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Optimizing Energy in Relay Transmission Schemes in LTE-A Networks

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Abstract

Background/Objectives: In order to achieve high reliability and throughput, cooperative communication is being used in wireless networks. This technology is an efficient approach in reducing the energy consumption. **Methods/Statistical Analysis:** In this sense, the Decode andForward Relay protocol is analyzed where the Physical Network Coding (PNC) with Slepian-Wolf is incorporated in the Decode and Forward Relaying (DF) protocol. The PNC with Slepian-Wolf usage reduces the energy consumption in relay communication due to the compression and reduced time slots, when compared to the traditional relay transmission schemes and also increases the coverage of the cell. **Findings:** The spectral efficiency is varied, PNC with Slepian-Wolf assures higher energy efficiency than the traditional scheme when the spectral efficiency is higher and when the spectral efficiency is lower, both the schemes consumes nearly the same energy. Again when the downlink rate is higher than the uplink rate, that is, in case of asymmetric traffic conditions, both traditional scheme using DF protocol and the proposed PNC with DF protocol have similar relay deployment and PNC with Slepian-Wolf shows lower energy consumption. **Conclusion/Improvements:** Thus, the proposed scheme shows good performance when the spectral efficiency is higher and the downlink rate is higher than the downlink rate.

Keywords: Decode andForward Relaying, LTE-A,Physical Network Coding, Relay Station

1. Introduction

Among those protocols used for Relaying, Decode and Forward Relaying has higher efficiency. Relay Communication is a good approach in optimizing or reducing the energy that is been consumed for transmission since the presence of relay could use more power than that without relay[5,6]. In this perspective, the idea is to reduce the time slots that is been used for transmission. Generally, it takes 4 Time Slots to make a single Bi-directional transmission in Relay Transmission. A nested lattice code for the uplink and structured binning for the downlink are used which shows an optimal improvement in the performance against the Signal-to-Noise ratio where the bit is reduced to bit from the bound[7]. It is the Physical Network Coding (PNC). Here, this PNC is used with Slepian-Wolf in DF protocol where the time slots used is reduced to only 2 in place of four, thus minimizing the energy consumption. In the paper[4], the dual-hop relay seems to be more efficient than the single hop relaying. Then the power and resource consumption of the relays and their deployment positions are investigated in realistic power consumption. The multi-hop relaying assures optimized total power consumption and overcomes the peak-power constraint. In paper[5], multiple relay assisted transmission towards multiple receivers is studied. The relation between the cooperation of the Base station and Relay Nodes in relaying and the power consumption is investigated. In order to increase the efficiency, the power consumption at the Base Station is increases, where chain graph representation is used to make the analysis among the different schemes using Markov modelling. Two relay stations for assisting the Base station and three receivers are considered. It is shown that the Relaying protocol seem to perform much better than the non-cooperative schemes. In paper[8], the one-way and two-way relaying are analysed. When traffic is high, the hybrid relaying disintegrates to two-way relaying for reducing energy optimization. When the traffic is low, the hybrid relaying performs better than one-way and two-way relaying in terms of energy efficiency.

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Thus, it is shown that much energy could be saved by the joint optimization. The rest of the paper is organized as follows: Section 2 gives the Decode and Forward Relaying with PNC Section 3 describes the mathematical modeling of Energy Equations for the protocols. Section 4 gives the performance evaluation and finally Section 5 gives the conclusion of this work.

2. Decode and Forward Relaying with Physical Network Coding

In Decode and forward Strategy, the BS transmits to the RS with half power in the first time slot. The signal that is received at the RS is then decoded and checked for errors. If any error is found, then the signal from the Base station is directly transmitted to the UE. If there is no error found, then the signal that was decoded at the RS is coded again and transmitted to the UE by itself[1,9]. The main advantage of this technology is that the noise is drastically reduced but may have some delays due to the coding and decoding processes. A simple model is shown in Figure 1. If N1 is considered as the noise of the source-relay path, G1 as the channel gain of the same and S as the signal from the source. Then the signal that is received at the Relay can be given as:

$$Y1 = \sqrt{\frac{P}{2}} * G1 * S + N1 \quad (1)$$

If N2 is considered as the noise of the source-destination path and G2 is the channel gain of the same. Then the signal that is received at the destination is given by:

$$Y2 = \sqrt{\frac{P}{2}} * G2 * S + N2 \quad (2)$$

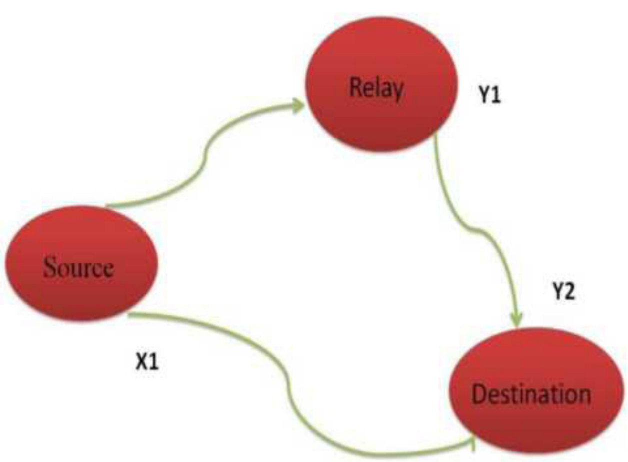


Figure 1. Relay model.

where P is the power and S is the signal from the BS. By this way, the error in the transmission can be effectively minimized.

Traditionally for the above process, four time slots are needed to make one complete bi-directional transmission among BS, RS and UE. The process is as follows: In the first time slot,the BS transmits its signal to the RS. In the Second Slot, the RS decodes the received signal and then forwards to the UE. Then the UE transmits its signal to the RS in the third time slot. Finally in the fourth time slot, the RS decodes the signal from the UE and then forwards to the BS. Thus four time slots are used. In PNC, only two time slots are needed to make a single complete bi-directional communication, thereby increasing the performance by 100%. In the first time slot, both the BS and UE transmit to the Relay Node (RN). After processing at the RN i.e. decoding and checking for errors since DF relaying is used, it is then transmitted to UE and BS accordingly in the second slot[10]. Figure 2 gives the schematic of 4TS and 2TS schemes. Let the signal from the BS be S1 and from the UE be S2 and QPSK PNC mapping is done at the Relay Node. PNC mapping refers to the processing of the signals at the RN where the signal to be transmitted further should be deduced from the received. At the RN, the received symbol will be a simple addition or XOR between the S1 and S2. Since QPSK is used, the possible values symbols of packets, S1 and S2 will be -1 or +1. Thus the received symbol at RN will be either 0 or 1. In order to separate one from other, mapping value (say m_a) will be -1 if the received symbol is 0 and will be 1 if the received symbol is 2.

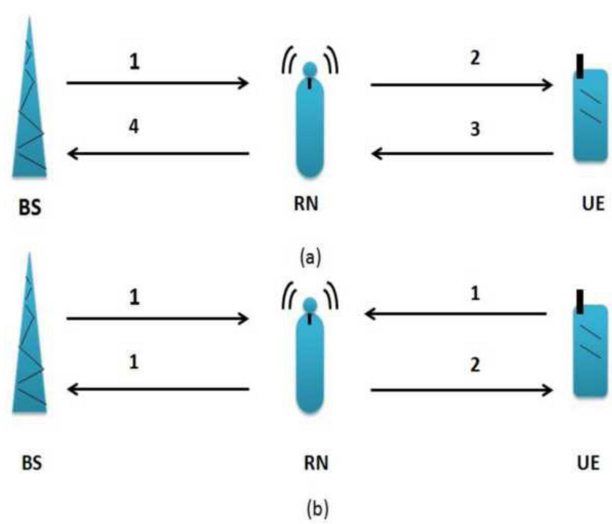


Figure 2. Relay transmission schemes. (**a**) Traditional 4TS scheme. (**b**) PNC scheme.

Then the RN transmits the signal to both BS and UE which is given as follows:

$$X = m_a \cos(\omega t) + m_a \sin(\omega t) \quad (3)$$

This signal will be received by both BS and UE where they will actually consider only the signal meant for it. The major difference between these two computations at the RN the symbols received will be separate at the RN from the BS and UE or to BS and UE with its respective noise in the traditional method. But here in PNC, the symbols at the RN will be some form of operation like XOR as in the above example which needs an effective decoding at the RN to separate or join the signals of BS and UE rather than the explicit decoding which is done in the 4TS scheme. This gives a simple network coding scheme.

One more modification done in this algorithm is that after the processing at the RN, the data is compressed by the coding which again reduces the power utilization for the transmission which actually provides again a coding gain of 4 dB over the system and up to 13 dB over non-use of compression schemes.

Then a distributed compression or source coding is employed to further improve the performance[11]. Slepian-Wolf coding is incorporated here in the basic level. The data A from the Base Station is compressed by entropy H (A) and the data B from the Mobile Station is compressed by entropy H (B). The decoding can be done at the Relay Node which is supposed to be only one decoder in this scenario. Thus the rate of compression will be R (A) + R (B) = H (A) + H (B). Thus an N-length data coming from the X will become X^N. Likewise, we have the other signal at the Relay Node which is produced at the Relay Node as a single data at the same time as said earlier using the same time slots.

The idea behind using this particular coding is, this one doesn't need the Base Station and the Mobile Station to communicate with each other. It may or may not communicate. And this combined rate compression is always greater than individual ones. This method is based on the concept of binning where all the possible values of the sequences are first analyzed. Then the bits are assigned to every sequence. Thus if the sequence is N long, 2^N bits will be needed to send the compressed data to the Relay Node.

3. Mathematical Modeling of Energy Equations

To simplify the derivation, the Additive White Gaussian noise is considered as the noise model and the noise power is considered to be the same for all the nodes. R is the distance between the BS and UE and g gives the relay deployment where the relay node is set up between the BS and RN. Whether it is BS, or UE or RN, the total power consumption can be written as follows:

$$P_{tot,j} = P_{D,j} + P_{c,j} \quad (4)$$

where j denote the node. P_D is actually the power consumed by the RF part of the node considered. P_{cj} is the constant power consumed by the respective node. Then we have,

$$P_{D,j} = p_{PA,j} + p_{tx} \quad (5)$$

$$P_{c,j} = \Omega_j (p_b + p_{ss}) \quad (6)$$

Q_j depends on the circuit power of the node j. p_b is the power consumed by the baseband signal processing, p_{PA} is the power consumed by the power amplifier, ptx is the dynamic power consumed during transmission other than power amplifier and pss is the power consumed by the small-signal transceiver. The above equations measures the total power consumed in the nodes. Then a parameter called ECI (Energy Consumption Index) is used to measure the energy consumed by them for a bi-directional transmission. This ECI is computed for both the traditional and PNC scheme and then compared with varying parameters to evaluate the performance.

The power modeling for the traditional scheme is given as follows. The optimal deployment of the RN for the traditional scheme is

$$R_{trad,opt} = (p_{BS}\,\Omega_{BS}\,a + p_{RN}\,\Omega_{RN}\,b) + (p_{MS}\,\Omega_{MS}\,c) \quad (7)$$

a, b and c in Equation 7 changes according to the spectral efficiency and n_{se}= Rs/B. B denotes the bandwidth of the signal. n_{se} and Rs are the spectral efficiency and the sum rate respectively. Sum rate denotes the sum of uplink and downlink rate. ß is the ratio of the downlink rate to the sum rate. p_{BS}, p_{RN} and p_{MS} are the maximum power output of the respective power amplifier.

Then the ECI of the traditional scheme is given by

$$ECI_{trad} = A\left(\frac{1}{1+R_{trad,opt}}\right)^{a} + B\left(\frac{R_{trad,opt}}{1+R_{trad,opt}}\right)^{a} + C(R_{trad,opt})^{a} \quad (8)$$

A, B and C in Equation 8 and 10 depends on the PAs of the MS, BS and RN used and also the Bandwidth of the system. Then the modeling of the PNC scheme is as follows:

$$R_{pnc,opt} = (p_{BS}\,\Omega_{BS}\,a + p_{RN}\,\Omega_{RN}\,c) + (p_{MS}\,\Omega_{MS}\,b) \quad (9)$$

a, b and c in Equation 9 are the parameters which depends on the spectral efficiency of the transmissions. The energy consumption index of the PNC scheme is given by

$$ECI_{pnc} = A\left(\frac{1}{1+R_{pnc,opt}}\right)^{a} + B\left(\frac{R_{trad,opt}}{1+R_{pnc,opt}}\right)^{a} + C\left(\frac{1}{1+R_{pnc,opt}}\right)^{a} \tag{10}$$

a is the path loss exponent. Then in the PNC method, since compression is used, its power also needs to be considered.

4. Performance Evaluation

The simulation parameters and the design parameters of the Relay Node, Base Station and the User Terminal are given in Table 1. The probability of the UE in the idle state is taken to be 0.6 and of that in the non-idle state is taken to be 4.5. The efficiencies of the Power Amplifiers for the RN, UE and BS and various other parameters are given in Table 2 referred from EARTH project[12] and from paper[13].

The path loss exponent a is taken to be 4.5 throughout. The simulation is carried out in the Matlab Software in the LTE-A scenario and the relationships between different parameters are analyzed. Then the comparison is made between traditional scheme and PNC with the addition of Slepian-Wolf compression in the Decode and-Forward Relaying.

Figure 3 gives the SNR with BER graph of PNC Scheme with Slepian-Wolf Compression where it seems

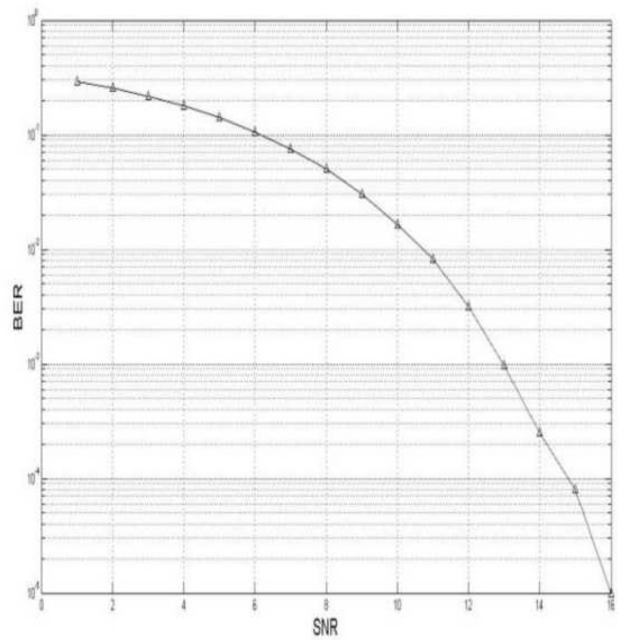


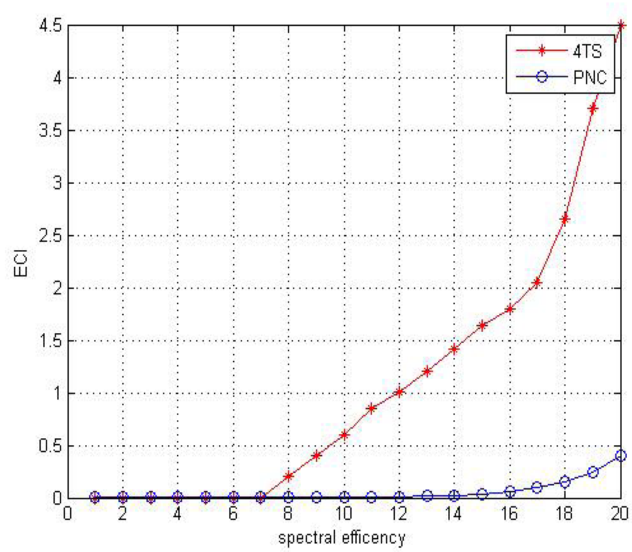
Figure 3. BER Vs. SNR graph of PNC with Slepian-Wolf compression.

to provide very less errors i.e. exponentially decreasing errors as the SNR increases.

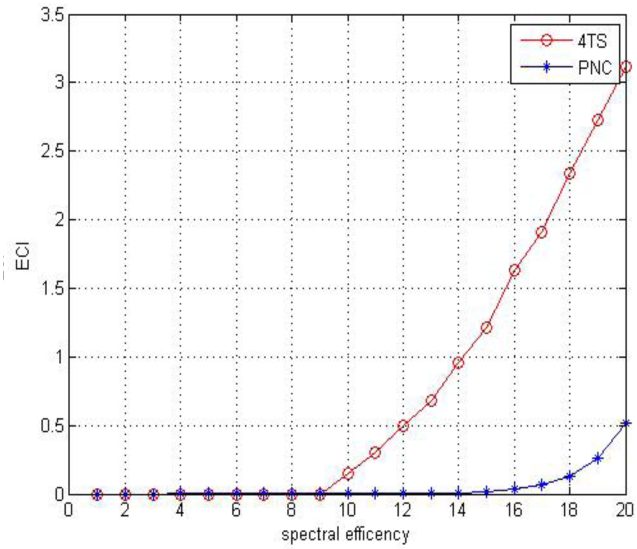
Figure 4(a) and 4(b) shows the graphs of spectral efficiency and the energy comparison index of both PNC 2TS scheme and traditional 4TS scheme when a is made constant and ß is varied as 0.3 and 0.8. It is seen from both the graphs that both the schemes perform almost the same when the spectral efficiency is low, but when it is increased, PNC scheme consumes much less energy

Table 1. Simulation parameters

Symbols	Meanings
a	Path loss Exponent
ß	Ratio of Downlink Rate to the Sum Rate Rs
nse	Spectral Efficiency
pb	Power consumed by the baseband processing of the signal
pss	Power consumed by the small signal transceiver
PPA	Power consumed by the power amplifier
ECI	Energy Consumption Index
^{n}PA,j	Power Efficiency of node j
pi	V^{p}max, i/^{n}PA
Pd	Power consumed by the dynamic (RF) part of the system
Pc	Constant power consumed by the system



(a)



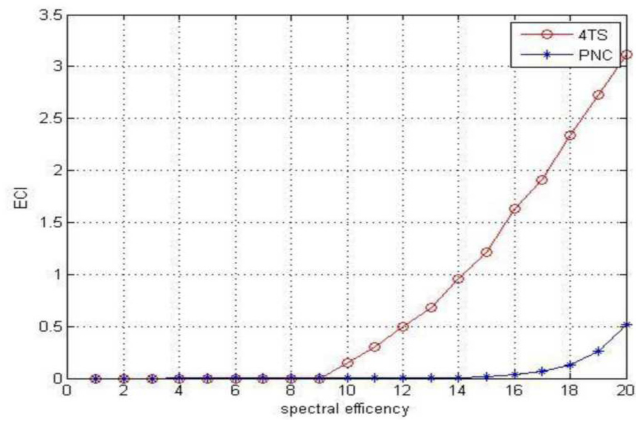
(b)

Figure 4. **(a)** Energy Consumption Index versus Spectral Efficiency when a = 4.5 and ß = 0.3. **(b)** Energy Consumption Index versus Spectral Efficiency when a = 4.5 and ß = 0.8.

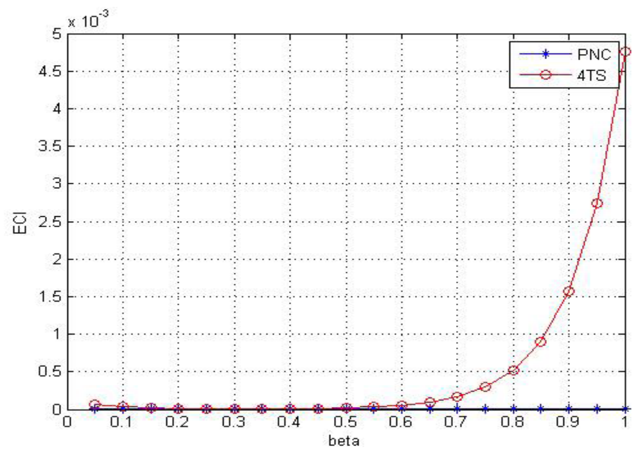
when compared to the traditional scheme. Thus PNC is much efficient when the spectral efficiency is high.

Figure 5(a) and 5(b) shows the graphs of ß versus ECI of both the traditional scheme and PNC scheme when spectral efficiency is constant and ß is varied. It can be seen that when the spectral efficiency is much lower, the traditional scheme consumes much less power than the PNC. When the Spectral efficiency is increased, both the schemes consume almost same power till a point where the uplink rate and downlink rate is same. When the downlink rate is higher than the uplink rate, PNC scheme consumes much less energy than the 4TS while the spectral efficiency is high.

Figure 6(a) to 6(d) shows the graphs of spectral efficiency and Beta versus Optimal Relay Deployment of both PNC and Traditional Scheme when one parameter is varied and another is kept constant. Here, it implies that in Figure 6(a) and 6(b), the PNC makes a peak with increase in spectral efficiency, but when it is further increased both the schemes have almost same optimal relay deployments. In Figure 6(c) and 6(d), it is seen that once when the uplink rate becomes lower than the downlink rate, both the schemes again have the same optimal deployment else the RN employing 4TS scheme needs to be placed little far away from the BS compared to the 2TS for uplink rate higher than downlink rate.



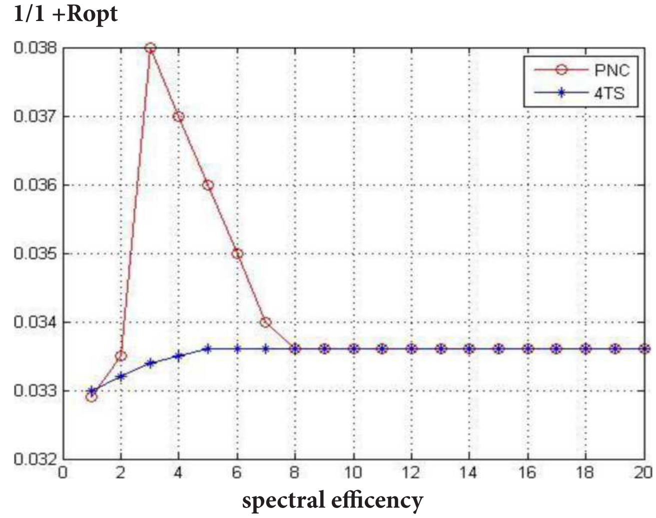
(a)



(b)

Figure 5. **(a)** Energy Comparison Index versus ß when a = 4.5 and Spectral Efficiency is 2bps/Hz. **(b)** Energy Comparison Index versus ß when a = 4.5 and Spectral Efficiency is 8bps/Hz.

1/1 +Ropt



(a)

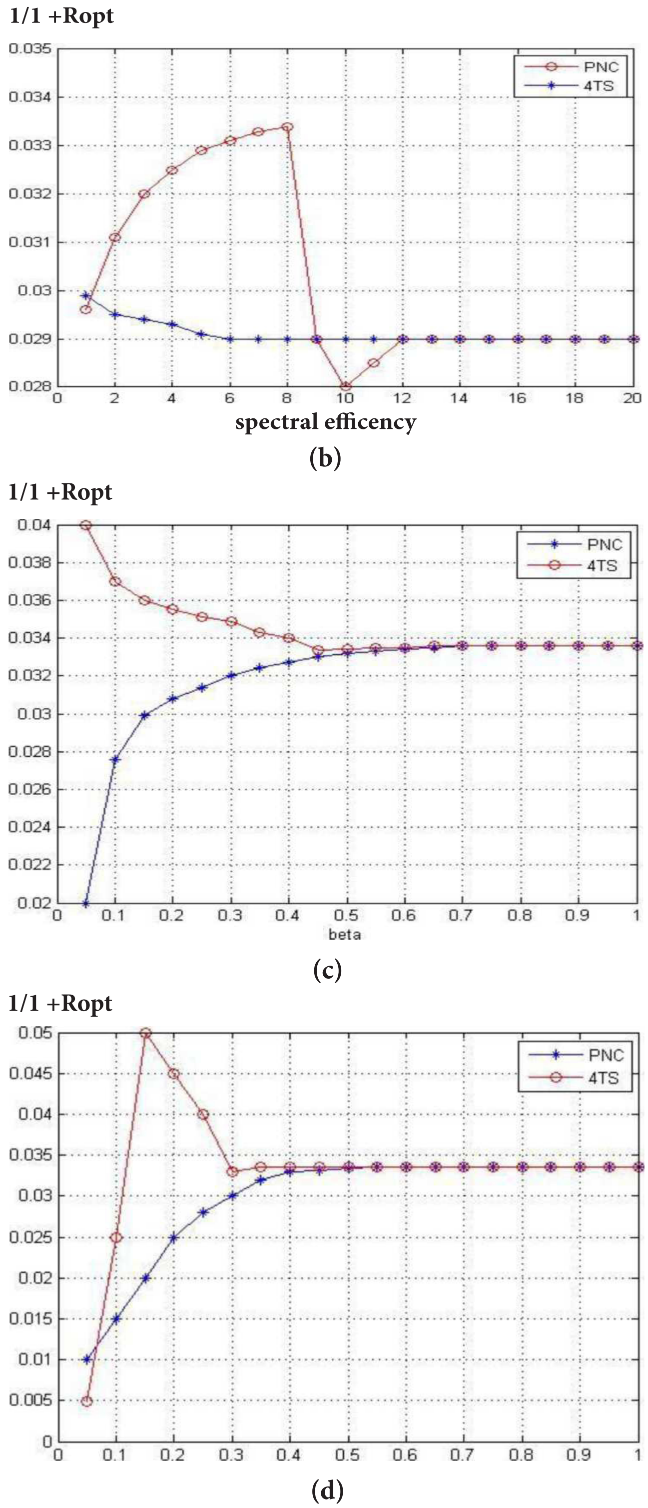


Figure 6. **(a)** Optimal Relay Development versus Spectral Efficiency when ß = 0.4. **(b)** Optimal Relay Development versus Spectral Efficiency when ß = 0.7. **(c)** ß versus Optimal Relay Development when Spectral Efficiency is 3bps/Hz. **(d)** ß versus Optimal Relay Development when Spectral Efficiency is 8bps/Hz.

5. Conclusion

The Decode andForward Relaying with PNC Scheme is investigated in the LTE-A Network scenario and then necessary comparisons are made with the DF protocol employing traditional 4TS Scheme in terms of energy consumption. It is seen that the PNC scheme with Slepian-Wolf works with minimal energy consumption when the spectral efficiency is higher compared to the 4TS Scheme. Also when the downlink rate is higher than the uplink rate and the spectral efficiency is lower, 4TS consumes lesser energy but when the spectral efficiency is increased, again PNC scheme with Slepian-Wolf consumes lower energy. Both the schemes show almost the same optimal relay deployment when the downlink rate is higher than uplink rate and spectral efficiency is high. All these pave the way to increase the cell coverage and it also improves throughput of the cell edge user.

6. Acknowlwdgement

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