A Novel ARQ Scheme Applied to Wireless Communication

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***Abstract*—In wireless communication, ARQ scheme plays an important role for the error control. The two basic ARQ schemes are the Selective Repeat ARQ and the Go-Back-N ARQ.GBN-ARQ scheme is easy to implemented while its throughput is proved to be not so perfect. On the other hand, SR-ARQ performs better than GBN-ARQ while its implementation is too complex. The two basic ARQ schemes cannot satisfy the requirement of the wireless communication. In this paper, an advanced ARQ scheme is proposed to solve the problem mentioned above. The correlative relationship of the key segments of the network data is used to recover the erroneous data. The proposed scheme is analyzed in theories and compared with the basic ARQ schemes by matlab simulation on throughput performance. The simulation results show that the proposed scheme has a lower complexity than that of SR-ARQ and it has a better throughput performance than that of GBN-ARQ.**

Keywords- wireless communication; correlative relationship; ARQ; error recovery

I. INTRODUCTION (HEADING 1)

With the development of the microcomputer and network, more and more computing capability is assigned to the personal terminals. Nowadays, as the whole communication framework becomes relatively perfect, how to improve performance of the communication system with the data processing technology is becoming a new research direction. The ATM (Asynchronous transfer mode)[9] protocol can provide multimedia services in single network. It is developed based on the optical fiber network. In ATM technology, any types of information will be divided into fixed length of short packets called the *ATM cell* and transferred by the single ATM network. When combined with the mobile communication services, the WATM (Wireless ATM) was born. In order to meet the demands of different types of multimedia services, the WATM support different types of QoS (Quality of Services)[1][3]. For example, the audio and video services are mainly sensitive to the delay while the data services are sensitive to the cell loss rate. In wireless mobile communication environment, the shadows and multipath effects will significantly improve the cell loss rate, so the error control method should be used to ensure the QoS. Talking of the error control method, the classical methods include the FEC (Forward Error Coding) and ARQ, FEC is always used to improve the error bit rate performance, however, due to the burst errors in the wireless environment, the single FEC can hardly meet the standard of the cell loss rate. The ARQ scheme can solve this problem by retransmits the erroneous cells, but the retransmission brings the delay, while audio and video services are sensitive to the delay. Single bit error will make the cell abandoned. The retransmission solves the reliability but it also increases the delay. So the designing of the ARQ scheme has a more restrict requirement. There are 2 classical ARQ schemes, the SR-ARQ (selective repeat ARQ) and the GBN-ARQ (Go-Back-N ARQ) Compared with the GBN-ARQ, SR-ARQ has a better performance, while it is more complicated to realize.

When transmitting data among special nodes, there may be correlative relationship among the nodes. For example, in ATM network, the cells transmitted between the neighboring nodes have the same VPI and VCI. In ATM protocol, VPI and VCI are the flow signs which determine which flow a cell belongs to. As the flow control segments, the VPI and VCI has a significant influence to the cell loss rate. The conventional ARQ scheme doesn't make use of the redundancy. Considering this, a fault-tolerant ARQ scheme is proposed in this paper. This novel ARQ scheme is an improved method from the GBN-ARQ scheme. It makes use of the potential relationships between the key segments of the ATM cells to repair the key segments before every retransmission to improve the accuracy and decrease the retransmission times so it will improve the performance of the ARQ scheme. According to the simulation results, this ARQ scheme has almost the same performance with the SR-ARQ scheme in certain channel condition while its complexity is far less than the SR-ARQ. What's more, the fault-tolerant ARQ scheme proposed in this paper can not only fit in the ATM communication system but also applied in other protocols for error control which is sensitive for the delay. This paper is made up of 6 sections, and the contents of each section are as follows: Section I is the Introduction. Section II mainly talks about the principle of the conventional ARQ schemes in the WATM, the GBN-ARQ[4] and the SR-ARQ[5]. Section III mainly proposed the improved ARQ scheme with fault-tolerant method. Section IV is the performance analysis between the conventional ARQ and the SR-ARQ. Section V shows the simulation results of comparison between the performance of

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the improved ARQ and the SR-ARQ and GBN-ARQ. The last section is the conclusion.

II. CONVENTIONAL ARQ SCHEME IN WATM

A. Selecting a Template (Heading 2)

Figure 1 shows a classical WATM protocol stack[2]. The ARQ scheme is applied in the DLC layer to recover the erroneous data transmitted in the wireless channel. Every ATM cell was transmitted as a packet with error check code. Several ATM cells consist a TDMA frame and each TDMA frame contains ARQ control information.

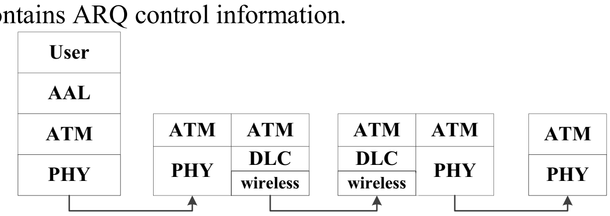

Figure 1 A Stack of the WATM

Figure 2 shows the scheme of the conventional SR-ARQ and the GBN-ARQ in wireless ATM. In this figure, each cube represents a wireless ATM cell, and the number in it stands for the receiving sequence of the cell. The control information is sent from right to left by the receivers. Figure 2(a) stands for GBN-ARQ and Figure 2(b) stands for SR-ARQ. Here, we assume that a TDMA frame includes 8 ATM cells and the shaded cubes represent the erroneous cells. From the figure we can see that SR-ARQ has a significantly better performance than GBN-ARQ. For example, the first transmission of cell 5, it is abandoned in GBN-ARQ due to bit error, while in SR-ARQ, it has been successful transmitted. Though the performance of the SR-ARQ is significantly better than the GBN-ARQ, its implement seems more complicated which may cause too much processing overhead. The senders of the SR-ARQ have to use complex flow control schemes to select the erroneous cells and retransmitted them. In wireless ATM, the services sensitive to the delay have high length requirements. Thus conventional SR-ARQ can hardly fit the QoS of WATM.

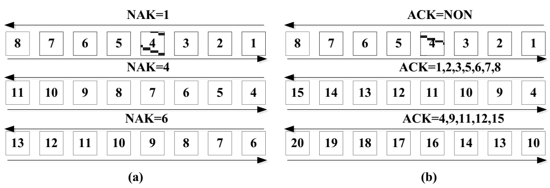

Figure 2 the conventional ARQ schemes in WATM

Nowadays, there are kinds of improved ARQ schemes [6][7]according to the conventional ones, however, none of them can solve the problems. So from the data received itself, a novel ARQ scheme to avoid the conflicts has been proposed.

III. THE PRINCPLE AND IMPLEMEMT OF AFT-ARQ

In order to solve the problem which exists in the wireless ATM, a novel ARQ based on the GBN-ARQ has been proposed, that is, AFT-ARQ. When communicating between special nodes, we may gain extra performance improvement[8]. One precondition of AFT-ARQ is that the distribution of the control segments of the communication nodes should be known first. Under ideal state, the accurate distribution of the control segments of the cells transmitted between different nodes has been estimated. The main idea of AFT-ARQ is that the receivers try to correct the erroneous cells before each transmission, and retransmit the ones still cannot pass the error checking.

A. Principle of AFT-ARQ

The active fault-tolerant idea is used to improve the GBN-ARQ scheme. Figure 3 shows the simple flow chart of the AFT-ARQ. The receiver checks if there is erroneous cell in the frame at the first time. If all of the cells in the frame are correct, next frame will be sent. Otherwise the first erroneous cell of the frame will be repaired, and then, another error check will be executed to check if there is still any erroneous cell. And the left of the operations are the same with GBN-ARQ.

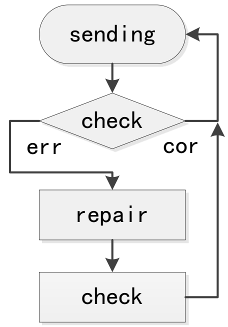

Figure 3 a simple flow chart of AFT-ARQ

The modification of the GBN-ARQ is that AFT-ARQ is added with a repair operation and a check operation. This operation improves the probability of the erroneous repaired to correct. As is shown in figure 4, cell 4 is erroneous in the first frame. According to the scheme of AFT-ARQ, it will be repaired to be correct. Thus it won't appear in the next frame. On the other hand, the active fault-tolerant operation is executed at the receive end, and it won't take too much overhead and it doesn't gain the redundancy of the ARQ control information.

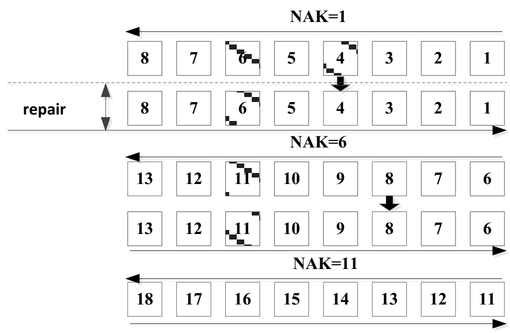

Figure 4 an example of the application of AFT-ARQ

B. The implementation of the active fault-tolerance

The active fault-tolerance of the cells is realized by the statistic information of the received segments. Assuming the sending segment is T, and the respective received segment is

R. The issue goes into a Bayesian Estimation that we estimate T from R. According to the Bayesian Equation, the best estimation of the sending segment should be

$$\begin{aligned} T_e &= \arg\max_{T} P(T/R) \\ &= \arg\max_{T} \frac{P(R/T)\cdot P(T)}{P(R)} \\ &= \arg\max_{T} P(R/T)\cdot P(T) \end{aligned} \tag{1}$$

So in order to estimate the sending cell, the priori probability *P(T)* and the likely probability *P(R/T)* should be first represented. And the structure of the ATM cell should be specially analyzed.

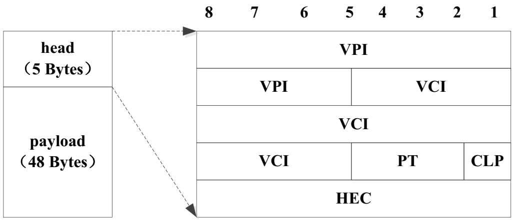

Figure 5 structure of the ATM cell

The ATM cell is consist of VPI, VCI, PT, CLP and HEC[9] as is shown in figure 5. Among the segments, VPI is the virtual path and VCI is the virtual channel. They two are closely connected with the transmission path of the cell. So they should be analyzed together. The PT segment infers the types of the cells. The CLP segment is the blocking sign. The HEC segment is the error checking segment. If the former 4 segments of the cell are known, the HEC segment will be certain, too. So the HEC segment is not taken into account. And the tolerant of the segment can be taken into 3 independent parts, that are {VPI/VCI}, {PT} and {CLP}. Let T be $\{t_1, t_2, t_3\}$. t_1 stands for {VPI/VCI} and t_2 stands for {PT} and t_3 stands for {CLP}. As the assuming above, the best estimation of the header of the cell should be

$$\arg\max_{T} P(R/T)P(T) \Rightarrow \begin{cases} \arg\max\limits_{t_1} P(r_1/t_1)P(t_1) \\ \arg\max\limits_{t_2} P(r_2/t_2)P(t_2) \\ \arg\max\limits_{t_3} P(r_3/t_3)P(t_3) \end{cases} \tag{2}$$

That is, to estimate each segment and the results together will be the best estimation of the whole header.

For any n, in the target equation $P(r_n/t_n)P(t_n)$, the priori part $P(t_n)$ can be estimated by the statistic of the network data in a period. And for segment t_n, we can calculate the distribution function of it and treat it as the $P(t_n)$.

The likely part $P(r_n/t_n)$ is associated with the bit error rate of the channel. Assuming the channel is the BSC channel. In bit error rate p_e, the hamming distance between the sending segment and the receiving segment is d, the length of t_n is L, so the likely part is represented by

$$P(r_n/t_n) = p_e^d (1-p_e)^{L-d} \tag{3}$$

IV. PERFORMANCE ANALYSIS

In the ATM communication systems, the length of the frame consists of ATM cells is fixed, so we assume that each frame contains M cells. So we measure the performance of the ARQ scheme by the expectation of the successfully transmitted number of cells in one frame.

Assuming the bit error rate of the channel is p_e, the error rate of the control segment of the cell is p_f, p_e and p_f have a fixed relationship as the following equation

$$p_f = 1-(1-p_e)^{40} \tag{4}$$

For conventional GBN-ARQ scheme, the probability that n cells successful transmitted in one frame is $P_{GBN}(n)$. In conventional situation, there are two kinds of conditions. That is when n is less than M, the first $n-1$ cells of the frame are correct and the cell n is erroneous or when n is equal to M, all of the cells are correct.

$$P_{GBN}(n) = \begin{cases} (1-p_f)^n \cdot p_f & ,n<M \\ (1-p_f)^n & ,n=M \end{cases} \tag{5}$$

The expectation of the conventional GBN-ARQ is

$$\begin{aligned} E_{GBN} &= \sum_{n=0}^{M-1} n\cdot(1-p_f)^n \cdot p_f + M\cdot(1-p_f)^M \\ &= \frac{1-(1-p_f)^M}{p_f} - M\cdot(1-p_f)^M \end{aligned} \tag{6}$$

For conventional SR-ARQ scheme, the probability that n cells successful transmitted in one frame is $P_{SR}(n)$. In conventional situation, there are n random errors in the M sending cells.

$$P_{SR}(n) = C_M^n (1-p_f)^n \cdot p_f^{M-n} \tag{7}$$

The expectation of the conventional SR-ARQ is

$$\begin{aligned} E_{SR} &= \sum_{n=0}^{M} n\cdot C_M^n (1-p_f)^n \cdot p_f^{M-n} \\ &= M\cdot(1-p_f) \end{aligned} \tag{8}$$

For AFT-ARQ scheme, assuming the successful repairing rate is p_s, the probability that n cells successful transmitted in one frame is $P_{AFT}(n)$. there are 4 kinds of conditions. That is when n is less than M, there is one random error in the first n-1 cells and repaired successfully and cell $n+1$ is erroneous or cell $n+1$is erroneous and cannot be repaired or when n is equal to M, one of the M cells is correct and can be repaired successfully or all of the cells are correct.

$$P_{AFT}(n) = \begin{cases} C_n^1 \cdot p_f \cdot (1-p_f)^{n-1} p_s \cdot p_f + \\ (1-p_f)^n \cdot p_f \cdot (1-p_s) & ,n<M \\ C_n^1 \cdot p_f \cdot (1-p_f)^{n-1} p_s + \\ (1-p_f)^n & ,n=M \end{cases} \tag{9}$$

The expectation of the conventional AFT-ARQ is

$$\begin{aligned} E_{AFT} = \sum_{n=0}^{M-1} n\cdot[&C_n^1 \cdot p_f \cdot (1-p_f)^{n-1} p_s \cdot p_f + \\ &(1-p_f)^n \cdot p_f \cdot (1-p_s)] + \\ &M\cdot C_M^1 \cdot p_f \cdot (1-p_f)^{M-1} p_s + (1-p_f)^M \end{aligned} \tag{10}$$

When M is 10, we draw the curves of the expectation of the successfully transmitted cells in one frame of the three kinds of ARQ schemes. From the curve we can see that when the bit error rate ranges from 10^{-4} to 10^{-2}, in real situation, the performance of AFT-ARQ is significantly better than that of GBN-ARQ and it is almost the same as SR-ARQ.

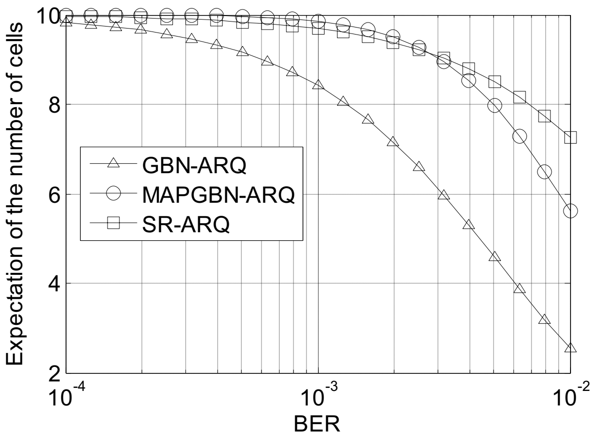

Figure 6 Ideal Performance Curve of ARQ

V. Simulation Analysis

Assuming that the sending cache of the frames is fixed, that means the total number of the cells is fixed. According to the wireless ATM protocol, cells transmit at a certain rate. We simulate the sending and receiving of the WATM frames and test the performance of different ARQ schemes.

The number of the frames to transmit certain number of cells is treated as the standard to compare the performance of different types of cells. The larger value means the more frames needed to transmit certain number of cells, thus the performance of the ARQ scheme is worse. Figure 7 shows that the performance of AFT-ARQ is much better than that of GBN-ARQ and it is close to that of SR-ARQ.

What's more, the influence of the length of the frame on the performance has been simulated. Figure 8 shows the performance of AFT-ARQ in different length of frames. Through the curves we can see that, the shorter frames have the better performance because the when the length of a frame increases the, the probability of the error cells increases, so the Performance of the AFT-ARQ decreases.

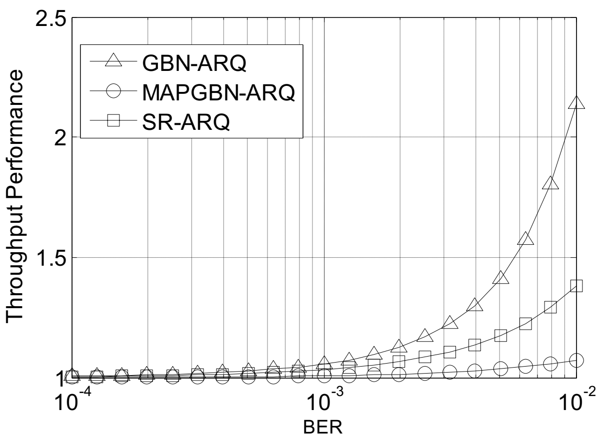

Figure 7 Comparison of the AFT-ARQ and conventional ARQ

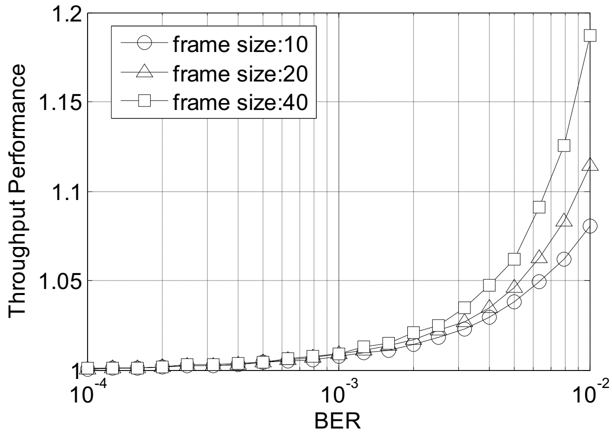

Figure 8 performances of different length of frames of AFT-ARQ

VI. Conclusion

The mainly characteristics of the conventional ARQ schemes applied in the WATM has been discussed in this paper. A novel ARQ scheme which makes use of the statistic relationships between the receiving data based on active fault-tolerance is proposed. Simulation results show that this ARQ scheme has a performance near the SR-ARQ while the complexity of its implementation is almost the same with GBN-ARQ. Though this ARQ scheme is designed for the wireless ATM communication, it can also be applied to other protocol not so sensitive to the error of data.

Acknowledgment

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