Relaying Schemes for Improving Coverage and Capacity In cellular system with Selectable User Equipment

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***Abstract*— Relays are a promising solution being currently considered to enhance wireless communications and the performance of wireless networks. In addition, it is a promising solution to the challengingly high data rate requirements of future wireless cellular systems. In this paper we investigate the use of relays for cost-effective throughput enhancement and coverage extension. We analyze the performance of several emerging half duplex relay strategies. The strategies under investigating will be demonstrated under two cases, one with direct reception at the user equipment (UE) from the relay station (RS) and another one with UE ability to select to receive from base station (BS) or RS. The performance of each strategy in terms of capacity, coverage and performance is discussed as a function of cell radius, relay station location, relay station transmitted power and users' locations. The investigated strategies are One-Way, Two-Way and Shared Relay.**

***Index Terms*— LTE, One way, Relay, Shared, Two way.**

I. Introduction

In cellular systems, the main target is to provide high throughput at a certain quality of service (QoS) to all users including those at the cell edge. To reach this target, good planning must be done to approach the maximum coverage and capacity per cell. Throughout the past decades, all system evolution has been targeting this performance metric [1]. In addition, cell edge performance is becoming more important as new cellular systems employ higher bandwidths with the same amount of transmitted power, and use higher carrier frequencies with infrastructure designed for lower carrier frequencies [2].

Future communication systems, such as Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution Advanced (LTE-Advanced) technologies, consider more advanced strategies that use signal processing method of the received signal. These strategies are ***Amplify and Forward*** relays that apply more linear transformation to the received signal, or ***Decode and Forward*** relays that decode the signal then re-encode it for retransmission. These strategies are based on the presence of a new terminal, called Relay Station (RS).

Relay transmission technique involves forwarding of UE units information to the local BSs via relay stations installed at different locations to carry out this process. Service coverage and the overall throughput can be enhanced by using this technique [3], [4].

A relay is used like the access point in the computer network. The relay receives the signal from base station (BS) or user equipment (UE) in the down link (DL) or up link (UL), respectively, and then sends the signal to UE or BS in the DL or UL, respectively. This helps in improving the coverage, capacity and throughput in the system. In DL for instance, the signal transmitted from the BS to an edge user is then received at the RS which then transmits to UE. The power of the signal transmitted to the UE at the cell edge is related to the maximum relay power. Hence, a relay can enhance coverage by being able to transmit to users further from cell center than the case where the edge users receive directly from BS. This is the essence of coverage extension. On the other hand, after using a relay, the power required to communicate with the user on the cell edge is no longer the maximum power of the BS. This reduces the resources a single user needs in a cell with the result that BS can now serve more users. That is, the capacity of the system can be enhanced because of the relay. The enhancement in capacity and coverage can then be readily translated to an increase in signal-to-interference-and-noise-ratio (SINR) and the overall throughput, as explained below.

Relays are often assumed to be half-duplex, i.e., they can either send or receive but not at the same time, or full-duplex, which means that, they can send and receive at the same time [5].

In this paper, we will investigate the performance of several promising relaying schemes for 3GPP-LTE-Advanced. We consider three specific schemes including one-way relays, two-way relays, and shared relays. The one-way relay possesses only a single antenna and is deployed once in every sector. It performs a decode-and-forward operation and must aid the uplink and downlink using orthogonal resources. The shared relay concept was recently proposed in IEEE 802.16m [6] but is readily applicable to 3GPP. The idea is to place a multiple antenna relay at the intersection of two or more cells. The relay decodes the signals from the intersecting base stations using the multiple receive antennas to cancel interference and retransmits to multiple users using multiple input and multiple output (MIMO) broadcast methods. The two-way relay, also called analog network coding [7] and bidirectional relaying [8], is a way of avoiding the half-duplex loss of one-way relays [9]. The key idea with the two-way relay is that both the base station and mobile station transmit to the relay at the same time in the first time slot. Then, in the second time slot, the relay rebroadcasts what it received to the base station and mobile station. Using channel state information and knowledge of their own messages, the base and mobile stations are able to decode information sent from the other party.

The performance of each scheme will be investigated under two scenarios the first one is the indirect reception through the RS and the second one is the UE select ability to receive from the BS directly or from the RS indirectly. In the second scenario the UE will be able to choose where it will receive the signal based on one of three methods. The methods are distance based method, path-loss based method and SINR based method. A detailed explanation of the different methods will be provide later in the paper.

To compare the performance of different relay schemes, we compare their performance using a system simulator. Channel models from the IEEE 802.16j specification [10] are used since they include models for fixed relays. The simulator places users in fixed locations in each sector and computes the sum rates derived in this paper assuming that the channel is fixed over the length of the packet. These rates are reasonable in that they are nearly achievable in real slow fading systems with powerful coding and aggressive adaptive modulation. Comparing the performance of different relaying schemes in a single set of simulations provides extensive comparability that is not possible when comparing different references.

The rest of this paper is organized as follows. Section II introduces the System model considered in this paper including explanation of the selection method in the second scenario. Section III discusses the one-way architecture as a baseline of comparison for the rest of the paper. Section IV considers two-way relaying scheme and its assumption based on network coding. Section V presents the shared relay scheme and its usage of zero forcing technique. Section VI discusses the comparison of all the presented scheme under different reception scenarios and produce the discussion and conclusion of the results.

II. System Model

In our analysis, we consider a hexagonal cellular network with base station located in the center of the cell and consist of six directional antennas, each serve a different sector of the cell. The channel model is specified in the IEEE 802.16j channel models [10], [11], [12]. The channel is assumed static over the length of the packet, and perfect transmit CSI is assumed in each case to allow foe comparison of capacity expressions. The cell is sectorized to six sectors "S=6", the BS antenna is orthogonal such that each antenna is serving one user in any given time/frequency resource. We assume the channels are narrowband in each time/frequency resource, constant over the length of a packet and independent for each packet. This is known as the block fading model. These assumptions corresponds to one ideal LTE OFDM sub-channel. The analysis in this paper considers only the downlink but similar analysis can be applied to the uplink in each case.

The general parameters used in the simulation are listed in Table 1. The simulation for each scheme is divided into two parts, the first one is considering the spectral efficiency verses the relay transmit power for both scenarios and the second part is considering the spectral efficiency verses the location of the user in the sector.

A. *One Way scheme and Two Way scheme*: in these schemes the locations of the RS and UE in each sector are shown in Fig. 1 for the first part of simulation. In this part of simulation the location of RS and UE are fixed in each sector and the varying term is the relay transmit power. For the second part of simulation the location of the RS is fixed and the UE will go from the BS towards the cell side along the line perpendicular to the cell side as shown in Fig. 2. The parameters of these two schemes are shown in Table 2.

B. *Shared Relay scheme*: in this scheme at the joint corner of three adjacent cells a single relay equipped with Nr antennas is located. In the first part of simulation the location of the RS and UE is fixed in each sector as shown in Fig. 3. In the second part of simulation the RS is at the corner of the cell and the UE location is vary along the line between the BS and the RS. The parameters of this scheme is shown in Table 3.

TABLE 1
General System Parameters

Symbol	Quantity	Value
P_BS	BS transmit power	47 dBm "50 W"
P_RS	RS transmit power	-25 dBw : 10 dBw
P_UE	UE transmit power	24 dBm "0.25 W"
D	Cell Radii	100m
f	Carrier Frequency	2 GHz
h_m	Mobile Height	1 m
h_r	Relay Height	15 m
h_b	Base Station Hight	30 m
N	Number of realization	10 000
BS-UE	BS to UE link model	Channel model IEEE 802.16j "Type B"
BS-RS	BS to RS link model	Channel model IEEE 802.16j "Type D"
RS-UE	RS to UE link model	Channel model IEEE 802.16j "Type B"
	Propagation enviroment	Sub-Urban

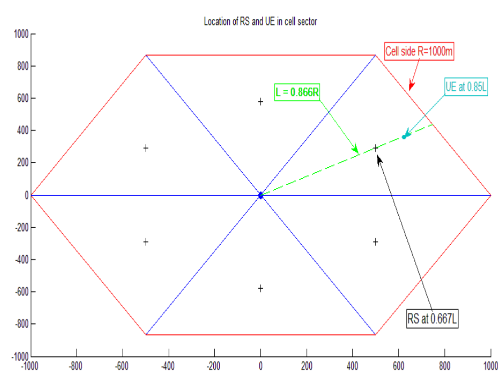

Fig. 1: One Way and Two Way scheme system model

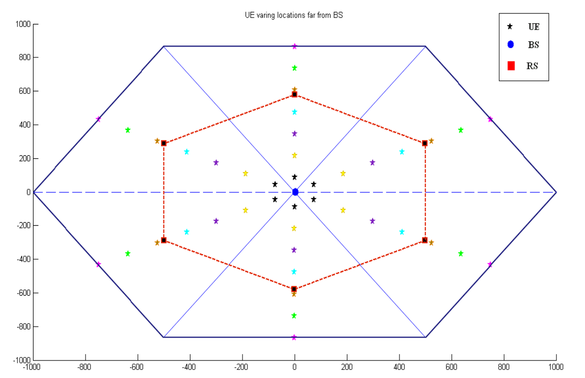

Fig. 2: Varying location of UE in sectors

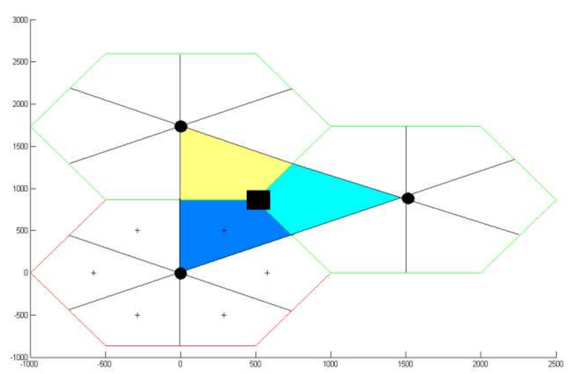
Fig. 3: Shared Relay Scheme system model

C. *Selection Methods:* In this paper, we investigate two scenarios of reception at the UE. The first scenario is reception from the RS and the second one is selecting between reception from BS or from RS based on three methods. The three methods are distance based method, path-loss method and SINR based method. For distance based method, the UE with the assist of GPS measures the distance between it and BS and RS then select to receive from the nearest node. For path-loss method, the UE measures the path-loss in each link between the UE and the BS and RS then select the link with the smallest path-loss to receive from. For SINR based method, the UE calculates the SINR for the links between UE and BS and RS then select the link with high SINR.

$$n_s = min[\, D_{BM} \,, D_{RM} \,] \qquad (1)$$
$$n_s = min[\, PL_{BM} \,, PL_{RM} \,] \qquad (2)$$
$$n_s = max[\, SINR_{BM} \,, SINR_{RM} \,] \qquad (3)$$

TABLE 2
ONE WAY AND TOW WAY SCHEMES PARAMETERS

BS Tx power	P_BS
Relay Tx power	P_RS/3
Antennas per BS/sector	1
Anetnnas per relay	1
Relays per sector	1
Anetnna per mobile	1

TABLE 3
SHARED RELAY SCHEMES PARAMETERS

BS Tx power	P_BS
Relay Tx power	P_RS
Antennas per BS/sector	1
Anetnnas per relay	3
Relays per sector	1
Anetnna per mobile	1
Relay location	Cell radius from BS

III. ONE WAY SCHEME

This section demonstrates the one way scheme. In this scheme communication takes place in two orthogonal phases. In the first phase the BS transmits while the RS receives "the UE may or may not receive" , the RS decodes the received signal and then encode it to be transmitted to the UE in the second phase. The uplink and downlink are divided orthogonally in time or frequency, depending on the duplexing method. In this scheme we allow one single antenna decode and forward relay per sector. The whole communication cycle take 4-time slots.

Assume all BS transmit at the same time, frequency and power, and that the cellular architecture is such that each cell sees the same average interference. We assume an i.i.d block fading model with perfect channel state information at Tx and Rx. Thus, we can focus on the transmission of a single block of packets over which the channel is static.

To calculate the spectral efficiency supported by a link, we use the capacity formula [12],[13], [14]:

$$\eta = \log_2(1 + SINR) \qquad (4)$$

The main term that must be calculated is the SINR at the receiving end, which is the relay in phase one and the user in phase two.

In phase one, the transmitted signal from BS goes through the channel and undergoes path loss. The received signal at the relay is:

$$y_{Rx,RS} = \frac{h\, x_1}{\sqrt{PL_{BR}}} + n_1 \qquad (5)$$

Where, h is the channel between BS-RS and it is represented in the simulation as complex Gaussian. x_1 is the symbol transmitted by the BS. PL_{BR} is the path loss between BS and RS. n_1 is representing the noise and interference term in the system at the RS.

The received power at the RS is:

$$P_{Rx\_RS} = \frac{P_{Tx\_BS} * |h|^2}{PL\_BR} \qquad (6)$$

Thus the rate in the first phase is:

$$R_1 = W \log_2\left(1 + \frac{P_{Rx\_RS}}{\sigma_I^2 + \sigma_N^2}\right) \qquad (7)$$

Where, $P_{Tx,BS}$ is the transmitted power from the BS. Assume the intercell interference is Gaussian with variance σ_I^2.

In phase two, after decoding the received signal at the RS it recodes and forwards it to UE. The received signal at the UE :

$$y_{Rx,UE} = \frac{g\, x_2}{\sqrt{PL_{RM}}} + n_2 \qquad (8)$$

Where, x_2 is the symbol transmitted by the RS. g is the channel between the RS-UE. PL_{RM} is path-loss between RS and UE. n_2 is representing the noise and interference term in the system at the RS.

The received power at the UE is:

$$P_{Rx,UE} = \frac{P_{Tx\_RS} * |g|^2}{PL\_RM} \qquad (9)$$

Thus the rate in the second phase is:

$$R_2 = W \log_2(1 + \frac{P_{Rx\_UE}}{\sigma_I^2 + \sigma_N^2}) \qquad (10)$$

Where, $P_{Tx,RS}$ is the transmitted power from the RS. Assume the intercell interference is Gaussian with variance σ_I^2.

In our work, we consider the DL only. Let the rate supported by the BS-RS link when BS transmits to it in phase one be R_1, and the rate supported by the RS-UE link when the relay transmits to it in phase two be R_2. We assume that the normalized durations of two phases of transmission are t and *(1-t)* with $0 \le t \le 1$. The capacity of the two-hop transmission is defined as the bottleneck of the two hops with optimal time sharing.

$$R = \min_{0\le t\le 1} \{tR_1 , (1-t)R_2\} \qquad (11)$$

That is, given t, the overall rate is the minimum of the two rates of the BS-RS and RS-UE links, each weighted by the fraction of time the link is utilized. We can then choose t in order to maximize the minimum rate.

The term "tR_1" is an increasing function of t, whereas "$(1-t)R_2$" is decreasing with *'t'*. The time sharing is thus optimal when the two terms are equal, which results in the optimal time sharing "$t^* = \frac{R_2}{(R_1 + R_2)}$" [1]. When using the optimal time-sharing, the rate of the two-hop scenario is:

$$r_{OW,DL} = \frac{R_1 R_2}{(R_1 + R_2)} \qquad (12)$$

Here, the subscript OW stands for One Way relaying. Parameter “r” is used to refer to the rate of a single user rather than a sum of users. Thus, the rate in (12) is the DL rate of one user in one sector of the network. In the simulation, we focus on the sum rate over adjacent sectors, which is simply the sum of (12) over users.

For the calculation of the case of direct reception from the BS, the received signal at the UE is:

$$y_{UE} = \frac{z\, x}{\sqrt{PL_{BM}}} + n \qquad (13)$$

Where, z is the channel between BS-UE and it is represented in the simulation as complex Gaussian. x is the symbol transmitted by the BS. PL_{BM} is the path loss between BS and UE. n is representing the noise and interference term in the system at the RS.

The received power at the RS is:

$$P_{Rx\_RS} = \frac{P_{Tx\_BS} * |z|^2}{PL\_BM} \qquad (14)$$

Thus the rate in the first phase is:

$$R = W \log_2(1 + \frac{P_{Rx\_UE}}{\sigma_I^2 + \sigma_N^2}) \qquad (15)$$

Where, $P_{Tx,BS}$ is the transmitted power from the BS. Assume the intercell interference is Gaussian with variance σ_I^2.

IV. Two Way Scheme

This scheme was developed to overcome the major drawback of the One Way scheme which is the half-duplex loss. This loss come from that the one way scheme required four time slots to transmit and receive a signal, but in the two way scheme the transmission and reception process will only require two time slots. The two way scheme based on the utilization of the relays as bidirectional terminals. The transmission cycle of the one way would be cut in half. In this scheme we shall refer to this simultaneous up link- down link transmission as one complete transmission cycle. In the first phase, both the BS and UE transmit to the relay at the same time. Then, in the second phase the relay rebroadcast what it received to the BS and UE. Thus, the two way scheme also called analog network coding or bidirectional relaying.

In our work we will consider using Amplify and Forward Relay type. Thus the relay node just amplifies the received signal from the transmitters and retransmits the amplified signal to its destination. In this relay type the complexity is low but the achievable rate can be affected by the amplification of noise. Analog Network Coding is used at the relay to combine the two received signals from the BS and RS, which is then amplified and rebroadcast to the receivers. Using channel state information and knowledge of their own messages, the BS and UE are able to decode information sent from the other terminal [15],[16], [17].

In Phase I, Both BS and UE transmits signal to the RS and then the received signal at the RS :

$$Y_{Rx\_RS} = \frac{h * x_1}{\sqrt{PL_{BR}}} + \frac{g * x_2}{\sqrt{PL_{RM}}} + n_1 \qquad (16)$$

Where, *h* is the channel between the BS and the RS. And *g* is the channel between UE and RS. *PL* is calculated from the IEEE 802.16j channel model for each link [18], [19]. n_1 is representing the noise and interference term in the system at the RS.

***In Phase II*;** The relay will amplify the received signal and rebroadcast it to both BS and UE. The transmitted signal from RS is:

$$Y_{Tx\_RS} = \gamma * Y_{Rx\_RS} \qquad (17)$$

We can satisfy the relay power constraint by using the following amplifying factor [20], [21]:

$$\gamma = \sqrt{\frac{P_{RS}}{P_{rx,RS}}} \qquad (18)$$

Where, P_{RS} is the transmitted power from the RS. P_{BS} is the transmitted power from the BS. P_{UE} is the transmitted power from UE. And we will normalize the noise power to one.

The received signal at UE is:

$$Y_{UE} = \frac{G * Y_{Tx_{RS}}}{\sqrt{PL_{RM}}} + n_2 \quad (19)$$

$$Y_{UE} = \frac{G * \gamma}{\sqrt{PL_{RM}}}\left[\frac{h * x_1}{\sqrt{PL_{BR}}} + \frac{g * x_2}{\sqrt{PL_{RM}}} + n_1\right] + n_2 \quad (20)$$

Due to analog network coding the UE can cancel the signal it received from the signal received from RS. So the received signal at the RS will be then:

$$Y_{UE} = \frac{G * \gamma * h * x_1}{\sqrt{PL_{RM}} * \sqrt{PL_{BR}}} + \frac{G * \gamma * n_1}{\sqrt{PL_{RM}}} + n_2 \quad (21)$$

And the received power at UE is:

$$P_{Rx\_UE} = \frac{|G|^2 * \gamma * |h|^2}{PL_{RM} * PL_{BR}} * P_{Tx\_BS} \quad (22)$$

Where, *G* is the channel between the RS and the UE in phase II. *h* is the channel between BS and RS in phase I. γ is the RS amplifying factor. *PL* is calculated from the IEEE 802.16j channel model [10],[18]. P_{Tx_BS} is the transmitted power from the BS.

The noise and interference term here will be:

$$\sigma_n = \sigma_{n2} + \frac{|G|^2 * \gamma}{PL_{RM}} * \sigma_{n1} \quad (23)$$

Where, $\sigma_{n1} = \sigma_{N1}^2 + \sigma_{I1}^2$ is the noise and interference term at RS in first phase and $\sigma_{n2} = \sigma_{N2}^2 + \sigma_{I2}^2$ is the noise and interference term at UE in second phase. The noise is considered as additive white Gaussian noise with variance σ_N^2. The inter cell interference is assumed to be Gaussian with variance σ_I^2. Thus the rate in the first phase is:

$$R = W \log_2\left(1 + \frac{P_{Rx\_UE}}{\sigma_n^2}\right) \quad (24)$$

V. Shared Relay Scheme

A shared relay is a relay that is the subordinate of multiple base stations, i.e., several base stations share the relay and employ it for improved transmission. Shared relaying has distinct advantages over the one-way model. This scheme employ multiple input multiple output (MIMO) techniques which constitute an essential technology for future wireless communication systems. By placing multiple antennas at the shared relay, interference can be canceled in both hops of communication. The shared relay behaves as a coordination of many single-antenna relays and thus alleviates the need for coordination among base stations. Thus, the shared relay achieves much of the capacity gain of base station coordination without the need for expensive information passing between distributed base stations [22], [23], [24], [25].

In the shared relay scheme, a single relay terminal equipped with Nr antennas is placed at the joint corner of three adjacent cells. The shared relay assists the transmission in a subset of sectors in the adjacent cells. Each shared relay coordinates an equal number of sectors denoted by Nc. In our work, we will consider that number of cells connected to the shared relay is (C=3) with each cell sectorized into (S=6) sectors and three center sectors, that is, Nc = 3, coordinated by single shared relay. As we assume one user in each sector so the relay communicates with three users Nu = 3. The main difference in system parameters between the one-way model and shared relay model are the number of antennas per relay, the relay transmit power and the number of relays per sector. Since over a large network there will be approximately 3 times fewer relays for shared relay model than the one-way model, shared relays are given 3 times the transmission power and 3 times the antennas.

In this scheme, we assume no base station coordination and perfect channel state information (CSI). As in the one-way model, DL communication occurs in two time slots (since we assume no base station coordination, even among sectors, the uplink analysis is identical to that of the DL with lower transmit power at the mobile). In this scheme the transmission protocol is divided into two phases:

(1) MIMO multiple access channel (MAC)
(2) MIMO broadcast channel (BC).

In phase one, the three BSs linked with the shared relay will transmit their signals through multiple access channel MIMO system. In this system multiple transmitters communicate with one receiver with multiple antennas. For that MIMO system there are several detection methods to cancel the interference In our work we will use zero forcing detector to separate the transmitted data streams. It is a simple linear receiver with low computational complexity, but it suffers from noise enhancement. The ZF receiver converts the joint detection problem into a symbol-by-symbol decoding problem, thereby significantly reducing receiver complexity. The ZF receiver uses a spatial filter to decouple the streams in the sectors of interest and decode the signals [26], [27], [28], [29], [30]. The used filter is:

$$W_{DL,1} = H^{\dagger} = (H^H H)^{-1} H^H \quad (25)$$

Where, H is Nr * Nc channel matrix between BSs and RS, Nr ≥ Nc. The received signal at the relay is:

$$y_{RS} = \sum_{i=1}^{N_r}\sum_{j=1}^{N_c} h_{ij}\, x_j + ISI + ICI + n_r \quad (26)$$

$$y_{RS} = H\, x + n_1 \quad (27)$$

Where, x is Nc * 1 vector of the transmitted symbols from the BSs. n_1 is the vector represents the noise and interference at the relay. The signal after detection is:

$$Y_{Rx,RS} = W_{DL,1}\, s + W_{DL,1}\, n_1 \quad (28)$$

Where, $s = \frac{H*x}{\sqrt{PL_{BR}}}$

The received SINR at the RS at certain antenna i:

$$SINR_i = \frac{P_{BS}}{PL_{BR}(i,1) * \sigma^2 * W_{DL,1}(i,i)} \quad (29)$$

Where, P_{BS} is the BS transmit power, we assume all the base stations transmit at the same power. PL_{BR} is the path loss between each BS and the RS. $W_{DL,1}$ is N_c*N_r detection filter.

The first hop of communication is the MIMO multiple access channel, and its capacity can be achieved via multiuser detection at the relay. That is, no coordination is necessary among the BSs beyond frame synchronization. We decode the transmitted signals in the receiving orders and the rate is calculated.

In phase two,, after decoding the received signal at the relay in the sectors of interest it must broadcast the information to the MSs in these sectors. We called this phase broadcast channel (BC) where, a single transmitter with multiple antennas communicates with multiple receivers with single antennas. A precoder is needed to be used to ensure that each data stream is transmitted to the corresponding UE with minimal or no interference from the other data streams. There is two types of precoder: linear and non-linear precoders. Only linear precoding is considered for 3GPP LTE. The precoder must be designed jointly for all data streams, such that interference between data streams can be minimized. The most common linear precoding schemes is Zero-Forcing (ZF) beam forming. ZF is a simple method which isolates the users' transmissions and hence decouples the multiuser channel into multiple independent sub-channels and reduces the design to a power allocation problem. The transmitter is designed under the assumption of power constraint and perfect CSI. The main benefits of ZF precoding is that the interference is pre-canceled at the transmitter side [31], [32], [33]. The ZF Precoder used is :

$$W_{DL,2} = G^H \, (G \, G^H)^{-1} \qquad (30)$$

Where, G is Nu _ Nr channel matrix whose rows are constructed from vectors gj = [gj1::::gjNr] the channel between RS and UEj and gij is the complex channel gain between user j and kth antenna of the RS.

The transmitted signal from RS is :

$$Y_{Tx,RS} = \sum_{j=1}^{N_u} \omega_j \sqrt{\gamma_j \, P_{RS} \, x_j} \qquad (31)$$

$$Y_{Tx,RS} = \sqrt{P_{RS}} \, W \, \Gamma \, x \qquad (32)$$

The received signal at the UE j is:

$$Y_{Rx,UE_j} = \frac{g_j \sqrt{P_{RS}} \, W \, \Gamma \, x}{\sqrt{PL_{RM,j}}} + n_2 \qquad (33)$$

Where, x_j is the unit-power symbol dedicated to the jth UE and Γ is a (Nu *Nr) diagonal matrix with elements $\sqrt{\gamma_i}$, $i = 1,2, \dots, N_u$ which is the fraction of relay power allocated to the jth UE. Thus the SINR at user j is:

$$SINR_j = \frac{\gamma_j \, P_{RS}}{PL_{RM,j} \, * \, \sigma^2} \qquad (34)$$

The rate of the entire communication link from BS to MS in the MAC and BC described above is then:

$$R_{SH,DL} = \max \sum_{k=1}^{K} \{\min[t \, R_{1k} \, , (1-t) R_{2k}]\} \qquad (35)$$

As in the one way we must optimize the time sharing between the two hops. In this case however, we have to optimize the sum rate not the rate for each user.

VI. Comparison and Conclusion

In this section we will produce the results of simulation and discuss these results for the different schemes and both reception scenarios. The spectral efficiency vs. the relay power for the threes schemes is presented in Fig. (4). This figure include the direct and indirect reception performance for each scheme. Due to fixed location of RS and UE in each sector the performance of the indirect reception and distance based selection method are the same.

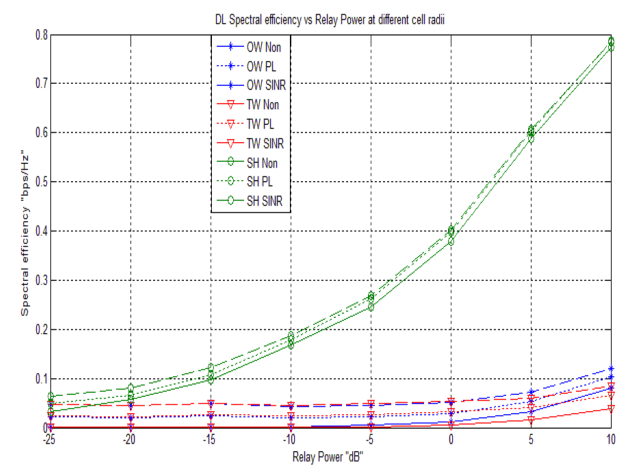

Fig. 4: Spectral efficiency vs. Relay power for each scheme “direct and indirect reception”

The spectral efficiency vs. the location of the UE far from the BS towards the cell side is presented in the following figures. The three schemes performance vs the location of the UE for both reception scenarios is shown below. For the one way and two way scheme the RS is located at “0.667L” but for the shared relay the RS is located at the cell corner at distance R from the BS. The figures will show the comparison between the indirect reception and the selecting methods. The simulation is for R=100m and P_RS=-5 dB.

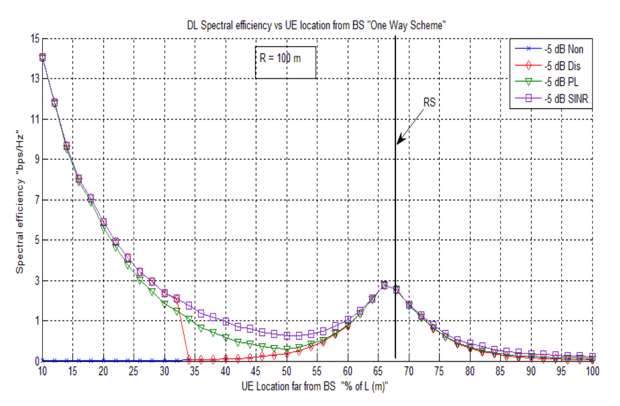

Fig. 5: Spectral efficiency vs. UE location “One Way Scheme”

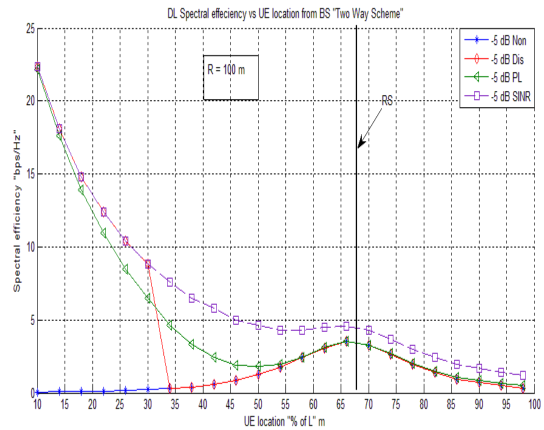

Fig. 6: Spectral efficiency vs. UE location "Two way scheme"

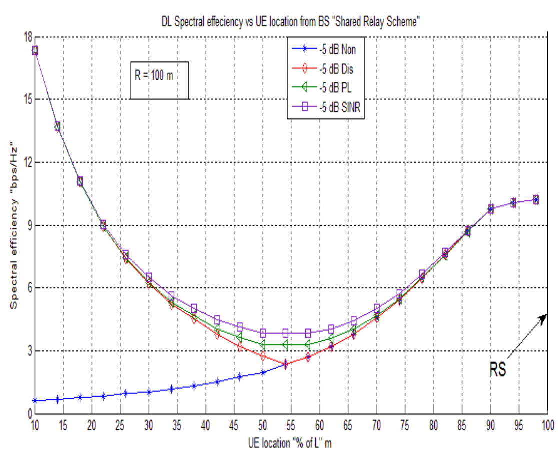

Fig. 7: Spectral efficiency vs. UE location "Shared Relay scheme"

From the shown figures we can see that the shared relay scheme produce a great enhancement in the performance over the other systems. The performance of the two way scheme is suffering from the noise amplification and the multiplexing gain is not apparent because we consider only the downlink in our work. The performance of the schemes is enhanced using the UE ability to select between direct and indirect reception. SINR give the most improvement in the performance and the distance based method gives the least one.

For the distance based method the UE directly receive from the BS until it is better to receive from the RS which is 1/3 the distance for the one way and two way scheme and half way for the shared relay scheme. For the path loss method it is better that the distance based one but also at a point near the switching point of reception of the distance based one turning to indirect reception due to the path loss in each link. The SINR based method gives the best performance over all the other methods.

After the analysis of the three schemes under the two reception scenarios we can conclude that, one way relaying does not support much gain near the cell edge because it does not directly treat interference. And the two way scheme overcomes the problem of the half-duplex loss but suffer from noise amplification. This was not surprising since the scheme is based on amplify and forward so the amplification process does not differentiate between the signal and interference even after subtraction of self interference. Sharing a multiantenna relay among the same sectors is a suitable way to achieve much of the gain but still has significant complexity within the relay itself. Cutting down the number of relays in the shared relay scheme to 1/3 the number of relays in the other two schemes which is cost sufficient to the system and reward the relay complexity.

With the UE ability to select between receiving directly from the BS or indirectly from the RS much gain is presented in the performance for all the schemes. The distance based method gives the least improvement and it is complicated as it based on GPS. The path-loss based method enhance the performance as it take into consideration the distance based path loss and fading loss. The SINR based method gives the beats enhancement in the performance due to taking the noise and interference terms into account not only the signal.

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