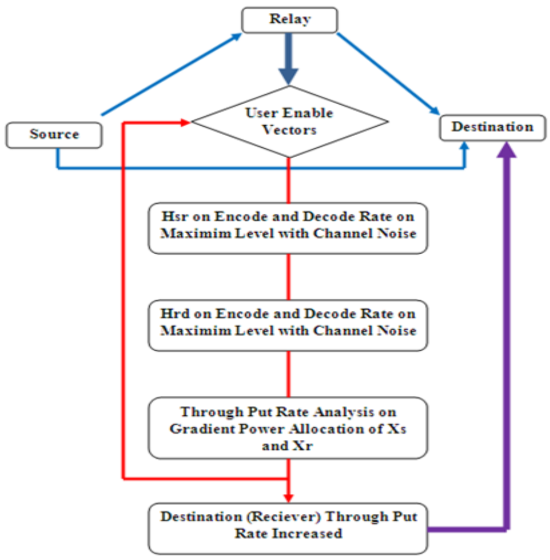

Figure 2: Flowchart gradient power allocation

ALGORITHM STEPS:

- **STEP 1:** Find Channel gain on H_{sr}(Source to Relay Gain);H_{rd} (Relay to Destination Gain);H_{sd} (Source Destination Gain) with help of set of parameters ,Users Enable Vectors and Relay Path Condition on 20 MHz Bandwidth
- **STEP 2:** Find Channel Encode and Decode Rate on Source to Relay Path on Trellis Encode and Viterbi Decode rate on Rayleigh Fading Channel.
- **STEP 3:** After gathering Decode rate on Source to Relay path again we need to find on destination path on encode and decode rate on Trellis Encode and Viterbi Decode rate on Rayleigh Fading Channel.
- **STEP 4:** After getting Yd(Decode rate) we need multiply with H_{sd} (Source to Destination Path of Gain).
- **STEP 5:** Like this we implement on 5 part of user enable sector on (5:5:55) times. Then Over all we gather through put rate more than Synchronous and Asynchronous case on Single relay path process.
- **STEP 6:** Find Maximum through put rate on decode rate for Source to Relay path.
  Xs=max(Xs);
- **STEP 7:** Find Maximum through put rate on decode rate for Relay to Destination path.
  Xr=max(Xr);
- **STEP 8:** Find Gradient Euclidean Distance Parameter on X and Y variable. For Here X is Source to Relay Path and Y is Relay to Destination Path

```
x=hsd*Xs;
y=hrd*Yd;
gr = mean(sqrt(x.^2 + y.^2));

%%%Gradient Magnitude on Euclidean Distance
```

- **STEP 9:** Highest achievable rate R(k,l) has a unified expression similar to the direct Transmission capacity:

$$R^{(k,l)} = \frac{p^{(k,l)}}{n}\log\left(1 + H^{(k,l)}P^{(k,l)}\right)$$

5. Simulation Results

To evaluate the performance of our subchannel and power allocation schemes simulation results are presented in three parts. The first part depicts the achievable rates obtained by the power dividing schemes in the single-user relay channel. The second part demonstrates the superiority of the optimal joint sub channel and power allocation The third part and fourth part contains the throughput and time duration Comparison between Single Relay path on synchronous and asynchronous case and Multiple Relay path on Asynchronous case

I. Performance of power dividing scheme for single-user relay channel

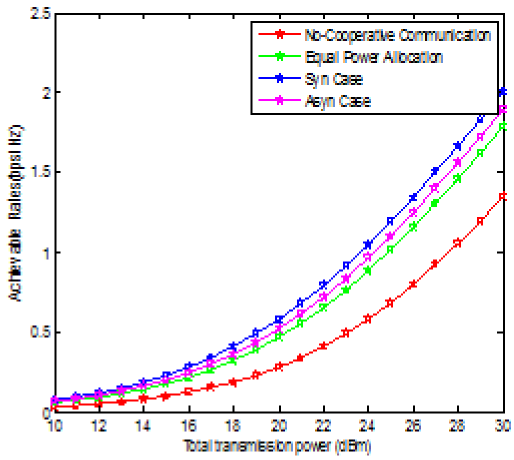

Figure 3: shows the performance comparison of single-user achievable rates in Rayleigh fading environments.

Table 1: Comparison of single-user achievable rates in Rayleigh fading Environments

	THROUGHPUT (bps/Hz)										
	Total transmission power(dbm)										
	10	12	14	16	18	20	22	24	26	28	30
Non-Cooperative transmission	0.035	0.056	0.086	0.133	0.202	0.301	0.437	0.615	0.837	1.102	1.397
Equal Power Allocation	0.062	0.096	0.147	0.223	0.331	0.476	0.665	0.897	1.169	1.473	1.803
Synchronous case	0.081	0.126	0.191	0.285	0.416	0.589	0.805	1.062	1.355	1.676	2.018
Asynchronous case	0.071	0.109	0.167	0.252	0.371	0.529	0.731	0.976	1.258	1.571	1.907

From figure 3 it is clear that, when total transmission power is increased from 10dbm to 30dbm in cooperative transmission with the help of a relay outperforms no-cooperative transmission in terms of achieving higher data rate. In terms of the comparison of the synchronous and Asynchronous case achievable rate obtained in synchronous case for 30dbm transmission power is 2.018 (bps/Hz) and in asynchronous case it is 1.907 (bps/Hz). In synchronous case achievable rate is more and Compared with the equal power dividing scheme, proposed optimal power dividing scheme achieved higher rate in both asynchronous case and synchronous case.

II. Performance of Optimal Resource Allocation for Throughput Maximization

We compare the throughput achieved by the optimal resource allocation in Algorithm 1 with the following two resource allocation schemes:

1) The user with the best channel quality is picked in each sub channel and power is distributed on the sub channels evenly. (Scheme1).
2) Both the sub channels and power are allocated equally among all users without any consideration of the channel conditions of each single user (Scheme).

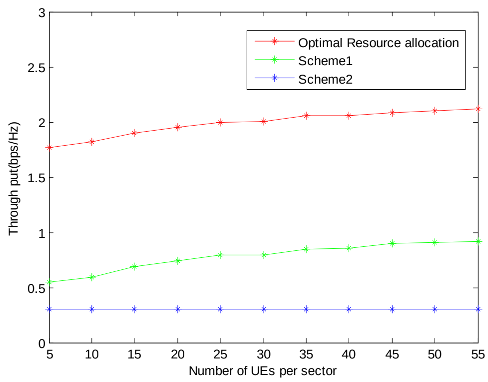

Figure 4: Comparison of overall throughput when RS operates in synchronous mode.

Table 2: Shows values of throughput rates obtained for optimal resource allocation scheme , scheme 1 and scheme 2 when RS operates in synchronous case

	THROUGHPUT (bps/Hz)										
	Number of UEs per sector										
	5	10	15	20	25	30	35	40	45	50	55
OPTIMAL RESOURCE ALLOCATION	1.776	1.852	1.870	1.955	1.974	2.021	2.058	2.042	2.068	2.098	2.094
SCHEME 1	0.510	0.625	0.665	0.754	0.782	0.817	0.850	0.855	0.882	0.913	0.903
SCHEME 2	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298

From Table 2 simulation results, it can be see that as no of UE's per sector are increasing from 5 to 55 obtained throughput values in optimal resource allocation scheme in synchronous case is higher compared to scheme 1 and scheme 2

From figure 4 ,it can be seen that as no of ue's per sector is 55 then throughput obtained using optimal resource allocation scheme in synchronous case is 2.094(bps/hz) whereas in scheme 1 it is 0.903(bps/hz), scheme 2 is 0.298(bps/hz).

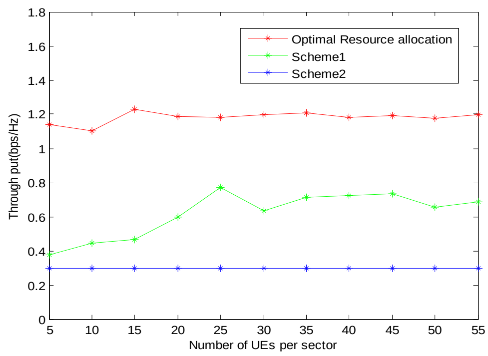

Figure 5: Comparison of overall throughput when RS operates in Asynchronous mode.

Table 3: Shows values of throughput rates obtained for optimal resource allocation scheme , scheme 1 and scheme 2 when RS operates in asyncronous case

	THROUGHPUT (bps/Hz)										
	Number of UEs per sector										
	5	10	15	20	25	30	35	40	45	50	55
OPTIMAL RESOURCE ALLOCATION	1.192	1.210	1.218	1.199	1.212	1.204	1.207	1.154	1.190	1.184	1.203
SCHEME 1	0.449	0.463	0.657	0.600	0.720	0.589	0.618	0.765	0.633	0.734	0.707
SCHEME 2	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298	0.298

From figure 4 ,it can be seen that as no of ue's per sector is 55 then throughput obtained using optimal resource allocation scheme asynchronous case is 1.203(bps/hz) whereas in scheme 1 it is 0.707(bps/hz), scheme 2 is 0.298(bps/hz).

III. Throughput Comparison between synchronous, asynchronous single Relay path and Multiple Relay path in Asynchronous case

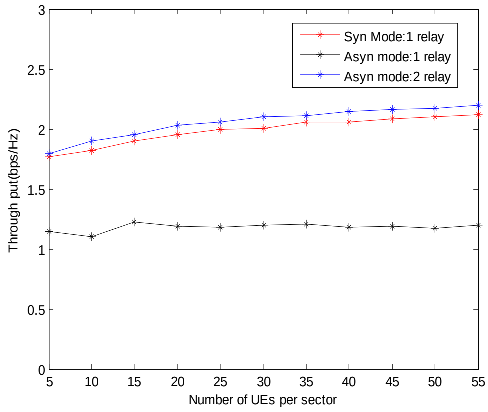

Figure 6: Comparison between synchronous, asynchronous single Relay path and Multiple Relay path in asynchronous case

Table 4: Comparison between synchronous, asynchronous single Relay path and Asynchronous Multiple Relay path

	THROUGHPUT (bps/Hz)								
	Number of UE's per sector								
	5	10	15	20	25	30	35	40	45
Asynchronous: 2 Relay Path	1.786	1.900	1.972	2.025	2.047	2.110	2.126	2.123	2.1
Asynchronous: 1 Relay Path	1.192	1.210	1.218	1.199	1.212	1.204	1.207	1.154	1.1
Synchronous 1 Relay Path	1.776	1.852	1.870	1.955	1.974	2.021	2.058	2.042	2.0

From table 4 simulation results, it can be see that as no of UE's are increasing throughput achieved in optimal resource allocation scheme in asynchronous case with multiple relays is more compared to synchronous single relay and asynchronous single relay case.

IV. Time duration Comparison between Single Relay path Synchronous and Asynchronous case and Multiple Relay path in asynchronous case

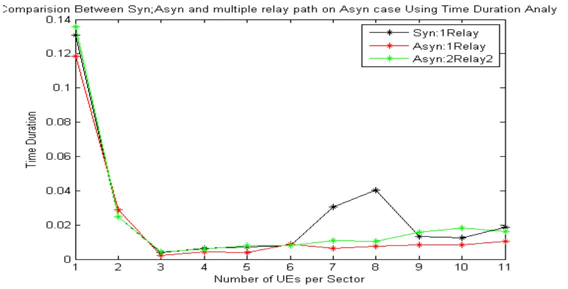

Figure 7: Time duration Comparison between Single Relay path Synchronous and Asynchronous case and Multiple Relay path in Asynchronous case

Comparison for time duration for single relay case using optimal resource allocation scheme for single synchronous case with asynchronous case then time duration is more for the synchronous case but if we use gradient power allocation then compare to single relay case using optimal resource allocation in asynchronous case time duration is less.

Summary

With the help of Single relay path on Encode and destination decode rate through put rate obtained in Synchronous mode is more compared to asynchronous mode but Synchronous case every time user want to come in straight line path of Source to relay and relay to destination. In asynchronous case no need of straight line path. So application based it is better to implement on asynchronous case. So in our modification gradient power allocation is implemented on multiple relay path on Asynchronous mode.

6. Conclusion

In this work, Adaptive subcarrier and power allocation schemes are employed in the downlink to improve the transmission efficiency in an LTE-Advanced cellular system where relays are installed. Instead of simply amplifying and forwarding the received signal, relays are expected to have more coding capability to achieve higher data rates. Used. Optimal subcarrier and power allocation schemes are proposed to maximize the overall throughput.

The simulations are carried out for the single-user achievable rates through the optimal power dividing schemes for the synchronous and asynchronous case, results shows that cooperative transmission with the help of a relay outperforms non-cooperative transmission in terms of achieving higher data rate. In terms of the comparison of the synchronous and Asynchronous case achievable rate obtained in synchronous case for 30dbm power is 2.018 (bps/Hz) and in asynchronous case it is 1.907 (bps/Hz). In synchronous case achievable rate is more since in most of the network environment the former one fully exploits the cooperation between the Evolved node b and relay station in the coding process. However, synchronous case leads to high coding complexity that will increase the implementation cost significantly.

Finally the Simulation results shown that for Performance of Optimal Resource Allocation for throughput maximization throughput achieved when no of UE'S are 55 in synchronous single relay case is 2.094 (bps/Hz) and asynchronous single relay case is 1.203 (bps/Hz) ,asynchronous multiple relay case is 2.204(bps/Hz) .Finally in asynchronous case by the use of multiple relays and gradient power allocation we obtained more throughput.

7. Future Scope

For the possible future work, can consider the joint uplink and downlink resource allocation where the relay station is capable of two-way Communications. Also, investigation of the cooperation among adjacent relays for DL coordinated multipoint transmission (CoMP) might also be a future topic.

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