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Analysis of the Retransmission Mechanism Based on Mass Storage and TDM for Buoy High-rate Communication

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Abstract. In order to meet the reliability requirement of the high-rate relay communication of maritime buoy, a retransmission mechanism based on mass storage and TDM (time division multiplexing) was proposed, to realize automatic retransmission lost data frames or on-demand playback historical data frames during the time slot of real-time image data transmission, and restructure and restore the data in the shore-based station data center. While transmitting real-time data of buoy, the Buoy relay communication terminal stores it into the mass storage medium NAND flash. In the process of receiving the real-time data, once data center observe data loss, retransmission instructions will be automatically generated and transmitted to the relay communication terminal through the forward link. In addition, the data center can retrieve any image data within 12 hours from the buoy's mass memory by on-demand playback.

1. Introduction
Under the complex sea state, the oceanographic buoy relay communication terminal antenna’s direction, influenced by random motion of buoy, deviates from the direction of the satellite [1-3], resulting in Poor or interrupted communication quality, and data loss is inevitable. Blindly improving the speed and accuracy of satellite tracking will increase the design difficulty and cost of relay communication terminals. Even so, Data loss can only be decreased correspondingly and cannot be eliminated. Data loss is not acceptable in reliable communication system, so it is very important to supplement retransmission mechanism based on TDM in high-speed relay communication system.

In order to meet the application demand of 4 Mbps real-time relay communication system, this paper proposed a retransmission mechanism based on mass storage and TDM, using hybrid automatic retransmission request (HARQ) technology [4], to solve the reliable communication problems of small buoy under the complicated sea state. In this paper, the system design of the retransmission mechanism based on mass storage and TDM is described, and the key parts of the mechanism are analyzed in detail, and the feasible design scheme is given.

2. System Architecture
This section firstly introduces the maritime buoy relay communication system. Secondly, the reasons of data loss of relay communication system under complex sea conditions are analyzed, and the necessity of the retransmission mechanism base on mass storage is emphasized. Finally, the system design of the retransmission mechanism is presented.
2.1. Maritime Buoy Relay Communication System

The maritime buoy relay communication system is shown in the figure 1, which consists mainly of remote buoys, satellites and shore-based stations. The backward link returns buoy image data to the shore base station at a bit rate of 4Mbps, and the forward link sends remote control instructions to the remote buoy at a chip-rate of 3Mcps. Relay communication terminal is installed in a Φ540 mm (diameter) × 650 mm (height) cylindrical buoy, which top is 300 mm above the sea level.

Spar buoy with its deep draft and large inertia experience low surge, sway, heave, roll, pitch and yaw motions in operating conditions. During the sea trial under the condition of three-stage sea condition, the buoy's attitude change is shown in figure 2. The data recording interval is 1s. Cylindrical buoy under the restriction of the anchor system, roll change within ±30°, pitching angle changes within ±20°, which is random. By FFT transformation of the data, it can be seen that buoy pitch change period is mainly distributed in 2-6s and roll change period is mainly distributed in 3-12s. During the sea trial, the acceptance EBR (Bit Error Rate) of shore-based stations reached 1×10⁻⁵. It can be inferred that under the higher sea conditions, buoy movement will be more intense and random. Excessive deviation of the antenna from the satellite direction will lead to higher BER, data loss, and even transmission interruption. In addition, high sea conditions have large waves, the sea water may cover the radome of the buoy, and the sharp attenuation of radio signals energy will also cause data loss.

![Figure 1. Maritime buoy relay communication system](image)

Ground station
Relay transceiver terminal
The forward link
The backward link
Satellite
Remote buoy
Data center
The forward link
The backward link
In order to combat complex sea channel environment, usually, buoy relay communication terminal will be designed in accordance with the worst sea condition, such as improving the response speed and precision of the satellite tracking unit, or increasing the transmission power of the relay communication terminal. On the one hand, there is not enough energy resources to meet the corresponding design requirements, owing to limited energy, resources, equipment volume and weight. On the other hand, buoy doesn’t always in the most severe sea condition. If blindly the relay communication terminal’s design in accordance with the worst condition, channel utilization rate will be low, and the increase of transmission power will lead to new problems such as heat dissipation, etc.

In this paper, a retransmission mechanism based on mass storage and TDM is proposed, and automatic retransmission request (HARQ) technology is used to solve the data loss problem in high sea condition.

2.2. The Retransmission Mechanism Based on Mass Storage and TDM

The retransmission mechanism principle block diagram is shown in figure 3. Relay communication terminal receive the data from buoy platform of observational image data, telemetry data and engineering parameters data, and transmit those data in real-time and backup. The green mark part in Fig. 3 is the real-time data path, the pink part is the delayed data path, and the yellow part is the playback data path. Real-time data path is the most basic function of buoy satellite relay communication system and has the highest transmission priority. The delay data path is the auxiliary of the real-time data path and has the priority of secondary transmission. The playback data path returns historical data with no timeliness and has lowest transmission priority. In the working process of the two-way links of relay communication system, relay communication terminal returns the buoy image data to shore-based station through the real-time data path, while the storage controller stored the real-time image data in the mass storage medium; When the shore-based station data center detects data loss of real-time data path, retransmission instructions will be automatically generated, and send to the relay communication terminal through forward link. The memory controller find out the lost data from NAND flash, and send to the shore-based station by the delayed data path. The data center receives and reassembles buoy image data and sends it to researchers within a fixed time delay The playback data path is a separate interactive transmission link that allows the researchers to manually replay historical data of buoy images within 12 hours on demand. As a key component of buoy relay communication terminal, the solid-state large-capacity storage controller can store, retransmit and replay real-time image data of buoy.
3. The Project Design

3.1. Mass NAND Flash Storage Controller

The buoy relay communication system has a return transmission rate of 4Mbps and the effective data rate of 2Mbps. The storage medium used by the controller needs to store effective image data for 12 hours and about 86.4 Gb. Neither compared with NOR Flash memory chip, NAND Flash chip features high unit density, fast write/erase speed, high reliability and low price. A 128 Gb MLC NAND flash chip can meet the requirements of this design. Micron model MT29F128G08CFAAAWP-ITZ NAND flash chip is used in this design. The minimum writing storage unit of NAND flash memory chip is one page, each page data store has 8 KB of data store and free storage area of 448 B, 256 pages forms a block, 8192 blocks make up a 128 Gb flash chips.

In the process of the read/write and erase of NAND flash memory chip, sudden or random errors of the solid-state memory data may occur owing to threshold voltage deviation, etc. Therefore, mass solid-state storage requires RS (256,252) coding to correct unexpected errors. This coding method is obtained by extending 1B verification bit on the basis of satellite channel coding RS (255,252) error correction coding, CCSDS 131.0-b-2 [5] standard recommendation code, which can correct 2B random errors [6]. Mass solid-state storage systems usually include storage management software and storage control hardware, consisting of CPU+FPGA. The CPU runs based on the operating system of the storage management software, and completes the file dynamic management for the solid storage media. The FPGA performs the functions of reading and writing, erasure operation and memory bad block maintenance to storage media through instruction analysis of CPU application software. Considering the relative simpleness of solid state storage function of buoy relay communication system, CPU documented dynamic management function is saved, the circulation erase, write and bad
block management function are completed by FPGA, and complete the read and playback function of data according to remote control instructions by the shore-based station. The workflow of the storage controller is shown in figure 4, which can be divided into the initial stage and the routine task management stage.

![System on power workflow](image)

### Figure 4. The storage controller workflow is shown in the figure

Initialization stage includes two tasks. After power on, the first is to read the free area of the first address page and take out the buoy data frame count of the current page as the reference address of the subsequent page address. Secondly, initialization successively restores the register state of each module globally, making the storage controller in the initial state and waiting for subsequent tasks. Storage, playback, reading and erasure operations are mainly implemented in the routine task management stage.

The storage operation first determines whether to write a new page, and successfully extracts the frame count information of the input data and writes it to the free area of the new page for data retrieval. Then all the received image data is written to the cache of FIFO. When the cache data reaches 252 bytes, start to RS (256, 252) coding, generating 256 byte code sequence, and write it into FIFO. The FIFO use double FIFO ping-pong operating, single FIFO has the capacity of one page data, which is 8192 bytes. When the FIFO is full of 8192 bytes, FLASH write operation will start. Before starting to write the program, the page read operations will conduct in the current spare area information to determine whether the page is blank. If not, just skip to the next page for the same operation, until find the blank pages, and write the data in the cache. After the data is written, the status information of the free zone is maintained.

The data playback process is carried out in pages and can be divided into sequential playback and on-demand playback according to instructions. When sequential playback is initiated, the playback address pointer points directly to the beginning page 0. When starting the page-by-page playback program, the playback length provided by the instructions. When the instructions on-demand playback, the frame of the physical storage address will be found out according to the instructions provided by the playback data frame count, and the data in the page will playback sequentially at this address.

The data reading process is carried out in the frame. According to the retransmission instruction, the frame count information is found in the free space. The reading address pointer is pointed to the data, the read operation is started and the reading length is provided by the instruction. The replay of data and the reading of data require RS (256, 252) decoding to be sent the corresponding data into FIFO. When the FIFO is full of 438 bytes of a transmission frame, it waits for the multiplexer to access.
The process of data erasure can be divided into instruction total erasure and sequential rollback erasure. Flash erase operation is united by block, therefore, when start the erase operation, it will scan fully in the free area of target block to judge whether the block is fail to written or exist invalid page. If any, all spare area within the block will be marked as invalid. When the data is about to overflow, the block of the initial address is erased in the order of physical address (time sequence) to ensure the storage of new data.

3.2. Automatic Retransmission Mechanism

Automatic retransmission mechanism has been realized by the interaction between buoy relay communication terminal and the shore-based station. First, the data center can monitor the loss or error of data frames in real time, and automatically generate retransmission instructions and send them to relay communication terminals under the forward link. After the storage controller receives the retransmission, the corresponding retransmission data from the flash solid-state memory chips in a FIFO 02, multiplex device in priority order, the channel coding, modulation, and enlarged into back to link to shore-based station; Thirdly, the data center will retransmit data back to cache data 02. Finally, the data center recombines real-time data and retransmission data within a fixed time delay, and sends the complete continuous near-real-time buoy observation image data to the researchers. In order to provide complete and continuous observation image data to the researchers, the data center conducts a short cache delay and reorganization. In the one-way link data transmission from buoy relay communication system to the base station, data processing will take 42 ms, and wireless transmission delay is 254 ms. Thus, the data retransmission delay is 592 ms. On this basis, the cache delay of the data center can be adjusted according to the actual situation. The design of image data does not require high real-time performance, and the cache delay can be set as 1.4s. 1.4s delay left to the data center for two requests for retransmission. When the data center fails to receive the retransmit data within 750ms after the first retransmission instruction, the retransmission instruction will be sent again. After 1.4s, the image data frames were taken out from the real-time data cache and the retransmission cache for recombination and transmitted to the researchers.

1.4s can only solve the problem of most lost count, nearly real-time data cannot fully guarantee the integrity of the image data. Therefore, the system designs manual on-demand playback function, which can display any image data within 12 hours. Playback and near real-time data need to be processed by the researchers in two different applications. Nearly real-time data is transmission channel needs to be ensured by the buoy communication systems, on the basis of it, the automatic retransmission and on-demand playback function is realized.

3.3. TDM

The real-time data path, the retransmission data path and the playback data path are completed on the same reentry link by TDM. In the satellite relay communication system, the link transmission bandwidth typically is bigger than the effective data bandwidth; the filled data need to be sent in the gap between valid data group frames, to ensure the continuity of the wireless link. In view of the image data retransmission and playback demand, relay communication terminal in the data link layer frame adopts time-division multiplexing method. The time of filling data will be used for sending retransmission or playback data. The backlink data transmission frame structure is shown in table 1. Each data transmission frame length is 512 bytes (2048 bits) in a fixed-length format, and the effective data length is 438 bytes. The multiplexer the virtual channel identifier (10 ~ 15 bit) to distinguish four different types of data. The virtual channel assignment and identifier are shown in table 2.
Table 1. Backlink data transfer frame structure

| The frame synchronisation head version number | GVCID spacecraft identifier | Virtual channel frame count | Signaling domain | The frame count | Bit stream data | RS checking |
|---------------------------------------------|-----------------------------|-----------------------------|------------------|-----------------|----------------|-------------|
| 32 2 8 6 24 8 32 3472 512                  |                             |                             |                  |                 |                |             |
| 4B 2B 3B 1B 4B 434B 64B                     |                             |                             |                  |                 |                |             |

Table 2. The virtual channel identifier configuration

| number | Data sources       | virtual channel identifier |
|--------|--------------------|-----------------------------|
| 1      | Real-time data     | 03                          |
| 2      | Retransmission data| 0b                          |
| 3      | dump data          | 30                          |
| 4      | Filling data       | 0F                          |

4. Conclusion

This paper introduces in detail the application of retransmission mechanism based mass storage and TDM, and analyse and discuss the high speed communication of buoy on the sea. Finally, a complete design plan is formed, which has the practicability and feasibility. This will be used in the science and technology innovation project of Chinese academy of sciences.

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