Intercontinental network control platform and robotic observation for Chinese Antarctic telescopes

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ABSTRACT

The Chinese astronomical exploration in Antarctic region has been initialized and stepped forward. The R&D roadmap in this regard identifies each progressive step. For the past several years China has set up Kunlun station at Antarctic Dome-A, and Chinese Small Telescope ARray (CSTAR) has already been up and running regularly. In addition, Antarctic Schmidt Telescopes (AST3_1) was transported to the area in the year of 2011 and has recently been placed in service for some time and followed with telescopes in larger size predictably more to come. Antarctic region is one of a few best sites left on the Earth for astronomical telescope observation, yet with worst fundamental living conditions for human survival and activities. To meet such a tough challenge it is essential to establish an efficient and reliable means of remote access for telescope routine observation. This paper outlines the remote communication for CSTAR and AST3_1, and further proposes an intercontinental network control platform for Chinese Antarctic telescope array with remote full-automatic control and robotic observation and management. A number of technical issues for telescope access such as the unattended operation, the bandwidth based on iridium satellite transmission as well as the means of reliable and secure communication among other things are all reviewed and further analyzed.

Keywords: Intercontinental network, Robotic observation, Iridium satellite

1. INTRODUCTION

The vast area of Antarctica is notable for its worst conditions for human living, yet with strategic significance for researches of physical geography and astronomical observation. Because of the excellent seeing notably at Dome-A around 0.2arcsecond to 0.3arcsecond and plus other favorable observation conditions Antarctica has become the front arena for international astronomical exploration[1]. A number of developed countries has competitively proposed and implemented a series of projects in this regard. Just to name a few: American 10-meter SPT (abbr. for South Pole Telescope). The French TRSS telescope (abbr. for Three Reflection Sky Survey).

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The Spanish and French IRAIT (abbr. for International Robotic Antarctic Infrared Telescope). The French and Italian KEOPS project (abbr. for Kilo-parsec Explorer for Optical Planet Search). The Australian French and Italian PILOT (abbr. for Pathfinder for an International Large Optical Telescope) etc. For the recent years the Chinese exploration in Antarctica has also been geared up. The milestones along the road of Chinese Antarctic exploration particularly with regard to Astronomy are as follows. In the year of 2005 the 21st Chinese Antarctic Expedition for the first time in the world's history successfully reached the summit of Dome-A, the highest icecap of Antarctica, approximately one thousand kilometers away from the Antarctic sciences research station, the Zhongshan Station. In the year of 2006 the Chinese Center for Antarctic Astronomy (CCAA) was set up with the united endeavor of Chinese astronomical community. In Jan. 12, 2008 the Chinese Small Telescope Array (CSTAR) was deployed at Dome-A ready for testing. In March 20, 2008 the CSTAR sent back the first picture. In Feb. 2, 2009 the Chinese Antarctic Kunlun Station was established at Dome-A. At the beginning of 2012 the AST3_1 was delivered and installed at Kunlun Station and started successfully sending back pictures. AST3_1 is one of a group of three AST3 telescopes. In addition, it has been reviewed and planed that a 2.5meter KDAST telescope and a terahertz telescope both will be built and installed at Dome-A for further boosting the capability in Chinese astronomical exploration at Antarctica. All these deployed telescopes now under the administration of the Chinese Antarctic Observatory (CAO) at Dome-A. In the long run, more powerful facilities with larger size are to be visualized and built and further deployed at Antarctica. The scenario afore mentioned about has given rise to two significant issues. The first issue is how to efficiently manage all the existent telescopes at Antarctica as a whole. The answer is a network infrastructure as the backbone to support all these inhomogeneous telescopes to operate harmoniously so as to make full use of the communication band, which is generally not enough at Antarctica for remote real-time application. The telescopes network should also provide adequate free interface ports left for anticipated new comers. Finally the telescopes network at Antarctica will extend to China for more connectivity so as to become an intercontinental network platform. The second issue lies in the need for the control of those unmanned Antarctica telescopes. One thing worthy mentioning is that it is still hardly possible for people to live through winter at Kunlun Station due to the extremely coldness in winter. Only around 20 days or so left workable for the Chinese expedition there. That is why the telescopes there are required to feature the function of remote and robotic observation. These two issues are discussed about in the following chapters.

2. CSTAR AND AST3_1: IRIDIUM SATELLITE COMMUNICATION AND REMOTE CONTROL

Due to the unique geographical factors at Antarctica the only means of option for intercontinental communication so far is probably still the iridium satellite communication[2]. This is fundamental resort for any telescopes at Antarctica to control remotely. The CSTAR is remotely implemented by receiving commands from an iridium-satellite. Since the CSTAR does not have to operate in tracking mode due to its operating mechanism, the remote control for it assumes relatively simple. Basically the control is involved in a series of operation of a shutter open/close and the power source regulation so as to send back a few pictures. Obviously this is not supposed to be a complete nor sophisticate control system. On the other hand, for the AST3_1 it is required o be in real-time tracking mode, therefore a complete remote control system is absolutely necessary. The configuration of the control system for AST3_1 is shown in figure 1 and figure 2[3].

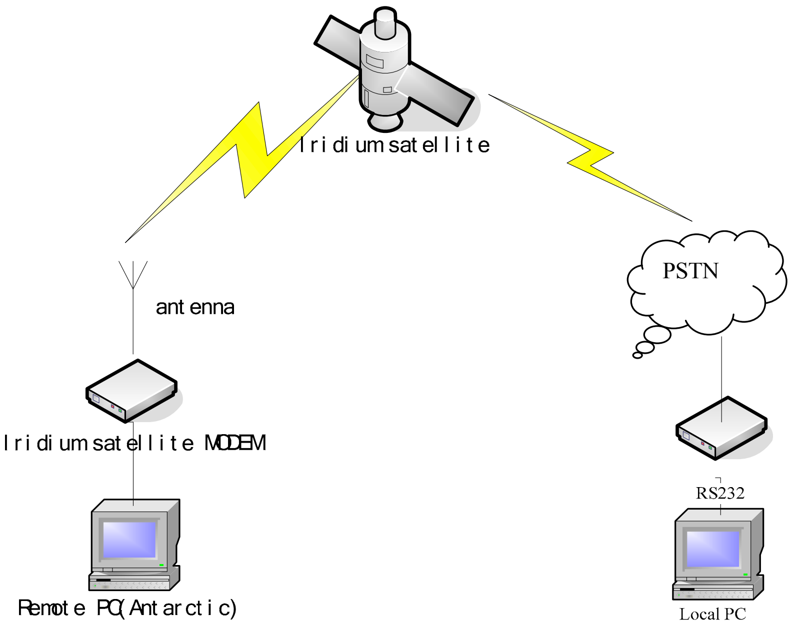

Figure 1: Configuration of Iridium satellite communication

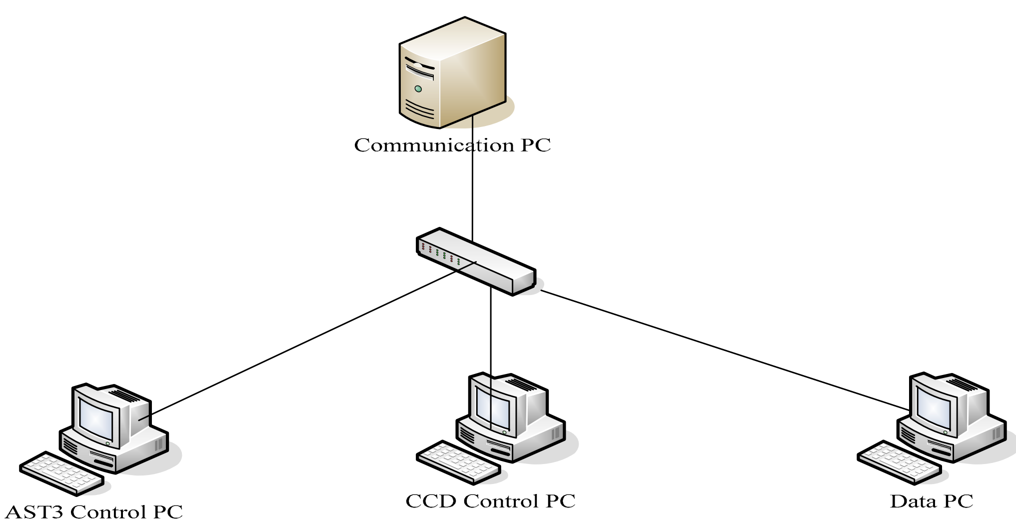

Figure 2: Schematic diagram of AST3_1 internal communication

The local master PC with a standard modem in it dials up through an Iridium gateway (or using OPENPORT mode) to connect to the remote Antarctica Iridium modem so as to set up a communication with the remote communication master PC. Once the connection is through, logon to the Antarctic communication master PC using SSH protocol then to communicate with AST3_1 control network. The components of AST3_1 control system based on a LAN at

Antarctica consists of Iridium communication PC, CCD master PC, data PC and telescope control PC. It is possible to logon through the Iridium Satellite to all these PCs in the LAN. There are two operating modes for the telescope to control remotely. The first mode is meant for the CCD master PC and the telescope control PC to deliver remote commands and feedback states by means of SOCKET connection using TCP/IP protocol. The second one is to directly conduct operation and states-acquisition for the telescope control PC using script files.

The communication coding is listed below:

- n1.n2.n3.i.j
- n1,n2,n3,i,j: all are natural numbers.
- n1: the coding for sub-system level.
- n2: the coding for sub-system's second level (or one level below the sub-system level).
- n3: the coding for sub-system's third level (or one level below the second level).
- i: it designates a command if i=0; a state if i=1 and an emergent alarm if i=2.
- J: J can be any number of the increasing sequence of integer from 0 to 3 representing deferent priority from low level to high level.

For example, <ID=2.1.4.0.0><pos=56.7> designates main axis control, azimuth, positioning, command, normal priority.

Based on the communication protocol a procedure flow is described generally as below.

- Message bus sends <ID=2.1.4.0.0><pos=56.7> to telescope control system.
- Telescope receives the command and returns <Info=ok>, meaning command can be implemented as usual. Then telescope control system starts implementing command.
- During the course of implementing it returns the message-bus <ID=2.1.2.1.0><pos=56.7><info=done>, meaning azimuth axis rotates 40 degree, and working state is normal.
- At the end of implementation it returns the message-bus <ID=2.1.2.1.0><pos=56.7><info=done>, meaning azimuth rotates into the target position and command implementation is completed.

If procedure runs error the implementation of communication protocol is described as below.

- Message-bus sends the telescope control system <ID=2.1.2.0.0><pos=56.7>.
- Telescope receives the command and returns <Info=ok>, meaning command can be implemented as usual. Then telescope control system starts implementing command.
- During the course of implementation it returns the message-bus <ID=2.1.2.1.3><pos=40><info=error><mess=alt disable>, meaning azimuth axis rotates for 40 degree, azimuth error comes out, needs to feedback the error message with highest priority.
- At the end it returns the <ID=2.1.2.1.0><pos=40><info=done>, meaning the command implementation completed.

3. REMOTE CONTROL SYSTEM FOR TELESCOPES AS A GROUP AT ANTARCTIC OBSERVATORY

With rapid pace of Chinese exploration at Antarctica it is anticipated that 4 or 5 more telescopes will be delivered and placed at Kunlun Station in next decade. The current remote communication mode individually dealing with each site telescope as described in second chapter is presumably not able to face new tough challenge for all the telescopes as a group entity at the Chinese Antarctic astronomical observatory. With foresighted strategic consideration it is essential to integrate the existing resources of telescopes and supporting platform at Dome-A and reserve a certain number of expansion interfaces so as to establish an intercontinental net control platform based on Iridium satellite communication for Antarctic telescope array operate from China with remote full-automatic control and robotic (unmanned) observation and management. The research involves three aspects. (1) A control system of Dome-A telescope array capable of coordinating among the telescopes, automatic observation, operation resume, self-updating, self-protection and self-checking. (2) An unmanned iridium satellite communication system carrying out the China-Antarctica two-way communication. In order to improve the communication efficiency high-techs such as image compression, encoding checking, broken-point resume in communication etc. are to be utilized. (3) Robotic scheduling system for observing time-sharing. This will open to public, both domestic and international. Online application for telescope time-sharing is expected. With some restriction of site meteorological conditions and user-priorities the observation plan will be automatically produced and executed. This done will greatly boost scientific-output, international collaboration and investment, and provide a powerful platform for public scientific education.

With the three research aspects given above the most difficult one is the design of control system for telescopes array at Kunlun Station. The design at system level comprises five software modules at sub-system level, namely the Command Scan and Parse (CSaP) module, the Message Bus (MB) module, the Fault Handling (FH) module, Status Analysis and Packing (SAaP) module and Log Book (LB) module. Each of the five is briefly discussed below.

- CSaP module

With responsibility for scanning the command package received from communication PC, extracting the command package, producing an observation scheduling and converting the observation scheduling into a message flow in accord with the internal communication protocol.

- MB module[4]

With responsibility for sending, in parallel and serial combination, message flow to each module, then receiving the feedback message from each module, further classifying the feedback message and handing over to the SAaP module for next process. If an error appears from the feedback message it will be put in the hands of FH module to deal with. The MB is formatted with binary linked list. The data structure for message is shown in figure 3 and described with C language as below.

```
Struct st_message
{
int i_degree;  //level number
char message[512]; //message entity
Struct st_message *pst_child ;//children linked field
Struct st_message *pst_brother; //brotherlinked field
int i_flag; //message identifier
int i_time; //over time span
```

char s_time ;//start time

}

A node in the linked list has two linked fields pointing to the first children node and the brother node respectively. Each linked list has 4 attributes of level number, message identifier, over time span and start time. The node number and the over time span are obtained from the message number list. In message bus parent's level number is larger than the one of their children's linked list. The level-numbers between two brother's linked lists are equal, which is shown in figure 3, where the linked list at the root points to the message linked list 8_1 with currently largest level-number. The children's linked list of 8_1 node points to the message linked list 6_1, which is a message linked list with the highest level-number yet below the level-number 8. The brother's linked list 6_1 points to the message linked list 6_2 at the same level as 6_2. At the same time the children's message field points to the linked list with the highest level number yet below level number 6. The message at the lowest level is implemented first. Only have all the messages at lower levels been implemented the message at one level up will be implemented. This is to ensure that the message flow can be sent out in parallel and serial combination.

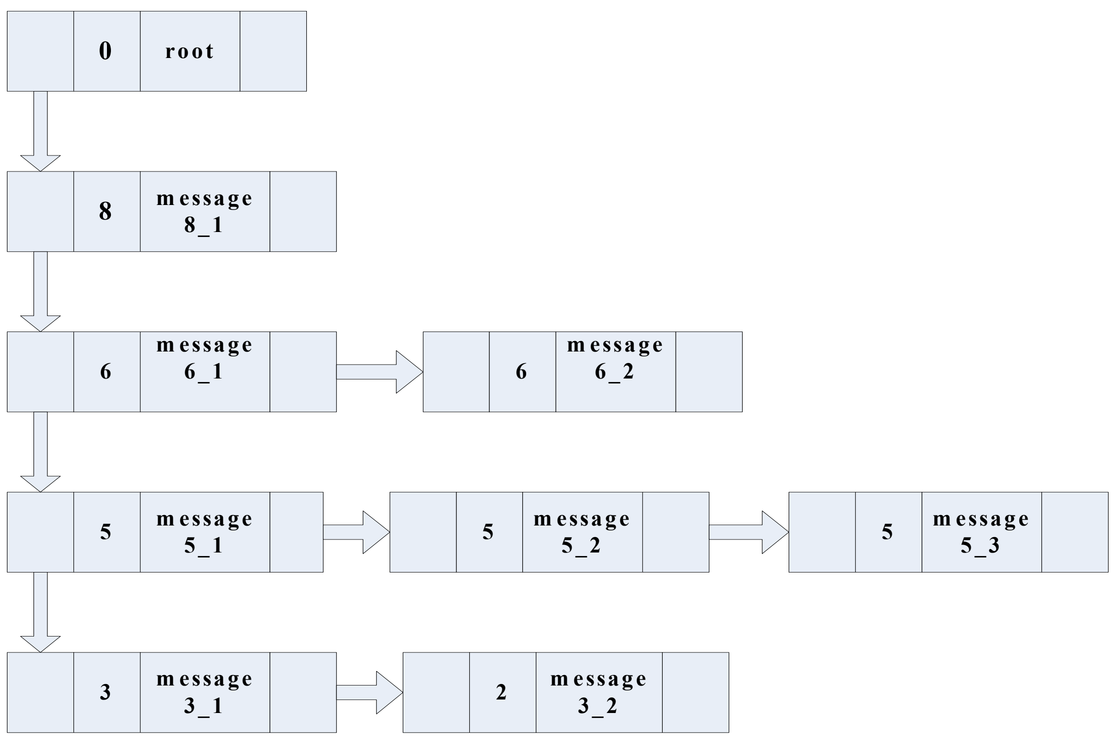

Figure 3: Message bus structure with binary linked list

- FH module

This module is meant to analyze the fault-status-message received from the message-bus. The fault handling strategies can be predefined on a case by case basis. Once a fault appears it can be dealt with according to the predefined strategies. This module also supports remote amendment and additions/deletions.

There are two modes of processing. One mode is to convert the message into handling strategies and to handle through message bus. The other is to control the related hardware restart by means of IP power regulation.

- SAaP module

This module is meant to classify the status messages, further to re-code and pack, then to send the package to communication PC.

- LB module

This module is meant to record the message sent/received so as to ease the daily maintenance.

4. SECURITY AND RELIABILITY FOR REMOTE CONTROL SYSTEM AT ANTARCTIC ASTRONOMICAL STATION

Dual host computer back-up mode is utilized in remote control system so as to prevent the telescope from stopping routing operation when one of the two host computers starts malfunctioning. The double-network-card binding technique gaining automatic load balancing is employed for the host computers. The communication between the general control computer and each sub-system PCs utilizes SOCKET communication mode based on TCP_IP. The general control computer takes charge of analyzing the commands from communication PC, and processes recoding, which is distributed to each corresponding sub-system PC node. This is to make harmonic interaction among all the sub-systems. The general control computer needs to initialize a number of different ports corresponding to each node to ensure the communication without mutual interference. Each node uses unified communication protocol. In this kind of control mode it effectively coordinates sub-systems on the network platform so as to boost observation efficiency and increase the scientific output.

5. CONCLUSION

Because of its specialty and environmental requirement the remote control system for Antarctic Astronomical Observatories must be built into a robotic system with high robustness. Still there are more issues to be considered and addressed in this regard. This paper only presents a rough framework. It certainly calls for more engineers and scientists to participate in developing more sophisticated facilities for Antarctic astronomical exploration.

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