Throughput Adaptation and Traffic Ratio Control in Cooperative Relay Networks with Network Coding and Asymmetric Traffic

Lin Shan†, Sonia Aïssa‡, Hidekazu Murata†, Susumu Yoshida†

† Graduate School of Informatics, Kyoto University, Kyoto, Japan
‡ INRS-EMT, University of Québec, Montreal, QC, Canada
Email: †contact-h24e@hanase.kuee.kyoto-u.ac.jp ‡ aissa@emt.inrs.ca

***Abstract*—Adaptive traffic ratio control (ATRC) with hybrid network coding and cooperative relaying is proposed to improve the overall throughput in an asymmetric data traffic network. The scheme is used in conjunction with adaptive transmission protocol and relay selection based on instantaneous channel state information. Simulation results show that (i) ATRC provides better trade-off between achieved throughput and traffic ratio and (ii) both maximum throughput and guaranteed traffic ratio can be simultaneously achieved by ATRC as offered traffic approaches symmetric.**

***Index Terms*—cooperative relaying, network coding, joint relay and protocol selection, asymmetric traffic, adaptive traffic ratio control**

I. Introduction

Cooperative relaying (CoR) and network coding (NC) are promising techniques for bidirectional communications. In CoR protocol, neighboring stations cooperate with a source station to transfer data towards the destination, in order to achieve spatial diversity and thereby improve the system throughput [1]. At the same time, network coding (NC), which allows for reducing the number of transmission time slots relative to the number of slots in CoR, has been extensively studied to improve the performance of wireless networks. Spatial diversity gains can also be achieved by the NC protocol through overhearing such as in MAC-layer XOR NC (MXNC) which uses time-division access over three transmission slots [2], [3].

In [4], PHY-layer NC over two transmission slots was introduced, in which a relay station has to process multiple signals that are transmitted simultaneously from source stations. In this paper, we assume that a relay station can only process one signal at any given time as in the cases of MXNC and CoR.

In NC-based bidirectional communication networks, asymmetric data traffic conditions might cause a significant decrease in the bidirectional total throughput [5]. In order to solve the problem, one solution is to design an optimal resource scheduling scheme using long-term averages of future channel state information (CSI). In mobile radio environments, however, future CSI is unavailable; thus it is impossible to use the scheme in such environments. Recently, an adaptive transmission protocol selection (PS) scheme has been proposed to improve throughput for asymmetric traffic [5], [6]. The scheme involves the concept of adaptive proportional fair scheduling (APFS), which achieves reasonable trade-off between throughput and fairness in multiuser networks [8].

Distributed relay selection (RS) based on decode-and-forward (DF) has been proposed to maximize the achievable rate in unidirectional networks [9], [10]. In this scheme, the best relay is selected depending on the end-to-end instantaneous CSI.

Since the PS and the RS could individually improve the performance of cooperative relay networks, combining both techniques could further improve the performance of bidirectional networks. In this paper, we propose a novel joint PS and RS (JPSRS) scheme to improve the overall throughput under asymmetric data traffic conditions in a network with multiple relays. The scheme involves the consideration of instantaneous CSI. In the JPSRS scheme, the trade-off between throughput and traffic ratio can be controlled by adjusting the traffic ratio control (TRC) parameters. For such control, two approaches are proposed to adjust the parameters: fixed TRC and adaptive TRC.

The remainder of this paper is organized as follow. Section II describes the system model, and Section III details the proposed JPSRS scheme. Section IV presents simulation results followed by the concluding remarks in Section V.

II. Network Model

We consider a bidirectional cooperative relay network consisting of two different sources (transceiver pair) and M relays. As shown in Fig. 1, S_1, S_2, and R_m denote the first source, second source, and mth relay ($m = 1, ..., M$), respectively. We assume that each station is equipped with an omnidirectional antenna and operates in a half-duplex mode. All stations are assumed to have the same transmit power and have perfect CSI of each communication link. We refer to the communication from S_1 to S_2 as forward transmission and that in the reverse direction as backward transmission.

Transmission Protocols: We consider that protocols of MXNC for bidirectional transmission, CoR for forward transmission (CoRF), and CoR for backward transmission (CoRB)

978-1-4673-1881-5/12/$31.00 ©2012 IEEE

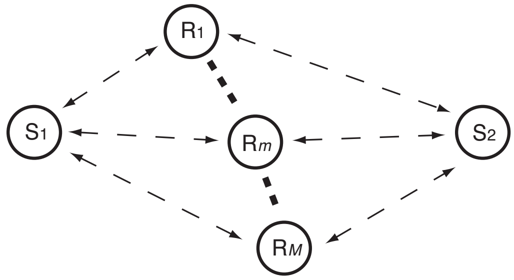

Fig. 1. Model of bidirectional communication with multiple relays.

can be adopted at the relays. For the MXNC protocol, time division access over three transmission slots is used in bidirectional transmission. In the first and second slots, each R_m receives the signals from S_1 and S_2 separately, and S_2 (S_1) can overhear a signal from S_1 (S_2). Then in the third slot, the selected relay (with index m^*) combines the received packets from S_1 and S_2 through XOR operation, and transmits to S_1 and S_2 simultaneously. Note that the selected relay m^* for each protocol must accurately decode the signals from S_1 and S_2. For the CoRF protocol based on DF, each R_m receives a signal from S_1 in the first slot, and S_2 can overhear the signal from S_1. Then in the second slot, only the selected relay (with index m^*) transmits to S_2 while S_1 remains silent. We consider that the transmission protocol and relay can be determined by S_1 and S_2 on the basis of CSI.

Traffic model: We assume a full buffer traffic model in which S_1 (S_2) has packets awaiting transmission to S_2 (S_1). The maximum possible system throughput can be evaluated for the full buffer traffic model, reflecting the cooperative diversity gain and NC gain on the throughput performance. We consider an offered traffic ratio as a constraint on the bidirectional traffic between forward and backward transmissions, and the achieved traffic ratio should match the offered traffic ratio as closely as possible.

III. Proposed Joint Protocol and Relay Selection Scheme and Traffic Ratio Control

A. Joint Protocol and Relay Selection Scheme

In this paper, we propose a novel joint protocol and relay selection (JPSRS) scheme in which the best transmission protocol and the best relay are jointly selected depending on four parameters: instantaneous data rate, average achieved data rate, offered traffic ratio, and TRC parameter.

In the proposed JPSRS scheme, three transmission protocols are chosen as candidates: MXNC for bidirectional transmission, CoR for forward transmission (CoRF), and CoR for backward transmission (CoRB). The scheduler attempts to select a transmission protocol with high transmission rate to maintain the total bidirectional throughput at a high value and to match the achieved traffic ratio with the offered traffic ratio as closely as possible. The proposed scheme takes advantage of the concept of adaptive proportional fairness scheduling (APFS). The latter cannot be directly applied to a NC-based bidirectional transmission protocol. Therefore, we develop a novel utility function for NC-based protocol.

Let $\mathcal{F}_{p,m}(n)$, $p \in \{\text{MXNC, CoRF, CoRB}\}$ and $m \in \{1, ..., M\}$, denote utility functions, defined as shown in (2) below. The selection criterion of the proposed JPSRS scheme is to maximize $\mathcal{F}_{p,m}(n)$ for every transmission frame n, where we assume block Rayleigh fading channels (fading channel state remains constant within transmission of each frame) and transmission protocols are determined by the scheduler for every frame. The selected protocol p^* and the selected relay m^* are jointly determined as follows:

$$(p^*, m^*) = \underset{\substack{p\in\{\text{MXNC, CoRF, CoRB}\}\\ m\in\{1,\ldots,M\}}}{\arg\max} \left\{\mathcal{F}_{p,m}(n)\right\}. \tag{1}$$

Inspired by the proportional fairness scheduling (PFS) [7] and APFS [8] utility functions, $\mathcal{F}_{p,m}(n)$ is defined as the ratio of the instantaneous data rate to the average achieved data rate via relay m using transmission protocol p at transmission frame n, according to

$$\begin{aligned}
\mathcal{F}_{\text{MXNC},m}(n) &= \frac{\left(R^*_{\text{MXNCF},m}(n) + R^*_{\text{MXNCB},m}(n)\right)^{\beta_{\text{MXNC}}}}{\overline{R}_{S_1S_2}(n) + \overline{R}_{S_2S_1}(n)}\\
\mathcal{F}_{\text{CoRF},m}(n) &= \frac{\left(R^*_{\text{CoRF},m}(n)\right)^{\beta_{\text{CoRF}}}}{(1+1/k)\,\overline{R}_{S_1S_2}(n)}\\
\mathcal{F}_{\text{CoRB},m}(n) &= \frac{\left(R^*_{\text{CoRB},m}(n)\right)^{\beta_{\text{CoRB}}}}{(1+k)\,\overline{R}_{S_2S_1}(n)},
\end{aligned} \tag{2}$$

where $R^*_{\text{MXNCF},m}(n) + R^*_{\text{MXNCB},m}(n)$ is the sum of the instantaneous maximum forward and backward rates of frame n, by MXNC via relay m. $R^*_{\text{CoRF},m}(n)$ and $R^*_{\text{CoRB},m}(n)$ are the instantaneous maximum forward and backward rates of frame n, by CoR via relay m. Further, β_p, $p \in \{\text{MXNC, CoRF, CoRB}\}$ are the aforementioned TRC parameters, which can be used to control the trade-off between the throughput and the traffic ratio. In the above, k denotes the offered traffic ratio of forward data rate to backward data rate. The adjustment of the TRC parameters will be explained in Section III.B. Besides, $\overline{R}_{S_1S_2}(n)$ and $\overline{R}_{S_2S_1}(n)$ are the average achieved forward and backward data rates, respectively.

The updating of $\overline{R}_{S_1S_2}(n)$ and $\overline{R}_{S_2S_1}(n)$ is similar to the case of PFS [7], except for the applicable situation which is different in our case. The average achieved data rates $\overline{R}_{S_1S_2}(n)$ and $\overline{R}_{S_2S_1}(n)$ are updated at each frame n according to

$$\begin{aligned}
\overline{R}_{S_1S_2}(n+1) &= \left(1 - \frac{1}{L}\right)\overline{R}_{S_1S_2}(n) + \frac{1}{L}\Delta_{S_1S_2}(n)\\
\overline{R}_{S_2S_1}(n+1) &= \left(1 - \frac{1}{L}\right)\overline{R}_{S_2S_1}(n) + \frac{1}{L}\Delta_{S_2S_1}(n),
\end{aligned} \tag{3}$$

where L is the average time window size over which throughput ratio in both directions is reflected, taken as 1000 frames

[8], and we have:

$$\Delta_{S_1S_2}(n) = \begin{cases} R^*_{\mathrm{MXNCF},m^*}(n) \\ \text{if protocol MXNC and relay } m^* \text{ are chosen,} \\ R^*_{\mathrm{CoRF},m^*}(n) \\ \text{if protocol CoRF and relay } m^* \text{ are chosen,} \\ 0 \\ \text{if protocol CoRB and relay } m^* \text{ are chosen,} \end{cases} \tag{4}$$

$$\Delta_{S_2S_1}(n) = \begin{cases} R^*_{\mathrm{MXNCB},m^*}(n) \\ \text{if protocol MXNC and relay } m^* \text{ are chosen,} \\ 0 \\ \text{if protocol CoRF and relay } m^* \text{ are chosen,} \\ R^*_{\mathrm{CoRB},m^*}(n) \\ \text{if protocol CoRB and relay } m^* \text{ are chosen.} \end{cases} \tag{5}$$

We elaborate the desirable properties of our proposed scheduling scheme. The scheduler attempts to select the transmission protocol with a high transmit rate to keep the bidirectional total throughput high as well as to keep the offered traffic ratio k by exploiting the advantages of PFS. In the following, we explain how the offered traffic ratio k is guaranteed.

First, let us consider the case that the achieved traffic ratio is less than k, which means the forward transmission is not being sufficiently serviced. In this case, it is quite possible that protocol CoR was chosen for backward transmission most recently. Then, $\Delta_{S_1S_2}(n) = 0$ by (4). Hence, the achieved average rate on the forward link, $\overline{R}_{S_1S_2}(n+1)$, is decreased by the scheduler as shown in (3). Thus, $\mathcal{F}_{\mathrm{CoRF},m}(n+1)$ increases by (2), which means the scheduler is more likely to select CoR for the forward transmission. As a result, the forward link transmission will be served in the next transmission frame. In the same way, the backward link transmission will be served if the achieved traffic ratio is higher than k.

B. Traffic Ratio Control: Adjusting TRC Parameter

The aim of the proposed TRC adaptation is to make the achieved traffic ratio equal to the offered traffic ratio and maintain the bidirectional throughput at a high level. Herein, we define the achieved traffic ratio, k_{ach}, as the ratio of the average achieved forward data rate to backward data rate.

The trade-off between the throughput and traffic ratio can be controlled by adjusting the value of TRC parameter β_p in (2). In the proposed JPSRS scheme, we consider two approaches for adjusting the TRC parameters.

(i) Fixed TRC: In our previous study, we assumed $\beta_{\mathrm{MXNC}} = \beta_{\mathrm{CoRF}} = \beta_{\mathrm{CoRB}} = \beta$ in the PS scheme for a single-relay network without considering relay selection [6]. We extend fixed TRC to JPSRS for a network with multiple relays.

(ii) Adaptive TRC: This is a novel approach, detailed as follows. Adaptive and individual updating of TRC parameter can achieve better trade-off between the throughput and traffic ratio. Indeed, increasing the value of β_p can increase the probability of selecting protocol p, and conversely decreasing the value of β_p decreases the probability of selecting protocol p. The updating of β_p is necessary when the achieved traffic ratio k_{ach} is not close to the offered traffic ratio k, i.e., $|k_{\mathrm{ach}} - k| > \Delta k$, where Δk is a tuning parameter that defines the allowance limit (permissible difference) between the offered traffic ratio and the achieved traffic ratio.

To achieve an offered traffic ratio, we consider an updating of each β_p is performed if the achieved traffic ratio k_{ach} has reached a stationary state. If $|k_{\mathrm{ach}}(n) - k_{\mathrm{ach}}(n-1)| < \delta$, then this indicates that k_{ach} has reached a stationary state, where δ is a system parameter which is decided by the system operator. A small value of δ results a long-term but precise decision, while a large value of δ results a short-term but rough decision. When the stationary state of k_{ach} is reached, the TRC parameter β_p is updated using the following rule:

$$\begin{cases} \beta_{\mathrm{MXNC}} = \beta_{\mathrm{MXNC}} + \Delta\beta, & \text{if } |k_{\mathrm{ach}} - k| \le \Delta k \\ \beta_{\mathrm{MXNC}} = \beta_{\mathrm{MXNC}} - \Delta\beta, & \text{if } |k_{\mathrm{ach}} - k| > \Delta k \\ \beta_{\mathrm{CoRF}} = \beta_{\mathrm{CoRF}} + \Delta\beta, & \text{if } k_{\mathrm{ach}} - k \le -\Delta k \\ \beta_{\mathrm{CoRF}} = \beta_{\mathrm{CoRF}} - \Delta\beta, & \text{if } k_{\mathrm{ach}} - k > \Delta k \\ \beta_{\mathrm{CoRB}} = \beta_{\mathrm{CoRB}} + \Delta\beta, & \text{if } k_{\mathrm{ach}} - k > \Delta k \\ \beta_{\mathrm{CoRB}} = \beta_{\mathrm{CoRB}} - \Delta\beta, & \text{if } k_{\mathrm{ach}} - k \le -\Delta k \end{cases} \tag{6}$$

where $\beta_p \ge 0$. The choice of $\Delta\beta$ depends on the speed of convergence requirement. Indeed, by increasing the value of $\Delta\beta$, faster convergence to the offered traffic ratio k can be achieved but with more oscillations around this value. In our simulations, we assume $\Delta\beta = 0.1$ in order to avoid these oscillations. The smaller the value of Δk, the smaller is the discrepancy between the offered traffic ratio k and the achieved traffic ratio k_{ach}.

Next, we discuss how to make the achieved traffic ratio k_{ach} equal to the offered traffic ratio k using this traffic ratio control algorithm. For example, if $k_{\mathrm{ach}} - k > \Delta k$, this means that the backward transmission is not being sufficiently served. Then, β_{CoRB} is updated to $\beta_{\mathrm{CoRB}} + \Delta k$, β_{CoRF} is updated to $\beta_{\mathrm{CoRF}} - \Delta k$, and β_{MXNC} is updated to $\beta_{\mathrm{MXNC}} - \Delta k$. The selection probability of backward transmission using CoRB increases with increasing β_{CoRB} while the selection probability of forward transmission using CoRF and MXNC decreases with decreasing β_{CoRF} and β_{MXNC}. Hence, achieved data rate of the forward transmission increases and that of backward transmission decreases after the updating of β_p. Consequently, the achieved traffic ratio k_{ach} becomes close to the offered traffic ratio k.

IV. Simulation Results

In this section, we show simulation results for the proposed JPSRS with fixed TRC (JPSRS/F) and with adaptive TRC (JPSRS/A). We consider a block Rayleigh fading channel model with independent channel realizations and assume path loss with exponent α. The wireless channels of the forward

TABLE I
SIMULATION PARAMETERS.

Parameters	Values
Path loss exponent α	3
Channel model	Block Rayleigh fading
Area environment	Noise-limited
Number of relays	1, 5, 10, 30
Scheduler's parameter β	0.01, 0.1, 10

TABLE II
COMPARISON OF CONVENTIONAL SCHEMES AND PROPOSED SCHEMES.

Schemes	Throughput	Traffic ratio control
MXNC/MTS [2]	maximum	unavailable
MXNC/FS [6]	• medium in the case of symmetric traffic • minimum in the case of asymmetric traffic	inflexible
MXNC/PFS	unavailable	
CoR/MTS [5]	low	unavailable
CoR/FS [6]	equal to CoR/MTS	inflexible
CoR/PFS [11]	equal to CoR/MTS	flexible
JPSRS/F JPSRS/A (in this work)	adjustable	flexible

transmission link and backward transmission link, between two stations, are assumed mutually identical within each bidirectional transmission frame. For the sake of simplicity, the effect of shadowing is not considered. Furthermore, for a fair comparison between the different schemes, equal average transmission power is considered in the compared protocols. Table I summarizes the parameters used in the following evaluation.

We evaluate and compare the throughput performance of the proposed JPSRS with three conventional schemes: MXNC with maximum bidirectional throughput scheduling (MXNC/MTS) [2] in which bidirectional throughput using MXNC protocol can be maximized, MXNC with fixed scheduling (MXNC/FS) [5] and CoR with fixed scheduling (CoR/FS) [6], in which the offered traffic ratio k can be perfectly guaranteed by applying FS. A comparison of the proposed JPSRS and conventional schemes is shown in Table II, and a detailed evaluation is presented below.

In the simulations, we assume that the relays are uniformly and randomly located on a straight line between transceivers S_1 and S_2. Rayleigh channel coefficient between two stations is assumed to be independent at each transmission frame and fixed over each frame. We define the throughput gain as $G_{\hat{p}} = R_{\hat{p}}/R_{\mathrm{DT}}$, where R_{DT} denotes the bidirectional throughput for the direct transmission (DT) without relaying, $R_{\hat{p}}$ denotes the bidirectional throughput for protocol $\hat{p}$, where $\hat{p} \in$ {JPSRS/F, JPSRS/A, MXNC/MTS, MXNC/FS, CoR/FS}. When the end-to-end SNR = 2dB, the average throughput (Shannon capacity) for DT is 1.37 bps/Hz.

Figures 2 (a) and (b) show the effect of the offered traffic ratio k and TRC parameter β_p on the throughput gain and achieved traffic ratio, when the total number of relays is assumed to be 10. In our proposed scheme, the trade-off between the throughput and the traffic ratio can be controlled

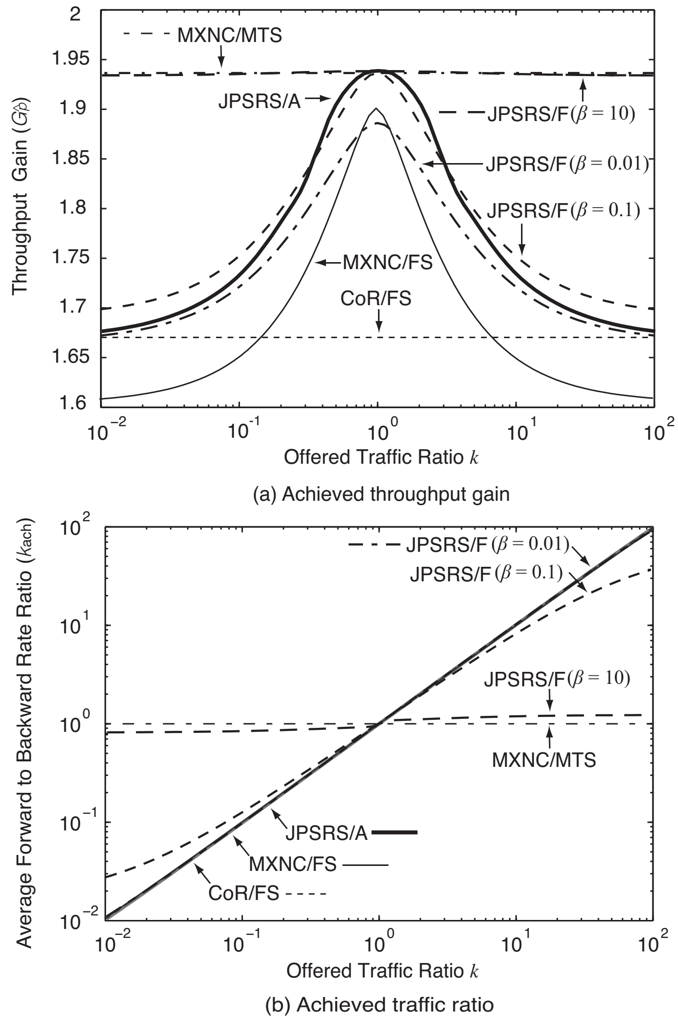

Fig. 2. Throughput gain vs. traffic ratio for the case with end-to-end SNR = 2 dB and the total number of relays M = 10, where the average duration in the simulation is 10000 frames.

by adjusting the TRC parameter β_p. In fact, the choice of $\beta_p \to 0$ makes the utility function $\mathcal{F}_n(p,m)$ equivalent to the selection metric based only on the average achieved data rate $\overline{R}(n)$ and the offered traffic ratio k, thus ignoring the instantaneous maximum data rate and cooperative diversity (relay selection). A value of $\beta_p \to \infty$ results in the utility used in the instantaneous maximum rate $R^*(n)$ regardless of the offered traffic ratio k. Thus, a choice of β_p between these two extreme cases helps in achieving a reasonable trade-off between the throughput and traffic ratio even in asymmetric data traffic conditions.

Therefore, when the throughput performance of the system is required to be high regardless of the traffic ratio constraint, the maximum throughput gain can be achieved by assigning a large value to β. For instance, JPSRS/F with β = 10 as shown in Fig. 2 (a). On the other hand, the offered traffic ratio can be guaranteed by assigning a small value to β. For instance, JPSRS/F with β = 0.01 when the system has serious constraint on the offered traffic ratio, as shown in Fig. 2 (b).

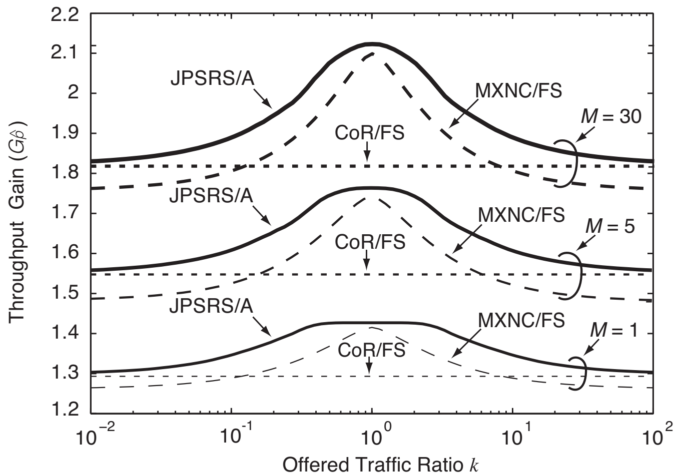

Fig. 3. Throughput gain vs. traffic ratio for the case with end-to-end *SNR* = 2 dB and various numbers of relays M.

However, in order to guarantee the offered traffic ratio, the throughput performance of JPSRS/F decreases with decreasing β. The proposed JPSRS/A, on the other hand, can match the offered traffic ratio as well as achieve higher throughput gain than JPSRS/F, for instance with $\beta = 0.01$. When the offered traffic ratio approaches the symmetric traffic ratio, the throughput can be maximized and the traffic ratio can be guaranteed simultaneously by the JPSRS/A, as shown in Fig. 2.

The average throughput gain for various numbers of relays is shown in Fig. 3. The proposed JPSRS/A provides better trade-off between the throughput and the traffic ratio compared to MXNC/FS and CoR/FS in a network with multiple relays. The benefits of cooperative diversity increase with the number of available relays, although cooperative relaying uses only a single relay (the best) in our case.

V. Conclusion

We proposed an adaptive throughput and traffic ratio control mechanism to improve the overall throughput for networks under bidirectional asymmetric traffic conditions. In conjunction with the adaptive scheme for protocol and relay selection, adaptive traffic ratio control can provide better trade-off between throughput and traffic ratio; in some cases, the throughput can be maximized and the traffic ratio can be guaranteed simultaneously.

Acknowledgments

This work is supported in part by a Grant-in-Aid for Scientific Research (A) (no. 20246067) from the Japan Society for the Promotion of Science (JSPS). The first author would like to thank Prof. A. Anpalagan of Ryerson University, Canada, Prof. Yamamoto Koji and Prof. Liang Zhao of Kyoto University, for their valuable comments.

References

[1] J. N. Laneman, D. N. C. Tse, and G. W. Wornell, "Cooperative diversity in wireless networks: Efficient protocols and outage behavior," IEEE Trans. Inform. Theory, vol. 50, no. 12, pp. 3062–3080, Dec. 2004.

[2] S. J. Kim, P. Mitran, and V. Tarokh, "Performance bounds for bidirectional coded cooperation protocols," IEEE Trans. Inform. Theory, vol. 54, pp. 5235–5241, Nov. 2008.

[3] F. Xue, C. H. Liu, and S. Sandhu, "MAC-layer and PHY-layer network coding for two-way relaying: achievable rate regions and opportunistic scheduling," Proc. IEEE Allerton Conf. on Commun., Control and Computing, pp. 396–402, Sept. 2007.

[4] R. H. Y. Louie, Y. Li, and, B. Vucetic, "Practical physical layer network coding for two-way relay channels: performance analysis and comparison," IEEE Trans. on Wireless Commun., vol. 9, no. 2, pp. 764–777, Feb. 2010.

[5] L. Shan, H. Murata, S. Aïssa, and S. Yoshida, "Hybrid network coding and cooperative relaying schemes for bi-directional communication systems," Proc. of the 73rd IEEE Vehicular Technology Conference (VTC2011-Spring), Budapest, Hungary, May 2011.

[6] L. Shan, H. Murata, S. Aïssa, and S. Yoshida, "Opportunistic scheduling for hybrid network coding and cooperative relaying techniques in wireless networks," IEICE Trans. on Commun. vol. E95-B, no. 5, pp. 1751–1760, May 2012.

[7] P. Viswanath, D. N. C. Tse, and R. Laroia, "Opportunistic beamforming using dumb antennas," IEEE Trans. Inf. Theory, vol. 48, no. 6, pp. 1277–1294, Jun. 2002.

[8] G. Aniba and S. Aïssa, "Adaptive scheduling for MIMO wireless networks: Cross-layer approach and application to HSDPA," IEEE Trans. on Wireless Commun., vol. 6, no. 1, pp. 259–268, Jan. 2007.

[9] A. Bletsas, A. Khisti, D. P. Reed, and A. Lippman, "A simple cooperative diversity method based on network path selection," IEEE Journal on Selected Areas in Communications, vol. 24, no. 3, pp. 659–672, 2006.

[10] S. Abdulhadi, M. Jaseemuddin, and A. Anpalagan, "A survey of distributed relay selection schemes in cooperative wireless ad hoc networks," Wireless Personal Commun., vol. 63, no. 4, pp. 917–935, April 2012.

[11] T. Saeki, K. Yamamoto, H. Murata, and S. Yoshida, "Impact and use of the asymmetric property in bidirectional cooperative relaying under asymmetric traffic conditions," IEICE Trans. Commun., vol. E93-B, no. 8, pp. 2126–2134, Aug. 2010.