Chapter 7
HARQ Scheme II in the DLC Protocol of Wireless ATM

Since the throughput of HARQ scheme is related to the coding gain of the code used, a better choice of code must lead to further improvement into the throughput. In this chapter, the HARQ scheme combines the performance of Turbo codes with the frugal use of the incremental redundancy inherent in RCPC codes so as to be able to apply all of the useful results on RCPT codes to HARQ scheme. On a basis of the previous FEC schemes (PT-UEP1 and PT-UEP2) in Chapter 5 and HARQ schemes (PC-HA1 and PC-HA2) in Chapter 6, new HARQ schemes (PT-HA1 and PT-HA2) are proposed to improve the throughput efficiency and CLR performance in wireless ATM networks further.

7.1 HARQ Scheme Using RCPT Codes

The same wireless ATM cell as Figure 2.10 are also adopted in the PT-HA1 and PT-HA2 schemes, where the information packet with 416 bits (4+48 bytes) is appended 16 bits (p=2 bytes) CRC for the error detection. The FEC utilizes RCPT code, which coding rate R_s is between R_H and R_P, where s=1,2 corresponds to the PT-HA1 and PT-HA2 schemes, respectively.

Supposing $R_s = \frac{k}{k+1}$, an exponential decrease in k may be desirable [66] for the HARQ applications with many channel variations. Then, let $k = 2^{4-i}$, R_s is in the form of $\frac{16}{16+2^i}$, for $i = 0, 1, \cdots, I$ (I is a non-negative constant). This would mean to perform less FEC decoding attempts than the maximum number of possible ones at a cost of slightly smaller throughput.

- For the PT-HA1 scheme, let $I = 5$. Then, we have the coding rate $R_1 \in \{\frac{16}{17}, \frac{8}{9}, \frac{4}{5}, \frac{2}{3}, \frac{1}{2}, \frac{1}{3}\}$. The additional parity bits per byte one step are selected via an index set {1, 1, 2, 4, 8, 16}. The transmitted parity length (bits per byte) $l_i \in \{1, 2, 4, 8, 16, 32\}$. Then, $l_5 = L$=32.
- For the PT-HA2 scheme, let $I = 4$. Then, we have the coding rate $R_2 \in$

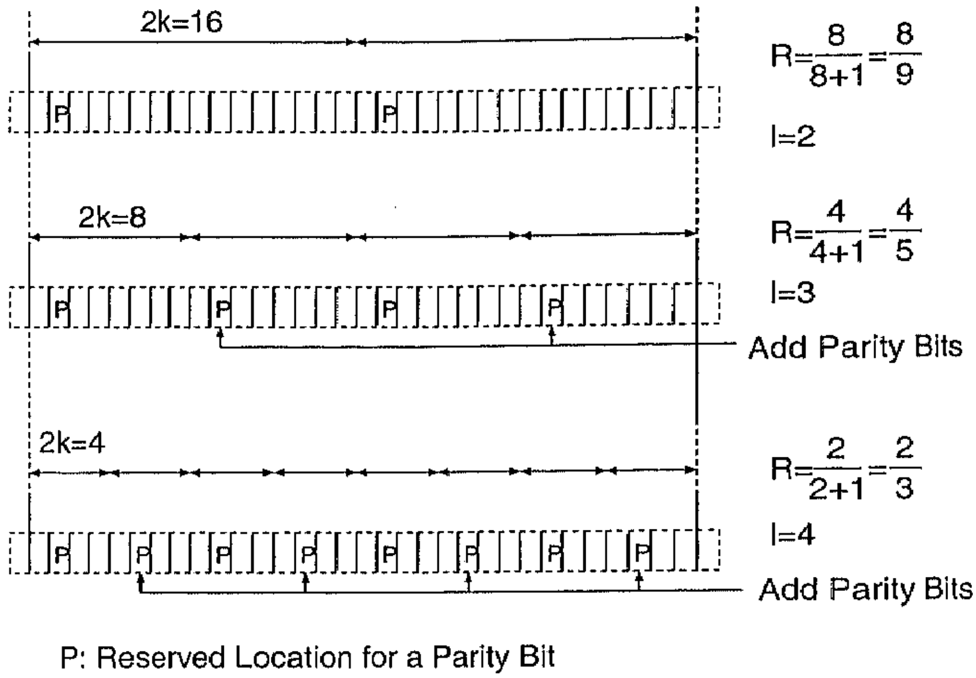

Figure 7.1: **Rate decreasing process of RCPT codes**

$\{\frac{16}{17}, \frac{8}{9}, \frac{4}{5}, \frac{2}{3}, \frac{1}{2}\}$. The additional parity bits per byte one step are selected via an index set {1, 1, 2, 4, 8}. The transmitted parity length (bits per byte) $l_i \in$ {1, 2, 4, 8, 16}. Then, $l_4 = L$=16.

The RCPT puncturing rule amounts to sending collections of one or more bits of the parity matrices so that at least 16 bits are sent in the initial transmission and no bit is sent more than twice. The codes with rates R_1 or R_2 follow this puncturing rule while allowing the insertion of extra parity bits to methodically lower the rate. Figure 7.1 depicts how to lower the rate firstly from $\frac{8}{9}$ to $\frac{4}{5}$, and then from $\frac{4}{5}$ to $\frac{2}{3}$, where each P in Figure 7.1 represents the reserved location for a parity bit. Note that the added parity bits are equally distributed and the distance between any of the successive two parity bits is $2k$, where it is equal to 16 for the rate transition from $\frac{8}{9}$ to $\frac{4}{5}$, and 8 for the rate transition from $\frac{4}{5}$ to $\frac{2}{3}$.

After substituting the RCPC encoder/decoder in Figure 6.1 with the RCPT encoder/decoder and applying an available puncturing table, we have a data transmission model for the PT-HA schemes as shown in Figure 7.2. Assuming that the receiver transmits ACK or NAK over an errorless and low capacity feedback channel, the HARQ scheme II performs the steps as shown in Figure 7.3, which has the same retransmission method as the HARQ scheme I in Chapter 6.

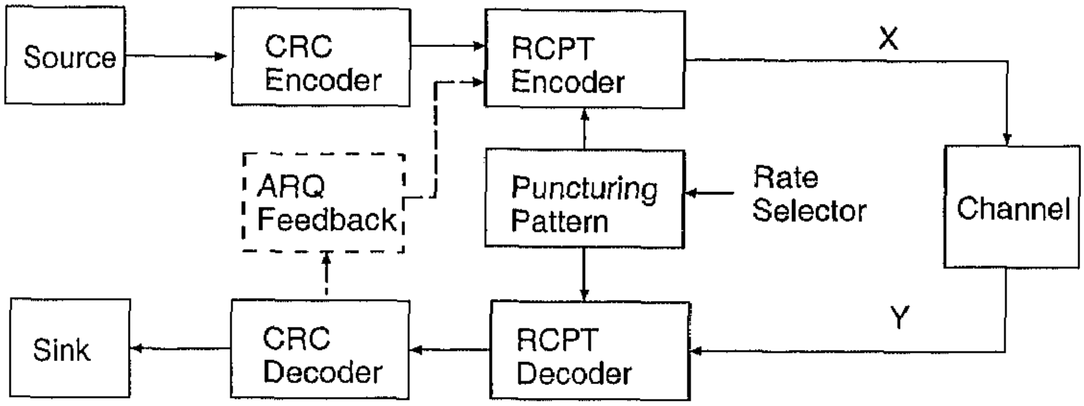

Figure 7.2: **Data transmission using RCPT codes**

If the decoding is not successful after the transmission of all $R = \frac{1}{3}$ code symbols, there are several system design options. The protocol is allowed to reset as shown in Figure 7.3. Alternatively, the simplest way is to give up and to accept a given BER upon failure at the lowest code rate ($R = \frac{1}{3}$), which is treated in the following simulation.

Like PC-HA schemes, no received information bit is discarded in PT-HA schemes, so their throughputs keep high from a standpoint of the information theory.

7.2 Throughput Analysis

When the SR-ARQ with bandwidth efficiency is applied to the PT-HA1 or PT-HA2 scheme, the throughput of the HARQ strategy is:

$$T_{AV} = \frac{(4+48)\times 8}{(4+48+2)\times 8} \cdot R_{AV} = \frac{13}{14} \cdot \frac{16}{16 + l_{AV}}, \tag{7.1}$$

where l_{AV} is the average number of additionally transmitted bits.

If the maximum retransmission number is I, the implementation of RCPT codes selects puncturing tables via the indices: $l_0 < ... < l_i < ... < l_I$, where $l_i = 2^i$ for all i. Let $P_F(l_i)$ be the probability that an FEC decoding attempt at the i-th step results in errors detected by the (432,416) block error detection code. When the protocol terminates (fails) after I transmissions, then the cell loss probability is simply $P_F(L)$. Note that cells with errors either at their headers or at their payloads are discarded here.

Assuming that the I decoding attempts have statistically independent outcomes, we have:

$$l_{AV} = \sum_{i=1}^{I} l_i(1 - P_F(l_i)) \cdot \prod_{j=0}^{i-1} P_F(l_j) + l_I \prod_{j=0}^{I} P_F(l_j). \tag{7.2}$$

For the incremental redundancy HARQ systems, one can derive a closed form solution for R_{AV}. For each coding rate R_s used in the HARQ protocol, if the required CLR can be determined, then the collection of these probabilities at a given SNR can be used to determine l_{AV}, and thus, R_{AV}. However, determining such probabilities analytically for Turbo codes is intractable. Moreover, while they are applied to the CLR in an attempt to lower bound the throughputs of the PT-HA systems, such bounds are found to be extremely weak [67]. In order to evaluate the efficiency of PT-HA systems, their throughputs have to be estimated by simulations.

7.3 Numerical Results

Under the same conditions as their corresponding FEC schemes in Chapter 5, simulations are conducted to estimate CLR and throughput of the HARQ schemes using RCPT codes. Their results are shown in Figures 7.4 and 7.5. From these figures, PT-HA1 has better CLR performance than PT-HA2 with about the same throughput. Both of them have much lower CLR than those of the uncoded, HEC, AWA, BC3 and PC-HA schemes. The HARQ schemes reach the same CLR as the corresponding FEC schemes by the higher throughputs. Besides, the PT-HA schemes outperform the PC-HA schemes in the performance of throughput too.

If $k = 2^{5-i}$ or $k = 2^{6-i}$, the initial coding rate becomes $\frac{32}{33}$ or $\frac{64}{65}$, respectively. Then higher throughputs must be obtained. Whereas less delay can be achieved if $\frac{8}{9}$ is defined as the initial coding rate.

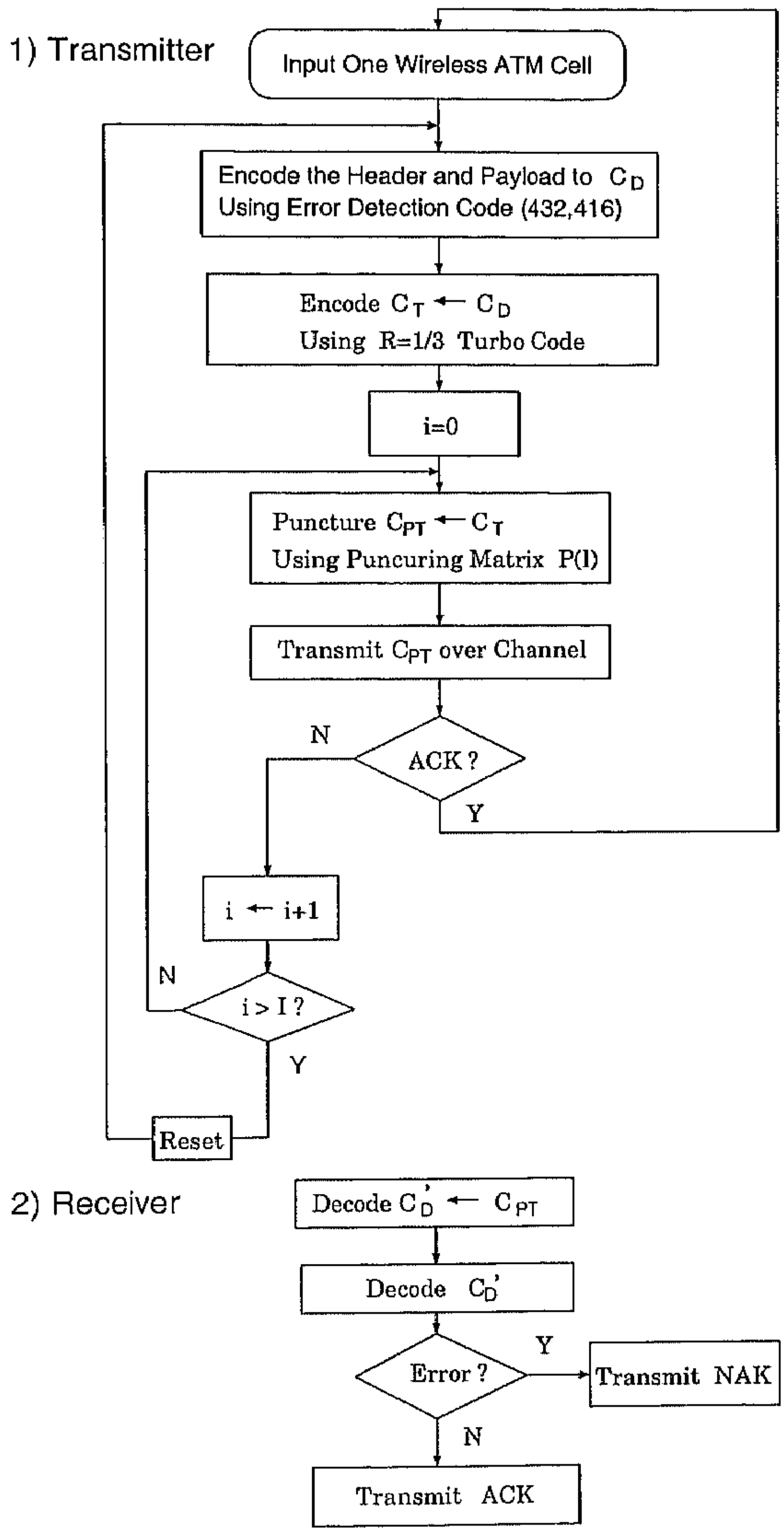

Figure 7.3: Flow chart of HARQ strategy using RCPT codes

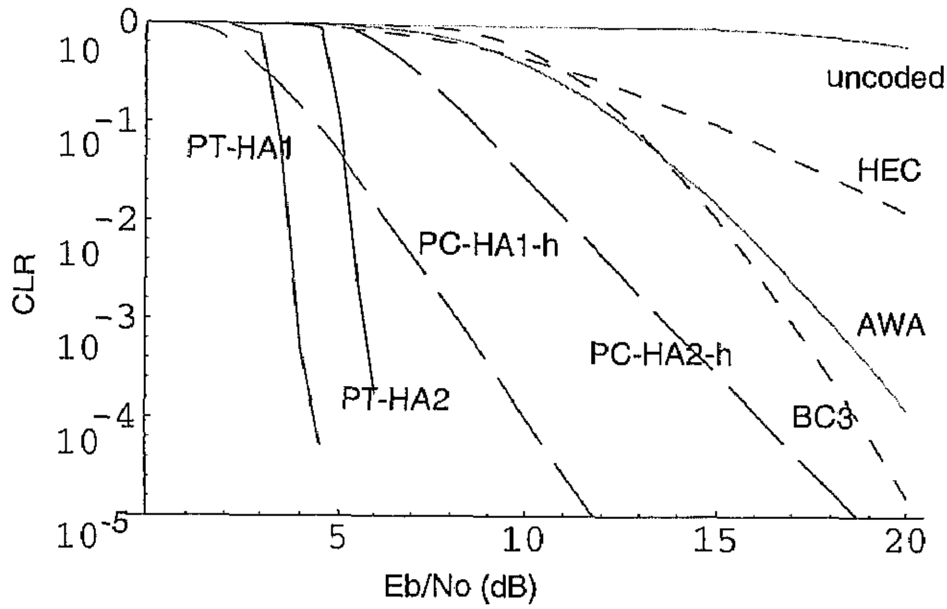

Figure 7.4: CLR versus SNR over Rayleigh fading channel

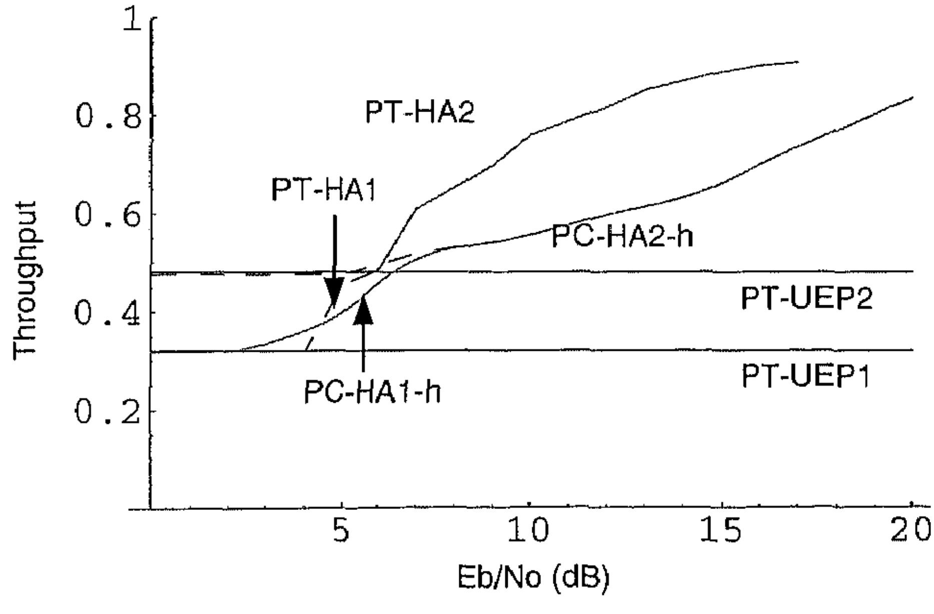

Figure 7.5: Throughput versus SNR over Rayleigh fading channel