Cross-Layer Design for Packet Retransmission Control Based on Superposition Modulation with Soft Combining

Shintaro Mori 1, Koji Ishii 2 and Shigeaki Ogose 2

1 Department of Electronics Engineering and Computer Science, Faculty of Engineering, Fukuoka University
8-19-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, Japan
2 Department of Electronics and Information Engineering, Faculty of Engineering, Kagawa University
2217-20 Hayashi, Takamatsu, Kagawa 761-0396, Japan
E-mail: 1 smori@fukuoka-u.ac.jp, 2 {kishii, ogose}@eng.kagawa-u.ac.jp

Abstract For adaptive packet retransmission control, network coding (NC)-based schemes have been proposed to reduce the number of packet retransmissions. However, the NC-based schemes have two fundamental drawbacks; the need for a counterpart packet of member packets and an overhearing packet management method. To mitigate these problems, we propose a novel superposition modulation (SM)-based scheme based on cross-layer design. However, when the SM technique is introduced into the system, the bit error probability increases. Therefore, to decrease the bit error probability, we utilize the soft combining (SC) technique. The effectiveness of our scheme is demonstrated through computer simulations.

Keywords: cross-layer design, packet retransmission control, superposition modulation, soft combining

1. Introduction

Recent advances in wireless and mobile communications systems are providing new services that are ubiquitous and customized to individual needs. To realize multimedia services over a wireless network with limited and varying radio propagation conditions is necessary error-free data transmission. In particular, current wireless network systems utilize the automatic repeat request (ARQ) method to control packet errors and retransmit lost packets. In the familiar traditional ARQ scheme, the transmitter side retransmits the same packet repeatedly until receiving an ACK message or reaching a pre-defined retry limitation.

In the above circumstance, to realize more intelligent signal processing for ARQ transactions and to reduce the number of packet retransmissions, the network coding (NC) technique [1] has been introduced into the packet retransmission control framework [2]–[4]. In the NC-based ARQ (NC-ARQ) scheme, the transmitter side selects a pair of retransmission packets to make up a member packet among the multiple lost packets. In the retransmission transaction, a member packet is encoded into one packet, and then this encoded packet, i.e., the XOR-ed packet, is retransmitted. To restore the required packet from an XOR-ed packet, the receiver side must know the counterpart packet, that is, the packet other than the desired member packet. Therefore, all receiver sides should gather the other users’ packets as overhearing packets. In the NC-ARQ scheme, there are two fundamental drawbacks. One is the requirement of a counterpart packet when the receiver side decodes any NC-encoded packet. The other is the necessity of introducing an overhearing packet management method that shares the information of all candidate counterpart packets among all user terminals. Therefore, the structural overhead of NC-ARQ schemes leads to declining network performance.

In this paper, to mitigate the above problems, we propose a novel packet retransmission control scheme based on the superposition modulation (SM) technique [5]. In particular, we focus on reducing the packet delay. The SM-based ARQ (SM-ARQ) scheme, in comparison with the NC-ARQ schemes, has the significant advantage that a counterpart packet is not necessary to decode an original packet at the receiver side. Therefore, the SM-ARQ scheme can avoid this structural overhead of NC-ARQ schemes. However, the SM-ARQ scheme has the weak point that the retransmission packet is more fallible in comparison with the NC-ARQ schemes and other tradi-
tional schemes. This is because the SM-ARQ scheme superimposes a member packet at the physical layer; hence these packets interfere with each other. To overcome this weakness, we additionally utilize the packet soft combining (SC) technique [6]. Furthermore, to realize adaptive signal processing for our proposed SM-ARQ with SC (SM-ARQ/SC) scheme, we apply a cross-layer design [7],[8].

In our paper, we present the following three contributions.

- The utilization of the SM technique to remove the structural overhead of NC-ARQ schemes.
- The utilization of the SC technique to reduce the packet error probability of the SM-ARQ scheme.
- The introduction of the cross-layer design to realize adaptive signal processing.

The rest of the paper is organized as follows. In the next section, we describe the conventional scheme. In Sec. 3, we describe our proposed scheme. In Sec. 4, we investigate the effectiveness of our scheme through computer simulations. Finally, in Sec. 5, we summarize this paper.

2. Conventional Scheme

In a wireless network system, one of the major concerns is how to control the transmission errors caused by radio channel noise and/or multipath propagations. To realize error-free data delivery among user terminals, there are two common approaches: the forward error correction (FEC) and ARQ schemes. The FEC scheme utilizes an error-correcting code (ECC) for detecting the transmission errors and protecting the original data. However, if decoding (or detecting) errors more difficult beyond the ability of ECC protection occur, it is harder to achieve error-free transmissions. Therefore, it is necessary to select a more powerful ECC method or to utilize the ARQ scheme. On the other hand, in the ARQ scheme, the sender side retransmits the same lost packet when a packet error occurs. The ARQ scheme can be simply implemented, hence it is widely utilized in current communications systems such as packet-switching data networks, computer communications networks, and wireless LANs [9].

For poor wireless or radio links, if we utilize the ARQ scheme, the sender side frequently retransmits the same packet. Therefore, increasing the number of packet retransmissions leads to serious packet delay. To solve this problem, several related groups have introduced the NC technique into the ARQ scheme. Specifically, the NC-ARQ scheme superimposes the multiple lost packets for different destinations, i.e., the member packet is XOR-encoded into one packet at the data link layer. For instance, to reduce the number of packet retransmissions, Ronzner et al. [2] addressed the issue of how to decide the member packet, which comprises a couple of packets with NC encoding. Kuo et al. [3] attempted to reduce the overhead that comprises extra control messages and marginal packet headers that are generated by using the NC technique. In terms of packet delay and jitter, Tani-gawa et al. [4] proposed and optimized a new algorithm for packet reordering and member packet selection.

3. Proposed Scheme

3.1 Overview of our scheme

Figure 1 shows the network model of our scheme. In brief, our scheme is specifically applied to an infrastructure-type wireless system in which a base station (BS) and user terminals directly communicate with each other. Additionally, we consider packet retransmission control for a downlink wireless link, and we assume that feedback messages, e.g., ACK and NACK, are perfectly exchanged to simplify the analysis.

As shown in Fig. 1, the BS transmits the first trial packet, $A_n$ ($n = 1, 2, \cdots, N$), to the $n$th user. If the $n$th user cannot correctly receive the first trial packet, $A_n$, the BS retransmits the retransmission packet, $B'_n$. In the traditional ARQ scheme, retransmission packets are sequentially retransmitted. In the NC-ARQ scheme, to reduce the number of packet retransmissions, two retransmission packets are superimposed (XOR-ing), in accordance with the NC technique. For example, if we select a pair of retransmission packets for the $n$th and $n'$th users, $B_n$ and $B_{n'}$, as a member packet, an XOR-ed packet, $B_n \oplus B_{n'}$ $(n' \neq n, n' = 1, 2, \cdots, N)$, is sent and received over wireless links. Here $\oplus$ denotes the XOR (mod 2) operator. In this situation, we define the $n$th and $n'$th users as the primary and secondary users, respectively.

In the NC-ARQ scheme, to restore the required packet, $B_n$, the $n$th user should calculate the XOR-ing operation between the XOR-ed packet, $B_n \oplus B_{n'}$, and $B_{n'}$. Therefore, the receiver side must store the first trial packet that is not addressed to oneself as the overhearing packet.
Additionally, the transmitter side must manage the overhearing packet for all receiver sides. Since the NC-ARQ scheme has an overhearing packet management framework, the NC-ARQ scheme can meet the condition that the receiver side must know the counterpart packet of the member packet. For example, if we define the pair of the receiver side must know the counterpart packet of the member packet. For example, if we define the pair of

\[ (A_n, B_n) \]

\[ \text{as a member packet,} \]

\[ (A_n', B_n) \]

\[ \text{as the overhearing packet, the} \]

\[ n \]

\[ \text{th user has} \]

\[ \text{the counterpart packet,} \]

\[ A_n' \]

\[ \text{as the overhearing packet, the} \]

\[ n \]

\[ \text{th user can restore the required packet,} \]

\[ B_n' \]

\[ \text{by means of an XOR-ing calculation between the XOR-ed packet,} \]

\[ B_n \oplus B_n' \]

\[ \text{and the counterpart packet,} \]

\[ B_{n'} = (A_{n'}). \]

Compared with the NC-ARQ scheme, the selection and superimposition of a member packet are similar. However, our scheme utilizes the SM technique for superposition. In comparison with the NC-ARQ scheme, since our scheme does not require overhearing packet management, there are two advantages. First, we can remove the facilities required for overhearing processing at the sophisticated receiver buffer and the notification channel of the overhearing status. Second, we can reduce the system complexity of the retransmission queue at the sender side. Specifically, to realize these features, it is necessary to classify and sort the retransmission packets for the individual destinations correctly. Therefore, the facilities should be constructed on the basis of complex structures such as those of a virtual buffer technique.

3.2 Procedure of our scheme

Figure 2 shows our cross-layer-design framework. Any packets from the network layer are stored in the first trial transmission queue at the data link layer. If a packet does not arrive at the receiver side, the unsuccessful packet is added to the retransmission queue as a retransmission packet. In the retransmission queue, two retransmission packets are grouped to form a member packet. In the NC-ARQ scheme, the member packet is superimposed bit by bit at the data link layer. On the other hand, in our scheme, the SM modulator superimposes the member packet symbol by symbol at the physical layer. To realize this process, the retransmission controller must fulfill adaptive transmission control across the data link and physical layers; thus we introduce the cross-layer-design concept. The details of the procedure performed by the SM-(de)modulator will be described in Sections 3.3 and 3.4.

As in the NC-ARQ scheme, the SM-ARQ scheme must select the member packet. In comparison with the NC-ARQ scheme, our scheme does not have to consider the member packet selection seriously. This is because, when the SM technique is utilized, the counterpart packet of the member packet need not be known when the receiver sides recover their original packets. Therefore, as shown in Fig. 2, we can select a simple rule such as the first-in-first-out (FIFO) algorithm. In short, as shown in Fig. 2, our scheme selects a pair of retransmission packets \( B_1 \) and \( B_2 \) as a member packet. If the packet \( A_4 \) must be resent, its retransmission packet \( B_4 \) is grouped with \( B_3 \) to form a member packet.

3.3 Transmitter-side implementation

Figure 3 shows the block diagram of the transmitter side. Generally, in the SM technique, after the serial-to-parallel (S/P) conversion, the information bits are first mapped into the transmission symbols via the element modulators. For expansion of the retransmission control framework, instead of the S/P converter, our SM modulator must input two packets, which are a pair of member packets, \( B_n \) and \( B_{n'} \).

\[ B_n = [b_1 \cdots b_L] \quad (b_i \in \{0, 1\}; \ i = 1, 2, \cdots, L) \]

\[ B_{n'} = [b_1' \cdots b_L'] \quad (b_i' \in \{0, 1\}; \ i = 1, 2, \cdots, L) \]

\[ \text{denote the retransmission packets and} \]

\[ L \]

\[ \text{represent the packet length. Afterwards, these packets are mapped into a symbol and linearly superimposed to create an output symbol,} \]

\[ x = \alpha \cdot s + \alpha' \cdot s' \quad \text{(1)} \]

\[ \alpha \]

\[ \alpha' \]

\[ s \]

\[ s' \]

\[ \text{Cross-layer design is a new paradigm in network architecture, involving the interaction and sharing of significant information among layers. Specifically, our cross-layer design is categorized into the design concept ‘Merging of adjacent layers’ of Srivastava and Motani [8]. In this concept, two or more adjacent layers are constructed together such that the service provided by the new superlayer is the union of the services provided by the constituent layers.} \]
### 3.4 Receiver-side implementation

Figure 4 shows the block diagram of the receiver side. At the receiver side, the estimated packets (which are handed up to the network layer), $\hat{A}_n = [\hat{a}_1 \cdots \hat{a}_L]$, $B_n = [\hat{b}_1 \cdots \hat{b}_L]$ ($\hat{b}_i \in \{0, 1\}$; $i = 1, 2, \cdots, L$), and $\hat{B}_n = [\hat{b}_1' \cdots \hat{b}_L']$ ($\hat{b}_i' \in \{0, 1\}$; $i = 1, 2, \cdots, L$), are calculated from the received signal, $y$, on the basis of the maximum likelihood (ML) detection rule. For the first trial packet, at the element modulator, the ML detection rule is expressed as

$$\hat{a}_i = \arg \min_{k=1,2,\cdots,m} |y_i - \varphi_k|^2 = \arg \min_{k=1,2,\cdots,m} \lambda_{i,k}$$

where $\lambda_{i,k}$ denotes the soft decision information for the $i$th bit and $k$th symbol, as utilized in the SC technique.

#### 3.5 MAC protocol

Figure 5 shows the media access control (MAC) protocol based on the distributed coordination function (DCF)
in the IEEE 802.11 wireless LAN specifications [10]. After the DCF interframe space (DIFS) and backoff durations, the SM-encoded packet is transmitted. When the primary and secondary users receive the SM-encoded packet, each user decodes its own original packet in accordance with Eqs. (2) and (3). After these user terminals have obtained their desired packet, they should reply with the ACK (or NACK) message to the BS. However, if the primary and secondary users transmit their ACK/NACK messages, after a short interframe space (SIFS) interval, their control packets will collide. Therefore, as shown in Fig. 5, each user terminal sequentially sends their ACK/NACK message just after the XIFS interval. In our scheme, the XIFS intervals of the primary and secondary users, $U_{XIFS}$ and $U'_{XIFS}$, respectively, are defined as

$$U_{XIFS} = T_{SIFS}$$

$$U'_{XIFS} = 2 \times T_{SIFS} + T_{(N)ACK}$$

where $T_{SIFS}$ is the SIFS duration and $T_{(N)ACK}$ is the duration required to transmit the (N)ACK message.

### 3.6 Definitions of packet delay

In this section, we describe the procedure of packet retransmission transactions and the packet structures among the conventional and proposed schemes. Additionally, we formulate the packet delay of the conventional schemes and our scheme based on our MAC protocol previously proposed in Sec. 3.5 designed for the IEEE 802.11 wireless LAN environment.

Figure 6 shows the procedure of packet retransmissions for the conventional frameworks, i.e., the traditional ARQ and NC-ARQ (i.e., DC-Sel [4]) schemes, and for the SM-ARQ (proposed) scheme. Although the traditional ARQ scheme requires two retransmission processes, the NC-ARQ and SM-ARQ schemes require only one retransmission transaction because of packet superimposition. Additionally, these three schemes differ in the response procedure at the receiver side. Specifically, in the traditional ARQ scheme, the two destination user terminals reply with the (N)ACK message for each retransmission packet separately. In the NC-ARQ scheme, to realize overhearing management, the BS must know the status information of all user terminals. Therefore, all user terminals reply with the (N)ACK message including the status information for an NC-encoded packet. That is when $N$ denotes the number of user terminals, it is necessary to deal with $N$ retransmission transactions. On the other hand, in the SM-ARQ scheme, the two destination user terminals reply with the (N)ACK message for the SM-encoded packet.

Figure 7 shows the packet structures for the traditional ARQ, NC-ARQ, and SM-ARQ schemes. In the NC-ARQ and SM-ARQ schemes, the header of the retransmission packet (i.e., NC-encoded or SM-encoded packet) contains the MAC addresses for the two destination user terminals (i.e., the primary and secondary users). Therefore, the header length of the NC-ARQ and SM-ARQ schemes is 48 bits longer than that of the traditional ARQ scheme. Moreover, the packet length of the ACK message, in the NC-ARQ scheme is 128 bits longer than that in the traditional ARQ and SM-ARQ schemes because of the overhearing management in the NC-ARQ scheme.

Let $D_{ARQ}$, $D_{NC}$, and $D_{SM}$ denote the packet delays of the traditional ARQ, NC-ARQ, and SM-ARQ schemes. On the basis of Figs. 6 and 7, we calculate these packet delays as

$$D_{ARQ} = \left( T_{DIFS} + T_{Backoff} + \frac{240 + L_{Payload}}{v} \right) \times 2 + \frac{L_{(N)ACK}}{v}$$

$$D_{NC} = \left( T_{DIFS} + T_{Backoff} + \frac{288 + L_{Payload}}{v} \right) \times 2 + \frac{L_{(N)ACK} + 128}{v}$$

$^3$We assume that our proposed MAC protocol is designed on the basis of the IEEE 802.11 wireless LAN. Therefore, in Fig. 7, the packet header (whose size is 240 bits) consists of frame control, duration/ID, address 1, address 2, address 3, sequence control and address 4, whose sizes are 16 bits, 16 bits, 48 bits, 48 bits, 48 bits, 16 bits, and 48 bits, respectively.
\[ D_{SM} = T_{DIFS} + T_{Backoff} + \frac{288 + L_{Payload}}{v} + \left( T_{SIFS} + \frac{L_{(N)ACK}}{v} \right) \times 2 \]  

where \( T_{DIFS}, T_{SIFS}, \) and \( T_{Backoff} \) are the DIFS, SIFS, and backoff durations, \( L_{Payload} \) and \( L_{(N)ACK} \) are the lengths of the payload and (N)ACK messages, respectively, \( v \) is the data transfer rate, and \( N \) is the number of user terminals.

### 3.7 Unified benchmark of packet delay

The definition of packet delays in Sec. 3.6 is not considered in the packet error probability. Therefore, in this section, we define the unified benchmark of packet delay that is included in the packet error probability using the bit error probability.

Let \( D \) denote either \( D_{ARQ}, D_{NC}, \) or \( D_{SM} \). We define the unified benchmark criterion of packet delay \( D \) as

\[ D(p_e, J) = D \times \left( 1 + \sum_{j=1}^{J-1} p_e^j \right) \]  

where \( J \) is the maximum number of packet retransmissions and \( p_e \) is the packet error probability.

Since \( 0 < p_e < 1 \), if \( J \to \infty \), Eq. (9) can be rewritten as

\[ D(p_e) = \lim_{J \to \infty} D(p_e, J) = D \times \frac{1 - p_e}{1 - p_e} \]  

Generally, if bit errors occur independently on the radio channels, we can calculate the packet error probability, \( p_e \), using the bit error probability, \( p_b \), and the packet length, \( l \), as

\[ p_e = 1 - (1 - p_b)^l \]  

4. Simulation Results

#### 4.1 Bit error probability

Figure 8 shows the signal-to-noise ratio (SNR), \( \gamma \), versus bit error probability as a result of exhaustive Monte Carlo simulation. As the parameter settings of the SM technique, the element modulators utilized the binary phase shift keying (BPSK) method, and the weight coefficients, \( \alpha \) and \( \alpha' \), at our SM modulator, were set as 0.75 and 0.25, respectively, on the basis of the SM-UPA technique [5]. Additionally, to simplify the computer simulations, we ignored the radio propagation loss and shadowing, and we assumed that the radio channel estimation and equalization were perfectly fulfilled. Hence, the radio propagation was dominated only by additive white Gaussian noise (AWGN).

In Fig. 8, the theoretical curve, \( P_b \), was calculated using [11]

\[ P_b = Q \left( \sqrt{2 \times \gamma} \right) \]  

where the Gaussian \( Q \)-function is defined as

\[ Q(z) \triangleq \frac{1}{\sqrt{2\pi}} \int_{z}^{\infty} e^{-\xi^2/2} d\xi, \quad z \geq 0 \]  

In comparison with the theoretical curve, the required SNR at a \( 10^{-5} \) bit error probability for primary and secondary users is degraded by 6.0 dB and 9.0 dB, respectively. This is because, in the SM technique, the primary and secondary users interfere with each other because of their superposition. Note that the theoretical curve is the same for the primary and secondary users.

In order to mitigate the bit error degradation when using the SM technique, our scheme is combined with the SM and soft combining (SC) techniques. To demonstrate the effectiveness of the proposed SM-ARQ with SC (SM-ARQ/SC) scheme, we compared it with the SM-ARQ with FEC (SM-ARQ/FEC) scheme. In this paper, for the SM-ARQ/FEC scheme, the ECC method utilizes convolutional coding (with constraint length \( k = 7 \) and coding rate \( R = 1/2 \)) and the Viterbi decoding algorithm.

As shown in Fig. 8, the proposed SM-ARQ/SC scheme can reduce the bit error probability compared with the
Table 1 Simulation parameters

| Parameter                      | Value              |
|-------------------------------|--------------------|
| Payload length, $L_P$         | 12,000 bit         |
| Data transfer rate, $v$       | 11 Mbit/s          |
| ACK message length, $L_{(N)\text{ACK}}$ | 304 bit           |
| DIFS duration, $T_{\text{DIFS}}$ | 50 $\mu$s        |
| SIFS duration, $T_{\text{SIFS}}$ | 10 $\mu$s        |
| Backoff duration, $T_{\text{Backoff}}$ | 640 $\mu$s      |

SM-ARQ/FEC scheme expect in the region where SNR = 5.8–9.2 dB at the primary user. Specifically, for the primary user, in the case of SNR = 5.8–9.2 dB, our scheme is degraded by 0.5 dB at maximum. In contrast, in our scheme, the required SNR at a $10^{-5}$ bit error probability for the primary and secondary users can be improved by 6.0 dB and 5.9 dB for the SM-ARQ scheme and by 0.2 dB and 1.3 dB for the SM-ARQ/FEC scheme, respectively.

4.2 SNR versus packet delay

Figure 9 shows the SNR, $\gamma$, versus packet delay for the traditional ARQ, NC-ARQ, SM-ARQ, SM-ARQ/FEC, and proposed SM-ARQ/SC schemes. As mentioned above, we calculated the unified benchmark of packet delay, $D$, in Eq. (10) using the bit error probability in Fig. 8. Table 1 summarizes the simulation parameters based on IEEE 802.11b [10], which are the constant values in Eq. (10). Note that these simulation parameters are utilized for Eqs. (6)–(8), which are required for Eq. (10).

In Fig. 9, since the packet delay depends on $N$ owing to overhearing management, we plot the results of the NC-ARQ scheme for $N = 2, 20, \text{and} 40$. In the case of $\gamma > 11$ dB, the traditional ARQ, NC-ARQ, SM-ARQ/FEC, and our schemes cannot be improved further, and in the case of $\gamma > 17$ dB, the SM-ARQ scheme cannot be improved further. The reason for this is that the upper limitations are reached owing to a sufficiently high SNR.

In the case of $N = 2$, the curve of our scheme agrees with the NC-ARQ curve because both our scheme and the NC-ARQ scheme completed the process with two $(N)\text{ACK}$ responses. Although our scheme is superior to the NC-ARQ scheme in terms of the packet length of the $(N)\text{ACK}$ message (see Fig. 7), Fig. 9 does not show a clear difference. Moreover, the simulation result shows that the packet delay of our scheme equals that of the SM-ARQ/FEC scheme.

As a result, our scheme reduces the packet delay in comparison with the traditional ARQ and SM-ARQ schemes. Without increasing system complexity, our scheme can obtain an effective performance comparable to that of the SM-ARQ/FEC scheme. When $N$ is large, our scheme is superior to the NC-ARQ scheme, as described in detail in Sec. 4.3.

4.3 Number of user terminals versus packet delay

Figure 10 shows the number of user terminals, $N$, versus packet delay, for $\gamma = 10$ dB and 15 dB. Although the packet delay of the NC-ARQ scheme depends on $N$, the traditional ARQ, SM-ARQ, SM-ARQ/FEC, and SM-ARQ/SC schemes have constant values. For the SM-ARQ scheme, in the case of $\gamma = 10$ dB, the curve is out of the range of Fig. 10 owing to the high bit error probability. The curves of the NC-ARQ and traditional ARQ schemes intersect at $N = 38$, and the curves of the NC-ARQ and SM-ARQ schemes intersect at $N = 13$ for $\gamma = 15$ dB. This is because the overhead of the NC technique is increased as a result of increasing $N$. Therefore, the advantage of the NC-ARQ scheme becomes small as $N$ increases. On the other hand, in comparison with the NC-ARQ scheme, in the cases of $N = 5, 10, 20, 30, \text{and} 40$, our scheme can reduce the packet delay by 7.19%, 17.1%, 31.7%, 41.9%, and 49.4% for $\gamma = 10$ dB and by 8.24%, 18.0%, 32.4%, 42.5%, and 50.0% for $\gamma = 15$ dB, respectively.
Consequently, our scheme reduces the packet delay in comparison with the NC-ARQ scheme.

5. Conclusions

In this paper, to realize effective ARQ transactions, we proposed a novel cross-layer design for packet retransmission control based on the SM technique. Moreover, we utilized the SC technique to overcome the high bit error probability problem caused by using the SM technique. Simulation results showed that our scheme is more effective than the traditional ARQ, NC-ARQ, SM-ARQ, and SM-ARQ/FEC schemes. Future work is necessary to expand the applicability of our scheme to multirate wireless transmission.

References

[1] R. Ahlswede, N. Cai, S. Y. R. Li and R. W. Yeung: Network information flow, IEEE Trans. Inf. Theory, Vol. 46, No. 4, pp. 1204–1216, 2000.
[2] E. Ronzner, A. Padmanabhalayer, Y. Mehta, L. Qiu and M. Jafry: ER: Efficient retransmission scheme for wireless LANs, Proc. ACM CoNEXT2007, New York, USA, 2007.
[3] F. C. Kuo, K. Tan, X. Y. Li, J. Jiansong and X. Fu: XOR rescue: Exploiting network coding in lossy wireless networks, Proc. IEEE SECON2009, Rome, Italy, 2009.
[4] Y. Tanigawa, J. O. Kim and H. Tode: Delay sensitive retransmission method based on network coding in wireless LANs, IEICE Trans. Commun., Vol. E93(B), No. 12, pp. 3345–3353, 2010.
[5] P. A. Hoher and T. Wo: Superposition modulation: Myths and facts, IEEE Commun. Mag., Vol. 49, No. 12, pp. 110–116, 2011.
[6] S. Mori, K. Ishii and S. Ogose: Cross-layer design for throughput improvement in wireless communications, Proc. SICE 2007, pp. 949–952, Takamatsu, Japan, 2007.
[7] V. Kawadia and P. R. Kumar: A cautionary perspective on cross-layer design, IEEE Wireless Commun., Vol. 11, No. 1, pp. 3–11, 2005.
[8] V. Srivastava and M. Motani: Cross-layer design: A survey and the road ahead, IEEE Commun. Mag., Vol. 43, No. 12, pp. 112–119, 2005.
[9] S. Lin, D. Costello and M. Miller: Automatic repeat request error control schemes, IEEE Commun. Mag., Vol. 22, No. 12, pp. 5–17, 1984.
[10] IEEE Std. 802.11-1999 (Reaff 2003): Wireless LAN medium access control (MAC) and physical layer (PHY) specifications, 2003.
[11] J. G. Proakis: Digital Communications, McGraw-Hill, 2000.