Outage Probability Performance of Adaptive Cooperative Scheme with Delayed-Feedback

Lili Guo[1(✉)], Ming Xiang Guan[1], and Yang Wang[2]

[1] Department of Electronics Communication Engineering, Shenzhen Institute of Information Technology, Shenzhen 518172, China
{guoll, guanmx}@sziit.edu.cn

[2] Departments of Sino-German, Shenzhen Institute of Information Technology, Shenzhen 518172, China
wangy@sziit.edu.cn

Abstract. In the paper, the Adaptive all Cooperative (AAC) scheme is raised to bring significant improvements in cooperative system property, which is combined self-adaption signal modulation with automatic repeat request. Then we develop the Adaptive scheme to the Adaptive Greedy Cooperative (AGC) scheme using greedy strategy selection, which can obtain the characteristics of cooperative system significantly enhanced with the same cooperative nodes. However, the Adaptive greedy cooperative (AGC) is more sensitive than the AAC under the delayed feedback. We calculated the closed relationship expression between the probability of abnormal outage for AAC and AGC. Considering delayed feedback, we also analyze outage probability of AAC and AGC frames with different retransmission times, delayed time and cooperative users.

Keywords: Cooperation frame · Adaptive modulation · MIMO · Automatic repeat request

1 Introduction

MIMO technology is very well-known, and it can get effective diversity gain with installing several wireless antennas at the signal transmitting terminal and signal receiving terminal. Recently, a reasonable technique to improve the high efficiency of the frequency spectrum has been clearly raised to obtain diversity gain based on the application connection relay cooperation, named cooperative diversity [1–5].

Laneman developed and designed Amplify-Forward cooperative frame, Decoded-Forward cooperative frame, Select wireless Relay cooperative frame and space time coding cooperative frame in [1]. Hunter clearly proposed the code collaboration [5].

Other key work includes the characteristic analysis of cooperative transmission. For example, Hasna analyzed the mean symbol error rate [6, 7] of the cooperative network in the wireless channel of Rayleigh and Nakagami. Reference [8], the closed relationship expression of the interruption probability of the DF system is obtained. Another way to alleviate the adverse effects of the decline of the wireless channels is to use the fully automatic retransmission request on link layer. In other words, transmitter

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must deal with the incorrectly accepted data. Based on the actual situation, in order to decrease the minimum delayed time and buffer area measure, the ARQ protocol has been generally selected to limit the larger retransmission count. Aiming at cooperative transmitting, Dai suggested combining ARQ system and cooperative transmission; also he proposed a cross layer model based on the MIMO that constitutes PHY and the ARQ of link layer [9]. Le further scientifically studied the property of the ARQ cooperative transmission model in the multi-hop network [10].

None of the above-mentioned thesis considers the transmission of variable rates and powers. Recently, the cross-layer design has caused great interest among everyone. The design has mutually improved the actual operation of several protocol layers to achieve significant feature enhancements. Liu clearly proposed the SISO cross-layer model which integrates adapt modulation and auto repeat request using the extreme wireless channel information [11]. The results that cross layered model can obtain stronger characteristics than the layered model are verified by system simulation.

In the paper, we used the cross-layer design principle and applied the shortened ARQ to the adapt MIMO cooperation model, resulting in the adaptive all cooperative frame (AAC). It integrates AM and ARQ based on the feedback of the adapt modulation. In order to further improve the characteristics, we clearly proposed the adaptive greedy cooperative frame (AGC) [12, 13] based on the basic theory of "greed scheduling". The theory only selects one wireless channel standard as the best the wireless relay node is pushed together with the source node. Taking full consideration of the feedback on the delay time in the specific communication environment, we calculated the closed expression of the outage probability of the AAC frame and the AGC frame, and analyzed the effect of the time delay, retransmission count and the cooperative nodes on the system characteristics. It also compares the system capability between the AAC and AGC frames.

Part of this paper is allocated as follows. The second section introduces the system entity model. In the third section, the system characteristics based on the outage probability are analyzed, the fourth section shows the numerical results, and the fifth section gives the conclusions.

2 System Model

There is immediate connection which is combined the source Sn with the target Dn, and there are K reserved connections according to the K wireless relays R_i. The source connection node, the wireless relay connection node and the destination connection node each have only one wireless antenna. The entire transmission must have 2 time ranges: in 1st time range, the data signal x is transmitted to the target Dn, and the data is amplified by the relay Ri in the 2nd time range, and is shared to target node Dn. In the 1st time range, the received data of overall target node Dn and i-th relay node obtained as:

$$r_1 = h_{s,d}x + N_{s,d} \tag{1}$$

$$r_2 = h_{s,i}x + N_{s,i} \tag{2}$$

Among them, $h_{s,i}$ indicates wireless channels between Sn and i-th wireless relay, and $h_{s,d}$ indicates wireless channel between Sn and the target Dn. $N_{s,\ i}$, $N_{s,d}$ are the noise vector values between Sn and the i-th wireless relay node, between Sn and target Dn, and e$\sim$ $CN(0, \sigma^2)$. In the 2nd time range, i-th wireless relay connection will receive the data r2 to increase the magnification using M_i, where $M_i^2 = \frac{P}{P|h_{s,i}|^2 + \sigma^2}$, P is the mean sign energy, and σ^2 is noise standard variance, severally. The second time range must be K time slots for transmission. The signal data received in the target node is indicated as

$$r_3 = M_i h_{i,d} r_2 + e_{i,d} \tag{3}$$

Among them, $h_{i,d}$ indicate the wireless channels between the cooperative user and the target Dn, and $e_{i,d}$ is noise value between the i-th wireless cooperative user and the target node Dn.

To carry out the comparison, we also considered the limit of the overall SNR, as

$$\gamma_{ov} \leq \gamma_{s,d} + \sum_{i=1}^{K} \gamma_i = \gamma_u \tag{4}$$

Among them, $\gamma_i = \min(\gamma_{s,i}, \gamma_{i,d})$, and its basis have been proved to be very accurate in [7].

Unlike [14], we considered two cooperative transmission conditions: AAC frame and AGC frame. The first stipulates that all wireless relay connection nodes transmit data signals together with the source, while the second allows only one wireless relay connection node with the best wireless channel condition to transmit signal. We consider the two mentioned above responsive transmission frames. The overall goal is to receive data signals from the source of the AAC frame and all K cooperative wireless relays. However, for the AGC frame, only one wireless relay user is chose from K cooperative users.

Subsequently, the destination connection node can select the modulation mode according to the channels state information, and feedback the deployment mode to the source Sn. If receiving signals are found incorrectly, the automatic repeat request maker can produce a repeat request based on the feedback to the Sn. Otherwise; retransmission is not required. Similar to [15], it is assumed that the slow transition of the wireless channel and the extreme incorrect check based on the CRC. In order to maintain the simplicity of hardware configuration, it is assumed that the responsive deployment is selected on account of the channel state information of all routing paths, but deployment method of every wireless cooperative routing protocol is not adapted.

Here, considering the AAC frame and the AGC frame under the fading wireless channel condition of IID.

1) AAC frame:
It is assumed that the wireless channel arguments of all cooperative transmission routing paths are all the same and separate.

For the AAC frame in the IID fading channel, the function of probability density with γ_{ub} can be showed as

$$p_{\gamma_{ub}}(\gamma) = \frac{b_0}{\bar{\gamma}_{s,d}} e^{-\frac{\gamma}{\bar{\gamma}_{s,d}}} + \sum_{i=1}^{k} (\frac{2}{\bar{\gamma}})^i b_i \gamma^{i-1} e^{-\frac{2\gamma}{\bar{\gamma}}} / (i-1)! \tag{5}$$

Among them, $b_0 = 1/(1 - \frac{\bar{\gamma}}{2\bar{\gamma}_{s,d}})^k$, $b_i = \frac{(\frac{2}{\bar{\gamma}})^{(k-i)}}{(k-i)!} \frac{\partial^{(k-i)}[(1+\bar{\gamma}_{s,d}s)^{-1}]_{s=-\frac{2}{\bar{\gamma}}}}{\partial s^{(k-i)}}$, the detailed calculation can be found in [16].

2) AGC frame: In order to obtain stronger system characteristics, the AGC frame is considered that, in which the best connection user is selected among K cooperative users, and the signal data is transmitted using the chose relay together with the source node. Let $\gamma_{\max}$ indicate the transmission routing path SNR of the selected wireless relay connection node, and be able to calculate cumulative distribution function of $\gamma_{\max}$ from the c.d.f of the cooperative routing path SNR $\gamma_i = \min(\gamma_{s,i}, \gamma_{i,d})$.

Since there are K replacement cooperative connection nodes, c.d.f can be calculated as

$$F(\gamma_{\max}) = (1 - e^{-\frac{2\gamma}{\bar{\gamma}}})^k \tag{6}$$

Since the random variables $\gamma_{\max}$ and $\gamma_{s,d}$ are separate, the MGF of the overall SNR received at target user can be calculated as.

$$\begin{aligned} MGF_{\gamma_{\text{tot}}}(s) &= MGF_{\gamma_{\max}}(s) \cdot MGF_{\gamma_{s,d}}(s) = (\sum_{nn=0}^{k-1} C_{k-1}^{nn} \frac{2k(-1)^{nn}}{nn+1} \cdot \frac{1}{2 + \frac{\bar{\gamma}}{nn+1}s}) \cdot (\frac{1}{1+\bar{\gamma}_{s,d} \cdot s}) \\ &= \sum_{nn=0}^{k-1} C_{k-1}^{nn} \frac{2k(-1)^{nn}}{nn+1} \frac{1}{2(nn+1)\bar{\gamma}_{s,d} - \bar{\gamma}} \cdot [\frac{(nn+1)\bar{\gamma}_{s,d}}{1+\bar{\gamma}_{s,d} \cdot s} - \frac{\bar{\gamma}}{2 + \frac{\bar{\gamma}}{nn+1}s}] \end{aligned} \tag{7}$$

For the optional cooperation frame, the p.d.f of γ_{ub} is expressed as

$$\tilde{p}_{\gamma_{ub}}(\gamma) = \sum_{n=0}^{k-1} \frac{2kC_{k-1}^{nn}(-1)^{nn}}{2(nn+1)\bar{\gamma}_{s,d} - \bar{\gamma}} [e^{-\frac{\gamma}{\bar{\gamma}_{s,d}}} - e^{-\frac{2(nn+1)\gamma}{\bar{\gamma}}}] \tag{8}$$

Where, $C_{k-1}^{nn} = \frac{(k-1)(k-2)\cdots(k-nn)}{nn!}$. Note that k indicates the total number of replacement wireless relay nodes.

3 Performance Analysis

Based on the cooperation frame and cross-layer basic theories considered above, this section clearly proposes a responsive full cooperation frame (AAC) with all wireless relay connection nodes and a response greed cooperation frame (AGC) only with selected wireless relay connection node. The AGC frame based on "greed productive scheduling" saves a lot of network bandwidth than the AAC frame. And the closing expression of the AAC frame and the AGC frame with the delay time of the feedback is obtained. Because of the delayed feedback, the delayed CSI and the practical CSI have a correlation coefficient $\rho^2 = J_0(2\pi f_d \tau)$, in which J_0 (.) is the first kind of zero-order bessel, and f_d is the largest doppler frequency [17].

1) AAC frame

For the AAC frame with the IID fading wireless channel, the probability analysis of selecting the constellation diagram size $M_n = 2^n$ is expressed as

$$P_n = \int_{\gamma_n}^{\gamma_{n+1}} p_{\gamma_{ub}}(\gamma)d\gamma = b_0(e^{-\frac{\gamma_n}{\bar{\gamma}_{s,d}}} - e^{-\frac{\gamma_{n+1}}{\bar{\gamma}_{s,d}}}) + \sum_{i=1}^{k} b_i(\mathrm{P}_i(\frac{2\gamma_n}{\bar{\gamma}}) - \mathrm{P}_i(\frac{2\gamma_{n+1}}{\bar{\gamma}})) \quad (9)$$

$\mathrm{P}_i(\mu) = e^{-\mu}\sum_{c=1}^{i-1}\frac{\mu^c}{c!}$ is poisson distribution and $p_{\gamma_{ub}}(\gamma)$ is calculated as (5).

Regarding the outdated feedback wireless channel, time delay will endanger the probability of mean incorrect signal. Because only one wireless antenna is configured for each cooperative connection node in the cooperation frame, and thus the MIMO space diversity is obtained, and k + 1 routing paths are regarded as k + 1 wireless antennas. Here instant packet incorrect ratio Per_n under delayed channel condition is resembled to PER in space diversity and Per_n can be shown that:

$$Per_n^{\tau}(\gamma) = A_n(\frac{1}{1 + g_n\bar{\gamma}(1-\rho^2)})^{k+1}\exp(-\frac{g_n\rho^2\gamma}{1 + g_n\bar{\gamma}(1-\rho^2)}) \quad (10)$$

Considering the AAC frame with IID the wireless channel, the mean error rate of packet $\overline{PE^{\tau}}$ in PHY is calculated as

$$\begin{aligned}\overline{PE^{\tau}} = 1/\sum_{n=1}^{N} R_n \cdot \{b_0(e^{-\frac{\gamma_n}{\bar{\gamma}_{s,d}}} - e^{-\frac{\gamma_{n+1}}{\bar{\gamma}_{s,d}}}) + \sum_{i=1}^{k} b_i(\mathrm{P}_i(2\gamma_n/\bar{\gamma}) - \mathrm{P}_i(2\gamma_{n+1}/\bar{\gamma}))\} \\ \times \{\sum_{n=1}^{N} R_n \times (\frac{C(n)b_0}{1+\bar{\gamma}_{s,d}CC(n)}(e^{-\gamma_n(\frac{1}{\bar{\gamma}_{s,d}}+1)CC(n)} - e^{-\gamma_{n+1}(\frac{1}{\bar{\gamma}_{s,d}}+1)CC(n)}) \quad (11) \\ + \sum_{i=1}^{k}\frac{C(n)b_i}{(1+\bar{\gamma}/2CC(n))^i}(\mathrm{P}_i(2\gamma_n/\bar{\gamma} + \gamma_n CC(n)) - \mathrm{P}_i(2\gamma_{n+1}/\bar{\gamma} + \gamma_{n+1}CC(n))))\}\end{aligned}$$

Among them, $C(n) = A_n(\frac{1}{1+g_n\bar{\gamma}(1-\rho^2)})^{k+1} CC(n) = \frac{g_n\rho^2}{1+g_n\bar{\gamma}(1-\rho^2)}$.

Among them, R_n indicates the information content speed of the data signal, using bits per wireless channel, and $R_n = R_c \log_2(M_n) = T_s B$, where T_s is the fixed marked signal transmission time, and B indicates the signaling network bandwidth. It is assumed that the idealized Nyquist data information pulse B = 1/Ts for each constellation mode. For no modulation without forward error correction, $R_c = 1$, so $R_n = \log_2(M_n)$. Taking into account the Nr-automatic repeat request in link layer, data packets that are incorrectly received are likely to be pushed for retransmission, and the largest retransmission frequency is set to Nr. Let $q^\tau = \overline{PE^\tau}$, so the average transmission frequency $\overline{N^\tau}$ is obtained by [12]:

$$\overline{N^\tau} = 1 - (q^\tau)^{N_r + 1} / 1 - (q^\tau) \tag{12}$$

Because there is no data transmission when the received signal noise ratio is less than the threshold value, and considering the ACC frame, the outage probability analysis is

$$P^\tau_{out} \_ N_r = \overline{N^\tau} \bullet \int_0^{\gamma_1} p_{\gamma_{ub}}(\gamma) d\gamma = \overline{N^\tau} \bullet \left\{ 1 - \left[b_0 e^{-\frac{\gamma_1}{\overline{\gamma}_{s,d}}} + e^{-\frac{2\gamma}{\overline{\gamma}}} \sum_{i=1}^{k} b_i \sum_{j=0}^{i-1} \frac{1}{j!} \left(\frac{2\gamma_1}{\overline{\gamma}}\right)^j \right] \right\} \tag{13}$$

2) AGC frame
Considering IID wireless channel, the probability of selecting method n for AGC could be indicated as

$$\begin{aligned} \tilde{P}_n &= \int_{\gamma_n}^{\gamma_{n+1}} \tilde{p}_{ub}(\gamma) d\gamma \\ &= \sum_{nn=0}^{k-1} \frac{2k^{nn}_{k-1}(-1)^{nn}}{2(nn+1)\overline{\gamma}_{s,d} - \overline{\gamma}} \{ \overline{\gamma}_{s,d} (e^{-\frac{\gamma_n}{\overline{\gamma}_{s,d}}} - e^{-\frac{\gamma_{n+1}}{\overline{\gamma}_{s,d}}}) + \frac{\overline{\gamma}}{2(nn+1)} (e^{-\frac{2(nn+1)\gamma_{n+1}}{\overline{\gamma}}} - e^{-\frac{2(nn+1)\gamma_n}{\overline{\gamma}}}) \} \end{aligned} \tag{14}$$

The p.d.f. $\tilde{p}_{ub}(\gamma)$ of the optional cooperation frame is obtained in (8).

Able to obtain the average packet incorrect ratio $\overline{\tilde{P}E^\tau}$ and average ARQ count $\overline{\tilde{N}}$ of the AGC frame, and that is follow as.

$$\overline{\tilde{P}E^{\tau}} = 1/\{\sum_{n=1}^{N} R_n \cdot \sum_{nn=0}^{k-1} \frac{2B(n)kC_{k-1}^{nn}(-1)^{nn}}{2(nn+1)\overline{\gamma}_{s,d} - \overline{\gamma}}[\overline{\gamma}_{s,d}(e^{-\gamma_n/\overline{\gamma}_{s,d}} - e^{-\gamma_{n+1}/\overline{\gamma}_{s,d}})$$
$$+ \overline{\gamma}/(2nn+2) * (e^{-2(nn+1)\gamma_{n+1}/\overline{\gamma}} - e^{-2(nn+1)\gamma_n/\overline{\gamma}})]\}$$
$$\times \left\{\sum_{n=1}^{N} R_n \times \sum_{nn=0}^{k-1} \frac{2B(n)kC_{k-1}^{nn}(-1)^{nn}}{2(nn+1)\overline{\gamma}_{s,d} - \overline{\gamma}} \right. \tag{15}$$
$$\times (\frac{e^{-(BB(n)+\overline{\gamma}_{s,d}^{-1})\gamma_n} - e^{-(BB(n)+\overline{\gamma}_{s,d}^{-1})\gamma_{n+1}}}{BB(n)+\overline{\gamma}_{s,d}^{-1}}$$
$$\left. + \frac{e^{-(BB(n)+2(nn+1)\overline{\gamma}^{-1})\gamma_{n+1}} - e^{-(BB(n)+2(nn+1)\overline{\gamma}^{-1})\gamma_n}}{BB(n)+2(nn+1)\overline{\gamma}^{-1}}) \right\}$$

$$\overline{\tilde{N}} = 1 - (\tilde{q}^{\tau})^{N_r+1}/(1-(\tilde{q}^{\tau})) \tag{16}$$

Where $B(n) = A_n(\frac{1}{1+g_n\overline{\gamma}(1-\rho^2)})^2$, $BB(n) = \frac{g_n\rho^2}{1+g_n\overline{\gamma}(1-\rho^2)}$.

The outage probability of the AGC frame is

$$\tilde{P}_{out}^{\tau}(N_r) = (\overline{\tilde{N}}) \cdot \int_0^{\gamma_1} \tilde{p}_{\gamma_{ub}}(\gamma)d\gamma$$
$$= \{\sum_{nn=0}^{k-1} \frac{2kC_{K-1}^{nn}(-1)^{nn}}{2(nn+1)\overline{\gamma}_{s,d} - \overline{\gamma}}(\overline{\gamma}_{s,d}e^{-\frac{\gamma_1}{\overline{\gamma}_{s,d}}} - \frac{\overline{\gamma}}{2(nn+1)}e^{-\frac{2(nn+1)\gamma_1}{\overline{\gamma}}}) \tag{17}$$
$$- \sum_{nn=0}^{k-1} \frac{2kC_{k-1}^{nn}(-1)^{nn}}{2(nn+1)\overline{\gamma}_{s,d} - \overline{\gamma}}(\overline{\gamma}_{s,d} - \frac{\overline{\gamma}}{2(nn+1)})\} \cdot \overline{\tilde{N}}$$

It must be noted that when the time delay is 0, the characteristics of the clearly proposed AAC and AGC frames can be obtained again by incorporating the formula calculations without the feedback delay time.

4 Numerical Results

In the section, we get simulation results for AAC frame and AGC frame on the Rayleigh fading wireless channel. The marked value result shows the characteristics of the ACC frame and AGC frame with IID wireless channel. It is considered that P_{loss} = 0.0001, the largest count of ARQ can be used is N_r = 2, and the count of collaborative users k = {1, 2, 3, 5}. For the specific communication environment, the data file the length is $N_p = 4096bits$ [18]. Let $\overline{\gamma}_{sd} = \overline{\gamma}$.

Figure 1 compares the probability of outage of the ACC frame IID and the ACC frame no IID accompanying the change with the delay time of feedback. We can observe that when K = 2, the outage characteristics of ACC (IID) are better than ACC (Non-IID), but the delay threshold of ACC (IID) is smaller, in other words, the ACC (IID) is more vulnerable to delay time.

Figure 2-Fig. 3 describes the outage probability of the AGC frame with different K and Nr and no delay time and delay time feedback. It can be seen from Fig. 2 that the AGC frame with K = 5 has a better probability of outage than the AGC frame with

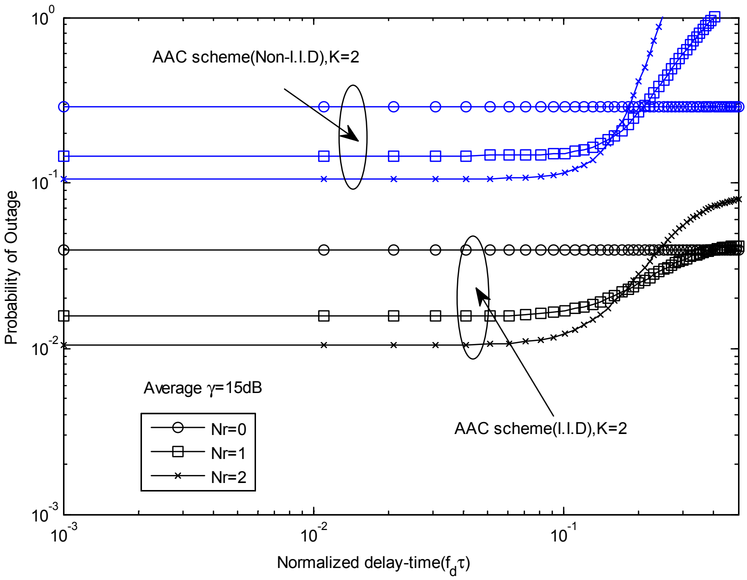

Fig. 1. Influence of delayed time on outage probability for AAC frame

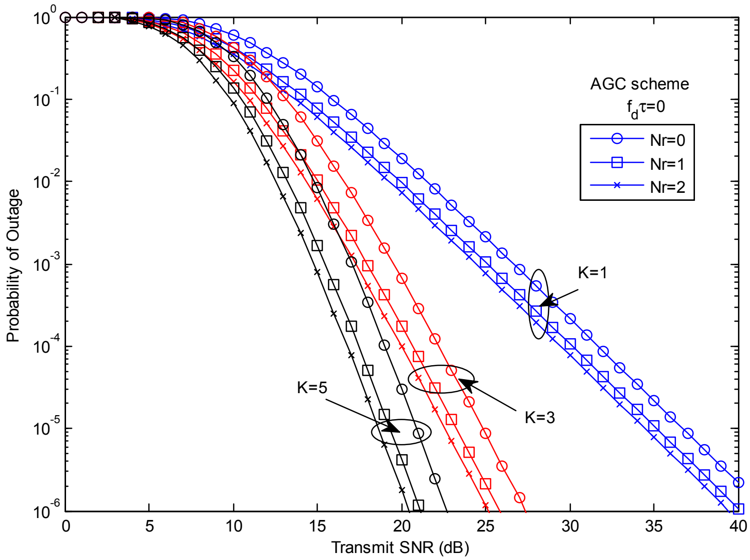

Fig. 2. Probability of outage for AGC frame with k and N_r under no delayed

K = 1 and K = 3. And with the increase of retransmission time, the AGC frame can get stronger probability of outage when N_r is 2.

Figure 3 compares the AGC frame and the ACC frame. It can be observed that the ACC frame with K = 3 has a stronger probability feature of outage. It is better than the K = 3 AGC frame. However, the probability of outage for the AGC frame with K = 5 is better than that for the ACC frame with K = 3. Therefore, we can choose the AGC frame with K = 5 to get a stronger performance of delay time feedback.

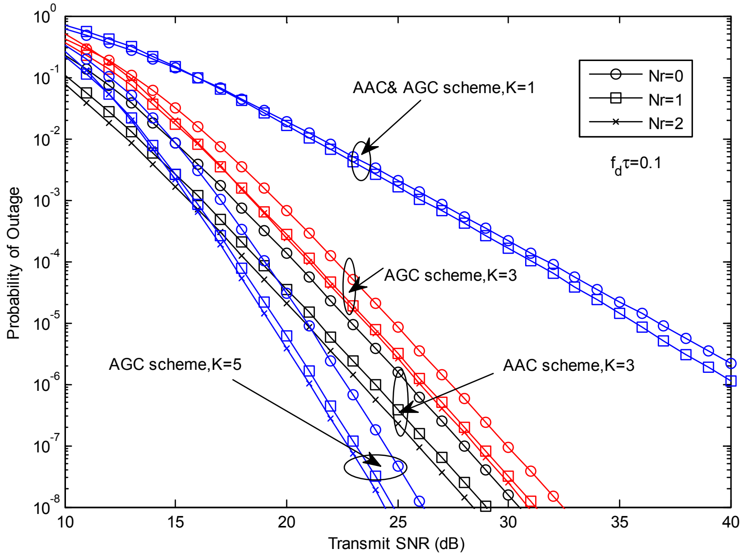

Fig. 3. Probability of outage for ACC and AGC with different k and N_r at $f_d\tau = 0.1$

Figure 4 illustrates that the probability of outage for the AGC frame when k = 1, 3, 5 is compromised under outdated channel time. In Fig. 4, we can observe that when the delayed time is large, automatic repeat request can reduce outage probability of AGC frame by a large number of cooperative nodes. Similarly, when there are a large number of collaborative nodes, the AGC probability of outage will also decrease. From Fig. 4, it is found that the AGC system with K = 5 is almost immune to the time delay.

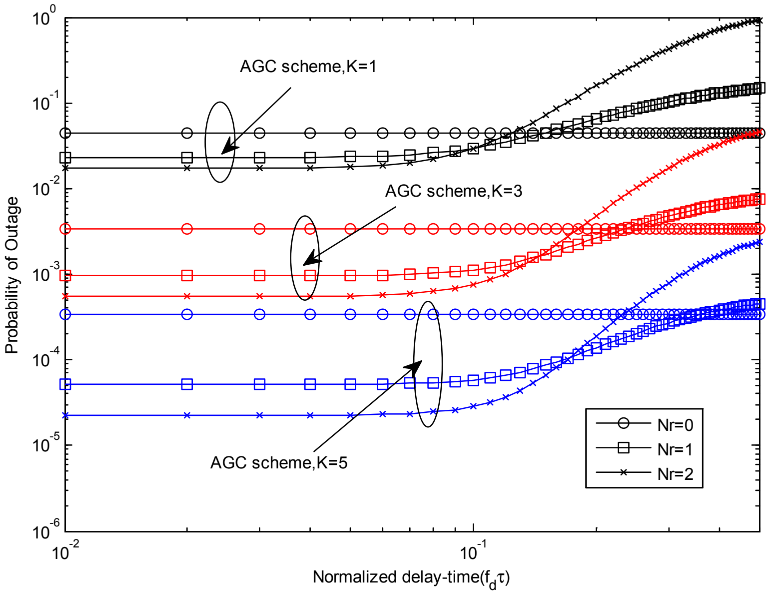

Fig. 4. Influence of delayed time on outage probability for AGC at $\bar{\gamma}$ = 15 dB

5 Conclusion

In the paper, the two responsive cooperation frames (AAC and AGC) are clearly proposed; and they both will have the AM application on the physical layer of the cooperative system and automatic repeat request system on link layer. The AAC frame stipulates that all wireless relay connection nodes participate in transmission, while the AGC frame only selects a wireless relay with the best wireless channel condition because of "greed for production scheduling". We calculated the closed relationship expression between the probability of abnormal outage for AAC and AGC. The marked value results show that the characteristics of cooperative system can be significantly enhanced by ARQ. For the same collaborative nodes, AGC has a greater probability of outage; however, it is not particularly sensitive to the time delay under the feedback of the delay time. Compared with other frames, the AGC frame with K = 5 has stronger outage probability. In fact, we can choose suitable transmission frames with different requirements in different natural environments.

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