Diversity Maximal Combining for Transparent Protocol with Cooperative Network Coding (CNC)

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***Abstract*—Cooperative communication system is not able fully to solve the problems all about multipath fading, there are many parameters to decrease signal level to the receiver. The author brings the solution to embedded with network coding, this paper focus to enhance research about cooperative with network coding (CNC), using transparent protocol i.e amplify-and-forward (AF) with BPSK and QPSK modulation. We proposed system at the receiver we used diversity maximal combining as known as maximal ratio combining (MRC) with decrease timeslot (time diversity), that combined two parameters between source-destination (S-D) and source-relay-destination (S-R-D). Component parameters were bit error rate (BER) and throughput. The simulation results throughput showed that cooperative communication systems with network coding better than cooperative system without network coding.**

Keywords: Cooperative Network Coding, Amplify-and-Forward BER, Throughput

I. INTRODUCTION

Cooperative communication has been proposed by some researchers to be an effective method for improving reliability, but on the other hand there are still many problems being faced by the cooperative communication, wireless communication network is now able to offer communication with a high speed, some application is the choice of the community such as multimedia streaming, web applications, content sharing, data transfer, etc [1]. 4G technology is considered finished by the researchers, some consortium of technology has begun to be switched on communication 5G [2], communication is not just using properties on the same network protocol, but is capable of using heterogeneous networks between protocols, so that they can communicate with each other, collaborative intelligence technology to accommodate a wide variety of emerging technologies. The one that initiated the development of 5G is a cooperative communication using network coding.

Sendonaris, et al [3] [4] the author who was invented communication cooperative by some of the principles used are sending, redirect, receiving, allows the modification. The main function of the cooperative is to help the source node (S) which can not be connected directly to the receiver (D), through a central node/relay (R), so that the use of an antenna on the side of the sender and recipient need not have the hardware specs or have a high frequency. In addition to the function as an auxiliary non-direct communication, also combines the signal between the direct (direct) and indirect (non-direct / relay) using techniques combining, so that the signal quality to be better than conventional direct communication received by D.

Research on the cooperative continues to evolve so that it appears the concept of network coding, network coding research because in the background backs by due to inefficiencies use of the channel in the relay, so as to optimize the use of the channel appears the concept of network coding, network coding has the definition incorporates information on the system at the relay, so that timeslot used can be reduced, the impact of the reduction of the use of network coding timeslot is to increase throughput. In some references, there are no mention among the definitions of network coding with coding is the same physical network.

Network coding was first proposed by Ahlswede et al, from the University of Hong Kong, in 2000 [5], this theory then the researchers developed further on network coding, especially those associated with the wireless communication network cooperative, in addition to saving the financing of the device, also optimizes channel resource use on the relay.

Before the familiar concept of cooperative, Van der Meulen [6], introduces communication using three terminals, namely, first as a transmitter, one as receiver and one relay, can be seen in Figure 1, due to the limited distance between the transmitter with the receiver is required channel relay to connect the two systems. In this study, a model that will be discussed is a two-way relay communication (TWRC) scheme, use the concept of dual-hop to the communication process, communication process does still modest between communication among S associated with R heading to D.

Relay strategy used generally use two relay protocol that is already known that a transparent relay and regenerative relay, the most famous examples are amplify-and-forward (AF) and decode-and-forward (DF). In this paper will be discussed strategies relay using protocols amplify-and-forward (AF), the AF signals coming in relay unchanged but the strengthening of the signal level, then by combining two signals arrive at the receiver side is used method of maximal ratio combining (MRC).

The rest of the paper are follows. In Chapter II, a model of cooperative network coding system for the traditional relay scenario, BPSK and QPSK modulation. In Chapter III, described research model, in chapter IV, combine the signals between the source and receiver with maximal ratio combining (MRC) and data analysis. In Chapter V, The results of the

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simulations that have been proposed. The last chapter is the conclusion of the results that have been obtained.

II. COOPERATIVE NETWORK CODING (CNC)

Cooperative communication system today has evolved so rapidly in some of these days. On the other hand, network coding also researched the role in cooperative communication systems. Technically these two systems can be combined the communication system cooperative with network coding, causing some of the advantages that can be improved, for example, the transmission bandwidth becomes more efficient, the transmission time is needed to be faster and also improve the security system more reliable [7] ,

Scheme transmission path can be seen in Table 2.1 details the process of how the direction of the communication system network coding work. On the table shows traditional column takes timeslot of 4 pieces of communication, while for the concept of network coding has been a reduction in that only requires 3 communication process/timeslot

Table 2.1 Simple Transmission Path [8]

TS	Traditional	CNC
TS 1	S → R	S → R
TS 2	D → R	D → R
TS 3	R → D	R → S ⊕ B
TS 4	R → S	

TS is timeslot, S and D are the source of the information with a different user. Network coding using XOR (exclusive-OR) concept in the process of merging data between two pieces of source. Half duplex communication can do transmit data as a source of the message sender or recipient of the message, as well as a goal can do as a sender or recipient of the message as well. S is the symbol period for S_1, R is S_2 and D is S_3.

The period of a symbol can be expressed by the equation:

$$r_2(t) = s_1(t) + s_3(t)$$
$$= [a_1\cos(wt) + b_1\sin(wt)] + [a_3\cos(wt) + b_3\sin(wt)]$$
$$= (a_1 + a_3)\cos(wt) + (b_1 + b_3)\sin(wt). \quad (1)$$

Where $s_i(t), i = 1$ or 3 is a bandpass signal transmitted by the source and relay. Relay will receive the second baseband signals are in-phase (**I**) and quadrature phase (**Q**), written by the following equation:

$$I = a_1 + a_3$$
$$Q = b_1 + b_3 \quad (2)$$

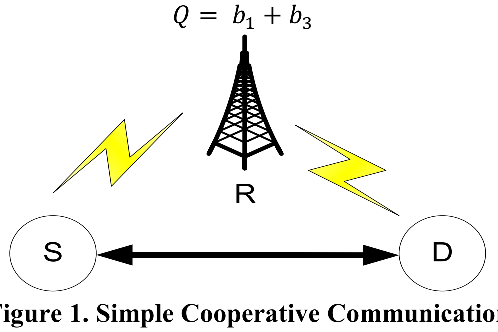

Figure 1. Simple Cooperative Communication

In Figure 1, using a simple process that requires a cooperative communication relay as auxiliary media for communication with other nodes. S can be directly connected to D, but if S had difficulty or a considerable distance may be assisted by a node R, to process further communication. R in practice can be symbolized by a base station (BS), access point, router or another device which has the function to communicate each other. There are several criteria in the communication protocol used in the relay.

2.1 Strategy Relay

One of the important things in a wireless communication system is the selection process used protocol relay, the relay can be also called intermediate node, the function of the relay is receiving a broadcast signal from node S and D, which acts both as the source. There are 2 types generally used to relay to pass data back to the receiver, the first mechanism is to amplify-and-forward (AF), a process that is done is to provide signal amplification of the signal received from the source to be forwarded to the recipient, is expected to signal amplification, the quality of the signal received at the destination better. The second mechanism is a decode-and-forward (DF), the process is carried out by coding the data to the signal coming from the source S, which received Relay for then encoded and proceed toward the destination (D). When combined with the use of the concept of network coding, to relay information received from various sources will be combined with the two different signals at the same frequency band. The research will focus on the use of protocol relay types amplify-and-forward (AF).

In the scheme of transparent relay (AF), relays amplify the signal received from the source and forward to the receiver, therefore no change in signal modification, only amplify the signal, the AF better known as non-regenerative relaying or transparent relay protocol, some kind of protocol similar to the AF Linear-Process-and-Forward (LF) and Nonlinear-Process-and-Forward (NLF). The relay does not have data encoding or the type of modulation used on the source, the advantage of this system work more simply, so as to provide better quality.

$$y_r[\aleph] = \hbar_{s,r}\sqrt{P_s}x_s[\aleph] + w_r[\aleph] \quad (3)$$
$$y_d^{(1)}[\aleph] = \hbar_{s,d}\sqrt{P_s}x_s[\aleph] + w_d^{(1)}[\aleph] \quad (4)$$

In phase II, the relay receives the signal to produce a normalized vector transmission $\mathbf{x}_r$ with $\mathbf{E}[|x_r[m]|^2] = 1$ for all m. If the channel gain $|h_{s,r}|^2$ is known in the relay, the relay can be multiplying signals received $y_r[m]$ to gain written by the equation:

$$A = \frac{1}{\sqrt{E\left[|y_r[\aleph]|^2/|\hbar_{s,r}|^2\right]}} = \frac{1}{\sqrt{P_s|\hbar_{s,r}|^2+\sigma_r^2}} \quad (5)$$

With value $x_r[\aleph]$:

$$x_r[\aleph] = G_r y_r[\aleph]$$
$$= \sqrt{\frac{P_s}{P_s|\hbar_{s,r}|^2+\sigma_r^2}}\hbar_{s,r}x_s[\aleph] + \frac{1}{\sqrt{P_s|\hbar_{s,r}|^2+\sigma_r^2}}w_r[\aleph] \quad (6)$$

The gain value of A depends on the value of the channel $\hbar_{s,r}$ and depending on the difference in the transmission interval. By using the power P_r, forward relay signal from x_r to the receiver, where the received signal can be written to the equation:

$$y_d^{(2)}[\aleph] = \hbar_{r,d}\sqrt{P_r}x_r[\aleph] + w_d^{(2)}[\aleph]$$
$$= \sqrt{\frac{P_sP_r}{P_s|\hbar_{s,r}|^2+\sigma_r^2}}\hbar_{s,r}\hbar_{r,d}x_s[\aleph] + \sqrt{\frac{P_r}{P_s|\hbar_{s,r}|^2+\sigma_r^2}}\hbar_{r,d}w_r[\aleph] +$$
$$w_d^{(2)}[\aleph] \quad (7)$$

For each m = 0, ..., M-1. The signals received at the receiver used to detect with or without diversity combining.

Scheme cooperative communication system is divided into two steps / phases that are divided into several timeslots. The signals received from each node can be described by the equation:

$$y_{s,t} = \hbar_{s,t} x_{s,t} + w_{s,t} \quad (8)$$

Where y and x is the received signal and the signal is sent from the node $\aleph$, w is an additive white Gaussian noise with zero-mean and variance unit, s is denoted as the sending node user 1 or user 2, t is the message received, user 1, user 2 and relay / Base Station. $\hbar_{\aleph,n}$ is a random variable i.i.d with rayleigh distribution and unit variance. It is assumed that the channel $\hbar_{s,t} = \hbar_{t,s}$, and the speed of rate R assumed to be equal to each codeword channel.

2.2 Phase I

In the first phase, user 1 and user 2 transmit broadcast information to the nearest node receiver on this scenario there are two, namely the relay and the destination, the received signal at each node are:

$$y_{s-r} = \sqrt{P_1}\hbar_1 x_1 + w_1 \quad (9)$$

$$y_{d-r} = \sqrt{P_2}\hbar_2 x_2 + w_2 \quad (10)$$

Where $\hbar 1 = \hbar 2$, shown in equation 7, the source node sends the information from the source to the relay node, while the equation 8, destination node sends information directly to the source node. P is power at the source, x is the information symbol transmitted, w_1, w_2 are additive noise. As well $\hbar 1$ and $\hbar 2$ is the channel gain on source-destination and source-relay.

$$y_{s-d} = \sqrt{P_1}\hbar_1 x_1 + w_3 \quad (11)$$

$$y_{d-s} = \sqrt{P_2}\hbar_2 x_2 + w_4 \quad (12)$$

Where $x_1 = a_1$ and $x_2 = a_2$. On the concept of network coding, 2 signals are sent simultaneously, frequency, time and phase delivered at the same timeslot.

2.3 Phase II

In the second phase, user 1 and user 2 combines the message between the two and after that do the multiplication by the amplifier gain A to corroborate the information that has been received, the method is called by amplify-and-forward (AF). Construction combination of the message and its gain factor, can be written by the equation:

$$x'_1 = A y_{s-r} + a_1 \quad (13)$$

$$x'_2 = A y_{d-r} + a_2 \quad (14)$$

The second phase on the destination side or base station (BS) are as follows:

$$y'_{r-s} = \sqrt{P_2}\hbar_1 x'_1 + w_5 \quad (15)$$

$$y'_{r-d} = \sqrt{P_1}\hbar_2 x'_2 + w_6 \quad (16)$$

From equation 7 and equations 10 to process network coding, BS or relay network coding to make the process so that the equation:

$$y_{nc} = y_{s-r} \oplus y_{d-s} \quad (17)$$

Decode process, the equation are :

$$y'_s = y_{nc} \oplus y_{s-d} \quad (18)$$

$$y'_d = y_{nc} \oplus y_{d-s} \quad (19)$$

Then is to make the process of diversity combining, using maximal ratio combining (MRC), written by the equation:

$$y_{mrc1} = y'_s + y_{s-d} \quad (20)$$

$$y_{mrc2} = y'_d + y_{d-s} \quad (21)$$

The next step is the process of m-PSK modulation, to obtain information about the data transmitted by the source to the destination. Several measurement parameters used are cooperative, where $S - R - D$ on the receiving side of the measurement signal, while the cooperative measurement, $S - R - D$ also be measured in addition to SD, then the signal is done.

III. Research Model

In this section will be introduced on a research model system using network coding, in figure 2

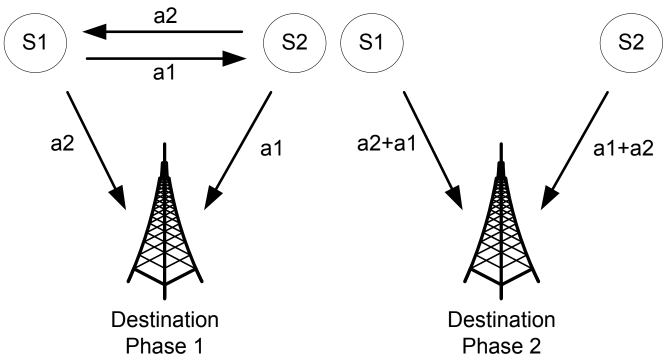

Figure 2. Cooperative Phase System

In Figure 2. Two terminal (S), known as User, and want to communicate with the Base Station / Destination (D) in the system [10]. Using the scheme of network coding, the first timeslot or also known as phase 1, user 1 and user 2 transmit their information in the form of messages $a1$ and $a2$, each user sends the information broadcast to each node that is closest. Phase 2, users who get information from the source, sending to the destination, the user receives this message and then forward it to the destination can be called with a relay (R). Relay combines messages between the personal data with data received from other sources with xor algorithm, $a1 + a2$ and $a2 + a1$. The channel between $S - R, S - D$, and $R - D$, has a value that is mutually independent in every timeslots. At the BS or D will reconstruct codeword and decode data using MRC.

IV. Simulation Results

The simulation resulted from the comparison between cooperative system with network coding (CNC) with cooperative traditional. Cooperative traditional was mean the system used need relay to communication with scheme two-way relay communication (TWRC).

The value of the data that is generated is equal to 10^6 bits, the modulation used is BPSK and QPSK, and using AWGN channel. From the simulation results obtained cooperative combining using Maximal Ratio Combining (MRC), BER using AWGN channel modulation by the following equation [11]:

$$BER_{BPSK} = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right) \quad (20)$$

Where erfc is error function complement and $\frac{E_b}{N_0}$ is a bit energy to noise ratio. The function of the erfc can be related to the function of Q, namely:

$$Q(x) = \frac{1}{2} erfc\left(\frac{x}{\sqrt{2}}\right) \quad (21)$$

As for equation QPSK modulation for BER on AWGN channels are as follows:

$$BER_{QPSK} = \frac{2}{log_2 4} Q\left(\sqrt{\frac{2E_b log_2 4}{N_0}} sin\frac{\pi}{4}\right) \quad (22)$$

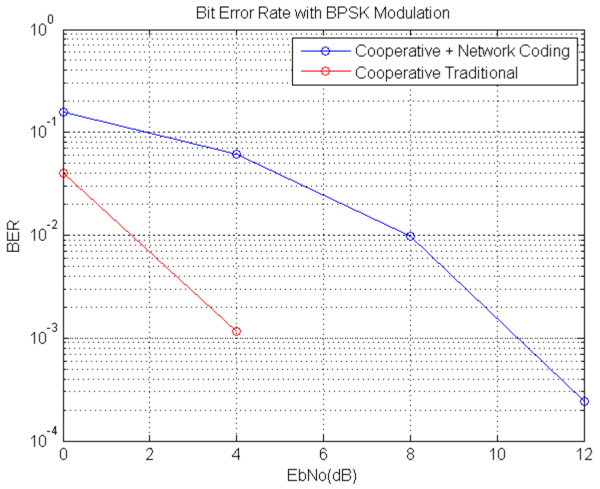

Figure 3. SNR CNC and BPSK

Figure 3 shows the sum SNR simulation and it is compared the signal to noise ratio BPSK modulation between use CNC(cooperative network coding) with cooperative traditional (without NC), the performance of the proposed scheme with equal power allocation. The value of the information data transmits equally to 10^6 bits. In the cooperative traditional system relays which are values bit error rate smallest then cooperative network coding (CNC), if the greater the SNR the worse quality of service, this is because the network coding has the amount of noise that is more in relays, so the quality of the signal level become worse.

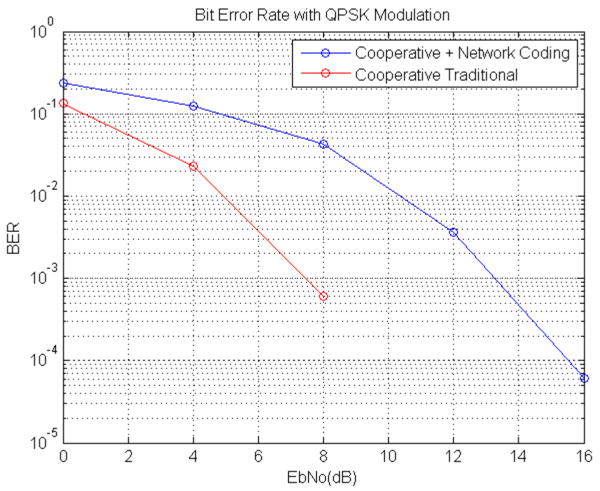

Figure 4. SNR CNC and QPSK

Figure 4, simulation results were shown to compare the signal to noise ratio between CNC and cooperative traditional with QPSK modulation. the value of the information data transmits equally to 10^6 bits. BER for cooperative traditional more effectively then CNC, that was because cooperative traditional only few coefficient fading was used.

For a comparison between BPSK and QPSK modulation, then from the simulation results showed that BPSK has a value smaller BER compared then QPSK modulation.

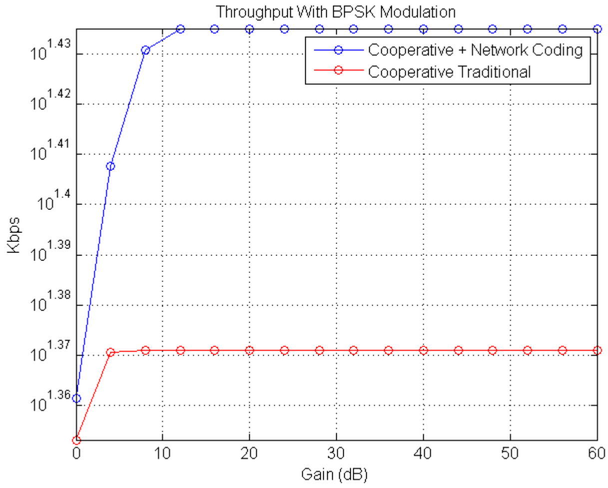

Figure 5. Throughput CNC and BPSK

In Figure 5, the result of the simulation using cooperative network coding and the parameter of throughput to measure BPSK modulation, overall cooperative network coding gives better results than cooperative traditional. Cooperative traditional its mean using cooperative system but without network coding. At this point of gain 10 dB, get the result cooperative traditional $10^{1.37}$ kbps, and CNC has $10^{1.43}$ kbps.

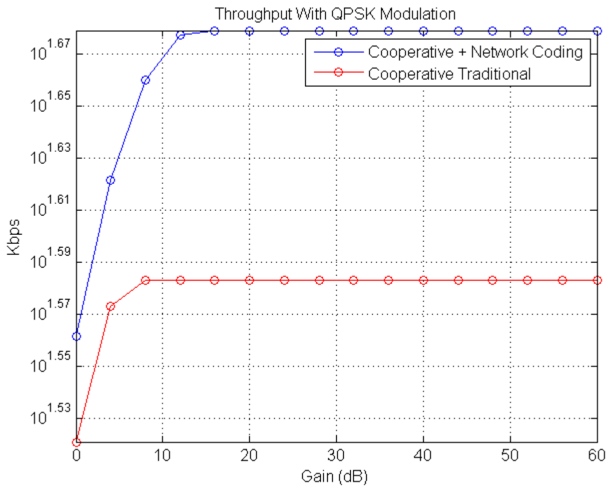

Figure 6. Throughput CNC and QPSK

In Figure 6, the result of the simulation using cooperative network coding and the parameter of throughput to measure QPSK modulation, overall cooperative network coding gives better results than cooperative traditional. Cooperative traditional its mean using cooperative system but without network coding.

Both of them results (BPSK and QPSK) throughput QPSK has better performance results than BPSK. This is because the process of efficient relay using reduce timeslot, thereby saving the use of the channel.

V. Conclusion

Cooperative communication systems have become an important part of the wireless network that expects the ability to flexibility and quality improvement. We proposed a scheme to combined the cooperative communications with network coding protocol (CNC) used in transparent protocol relay (amplify-and-forward). The simulation results throughput showed that cooperative communication systems with network coding is better than cooperative system without network coding for both types of modulation. In the future work, we can use regenerative protocol i.e decode-and-forward, and compare the performance using two strategy protocol cooperative.

References

[1] V. Miliotis, L. Alonso, and C. Verikoukis, “CooPNC: A cooperative multicast protocol exploiting physical layer network coding,” *Ad Hoc Netw.*, vol. 14, pp. 35–50, Mar. 2014.

[2] A. Osseiran, F. Boccardi, V. Braun, K. Kusume, P. Marsch, M. Maternia, O. Queseth, M. Schellmann, H. Schotten, H. Taoka, H. Tullberg, M. A. Uusitalo, B. Timus, and M. Fallgren, “Scenarios for 5G mobile and wireless communications: the vision of the METIS project,” *IEEE Commun. Mag.*, vol. 52, no. 5, pp. 26–35, May 2014.

[3] A. Sendonaris, E. Erkip, and B. Aazhang, “User cooperation diversity. Part I. System description,” *IEEE Trans. Commun.*, vol. 51, no. 11, pp. 1927–1938, Nov. 2003.

[4] A. Sendonaris, E. Erkip, and B. Aazhang, “User cooperation diversity. Part II. Implementation aspects and performance analysis,” *IEEE Trans. Commun.*, vol. 51, no. 11, pp. 1939–1948, Nov. 2003.

[5] R. Ahlswede, N. Cai, S.-Y. R. Li, and R. W. Yeung, “Network information flow,” *IEEE Trans. Inf. Theory*, vol. 46, no. 4, pp. 1204–1216, Jul. 2000.

[6] E. C. V. D. Meulen, “Three-Terminal Communication Channels,” *Adv. Appl. Probab.*, vol. 3, no. 1, pp. 120–154, Apr. 1971.

[7] H.-H. Chen, Y.-L. Sung, A. Morales, and S. Agili, “Cooperative communication with network coding,” in *2012 IEEE 16th International Symposium on Consumer Electronics (ISCE)*, 2012, pp. 1–3.

[8] K. Lu, S. Fu, and Y. Qian, “Capacity of Random Wireless Networks: Impact of Physical-Layer Network Coding,” in *IEEE International Conference on Communications, 2008. ICC ’08*, 2008, pp. 3903–3907.

[9] S. Zhang, S.-C. Liew, and P. P. Lam, “On the Synchronization of Physical-Layer Network Coding,” in *IEEE Information Theory Workshop, 2006. ITW ’06 Chengdu*, 2006, pp. 404–408.

[10] X. Liu, G. Wang, and B. Li, “A Physical-network-coding-based amplify and forward cooperation scheme,” in *Communications and Signal Processing (ICICS) 2013 9th International Conference on Information*, 2013, pp. 1–5.

[11] K. D. Rao, *Channel Coding Techniques for Wireless Communications*. Springer India: Springer 2015, 2015.