

# Fault-Tolerant Transmission Protocol for Distant Agricultural Image Acquisition

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**Abstract**—To solve the problem of the high cost in the GPRS communication and the limit transmission distance of WiFi, a transmission scheme for distant agriculture image acquisition was designed based on digital transmission radio in this paper. However, the majority of current digital transmission radio was designed for a small amount of data transmission. It could get a greater transmission distance with the help of the digital transmission radio, but the signal interference increased heavily when the digital transmission radio was used for image transmission. A fault-tolerant transmission protocol for agriculture image (FTTP-AI) based on digital transmission radio was designed in this paper. Packet verification was used to reduce the data errors caused by the signal interference of the digital transmission radio. At the same time, overtime retransmission and the lost packet retransmission were used to overcome the problem of packet loss. Experiments showed that the FTTP-AI could send the agriculture image to a remote computer center successfully in the field. With the help of the FTTP-AI, the rate of accuracy of data transmission was up to 99.2%, the success rate of image transmission was up to 95.8%, the costless distant transmission can achieve several kilometers. This scheme could satisfy the requirement of the low-cost for distant agriculture images transmission reliably.

**Index Terms**—Image Transmission, Fault-Tolerant Transmission Protocol, Packet Verification, Retransmission, Digital Transmission Radio

## I. INTRODUCTION

The acquisition technique of the fast agricultural information is one of the key techniques in the field of the precise agriculture. The images teletransmission technique, as one kind of the information acquisition techniques, can be used in the agricultural field to perform tele-observation on the growing situation, plant diseases and insect pests of the crops [1]. In this way, the precise information collection of the site, as well as the real time monitoring of the field can be achieved to create the conditions for the modernization of the agricultural management. Nowadays, Wi-Fi, Blue Teeth, Zig-Bee and RFID[2, 3] are the main techniques in the short distance data wireless transmission, on the other hand, GPRS and 3G net are the main techniques in the long distance transmission [4, 5]. Xiong et al. [6] and Liu et al. [7] have already realized the above techniques respectively.

In the acquisition techniques of the distant agricultural images information, common Wi-Fi technique is unable

to finish the long distance transmission [8]; however, GPRS [9, 10] and 3G [11] transmission depend on mobile business operator thus high expense cost is inevitable. It has become a bottleneck that the collection of images data several kilometers away frequently through the sensor net of the distant agricultural images. To solve the high cost of the GPRS as well as the limit transmission distance problem, the wireless digital transmission radio is used.

The DTR (digital transmission radio) [12] is a professional data transmission radio station of high-performance based on DSP and wireless radio techniques. The DTR is able to transmit various kinds of data such as digital voice, dynamic images, tele-control and tele-metering data etc. The DTR offers transparent RS232 interface and is able to achieve 19.2Kbps transmission rate as well as 2-10 kilometers transmission distance. In our earlier work [13], we used the DTR JZ875 to perform the transmission of the water data and achieved satisfied result of 6.5 kilometers transmission distance. Based on the above research and experiments, we studied the use of the DTR for the image transmission in this paper.

The commercial DTR JZ875 was used as the transceiver. In the transmission performance test of JZ875, bit error rate was found to be relative low and could be adopted to transmit images. However, JZ875 was interfered seriously due to the rapid increase of the amount of the images data in the process of transmission. This case brought problems such as the reception of the error data and the lost of the data packet.

In order to apply the DTR on the images transmission without above mentioned problems, a low-cost wireless sensor network for distant agriculture image acquisition was built in this paper. FTTP-AI (fault-tolerant transmission protocol for agricultural image) was specially designed to improve the rate of accuracy and success during the images transmission. In the rest of this paper, we would introduce our work in detail with the following structure. In part II, the system architecture for images transmission based on the DTR would be specified. In part III, we propose the protocol rule, the format of the packet and transmission procedure of FTTP-AI based on DTR. In part IV, the detail design of FTTP-AI such as Packet encapsulation and confirmation mechanism would be defined. In part V, the experimental results were given with the comparison of the data transmission effect with and without FTTP-AI and then

the statistic data would be presented to analysis these results. At the end of this paper, we conclude the achievements of our work as well as the standing problems in part VI.

## II. THE SYSTEM ARCHITECTURE FOR IMAGES TRANSMISSION BASED ON THE DTR

Fig. 1 shows the system architecture for the agricultural images sensor network in this paper. Within the transmission distance of Wi-Fi, the images data collected by the images collection nodes was sent to the base station via Wi-Fi. Then within the transmission distance of the DTR, the images data collected by the base station was sent to the remote computer center via the DTR. In the next step, the remote computer center would send the images data to the system sever via 3G net or internet. After all, the user terminal could get the agricultural images from the system sever via the internet and perform further study on the images data.

In the actual deployment of the experiment, the base station in the Fig. 1 located at the experimental plots of Chen-cun, Tian-he district in Guangzhou, and the remote computer center located at the informatics college building of SCAU (South China Agricultural University). The linear distance between them is about 2.1 kilometers, which is out of the transmission distance of Wi-Fi. In order to cut down the cost, the commercial DTR JZ875 was used to transmit the images data in a long distance in this paper.

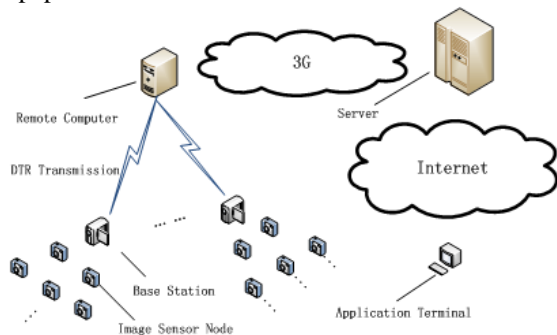


Figure 1. System architecture

## III. FTTP-AI BASED ON THE DTR

To solve the above mentioned problems in data transmission of the DTR, FTTP-AI based on the DTR was designed as follows.

### A. The Design of the Fault-Tolerant Rule

One of the problems in the DTR transmission is the signal interference. Robust frame synchronization [14-17] was used to test the data in this paper, including bytes-count law and head-tail-mark law.

The other problem is the lost of the data packets in the DTR transmission. The continuum re-transmission mechanism [18] was used to check if there were lost data packets after all data was sent, and re-transmit the lost data packets.

### B. The Design of the Packet

The unify format of the packet as table I was adopted in this paper and there were eleven different type codes as table II.

TABLE I. THE FORMAT OF THE PACKET

Preamble	Type code	Packet data	Postamble
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TABLE II. TYPE SIZES FOR CAMERA-READY PAPERS

ID	Code	Size	Usage
1	0x01	12	SYN
2	0x02	11	SYN confirmation
3	0x03	512	Image data
4	0x04	10	Send completed
5	0x05	11	Send completed confirmation
6	0x06	10+count	Re-transmission list
7	0x07	11	Re-transmission list confirmation
8	0x08	512	Re-transmission of image data
9	0x09	10	Re-transmission completed
10	0x10	11	Re-transmission completed confirmation
11	0x11	13	Transmission confirmation

### C. The Procedure of the Protocol

The procedure of the protocol was as Fig. 2. The sending terminal S and the receiving terminal R completed the images transmission base on the protocol.

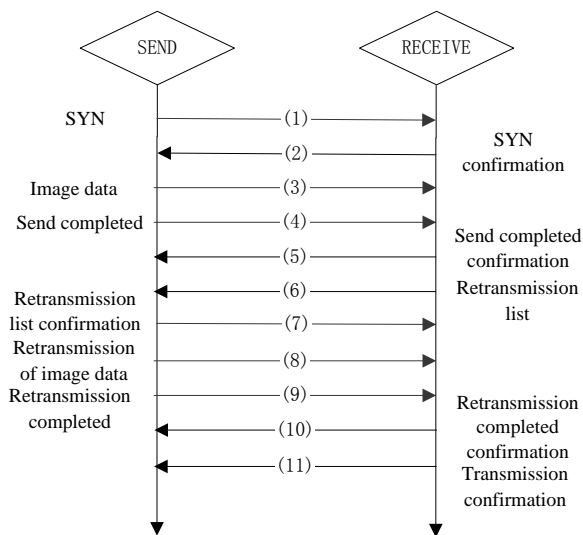


Figure 2. The flowchart of the protocol

Step 1: The sending terminal S sends the synchronization data packets.

Step 2: The receiving terminal R returns the confirmation packets.

Step 3: The sending terminal S sends the images data packets.

Step 4: The sending terminal S sends the finished-mark packets.

Step 5: The receiving terminal R sends the completed confirmation packet to confirm if the sending is finished and check whether the images data received is integrity. If it is, then turn to Step 11; otherwise, go on Step 6.

Step 6: The receiving terminal R sends the packet including the list of the lost packets.

Step 7: The sending terminal S returns the packet to confirm the lost packets.

Step 8: The sending terminal S re-sends the lost packets.

Step 9: The sending terminal S re-sends the finished-mark packets.

Step 10: The receiving terminal R re-sends the completed confirmation packet to confirm if the sending is finished and check whether the images data received is integrity again. If it is, then go on Step 11; otherwise, turn to Step 6.

Step 11: The receiving terminal R sends transmission confirmation packet to confirm that the transmission is finished.

#### IV. THE DETAIL DESIGN OF THE FTTP-AI

##### A. Packet Encapsulation

In order to solve the problem of the data interference in the DTR transmission, the SYN code and bit-count were imported to allow for error control. The packet data was designed to include the preamble, initial length of the packet  $L_{\text{packet}}$ , initial data and the postamble. Four bytes EBH 90H EBH 90H were selected as the preamble, and three bytes EBH 90H EBH were selected as postamble.  $L_{\text{packet}}$  was included in the head of the packet to perform error control judgment.

When the receiving terminal received the data, the preamble and postamble would be decided whether it was right, if not, the data would be judged as the interference data and not to be processed in the next step; otherwise the packet would be unpacked, then the preamble and postamble would be extracted. Finally we would have  $L_{\text{packet}}$  from the head of the packet and judge if it was equal to  $L_{\text{received}}$ . If it was, the data would be accepted.

##### B. Confirmation Mechanism

Due to the possibilities of the lost packet in the transmission, the response mechanism was used to make sure that the packets could be sent to the receiving terminal successfully.

The total time of the packet transmitting from the sending terminal S to the receiving terminal R [19] is as:

$$t_{\text{total}} = t_{\text{send}} + t_{\text{spread}} + t_{\text{receive}} + t_{\text{process}} \quad (1)$$

where  $t_{\text{send}}$  is the send-delay,  $t_{\text{spread}}$  is the transmit-delay,  $t_{\text{receive}}$  is the receive-delay,  $t_{\text{process}}$  is the process-delay. Among the four delay time,  $t_{\text{spread}}$  is decided by the velocity and the distance of the spread. The spread velocity of the radio waves in the air is  $3 \times 10^8 \text{m/s}$ , and the spread distance of the DTR is 2-10 kilometers. So  $t_{\text{spread}}$  would be microsecond time and could be ignored here. Also,  $t_{\text{receive}}$  is always ignored in the serial wireless communication [20] and so as the  $t_{\text{process}}$  because the frequency of the ARM processor has already reached more than 100MHZ and the size of the packet as table I is small enough. After all, it turns out to be as:

$$t_{\text{total}} = t_{\text{send}} = l / r \quad (2)$$

where  $l$  is the length of the packet,  $r$  is the baud rate for serial ports. According to table I, the max length of the packet is 512 bytes and the lowest spread velocity of the DTR JZ875 is 19200bit/s. So the maximum of  $t_{\text{total}}$  would be  $512 \times 8 / 19200 = 0.213 \text{s}$ . Considering the round-send-delay and others kinds of delay, the overtime  $t_{\text{timeout}}$  would be 1s in this paper.

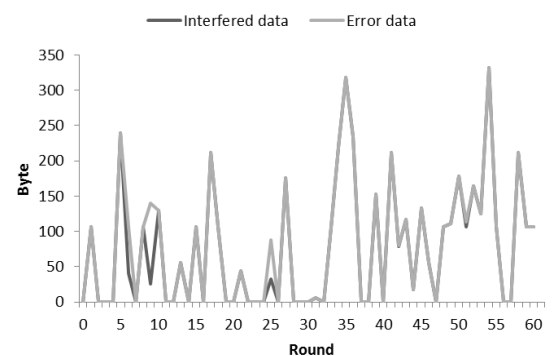
The retransmission time out mechanism was designed as follows. When a packet which needed to be confirmed was sent out, a timer would be invoked. If the confirmation packet was received within  $t_{\text{timeout}}$ , the timer would stop and went on with next moves. If not, the packet would be judged as lost and retransmitted.

The integrity check mechanism for images data was designed as follows. When the packet with the type code 0x01 was received, the number of the image packets  $N_{\text{packet}}$  would be read out.  $N_{\text{received}}$  would be compared with  $N_{\text{packet}}$  after the packet with the type code 0x05 or 0x10 was received. If they were equal then the packet with type code 0x11 would be returned and the image data would be saved, otherwise a list containing the lost packets would be returned instead.

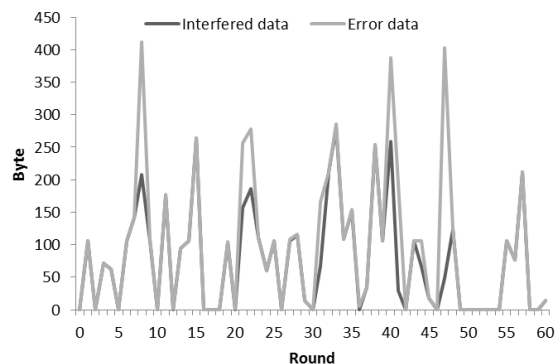
#### V. EXPERIMENTAL RESULTS AND ANALYSIS

##### A. Experiment Results without FTTP-AI

The data is easy to be interfered when transmitted using the DTR JZ875, which leads to error codes and lost packets. To detecting how the data was interfered, experiments have been conducted as follows: the test data with fixed size was sent after a fixed time interval, which would be analyzed after received.



a. The test result of the "100KB.txt"



b. The test result of the "150KB.txt"

Figure 3. Data analysis without any protocol

As Fig. 1, the cameras with 1.3 million pixels were adopted as the images collection nodes. The size of the photos collected was between 100KB and 150KB. So the 100KB and 150KB were set to be the threshold to check the size of the files. The test files “100KB.txt” and “150KB.txt” contained all ‘1’ text and all ‘0’ text respectively. The sending terminal took turns to send “100KB.txt” and “150KB.txt” with one hour interval. The total time of the test was 120 hours. The result of the test was as Fig. 3.

It can be seen in the Fig. 3 that the data was interfered seriously during the transmission without any protocols, and the interfered data even changed without rule. Compared with Fig. 3a, obviously Fig. 3b shows more serious interference. It follows that the larger the amount of data is, the more serious the interference would be. The amount of the interfered data was equal to that of the error data in most of the test periods. But in a few cases the amount of the error data was larger than the interfered, which was caused by the crosstalk-induced effects on the normal receiving data.

### B. Experimental Results with FTTP-AI

In the following experiments, the FTTP-AI was applied in the transmission with the DTR JZ875.

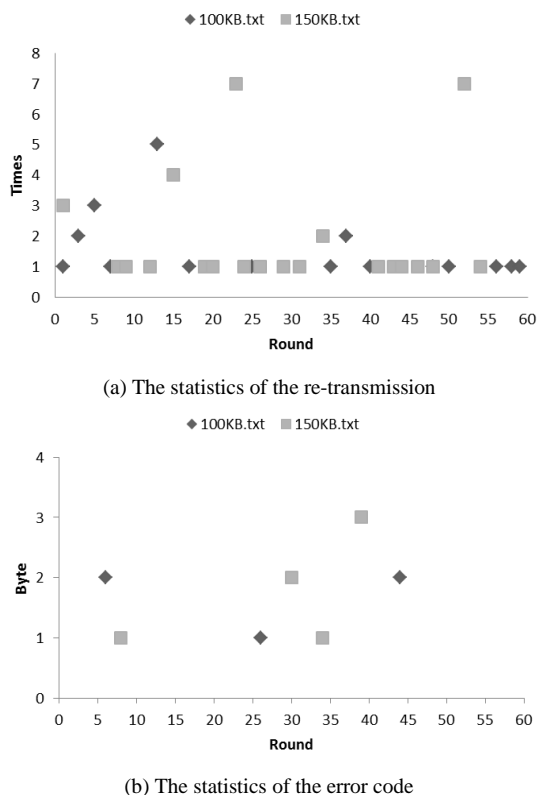


Figure 4. Data analysis with FTTP-AI

In the text files transmission experiment, the test files were the same as above mentioned in the experiments without FTTP-AI. “100KB.txt” and “150KB.txt” contained all ‘1’ text and all ‘0’ text respectively. The sending terminal took turns to send “100KB.txt” and “150KB.txt” with one hour interval. The total time of the test was 120 hours. FTTP-AI was applied to the

transmission between the sending terminal and the receiving terminal.

The experimental result shows that the amount of the sending data is equal to that of the receiving data, which means the interference data is zero. Fig. 4 shows the number of the re-transmission of the sending terminal as well as the error rate of the receiving terminal.

It can be seen from the Fig. 4a that the rate of re-transmission tends to be larger on the large files more than the small files. In most cases the data could be transferred integrally through re-transmission just one time even when it was interfered in the DTR transmission, and only in a few cases several times of re-transmission were needed.

It can be seen from the Fig. 4b that there are few cases where error codes occur. Error codes happened to occur in 7 of 120 files. The total error codes were 12 bytes. So the rate of success to transmit text files is  $(120-7)/120 \times 100\% = 94.2\%$ , which means the total rate of the error codes is  $12 / (100 \times 60 + 150 \times 60) \times 100\% = 0.08\%$ . It is effective to improve the text files transmission rate of success using the FTTP-AI.

In the image files transmission experiment, the real-time images collected from the farmland were transmitted to the remote computer center. The linear transmission distance was 2.1 kilometers and the sending interval was one hour. The total time of the test was 120 hours. FTTP-AI was applied to the transmission between the sending terminal and the receiving terminal.

The experimental result shows that 120 image files with size between 94KB and 124KB were sent, and the receiving terminal received all the image files. Fig. 5 shows the number of re-transmission in the image files transmission experiment. Most of the image files could be transferred integrally after 1 to 3 times re-transmission. Few periodic images should be re-transmitted more than 3 times.

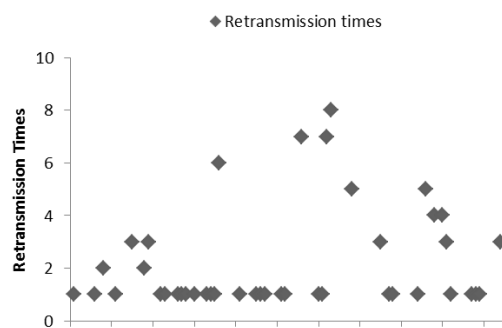


Figure 5. Retransmission times of image transmission

In the transmission test of the image files, there were 5 images which error code occurred. Compared with the effect of the image received successfully (on the left), Fig. 6 shows the example of image received with error code (on the right). So the rate of success to transmit image files was  $(120-5)/120 \times 100\% = 95.8\%$ . It is effective to improve the image files transmission rate of success using the FTTP-AI.





Figure 6. Contrast for image transmission

## VI. CONCLUSION

To solve the problem of the high cost of the GPRS and the limit transmission distance of the Wi-Fi, the DTR was imported to the transmission of the agricultural images and the FTTP-AI protocol was designed based on the DTR in this paper. The study offered a solution to cover the low-cost requirement, at the same time insured the distant transmission of the agricultural images. With FTTP-AI, the rate of accuracy of data transmission was up to 99.2%, the success rate of image transmission was up to 95.8%, the costless distant transmission could achieve several kilometers. This scheme could satisfy the requirement of the low-cost for distant agriculture images transmission reliably.

Even though the application of the FTTP-AI on the DTR JZ875 can realize the low-cost for distant agriculture images transmission, which is perfect for agriculture because of the relative low data amount requirement. However, for transmission with much further distance, the rate of error codes will increase rapidly due to the signal attenuation of the DTR. Meanwhile, the FTTP-AI protocol is not fast enough for the situation where the images data need to be transmitted frequently for the data amount limit of the DTR itself. To perform transmission with further distance, a proposal integrated with high efficiency correcting error mechanism and 3G would be the key points in the future study.

## ACKNOWLEDGMENT

The authors would thank the project of the National Key Technology RD Program (Project Name: Key Technologies for Agricultural Field Information Comprehensive Sensing and Rural Extension, Contact Number: 2011BAD21B01); the Province Natural Science Foundation through the Guangdong (Contact Number: S2012040007370).

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