# Multi-group Multi-way Relaying with Multi-stage Non-Regenerative Relay Stations

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***Abstract*—In this paper, we propose a signal transmission model for multi-group multi-way (MGMW) relaying which allows complete information exchange among users belonging to different user groups, with applications such as file sharing among users separated by large distances. We achieve this through the use of multi-stage non-regenerative relay stations (RSs). The groups of multiple users are connected to the nearest RS stages which are again connected via RSs at the next nearest stage and so on. The RSs at each stage obtain messages from user groups connected through the next RS stage by subtracting information extracted from the previous RS stage. We formulate the achievable sum rate of such a network and investigate the impact of system parameters on it. We show that increasing the number of users per group, while keeping a smaller number of user groups, improves the sum rate.**

***Index Terms*—multi-group multi-way relaying, non-regenerative relaying, sum rate.**

## I. Introduction

Multi-group multi-way (MGMW) relaying has recently attracted significant research interest by allowing the capacity and spectral efficiency benefits of relay networks to be harnessed by multiple user groups, exchanging messages through an intermediate relay station (RS). MGMW relaying has been proposed in [1]–[3] for practical applications like video-conferences, multi-player games or satellite communications.

Prior works on MGMW relaying consider either regenerative [4] or non-regenerative [5]–[7] relaying process, where the RS decodes or amplifies the received signal, respectively. To improve the transmission efficiency of MGMW relaying, analog or physical layer network coding protocols have been incorporated in [2], [3], [6], [7]. In [2], analog network coding aware transceive beamforming is designed and the sum rate has been obtained for symmetric ad asymmetric traffic. In [3], different algorithms for spatial multiplexing transceive beamforming have been compared in terms of the achievable sum rate. In [6], the spatial processing at the RS have been combined with the joint temporal processing at the users and a RS transceive filter has been designed. In [7], self and known interference cancellation are applied at the users to achieve better sum rate compared to existing schemes.

Though the previous works on MGMW relaying in [1]–[7] have investigated efficient beamforming and relay processing scheme design, all these works considered only intra-group data exchange among users belonging to the same user group. However, information exchange among different user groups could be desirable in many practical scenarios involving, e.g., file sharing in device to device networks, where users may be separated by large distances. In such cases, due to large distances, these users may not be served by a single intermediate RS and hence, separate RSs, connected to different user groups, are required to serve these users. Moreover, to ensure interconnection among different RSs (so that users from different groups can access each other's messages), multiple stages of RSs are required.

In this paper, we propose MGMW relaying with $G$ groups of users, $N$ users per group and $L$ non-regenerative RS stages with $N_\ell$ ($\ell \in [1, L]$) RSs at each stage. We consider all users and all RSs to be half-duplex with single antennas and perfect channel state information (CSI) is available to all the users and the RSs. In the proposed protocol, a total number of $2L$ time slots are required for complete message exchange among all the user groups through $L$-stage MGMW relaying.

The main contributions of the paper are as follows:

- We propose a signal transmission protocol for MGMW relaying with multi-stage non-regenerative RSs that allows a user group to receive information from other user groups via the nearest RS stage. Note that the proposed MGMW relaying with multi-stage RSs serves as a generalized model which includes existing models as special cases, e.g., single group multi-way relay networks (MWRNs) [8]–[13] (for $G = 1$, $L = 1$), multi-pair two-way relay networks (TWRNs) [14]–[16] (for $L = 1$, $N = 2$) and traditional TWRN [17]–[20] (for $G = 1$, $L = 1$, $N = 2$).
- We formulate the achievable sum rate and use it to assess the impact of system parameters on the sum rate performance. We show that increasing the number of users per group, while decreasing the number of user groups, results into better sum rate, as more users' signals can be detected through the nearest RS.

The rest of the paper is organized as follows. The proposed system model is presented in Section II. The proposed signal transmission protocols in MGMW relaying with multi-stage non-regenerative RSs are discussed in Section III. The

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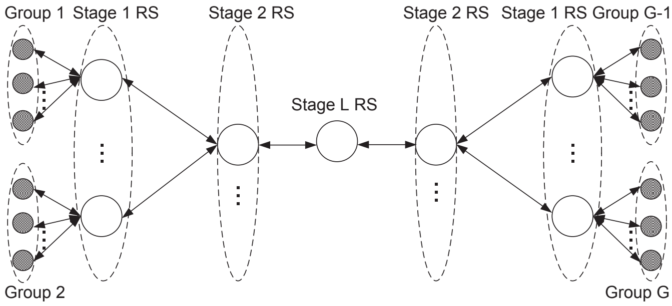


Fig. 1. System model for MGMW relaying with multi-stage RSs, with $G$ user groups, $N$ users per group and $L$ RS stages, where the users/RSs at each stage can directly communicate only with the users/RSs at the previous and the following stage.

TABLE I
PROPOSED MESSAGE EXCHANGE PROCESS IN A NETWORK WITH $L = 3$, $G = 4$, $N_1 = 4$, $N_2 = 2$ AND $N_3 = 1$, WHERE THE USERS IN GROUP 1 EXTRACT OTHER USER GROUPS' MESSAGES

| $t_s$ | Transmitting node | Receiving node | Received messages at $g = 1$ |
|---|---|---|---|
| 1 | $g = 1, 2, 3, 4$ | $\ell = 1$ RSs | |
| 2 | $\ell = 1$ RSs | $g = 1, 2, 3, 4$, $\ell = 2$ RSs | intra-group |
| 3 | $\ell = 2$ RSs | $\ell = 1, 3$ RSs | |
| 4 | $\ell = 1, 3$ RSs | $\ell = 2$ RSs, $g = 1, 2, 3, 4$ | From $g = 2$ |
| 5 | $\ell = 2$ RSs | $\ell = 1$ RSs | |
| 6 | $\ell = 1$ RSs | $g = 1, 2, 3, 4$ | From $g = 3, 4$ |

achievable sum rate is formulated in Section IV. The numerical results are provided in Section V. Finally, conclusions are drawn in Section VI.

## II. Proposed System Model

We consider MGMW relaying with $G$ groups of users, $N$ users per group and $L$ RS stages with $N_\ell$ ($\ell \in [1, L]$) RSs at each stage. Each user group connects to a different first-stage RS, thus, $N_1 = G$ first-stage RSs are required for message exchange within the user groups. For the last (i.e., $L^{th}$) stage, $N_L = 1$ RS is connected to the RSs at the $(L-1)^{th}$ stage. In general, at the $(\ell-1)^{th}$ stage, $N_{\ell-1}$ RSs connect with $N_\ell$ RSs from the $\ell^{th}$ stage, where, $\frac{N_{\ell-1}}{N_\ell} \in \mathbb{Z}$ and $\mathbb{Z}$ denotes the set of integers. Thus, the RSs at the $\ell^{th}$ stage form $N_\ell$ groups with $\frac{N_{\ell-1}}{N_\ell}$ RSs per group from the $(\ell-1)^{th}$ stage. For example, in Fig. 1, each RS at stage 2 is connected with $\frac{N_{\ell=2}}{N_{\ell=1}}$ RSs from stage 1.

We choose the index for the user groups as $g$, where $g \in [1, G]$, the index for users in the $g^{th}$ group as $i$, where $i \in [1, N]$, the index for RS groups connected to RSs at the $\ell^{th}$ stage as $k$, where $k \in [1, N_\ell]$ and the index for RSs at the $\ell^{th}$ stage and the $k^{th}$ group as $r_\ell$, where $r_\ell \in [1, \frac{N_{\ell-1}}{N_\ell}]$. Also, we choose the index for time slots as $t_s$.

We denote the channel from node $a$ to node $b$ and the channel from node $b$ to node $a$ corresponding to user/RS group $c$ (where, $a, b \in \{i, r_\ell\}$ and $c \in \{g, k\}$) by $h^c_{a,b}$ and $h^c_{b,a}$, respectively. We make the following assumptions regarding the system model:

1) The users' and the RSs' transmissions are half-duplex in nature.
2) The users, as well as, the RSs in the same or different stages do not have any direct link between them. The users have direct links only with the $\ell = 1^{st}$ stage RSs. The RSs at the $\ell^{th}$ stage have direct links with only the RSs at the $(\ell-1)^{th}$ and the $(\ell+1)^{th}$ stage.
3) The channels between users and the first stage RS, as well as, the channels between RSs at different stages, are block Rayleigh fading reciprocal channels and they remain constant for a certain time slot.
4) The channel coefficients are zero mean complex-valued Gaussian random variables with variances $\sigma^2_{h^c_{a,b}} = \sigma^2_{h^c_{b,a}}$.
5) Every user has instantaneous channel state information (CSI) about the RS stages that help the user to access the desired messages. The assumption of perfect CSI is commonly adopted in the literature to enable the best system performance to be determined [6], [9].
6) Perfect channel phase synchronization is assumed to allow benchmark performance to be determined [17], [21].

In MGMW relaying with multi-stage RSs, a total number of $2L$ time slots are needed for complete information exchange including both intra-group and inter-group messages.

### A. Steps for Message Exchange

- At the $t_s = 1^{st}$ time slot, the users transmit signals to the RSs at the $1^{st}$ stage.
- For $t_s = 2^{nd}$ time slot, the users in each group subtract self information from the network coded signal received from the RSs at the $1^{st}$ stage to extract intra-group messages.
- For $2 \leq t_s \leq L$, at the $t_s^{th}$ time slot, the RSs at the $(t_s - 1)^{th}$ stage amplify and broadcast[1] messages to the following and the previous stages.
- For $3 \leq t_s \leq L+1$ time slots, the RSs at the $(t_s - 2)^{th}$ stage subtract the previously received signal to extract the messages of the user group connected to these RSs by the following RS stage and then forward to the previous RS stage after amplification.
- For $L + 1 < t_s \leq 2L$, at the $t_s^{th}$ time slot, RSs at the $(t_s - j)^{th}$ stage amplify and broadcast messages to the previous stage, where, $j$ is an odd integer and $1 \leq t_s - j \leq L$.

The above message exchange process is illustrated in Table I for MGMW relaying with $L = 3$, $G = 4$, $N_1 = 4$, $N_2 = 2$ and $N_3 = 1$.

[1]The signal transmission model is also applicable for other relaying protocols like decode-and-forward and compute-and-forward. However, the signal processing complexity at the relay would be higher for these protocols.

## III. Signal Transmission Protocols

In this section, we elaborate the signal transmission protocols at different time slots defined in Section II-A. Here, we consider equal and unity power at the users and the RSs. Thus, the signal to noise ratio (SNR) can be defined as $\frac{1}{N_0}$.

### A. Stage 1 RSs Receive from Users ($t_s = 1$)

At the first time slot, all the users in each of the $g^{th}$ group transmit their signals $X_{i,g}$ and the corresponding first stage RS receives the network coded signal as

$$Y_{r_1,g} = \sum_{i=1}^{N} h_{i,r_1}^{g} X_{i,g} + n_{r_g,1} \tag{1}$$

where $h_{i,r_1}^{g}$ represents the channel gain and $n_{r_g,1}$ represents the complex additive white Gaussian noise (AWGN) at the $g^{th}$ RS at the $1^{st}$ stage with variance $\sigma^2_{n_{r_g,1}} = \frac{N_0}{2}$. Then the $g^{th}$ RS at the $1^{st}$ stage amplifies the received signal with an amplification factor, $\alpha_{g,1} = \sqrt{\frac{1}{\sum_{i=1}^{N} |h_{i,r_1}^{g}|^2 + \frac{1}{\rho}}}$ and broadcasts the signal to the $g^{th}$ user group and the $k^{th}$ RS at the second stage. The factor $\alpha_{g,1}$ is chosen to maintain unity power at the $g^{th}$ RS at the $1^{st}$ stage.

### B. Users Receive from Stage 1 RSs ($t_s = 2$)

The $j^{th}$ ($j \in [1, N]$) user in the $g^{th}$ group receives the signal from the first stage RS as

$$Y_{j,g,1} = \alpha_{g,1} h_{r_1,j}^{g} \left( \sum_{i=1}^{N} h_{i,r_1}^{g} X_{i,g} + n_{r_g,1} \right) + n_{j,g} \tag{2}$$

where $n_{j,g}$ represents the complex AWGN at the $j^{th}$ user in the $g^{th}$ group with variance $\sigma^2_{n_{j,g}} = \frac{N_0}{2}$.

Then the $j^{th}$ user in the $g^{th}$ group subtracts its own signal $X_{j,g}$ after multiplication with $\alpha_{g,1} h_{r_1,j}^{g} h_{j,r_1}^{g}$ from the signal received from the $g^{th}$ first stage RS and obtains

$$\begin{aligned}\hat{Y}_{j,g,1} &= \alpha_{g,1} h_{r_1,j}^{g} \left( \sum_{i=1}^{N} h_{i,r_1}^{g} X_{i,g} + n_{r_g,1} \right) + n_{j,g} \\ &\quad - \alpha_{g,1} h_{r_1,j}^{g} h_{j,r_1}^{g} X_{j,g} \\ &= \alpha_{g,1} h_{r_1,j}^{g} \left( \sum_{i=1, i\neq j}^{N} h_{i,r_1}^{g} X_{i,g} + n_{r_g,1} \right) + n_{j,g} \end{aligned} \tag{3}$$

Then the $j^{th}$ user performs maximum likelihood detection to extract the signals of other users in the group as $\hat{X}_{i,g}$ ($i \neq j$).

### C. RSs Receive from Previous Stage ($2 \leq t_s \leq L$)

The RSs at the $\ell^{th}$ stage and the $k^{th}$ group receive amplified network coded signal from the previous RS stages as

$$\begin{aligned}Y_{r_\ell,k} &= \prod_{p=2}^{\ell} \sum_{k=1}^{\frac{N_{p-1}}{N_p}} \alpha_{k,p-1} h_{r_{p-1},r_p}^{k} \sum_{i=1}^{N} h_{i,r_1}^{g} X_{i,g} + \\ &\quad \sum_{q=1}^{\ell-1} \sum_{k=1}^{\frac{N_q}{N_{q+1}}} n_{r_k,q} \prod_{p=q}^{\ell-1} \alpha_{k,p} h_{r_p,r_{p+1}}^{k}\end{aligned} \tag{4}$$

and broadcasts to the $(\ell-1)^{th}$ and the $(\ell+1)^{th}$ stage after amplification[2] with a factor $\alpha_{k,\ell}$ given by (5), shown at the top of the next page.

The signal received at the $(\ell-1)^{th}$ stage RS from the $\ell^{th}$ stage RS is given by:

$$Y_{r_{\ell-1},k,\ell} = \alpha_{k,\ell} h_{r_\ell,r_{\ell-1}}^{k} Y_{r_\ell,k} + \sum_{q=\ell-1}^{\ell} n_{r_k,q} \alpha_{k,\ell} h_{r_\ell,r_{\ell-1}}^{k} \tag{7}$$

### D. RSs Subtract Signals ($3 \leq t_s \leq L+1$)

The RS at the $(\ell-1)^{th}$ stage subtract the signal received from the $(\ell-2)^{th}$ stage from (10) after multiplication with $\alpha_{k,\ell} h_{r_\ell,r_{\ell-1}}^{k}$ to obtain the messages of user groups connected via the corresponding $\ell^{th}$ stage RS, as:

$$\begin{aligned}\hat{Y}_{r_{\ell-1},k,\ell} &= \alpha_{k,\ell} h_{r_\ell,r_{\ell-1}}^{k} \left( \sum_{k=1}^{\frac{N_{\ell-1}}{N_\ell}} \alpha_{k,\ell-1} h_{r_{\ell-1},r_\ell}^{k} \sum_{i=1}^{N} h_{i,r_1}^{g} X_{i,g} \right. \\ &\quad \left. + \sum_{k=1}^{\frac{N_{\ell-1}}{N_\ell}} n_{r_k,\ell-1} \alpha_{k,\ell-1} h_{r_{\ell-1},r_\ell}^{k} \right) + \sum_{q=\ell-1}^{\ell} n_{r_k,q} \alpha_{k,\ell} h_{r_\ell,r_{\ell-1}}^{k}\end{aligned} \tag{8}$$

Then the RS at the $(\ell-1)^{th}$ stage forwards the signal in (8) to the RSs at the $(\ell-2)^{th}$ stage after multiplication with $\alpha_{k,\ell-1}$. This process continues downward up to stage 1 RSs until all the user groups connected to the corresponding $(\ell-1)^{th}$ stage RS receive each other's messages. Thus, the signal received at the $j^{th}$ user in the $g^{th}$ user group from the corresponding $\ell^{th}$ stage RS (after signal subtraction at the $(\ell-1)^{th}$ stage and amplification via the intermediate RS stages) can be given by:

$$\begin{aligned}Y_{j,g,\ell} &= \prod_{q=2}^{\ell-1} \alpha_{k,q} h_{r_q,r_{q-1}}^{k} \alpha_{g,1} h_{r_1,j}^{g} \hat{Y}_{r_{\ell-1},k,\ell} + \\ &\quad \sum_{q=2}^{\ell-2} n_{r_k,q} \prod_{p=2}^{q} \alpha_{k,p-1} h_{r_p,r_{p-1}}^{k} + n_{j,g}\end{aligned} \tag{9}$$

### E. RSs Receive from the Following Stages ($L+1 < t_s \leq 2L$)

The RS in the $k^{th}$ group at the $\ell^{th}$ stage receives the signal from the $L^{th}$ RS stage (via intermediate RS stages) as:

$$\begin{aligned}Y_{r_\ell,k} &= \prod_{q=\ell+1}^{L-1} \alpha_{k,q} h_{r_q,r_{q-1}}^{k} \hat{Y}_{r_{L-1},k,L} + \sum_{q=\ell}^{L-1} n_{r_k,q} \prod_{p=\ell+1}^{q} \alpha_{k,p-1} \\ &\quad \times h_{r_p,r_{p-1}}^{k}\end{aligned} \tag{10}$$

where the signal $\hat{Y}_{r_{L-1},k,L}$ is obtained as in (8) with $\ell$ replaced by $L$. Then the above signal is amplified and forwarded to the previous RS stage and the process continues until the corresponding user groups can extract messages of those other user groups who are connected only through the last RS stage. Thus, the signal received at the $j^{th}$ user in the $g^{th}$ group from

[2]Due to noise accumulation, having large number of RS stages may not be feasible in practice.

$$\alpha_{k,\ell} = \sqrt{\frac{1}{\prod_{p=2}^{\ell}\sum_{k=1}^{\frac{N_{p-1}}{N_p}}\alpha_{k,p-1}^2|h_{r_{p-1},r_p}^k|^2\sum_{i=1}^{N}|h_{i,r_1}^g|^2+\sum_{q=1}^{\ell-1}\sum_{k=1}^{\frac{N_q}{N_{q+1}}}N_0\prod_{p=q}^{\ell-1}\alpha_{k,p}^2|h_{r_p,r_{p+1}}^k|^2}} \tag{5}$$

$$\gamma_{j,i,g',g} = \begin{cases} \frac{\alpha_{g',1}^2|h_{r_1,j}^{g'}|^2\sum_{i=1,i\neq j}^{N}|h_{i,r_1}^g|^2}{\alpha_{g',1}^2|h_{r_1,j}^{g'}|^2N_0+N_0} & g=g' \\ \frac{A_\ell|h_{i,r_1}^g|^2}{A_\ell N_0+2\alpha_{k,\ell-1}^2|h_{r_{\ell-1},r_\ell}^k|^2N_0+N_0\sum_{q=\ell}^{L-1}\prod_{p=\ell+1}^{q}\alpha_{k,p-1}^2|h_{r_p,r_{p-1}}^k|^2|} & \frac{N_1}{N_{\ell-1}}+1\leq g\leq\frac{N_1}{N_\ell}, g\neq g', \ell<L \\ \frac{A_L|h_{i,r_1}^g|^2}{A_LN_0+\sum_{q=2}^{L-1}N_0\prod_{p=2}^{q}\alpha_{k,p-1}^2|h_{r_p,r_{p-1}}^k|^2+N_0} & \frac{N_1}{N_{L-1}}+1\leq g\leq\frac{N_1}{N_L}, g\neq g', \ell=L \end{cases} \tag{6}$$

the $L^{th}$ stage (after signal subtraction at the $(L-1)^{th}$ stage and amplification through the intermediate RS stages) is:

$$Y_{j,g,L} = \prod_{q=2}^{L-1}\alpha_{k,q}h_{r_q,r_{q-1}}^k\alpha_{g,1}h_{r_1,j}^g\hat{Y}_{r_{L-1},k,L}+ \sum_{q=2}^{L-1}n_{r_k,q}\prod_{p=2}^{q}\alpha_{k,p-1}h_{r_p,r_{p-1}}^k+n_{j,g} \tag{11}$$

### F. Signal Extraction

The $j^{th}$ user extracts the signal of the other users in its own group from the signal received from the corresponding stage 1 RS (as in (3)). Similarly, the $j^{th}$ user extracts the signal of the $g^{th}$ (where $2\leq g\leq\frac{N_1}{N_2}$) user group from the corresponding second stage RS. Thus, in general, for $\frac{N_1}{N_{\ell-1}}+1\leq g\leq\frac{N_1}{N_\ell}$, the signal is extracted from the $\ell^{th}$ stage RS. For $\ell<L$, the user's messages from the $g^{th}$ group are extracted from the signal in (9) and for $\ell=L$, the messages are extracted from the received signal in (11).

Using (3), (9) and (11), the SNR of the $i^{th}$ user's signal from the $g^{th}$ group at the $j^{th}$ user from the $g'^{th}$ group is given by (6), shown at the top of this page, where $A_\ell = \alpha_{g',1}^2|h_{r_1,j}^{g'}|^2\prod_{q=2}^{\ell-1}\alpha_{k,q}^2|h_{r_q,r_{q-1}}^k|^2\alpha_{k,\ell}^2|h_{r_\ell,r_{\ell-1}}^k|^2\sum_{k=1}^{\frac{N_{\ell-1}}{N_\ell}}\alpha_{k,\ell-1}^2 \times|h_{r_{\ell-1},r_\ell}^k|^2|$ and $A_L$ is the same as $A_\ell$ with $\ell$ replaced by $L$.

## IV. Sum Rate

The sum rate of a MWRN can be defined as the sum of the achievable rates of all the users for a complete round of information exchange [4]. Thus, the sum rate for MGMW relaying with multi-stage non-regenerative RSs can be given as

$$R_s = \frac{1}{2L}\left(\sum_{g'=1}^{G}\sum_{j=1}^{N}\sum_{g=1,g\neq g'}^{G}\sum_{i=1}^{N}R_{j,i,g',g}+\sum_{i=1,i\neq j}^{N}R_{j,i,g',g'}\right) \tag{12}$$

where, $R_{j,i,g',g}$ represents the information rate corresponding to the information of the $i^{th}$ user in the $g^{th}$ group received at the $j^{th}$ user in the $g'^{th}$ group and can be defined as [9]:

$$R_{j,i,g',g} = \log(1+\gamma_{j,i,g',g}) \tag{13}$$

where $\gamma_{j,i,g',g}$ is defined in (6). Using (6) and (13), the sum rate can be obtained from (12).

## V. Results

In this section, we present numerical simulations to illustrate the achievable sum rate results for MGMW relaying with multi-stage non-regenerative RSs, where each user transmits a data packet of $T = 1000$ bits. Following [9], the average channel gain of the $j^{th}$ user is $\sigma_{h_{j,r}}^2 = (1/(d_j/d_0))^\nu$, where $d_0$ is the reference distance, $d_j$ is the distance between the $j^{th}$ user and the RS at the last stage, which is assumed to be uniformly randomly distributed between 0 and $d_0$, and $\nu$ is the path loss exponent, which is assumed to be 3. The intermediate RS stages are equally spaced between the users and the last RS stage. Thus, the distances between any two stages is $\frac{d_0}{L}$. The SNR is assumed to be the SNR per bit per user and the simulation results are averaged over 100 time frames.

### A. Impact of the Number of User Groups

Fig. 2 shows the sum rate results for MGMW relaying with multi-stage non-regenerative RSs, formulated in (12), for two different combinations of user groups: (i) $G = 4, N = 3$ and (ii) $G = 2, N = 6$. From this figure, we can see that the sum rate decreases when the number of users per group decreases (or in other words, the number of groups increases). This is because, for $G = 4, N = 3$, each user can extract 2 other users' signals through the closest RS (the first relay stage), whereas, for $G = 2, N = 6$, each user can extract 5 other users' signals through the closest RS. Thus, from Fig. 2, increasing the number of users per group from 3 to 6 in a two-stage MGMW relay network, results into 1 dB improvement in the sum rate. Though combining more number of users in a group can improve the sum rate, it might not always be feasible due to large distances among the users.

### B. Impact of the Number of RS Stages

Fig. 3 shows the impact of the number of RS stages on the sum rate performance. It can be noted from this figure that increasing the number of RS stages decreases the rate of sum rate improvement with SNR. This is because, in the proposed system model, each of the RSs at each stage amplifies the

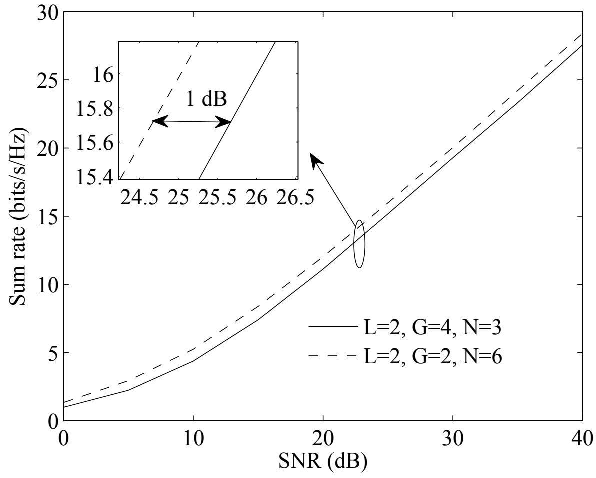


Fig. 2. Sum rate of MGMW relaying with $L = 2$ non-regenerative RS stages and the combinations, $G = 4$, $N = 3$ and $G = 2$, $N = 6$.

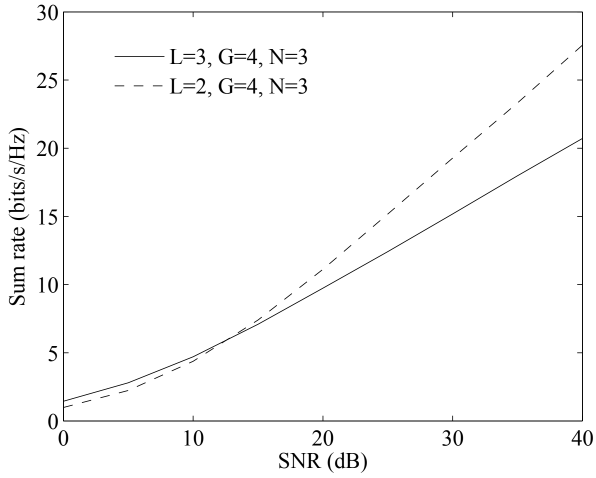


Fig. 3. Sum rate of MGMW relaying with $G = 4$, $N = 3$ and $L = 2$ and $L = 3$ non-regenerative RS stages, respectively.

noise received from the previous stage, which would mean more noise and lower SNR for increasing number of RS stages. Thus, increasing one RS stage might result into slight improvement in the sum rate at low SNR but as SNR improves, the sum rate for smaller number of RS stages improves at a higher rate compared to that of larger number of RS stages.

## VI. Conclusions

In this paper, we studied MGMW relaying with multi-stage non-regenerative RSs, where, a user group exchanges messages with the other user groups through the nearest RS stage. In the proposed network, RSs at each stage subtract information extracted from the previous RS stage to obtain messages from user groups connected to them by the following RS stage. We analyzed the achievable sum rate of this network and investigated the impact of system parameters on the sum rate. Our analysis shows that when there are more number of users per group with smaller number of groups, the sum rate improves. However, for more number of RS stages, the sum rate degrades due to noise amplification at each stage.

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