Chapter 1
Introduction

1.1 Background and Purposes

In recent years, due to the increasing attention to mobile services and wireless equipments, the wireless interfaces of asynchronous transfer mode (ATM) networks have been very important. Wireless ATM is to connect the wireless access networks to the ATM backbone network in a seamless manner, which may be viewed as a general solution for next generation personal communication networks to support multimedia service [1]. Usually, a wireless ATM network is constructed as shown in Figure 1.1 [2], where UNI is the user network interface of the standard ATM network. For realizing mobility, corresponding servers and databases are set up. In this approach, an ATM cell serves as the basic unit for protocol processing and switching in both wired and wireless portions of the network, i.e., the ATM cell is transmitted via radio frames (wireless ATM cells) between a base station (BS) and a mobile station that includes a terminal equipment (TE) and a radio module (RM).

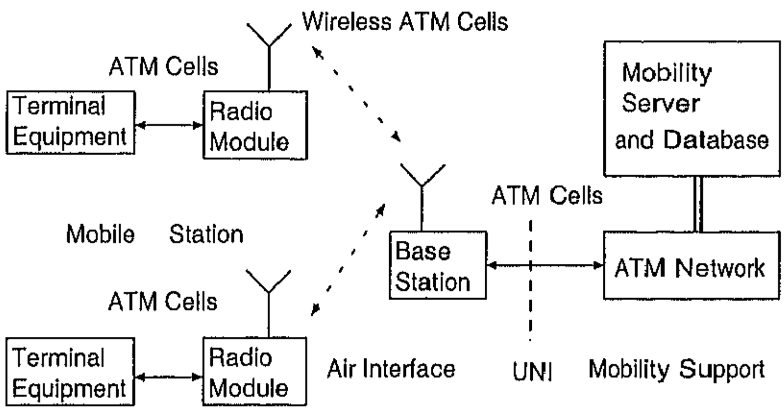

Figure 1.1: The construction of wireless ATM network

The air interface of wireless ATM network is a band-limited channel with much higher error rate than the wired one. Thus, powerful error control methods are needed not only in end-to-end but also in link-by-link connection [3].

There are two important error control techniques, i.e., forward error correction (FEC) and automatic repeat request (ARQ). Conventional applications of an FEC coding usually consist of the selection of the fixed rate coding schemes which are well suited to the channel characteristics and the acceptable error rates for the data to be transmitted [4]. In some cases, however, a more flexible scheme may be desirable to accommodate the different error protection requirements, or the channels with unknown or time varying parameters [5]. Besides, ARQ protocols [6] have been successfully employed to adapt to the changes in transmission media.

For time-sensitive services, such as audio and video, FEC schemes are often used to achieve real-time transmission with available quality. A tradeoff between quality (coding gain) and capacity (coding rate) is very important in designing the FEC schemes. In a wireless ATM interface, header and various payloads to be transmitted have different importances or error protection needs, expressed by the source significance information (SSI). It is supposed that cell loss occurs only if there are errors in the header. Therefore, header bits are considered more important than payload bits.

The previous FEC schemes in wireless ATM only use block codes (BCs), such as HEC[7], BC1, BC2, BC3[8] and AWA[9], the other important codes—convolutional codes (CCs) are not discussed. Generally, CCs have better performance than BCs. But their usages are primarily restricted to the cases of the lower rates or the higher rates but shorter constraint length due to their decoding complicity. However, in wireless channel, their transmission rates must be high while each bandwidth is strictly limited. But the decoding of high rate CCs becomes very complex. This thesis firstly induces Theorem 1 and Theorem 2 about the algebraic properties of the high rate punctured CCs (PCCs). By virtue of these properties, the puncturing realizations of the known good nonsystematic and systematic high rate CCs are put forward. Therefore, their decoding algorithms become as simple as its corresponding original low rate CC so as to be able to applied to wireless channel efficiently.

Turbo code (TC) is the new class of convolutional codes [10]. It offers unprecedented coding gains with relatively simple iterative decoding so as to advance to the limit of the second Shannon theorem gradually. By puncturing the CCs and the TCs with the compatibility restriction, the rate compatibility punctured convolutional (RCPC) codes and the rate compatibility punctured Turbo (RCPT) codes are realized. This thesis introduces RCPC and RCPT codes with different coding rates to realize unequal error protection (UEP) so as to obtain better performance than the previous FEC schemes in wireless ATM .

For time-insensitive services, such as data transfer, an ARQ scheme should be applied to achieve high quality or throughput. In this case, retransmission or cell loss occurs if there are errors in the header or the payload. For providing higher reliability than an FEC system alone and higher throughput than a system with an ARQ alone, this thesis applies hybrid ARQ (HARQ) scheme to wireless ATM network, which incorporates both FEC and ARQ schemes. Based on RCPC and RCPT codes, the HARQ schemes in this thesis are quite effective to enhance the throughputs of wireless ATM networks.

1.2 Methodology

The research methodologies applied throughout this thesis are mathematical analysis and computer simulation. The symbolic manipulation package Mathematica is used to speed up and carry out some complicated calculations. Most of the simulations are performed using custom coded C language programs running at dual processors (Penitum III) on FreeBSD 4.2-Release.

1.3 Thesis Outline

This thesis investigates the error control schemes applied to the data link control (DLC) protocols of wireless ATM. These schemes are used to enhance the performance of cell loss rate (CLR) and throughput with available implementation complexity.

Chapter 2 describes the construction of wireless ATM and its protocol stack, and then mainly discusses wireless ATM cell.

Chapter 3 depicts the generator polynomial matrices and the upper bounds on the constraint length for PCCs, respectively. By a virtue of them, PCCs can be easily constructed, which are the same as those known good regular nonsystematic and systematic high rate CCs.

Chapters 4 and 5 propose FEC scheme I and II that apply RCPC and RCPT codes to the DLC protocol, respectively. On the basis of them, Chapters 6 and 7 utilize RCPC and RCPT codes to realize HARQ scheme I and II of the DLC protocol. In these chapters, mathematical analysis and computer simulation are applied to evaluate these FEC and HARQ schemes.

Chapter 8 concludes this thesis and describes the author's plans for future work.

Appendix A derives the proof of Theorem 1 about the generator polynomial matrices of PCCs. Appendix B depicts the decoding algorithm of Turbo codes.

1.4 Achievements

We summarize below the original contributions of this thesis.

- Two DLC packet formats of wireless ATM cell are proposed for the different service classes using rate compatible codes[11][12] (Chapter 2).
- Two fundamental theorems about algebraic properties of PCC are derived. On the basis of them, the puncturing realization of the known good high rate CCs is given[13](Chapter 3 and Appendix A).
- An adaptive two-level UEP code scheme is constructed by RCPC codes and their performance over Gaussian and fading channels is analyzed in detail. The characteristic results about CLR and bit error rate (BER) are obtained [11][14] (Chapter 4).
- RCPT codes are applied to realize the adaptive two-level UEP code scheme. Better results over the Rayleigh fading channel are obtained[15][16] (Chapter 5).
- RCPC codes are applied to the HARQ scheme according to the principle of equal error protection (EEP). Their performance over Gaussian and the fading channels is analyzed [12] (Chapter 6).
- RCPT codes lead to further improvement into the throughput over Rayleigh fading channels when they are applied to realize an HARQ scheme[17] (Chapter 7).