# Performance Analysis of Hybrid-ARQ over Full-Duplex Relaying Network Subject to Loop Interference under Nakagami-$m$ Fading Channels

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***Abstract*—In this paper, the outage performance of hybrid automatic repeat request (hybrid-ARQ) over a full-duplex decode-and-forward relay network is analyzed. Nakagami-$m$ distribution is assumed for fading channels such that the analysis results can be easily extended to other fading distributions. Compared to the conventional half-duplex relay mode, full-duplex relay network enables the relay nodes to receive and transmit data with the same time interval and the same frequency band, which leads to improved spectral efficiency and overcomes the loss of limited resources. Due to the full-duplex operation of the relay node, the transmitted signal from the relay node to the destination node will interfere through echo interference channel with the signal coming from the source node since both transmissions occupy the same frequency band. The expressions for the outage probability of the relay network with two different types of hybrid-ARQ schemes, namely type-I hybrid-ARQ and hybrid-ARQ with chase combining, are derived. It is shown that the existence of the loop interference affect the system performance in several ways.**

***Index Terms*—Hybrid automatic repeat request (ARQ), chase combining, full-duplex relaying (FDR), cooperative network, relaying channels, loop interference, outage probability.**

## I. Introduction

Over the last decades, wireless relaying technique has gained huge interests from both the academia and industry thanks to its numerous benefits. By implementing intermediate relay nodes to support the data transmission from a source to a destination, it has been shown that a substantial increase in the multiplexing gain and spatial diversity can be achieved for the the communication system, which leads to improved network coverage and enhanced system throughput [1]–[3].

Depending on the nature and complexity of the relaying technique, relay strategies can be generally classified into two categories, namely amplify-and-forward (AF) and decode-and-forward (DF) [4, pp. 412–416]. Based on whether the relay is capable of transmitting and receiving simultaneously, the relaying modes can also be categorized into half duplex relaying (HDR) [3] and full duplex relaying (FDR) [5]. Compared to the conventional HDR mode, the FDR mode usually suffers from self-interference or loop interference at the receiving antenna of the relay nodes, but it enables the relay nodes to receive and transmit data with the same time interval and the same frequency band, which improves the spectral efficiency and overcomes the loss of limited resources [6].

The performance of relay-aided network can be further improved by the combined implementation of the relaying technique in the physical layer and the hybrid automatic repeat request (hybrid-ARQ) scheme in the link layer [7]. The hybrid-ARQ is a well-established retransmission mechanism which has been utilized in virtually all modern communication systems. Besides type-I ARQ, hybrid-ARQ is usually categorized into Chase combining (CC) and incremental redundancy (IR), depending on whether the retransmission is identical to the original transmission or it consists of new redundancy bits from the channel encoder [4, pp. 96–101]. The ARQ systems can be interpreted as channels with sequential feedback, where the system performance can be improved by retransmitting data that has been impaired by unfavorable channel conditions through the use of both error correction and error detection codes. These advantages of relaying and ARQ motivated to study the performance of relaying system and/or hybrid-ARQ with different configurations and topologies [8]–[14].

The outage performance of a three-node full-duplex fixed-gain AF relaying network over Rayleigh and Nakagami-$m$ fading channels is analyzed in [8]. The performances of hybrid-ARQ with IR and CC over double Rayleigh fading channels are analyzed in [9] and [10], respectively, which are equivalent to the analysis of hybrid-ARQ with IR and CC over a three-node full-duplex AF relay network without loop interference under Rayleigh fading channels. In [11], the throughput and outage probability of a three-node half-duplex relay network with hybrid-ARQ and long-run sum power constraint are analyzed. The performance of full-duplex DF relaying system over Nakagami-$m$ fading is investigated with new efficient cooperative protocols proposed in [12]. In [13], the outage probability performance of a full-duplex variable-gain AF relaying network over Rayleigh fading channels with direct link between source and destination nodes is investigated. The outage probability of a full-duplex variable-gain AF relay network taking into consideration processing delay and residual self-interference is derived in [14]. From the above up-to-dated reported works, it can be found that most reported work on the performance of hybrid-ARQ over relaying networks are based on half-duplex relay network. In this paper, we will conduct the performance analysis of hybrid-ARQ over a three-node full-duplex DF relay network, which, to our best knowledge, is unexplored.

The remainder of the paper is organized as follows. In Section II, we describe the relay-aided full-duplex system and the channel model. The outage performance analysis of the investigated full-duplex relay network is conducted for two different hybrid-ARQ protocols in Section III. The analytical and simulation results are presented in Section IV. Section V concludes the paper.

## II. System and Channel Model

We consider a cooperative communication setup consisting of a source node, a relay node and a destination node as shown in Fig. 1. The source node and the destination node are equipped with one antenna. There exists no direct link between the source node and the destination node and they communicate with each other via a full-duplex relay node. The relay node has one transmitting and one receiving antennas. The relay node uses DF relaying strategy for the signal transmission between the source and destination nodes. We assume that the relay node works in the FDR mode since the FDR can improve the resource efficiency in cooperative relay networks by reducing resource wastage [15]. Due to the FDR operation, the transmitted signal from the relay node to the destination node will interfere through echo interference channel with the signal coming from the source node because both transmissions occupy the same frequency band.

The channel fading coefficients for the source-relay link, relay-destination link, and the loop interference link in the relay node are denoted as $h_{sr}$, $h_{rd}$, and $h_{li}$, respectively. The fading distributions of all links are assumed to be Nakagami-$m$ distribution due to the fact that Nakagami-$m$ distribution is able to describe a wide range of fading distributions via the $m$ parameter [16], [17]. Therefore, our analysis can be readily extended to other fading scenarios by simply varying the model parameters.

Under the investigated system, the instantaneous signal-to-interference-plus-noise ratio (SINR) seen at the receiving antenna of the relay node and the signal-to-noise ratio (SNR) at the destination node, denoted as $\gamma_r$ and $\gamma_d$, respectively, can be written as

$$\gamma_r = \frac{|h_{sr}|^2}{|h_{li}|^2 + n_0}, \tag{1}$$

$$\gamma_d = \frac{|h_{rd}|^2}{n_0}, \tag{2}$$

where $n_0$ represents the power of the additive white gaussian noise (AWGN).

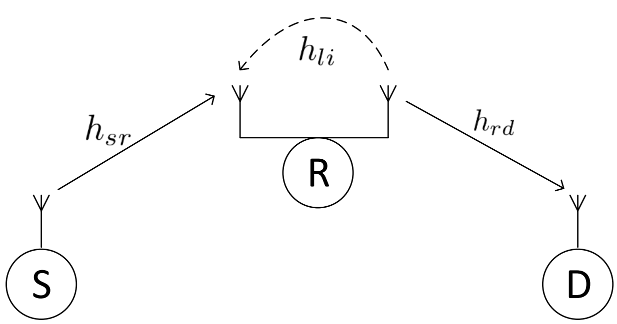


Fig. 1: The investigated system model.

As the channel fading coefficients of the three considered links follow Nakagami-$m$ distribution, the squared terms $h_{xy}^2$, $\{xy\} = \{sr, rd, li\}$, will follow Gamma distribution with probability density function (PDF) given by

$$f_{h_{xy}^2}(h) = \frac{1}{\Gamma(m_{xy})} \cdot \frac{m_{xy}^{m_{xy}} \cdot h^{m_{xy}-1}}{\overline{\gamma}_{xy}^{m_{xy}}} \cdot \exp\Big(-\frac{m_{xy} \cdot h}{\overline{\gamma}_{xy}}\Big), \tag{3}$$

where $\Gamma(\cdot)$ is the Gamma function defined as $\Gamma(\tau) = \int_0^\infty t^{\tau-1} e^{-t}\, dt$, $m_{xy}$ and $\overline{\gamma}_{xy}$ denote the Nakagami parameter and the average SNR of the corresponding fading link.

## III. Outage Performance Analysis

Outage probability is a widely used performance metric for the evaluation of hybrid-ARQ systems. We assume that information-theoretic capacity achieving channel coding is used. With the DF relaying, the relay node will try to decode the information first. After successful decoding at the relay node, it will send an acknowledgement (ACK) to the source node and start forwarding the message to the destination node in the following ARQ round(s)[1]. The (re)transmission will fail when the accumulated information at the corresponding node is less than the information rate $R$.

### A. Type-I ARQ

We first analyze the scenario where the relay-ARQ system employs the type-I ARQ scheme. In this protocol, the packet received in each retransmission is decoded independently. We denote Tr as the event that the relay node successfully decodes the packet. Then, the outage probability after $k$ ($k \geq 2$) hybrid-ARQ rounds can be reformulated as

$$\begin{aligned} P_{out}^{(k)} &= \sum_{t=1}^{k-1} \Pr\big(\gamma_{d,t+1} < 2^R - 1, \cdots, \gamma_{d,k} < 2^R - 1\big) \cdot \Pr(\mathrm{Tr} = t) \\ &\quad + \Pr(\gamma_{r,1} < 2^R - 1, \cdots, \gamma_{r,k-1} < 2^R - 1) \qquad (4) \\ &= \sum_{t=1}^{k-1} \big[\Pr(\gamma_{d,i} < 2^R - 1)\big]^{k-t} \cdot \Pr(\mathrm{Tr} = t) \\ &\quad + \big[\Pr(\gamma_{r,i} < 2^R - 1)\big]^{k-1}, \qquad (5) \end{aligned}$$

where $\gamma_{r,i}$ and $\gamma_{d,i}$ are the SINR and SNR seen at the relay and destination nodes at the $i$-th transmission round, respectively.

Under AWGN channel, the Nakagami-$m$ fading channel condition leads to the instantaneous SNR following Gamma function [17]. Therefore, the probability $\Pr(\gamma_{d,i} < 2^R - 1)$ can be obtained from the cumulative distribution function (CDF) of Gamma distribution and is expressed as

$$\Pr(\gamma_{d,i} < 2^R - 1) = \widetilde{\Gamma}\Big(m_{rd}, \frac{m_{rd} \cdot (2^R - 1)}{\overline{\gamma}_{rd}}\Big), \tag{6}$$

where $\widetilde{\Gamma}(\cdot, \cdot)$ is the normalized lower incomplete Gamma function defined as $\widetilde{\Gamma}(\tau, y) = \frac{1}{\Gamma(\tau)} \int_0^y t^{\tau-1} e^{-t}\, dt$.

[1] In the context of this paper on FDR with hybrid-ARQ, one ARQ round refers to one transmitting time slot. The information sent at source-destination link at time slot $s$ will be potentially available for the relay-destination link only after time slot $s$. Therefore, it requires at least two time slots to send the information successfully from the source to the destination, i.e., the outage probability after one round is defined as $P_{out}^{(k=1)} = 1$ for both ARQ schemes.

The probability $\Pr(\mathrm{Tr}=t)$ under type-I ARQ is written as

$$\Pr(\mathrm{Tr}=t)=\Pr(\gamma_{r,1}<2^R-1,\cdots,\gamma_{r,t-1}<2^R-1,\gamma_{r,t}>2^R-1)=\prod_{i=1}^{t-1}\left[\Pr(\gamma_{r,i}<2^R-1)\right]\cdot\Pr(\gamma_{r,t}>2^R-1) \quad (7)$$

With $h_{sr}$ and $h_{li}$ being Nakagami-$m$ distributed random variables (RVs), the distribution function $f_{\gamma_r}(\cdot)$ of the RV $\gamma_r$ expressed in (1) is given by [12], [18]

$$f_{\gamma_r}(\gamma)=\frac{1}{B(m_{sr},u)}\cdot\Big(\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\Big)^{m_{sr}}\cdot\gamma^{m_{sr}-1}\cdot\Big(1+\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\cdot\gamma\Big)^{-m_{sr}-u}, \quad (8)$$

where $B(\cdot,\cdot)$ is the beta function [19]; the parameters $u$ and $v$ are expressed as follows:

$$u=\frac{m_{li}\cdot(\overline{\gamma}_{sr}+n_0)^2}{\overline{\gamma}_{sr}^2},\qquad v=\frac{\overline{\gamma}_{sr}^2}{m_{li}\cdot(\overline{\gamma}_{sr}+n_0)}. \quad (9)$$

Utilizing the relationship between the PDF and CDF, the CDF $F_{\gamma_r}(\gamma)$ of the RV $\gamma_r$ can be obtained from the equality [19, Eq. 3.194.1] as

$$F_{\gamma_r}(\gamma)=\frac{1}{B(m_{sr},u)}\cdot\Big(\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\Big)^{m_{sr}}\cdot\frac{\gamma^{m_{sr}}}{m_{sr}}\cdot{}_2F_1\Big(m_{sr}+u,m_{sr};m_{sr}+1;-\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\cdot\gamma\Big), \quad (10)$$

where ${}_2F_1(\cdot,\cdot;\cdot;\cdot)$ is the Gauss hypergeometric function [19, Eq. 9.111]. Then, the probability $\Pr(\gamma_{r,i}>2^R-1)$ in (7) is simply related to the CDF $F_{\gamma_r}(\cdot)$ in (10) as follows:

$$\Pr(\gamma_{r,i}>2^R-1)=1-F_{\gamma_r}(2^R-1). \quad (11)$$

Substituting (6), (7), and (10) into (5), the outage probability for type-I hybrid-ARQ over the investigated full-duplex relay network is expressed as

$$P_{out}^{(k)}=\sum_{t=1}^{k-1}\Big[\widetilde{\Gamma}\Big(m_{rd},\frac{m_{rd}\cdot(2^R-1)}{\overline{\gamma}_{rd}}\Big)\Big]^{k-t}\cdot\Big\{\big[F_{\gamma_r}(2^R-1)\big]^{t-1}\cdot\big[1-F_{\gamma_r}(2^R-1)\big]\Big\}+\big[F_{\gamma_r}(2^R-1)\big]^{k-1}, \quad (12)$$

where the CDF $F_{\gamma_r}(\cdot)$ of the RV $\gamma_r$ is given in (10).

*B. Hybrid-ARQ with Chase Combining*

For hybrid-ARQ with chase combining, the packet received in the $k$-th transmission round is combined with the previous received packets and decoding is performed on the combined packet. With the optimal combining of the received signals, the mutual information is obtained by combining received SNR over the $k$ transmission rounds [20]. Then, the outage probability after $k$ ($k\geq 2$) ARQ rounds can be expressed as

$$P_{out}^{(k)}=\sum_{t=1}^{k-1}\Pr\Big(\sum_{i=t+1}^{k}\gamma_{d,i}<2^R-1\Big)\cdot\Pr(\mathrm{Tr}=t)+\Pr\Big(\sum_{i=1}^{k-1}\gamma_{r,i}<2^R-1\Big)=\sum_{t=1}^{k-1}\Pr\big(\mathcal{X}^{(t+1,k)}<2^R-1\big)\cdot\Pr(\mathrm{Tr}=t)+\Pr\big(\mathcal{Y}^{(1,k-1)}<2^R-1\big), \quad (13)$$

where the RV $\mathcal{Y}^{(1,k-1)}=\sum_{i=1}^{k-1}\gamma_{r,i}$ is the sum of $(k-1)$ independent and identically distributed (i.i.d.) RVs $\gamma_r$, the RV $\mathcal{X}^{(t+1,k)}=\sum_{i=t+1}^{k}\gamma_{d,i}$ is Gamma distributed since the sum of $(k-t)$ i.i.d. Gamma RVs is still Gamma distributed. It is straightforward to show that the CDF $F_{\mathcal{X}^{(t+1,k)}}(\cdot)$ of the RV $\mathcal{X}^{(t+1,k)}$ is expressed as

$$F_{\mathcal{X}^{(t+1,k)}}(x)=\widetilde{\Gamma}\Big((k-t)\cdot m_{rd},\frac{m_{rd}\cdot x}{\overline{\gamma}_{rd}}\Big). \quad (14)$$

Then, the expression for the probability $\Pr\big(\mathcal{X}^{(t+1,k)}<2^R-1\big)$ in (13) can be simply written as

$$\Pr\big(\mathcal{X}^{(t+1,k)}<2^R-1\big)=F_{\mathcal{X}^{(t+1,k)}}\big(2^R-1\big)=\widetilde{\Gamma}\Big((k-t)\cdot m_{rd},\frac{m_{rd}\cdot(2^R-1)}{\overline{\gamma}_{rd}}\Big). \quad (15)$$

Next, we derive the probability that the successful decoding of the information at the relay node occurs at the $t$-th transmission round, namely $\Pr(\mathrm{Tr}=t)$. The probability can be reformulated for $t=2,\cdots,(k-1)$, as

$$\Pr(\mathrm{Tr}=t)=\Pr\Big(\sum_{i=1}^{t}\gamma_{r,i}\geq 2^R-1\Big)-\Pr\Big(\sum_{i=1}^{t-1}\gamma_{r,i}\geq 2^R-1\Big)=\Pr\big(\mathcal{Y}^{(1,t-1)}<2^R-1\big)-\Pr\big(\mathcal{Y}^{(1,t)}<2^R-1\big)=F_{\mathcal{Y}^{(1,t-1)}}(2^R-1)-F_{\mathcal{Y}^{(1,t)}}(2^R-1), \quad (16)$$

where $F_{\mathcal{Y}^{(1,t)}}(\cdot)$ denotes the CDF of the RV $\mathcal{Y}^{(1,t)}$.

For the case of $t=1$, the probability is given as

$$\Pr(\mathrm{Tr}=1)=1-F_{\mathcal{Y}^{(1,1)}}\big(2^R-1\big)=1-F_{\gamma_r}\big(2^R-1\big). \quad (17)$$

In order to derive the CDF $F_{\mathcal{Y}^{(1,t)}}(\cdot)$ in (16), we use the moment-generating function (MGF) approach, i.e.,

$$F_{\mathcal{Y}^{(1,t)}}(y)=\mathcal{L}^{-1}\Big[\frac{1}{s}\cdot\mathcal{M}_{\mathcal{Y}^{(1,t)}}(-s)\Big], \quad (18)$$

where $\mathcal{L}^{-1}[\cdot]$ represents the inverse Laplace transform and the $\mathcal{M}_{\mathcal{Y}^{(1,t)}}(\cdot)$ represents the corresponding MGF. We first calculate the expression for the MGF $\mathcal{M}_{\gamma_r}(\cdot)$ as follows:

$$\begin{aligned}\mathcal{M}_{\gamma_r}(s)&=\int_0^\infty\exp(-s\cdot\gamma_r)\cdot f_{\gamma_r}(\gamma_r)\,d\gamma_r\\&=\frac{1}{B(m_{sr},u)}\cdot\Big(\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\Big)^{m_{sr}}\cdot\int_0^\infty\gamma_r^{m_{sr}-1}\cdot\exp(-s\cdot\gamma_r)\cdot\Big(1+\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\cdot\gamma_r\Big)^{-m_{sr}-u}d\gamma_r\\&=\frac{1}{B(m_{sr},u)}\cdot\Big(\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\Big)^{m_{sr}}\cdot\Gamma(m_{sr})\cdot\Big(\frac{\overline{\gamma}_{li}}{m_{sr}\cdot v}\Big)^{-m_{sr}}\cdot\Psi\Big(m_{sr};1-u;-\frac{m_{sr}\cdot v\cdot s}{\overline{\gamma}_{li}}\Big),\end{aligned} \quad (19)$$

where $\Psi(\cdot;\cdot;\cdot)$ denotes the Tricomi confluent hypergeometric function [21, Eq. 8.1.10] and the last equality in (19) results from the equality [19, Eq. 3.383.5].

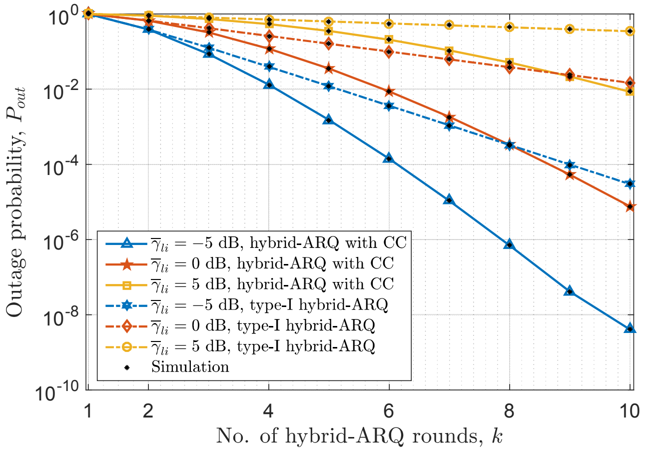


Fig. 2: Outage probability versus the maximum transmission rounds with different loop interference levels for both ARQ schemes.

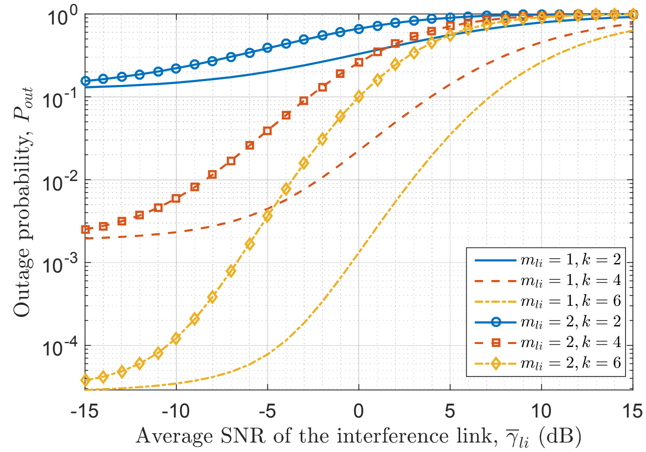


Fig. 3: Outage probability versus average SNR of the loop interference link with different values of $m_{li}$ and $k$ for type-I ARQ.

The MGF $\mathcal{M}_{\mathcal{Y}^{(1,t)}}(s)$ of the RV $\mathcal{Y}^{(1,t)}$ follows immediately from its property on the summation of independent RVs as

$$\mathcal{M}_{\mathcal{Y}^{(1,t)}}(s) = \left[\frac{\Gamma(m_{sr})}{B(m_{sr}, u)} \cdot \Psi\Big(m_{sr}; 1-u; -\frac{m_{sr} \cdot v \cdot s}{\overline{\gamma}_{li}}\Big)\right]^t. \tag{20}$$

It is generally difficult to solve the inverse Laplace transform in (18). Therefore, we apply the Euler summation-based method [22] to obtain a close approximation for the inverse Laplace transform. Then, the CDF $F_{\mathcal{Y}^{(1,t)}}(\cdot)$ of the RV $\mathcal{Y}^{(1,t)}$ is computed as

$$F_{\mathcal{Y}^{(1,t)}}(y) = \sum_{q=0}^{Q} 2^{1-Q}\binom{Q}{q}\Bigg[\sum_{w=0}^{W+q} \frac{e^{\frac{P}{2}}(-1)^w}{\beta_w} \cdot \mathrm{Re}\Bigg\{\frac{\mathcal{M}_{\mathcal{Y}^{(1,t)}}\big(-\frac{P+2\pi j w}{2\cdot y}\big)}{P+2\pi j w}\Bigg\}\Bigg] + \varepsilon(P) + \varepsilon(W,Q), \tag{21}$$

where $\mathrm{Re}\{\cdot\}$ denotes the real part of the complex number, the MGF $\mathcal{M}_{\mathcal{Y}^{(1,t)}}(\cdot)$ is given in (20) and

$$\beta_w = \begin{cases} 2 & \text{if } w = 0 \\ 1 & \text{if } w = 1, \ldots, W+q, \end{cases} \tag{22}$$

and $P$ is an arbitrary parameter controlling the discretization error $\varepsilon(P)$, which is bounded by

$$|\varepsilon(P)| \leq e^{-P}, \tag{23}$$

and the overall truncation error $\varepsilon(W,Q)$ approximates to

$$\varepsilon(W,Q) \simeq e^{\frac{P}{2}} \cdot \sum_{q=0}^{Q} 2^{1-Q}(-1)^{W+q+1}\binom{Q}{q} \cdot \mathrm{Re}\Bigg\{\frac{\mathcal{M}_{\mathcal{Y}^{(1,t)}}\big(-\frac{P+2\pi j(W+q+1)}{2\cdot y}\big)}{P+2\pi j(W+q+1)}\Bigg\}. \tag{24}$$

Finally, utilizing (21) in (16), we can obtain the expression for the probability $\Pr(\mathrm{Tr} = t)$. Substituting the expressions for $\Pr(\mathrm{Tr} = t)$, $\Pr\big(\mathcal{Y}^{(1,k-1)} < 2^R - 1\big)$, and $\Pr\big(\mathcal{X}^{(t,k)} < 2^R - 1\big)$ into (13), we obtain the outage probability of hybrid-ARQ with chase combining over the investigated full-duplex relay network.

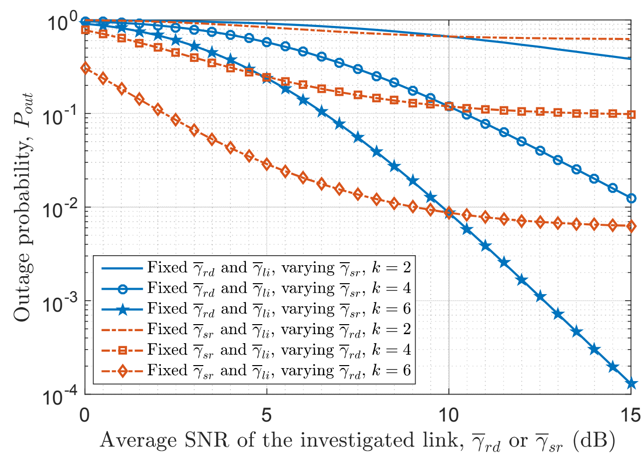


Fig. 4: Outage probability versus average SNR of the investigated link with fixed loop interference level for hybrid-ARQ with CC.

## IV. Numerical Results

In this section, we present the analytical and simulation results for type-I ARQ and hybrid-ARQ with CC over the investigated full-duplex network subject to the loop interference. Unless stated otherwise, the following simulation parameters are used: $m_{sr} = 1$, $m_{rd} = m_{li} = 2$, $\overline{\gamma}_{sr} = \overline{\gamma}_{rd} = 10$ dB, $\overline{\gamma}_{li} = 0$ dB, and $R = 2$ bps/Hz.

Figure 2 shows the outage probability of both ARQ schemes with varying loop interference levels after different ARQ transmission rounds. As expected, the hybrid-ARQ with CC outperforms the type-I ARQ in our investigated system. The performance difference between the two schemes enlarges while the maximum number of transmission rounds $k$ increases or the loop interference level decreases. Fig. 3 illustrates the effects of loop interference link for type-I ARQ. It can be seen that the loop interference degrades the system performance greatly and the system performance can be improved by increasing the number of ARQ transmission rounds and creating a loop interference channel with a lower $m$ value. Similar results are also found for the hybrid-ARQ with CC.

The effects of source-to-relay and relay-to-destination links

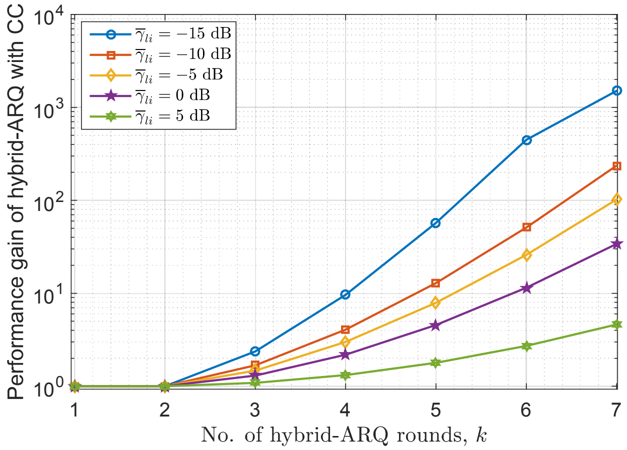


Fig. 5: Outage performance gain of the hybrid-ARQ with CC over the type-I ARQ under different loop interference levels.

with fixed interference level are investigated in Fig. 4 for hybrid-ARQ with CC. Due to the presence of the loop interference received by the transmitting antenna of the relay node, the two investigated links have quite different effects on the system performance. It is observed from the red curves in Fig. 4 that while the average SNR for the relay-destination link grows larger than the average SNR for the source-relay link (10 dB in our setting), the system performance will not improve significantly by further increasing the SNR for the relay-destination link.

Figure 5 displays the outage performance gain of the hybrid-ARQ with CC over the type-I ARQ, which is defined as the ratio between the outage probability for type-I ARQ and that for hybrid-ARQ with CC. It is expected that the hybrid-ARQ with CC should not underperform type-I ARQ in any cases since the former scheme requires additional processing and memory at the receiver side and is more complicated. However, the investigated performance gain will decrease with increasing loop interference level and lower values of the transmission rounds $k$. This indicates that while the interference level is significantly high and the allowed maximum number of ARQ transmission rounds is low, the type-I ARQ might be considered due to its simplicity as well as the possibly low performance gain of using more sophisticated schemes.

## V. Conclusion

In this paper, we have investigated the outage performance of type-I ARQ and hybrid-ARQ with CC over full-duplex network subject to the loop interference. The expressions for the outage probability under the two different ARQ schemes are derived. It is found that the system performance will not be improved significantly by further increasing the SNR for the relay-destination link after it reaches that of the source-relay link. It is observed that the presence of the loop interference significantly degrades the system performance, and in the case of high interference level and low allowed maximum number of ARQ rounds, the type-I ARQ might be considered due to the simplicity of the scheme as well as the possibly low performance gain of using more sophisticated schemes.

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