

Computer Network: Control Infrastructure of Large Astronomical Telescopes

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Abstract. A high-tech Large Astronomical Telescope (LAT) integrated with cutting-edgy technologies is universally regarded as one of eye-catching events indicating comprehensive national strength in science and technology. Powerful functions and incredible performance of the telescope control system largely rest on its control infrastructure, which again is built on computer network. In the nut shell, computer network is a foundation stone for the LAT control infrastructure. This paper takes the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) [1], a national large-scale astronomical facility, as an example to focus on its control infrastructure associated with its network configuration features. As the advent of so called 3G age and foreseeable Internet of Things (IOT) some points of analysis regarding the impact of next generation network on the design of contemporary and future astronomical telescope control system is also discussed and envisioned in this paper.

Keywords: Large Astronomical Telescope, computer network, control infrastructure, control system, LAN.

1 Introduction

Galileo built his first telescope and took it to observe the sky about 400 years ago. The telescope was merely an optic-mechanical gadget seen today, yet a revolutionary event in astronomy. Since then the persisting exploration of mysterious universe has greatly pushed the development of astronomical telescopes. The R & D of astronomical telescopes has experienced smoothly evolution and dramatic advancing at times. Astronomical telescopes have become more and more powerful and sophisticated for deep space probing. Particularly a LAT itself turns out to be a comprehensive optical-mechanical-electrical integration. The integrated telescope consists of many components at hierarchical levels to interact each other within a network system plus numerous plug-in accessorial detectors as service devices. Besides, modern LATs, from ground based to space, are capable of acquiring

enormous astronomical data at amazing high rate. These massive data require online reduction or offline analyzing, which again call for huge computing capacity. A telescope or an array of telescopes must be under complex and strict subtle control to move around for targeting celestial objects. It normally involves harmonic collaboration among multi-optical-mechanical-electrical components of telescopes. In addition, thousands of or even tens of thousands of varieties of sensors keep monitoring day and night all kinds of telescope parameters and environmental variables to ensure everything in smooth processing. What is more, remote control and observation services are definitely needed, and robot working mode is highly demanded for facility efficiency and massive scientific output. Given the highlights illustrated above, the R & D of LATs inevitably have turned to cutting-edge technologies available at the time. One of such state-of-the-art technologies is computer network, which enable to forge a powerful infrastructure in distributed form for all telescope components to interact each other consistently. From the perspective of automation a modern telescope control system is a non other than networking system with its each node, normally some hardware and software combination, to play certain functions and to communicate systematically in the topology structure. After all, computer network technology brings about revolutionary breakthrough in the design of control infrastructure for modern LATs.

This paper takes a national large scientific and engineering project LAMOST telescope as an example to focus on its network infrastructure. The telescope has been built mostly in Nanjing Institute of Astronomical Optics & Technology (NIAOT), Chinese Academy of Sciences (CAS). The Chinese ever ambitious LAMOST, which was completed and passed inspection and acceptance test by national evaluation in 2008, has become so far the world's most powerful ground based optical astronomical survey telescope with meter-class aperture. It has set the world record with the number of 4000 stars to magnitude 20.5 that can be surveyed simultaneously by the telescope. With the above facts in mind it is imaginable that the control infrastructure of the telescope with computer networking as its core structure must be powerful, flexible and robust. Throughout 10 years of R & D the control team members in NIAOT have fully investigated and searched the network market for high cost-effective products and upgraded the hardware and software properly. The road map, from lab computer simulation to LAMOST model preliminary test in NIAOT campus and finally to the site engineering and testing and installation on Xinglong mountain of Hebei province, has witnessed how the advancing network technology has boosted and perfected the design of control infrastructure for modern LATs. The trend of networking for LAT control infrastructure currently still goes on as nowadays remote control, robot telescope, space telescope and virtual telescope and observatory all has become popular thanks largely to new generation of network comes along. Recently in the IT area the concept of IOT is frequently and loudly covered by the media. Also the problem of Internet Protocol Version 4 (IPv4) address exhaustion is much discussed. A possible solution is to make transition from IPv4 to IPv6. The implication of these big network events for LAT controls system design is presented in this paper.

2 Road Map of Network Technology in LAT Design

A computer network, often simply referred to as a network, is a collection of computers and devices interconnected by communications channels that facilitate communications among users and allows users to share resources. The concept in this regard has already been general knowledge today and widely applied in control and communication system design. Not until the 80's of last century, however, did the Single-Chip Microcomputer (SCM) at China market became commercial available then. Such as 8031/8048/8051/8098 SCMs were among very popular ones. The second author of this paper in 1992 successfully built an 8098 based development system as a front end controller in the master-slave cascade control for first Chinese Stellar Interferometer prototype. However, this kind of control was far from networking in real sense. Most of job still had to be done painfully by connecting varieties of discrete elements and Small-Scale Integrated Circuit (SSIC). The same situation happened during the course of building 2.16 meter astronomical optical telescope, the largest one of its kind then in Far East Asia prior to the LAMOST. In the beginning of 90's of last century desktop Personal Computer (PC) became available at domestic market and hit the market instantly. In a couple of years computer control became a fashion. Most likely the small control system was only comprised of a single PS as the host machine with a drive card plug-in as the interface to external SCM slave controller, which again drives a device, say a motor. Still such a kind of control is not considered as network control. Control engineers specializing in design for LAT expected much more than that. History stepped forward, and so did the technology. In another several years to the end of last century the PC's performance amazingly boosted with the networking technology dramatically changed from embedded controller, Local Area Network (LAN) up to Internet. By the time the LAMOST project started preliminary design in 1998 control engineers fully took the advantage of new technologies of controller, computer, network, etc. in their design for LAMOST control infrastructure. A new era in the sense of control system design for LATs in China thus arrived.

3 Networkised LAMOST Control Infrastructure

Figure 1 shows the LAMOST high-level control and interfaces. Some abbreviations are explained briefly below [2], [3].

- The Observatory Control System (OCS) is at the top in the hierarchy responsible for supporting the on-site observer and system operator in their tasks and coordinates the activities of the other three principal systems immediately at one level below the OCS in the hierarchy, namely Telescope Control System (TCS), Instrument Control System (ICS) and Data Handling System (DHS).
- The DHS archives the observed data into the Spectroscopic Database (SDB) and implements varieties of processes such as observation planning from the input Catalogue Database (CDB), image processing, spectrum analysis and data publish.

- The ICS controls the instruments, such as the fiber positioning system, spectrographs and CCDs.
- The TCS receives observation commands with coordinates of the right ascension and declination of the sky area center to be observed and manipulates its subsystems in conjunction with ICS to complete the pointing and tracking of the target. For better tracking the TCS might also get a set of guide stars' coordinates in the target sky area as the tracking references.
- Each subsystem of the TCS is listed below.
 - ✓ Mount Control System (MCS).
 - ✓ Focal Plane Control System (FPCS).
 - ✓ Star Guide Control System (SGCS) .
 - ✓ MA Active Optics Control System (MAAOCS).
 - ✓ MB Active Optics Control System (MBAOCS)..
 - ✓ Dome Control System (DCS) .
 - ✓ Environment Monitor & Control System (EMCS)..

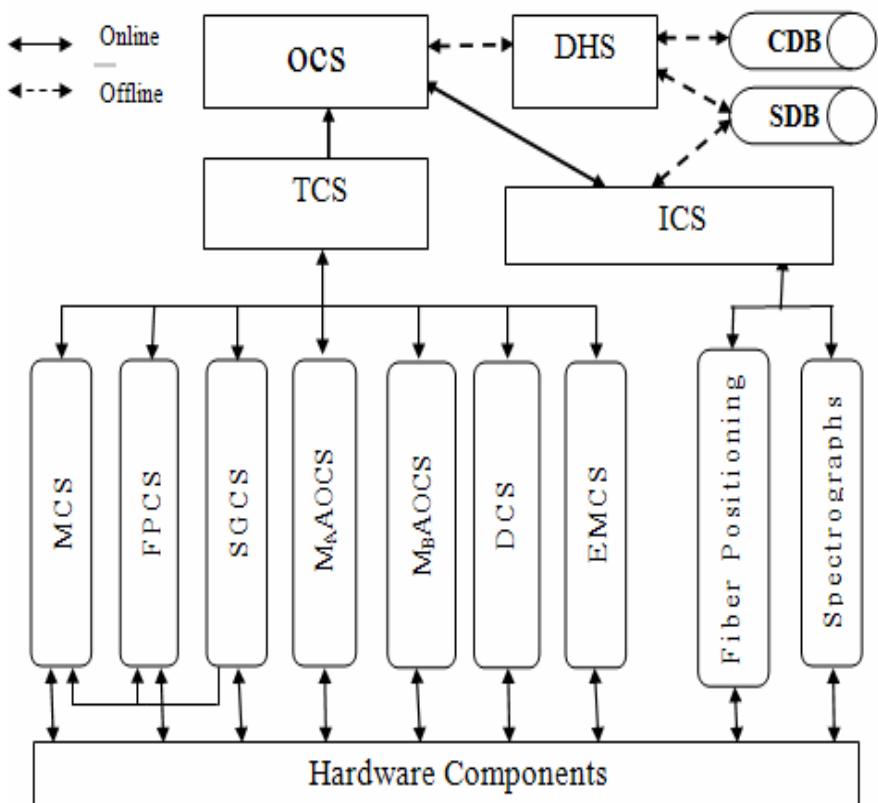


Fig. 1. LAMOST high-level control and interfaces

The TCS LAN features distributed, hierarchy and expandable. A Local Control Unit (LCU) with embedded QNX [4] microkernel and task specific codes controls each main hardware component. QNX is one of well-known real time operating systems on the current world market. The cost effectiveness of the QNX contributed to our consideration of choice of real time system under our limited budget. The LAN is built on Ethernet connection with TCP/IP standard for data traffic. In addition, there is also proprietary Fleet protocol among the QNX nodes machines, which makes them behave like a virtual computer with combined individual computer capacity, resources shareable and transparency. The idea to employee LCUs is to isolate the hardware components from the TCS main working station and lend a hand to software programmers to write high-level software module without worrying too much the specific nature of each hardware component [5], [6]. Obviously such a network layout is characterized with plain module design, economy and easy maintainability. Typically the time scale among the real time QNX nodes can reach 1ms accuracy thanks to the Fleet protocol, which is enough to meet all the real time task requirements for LAMOST. A real time distributed database has been built under QNX OS v6 environment. It is an important mechanism for a variety of system functions occurring on the TCS LAN such as recording various kinds of data for online data analysis or offline play back study. A number of advanced skills, such as the shareable memory and dynamic creation of objects and tables etc, have been implemented, which has made the database management system easy to manipulate with Windows style.

At the early R & D stage of LATs the approach of simulation is a wise and efficient way of doing, which again heavily depends on the computer network technology available at the time. Here is how it works. Generally several high performance computers hook up together making a LAN with each node of compute at hierarchical level simulating a specific function module. Often some computers at low levels have interface boards plug-in the mother board slots for driving external devices. This is similar to the master-slave application at SMC age in the 80's last century. However for high-level software package analysis and debugging more often than not it has to be implemented on network platform. In LAMOST case the concept of virtual telescope that was originally associated with pointing/tracking has been around for a couple of decades. However as the advent of networking edge the R & D of LATs have undergone a forward leap in the control infrastructure design from concept down to practice. The LAMOST simulation approach in its control system development is divided into three progressive phases from level-0 simulator up to level-2 as follows.

- Level-0 is a lowest level of the simulator giving the feel and look for the user interfaces. Virtual hardware components are represented with graphical sketches when needed to show on screens, and so is the status transition of components generated by the simulation status generator. One simple such an example is when a hand controller is shown on the screen .the user is asked to pre-select one of the three possible velocity and then keep press of the mouse on any direction key of the four possible choices, that way would make a virtual mount shown on another screen to move accordingly until the mouse is released. It is a visual simulation in its nature for user interfaces and gives responses graphically on the screens.

- Level-1 is upgrade of the level-0 simulator with major portion of the codes for the basic LAMOST control modes available. The simulator of this level can work on its own with virtual hardware components, it should also, if needed, work for the real telescope on site to receive first light manually, which can be called hardware-in-the-loop simulation. Characterization of the mount drive servo and the actively controlled optics has to be done during this phase in order to get important parameters for the simulator.
- Level-2 is upgrade of the level-1 simulator, a comprehensive working software package featuring fully automatic with all codes needed available. The simulator should work almost perfectly in reality on site, and provide simulated operation environment in lab for the users perfectly.

In a word, this chapter gives example of LAMOST to show how the computer network technology brings about dramatic advance in the LAT control infrastructure design.

4 Future Vision

3G stands for third generation and is the third generation of wireless network technology. 3G Internet refers to a type of Internet access provided by mobile phone companies that subscribers can use to access faster speeds than previous versions, such as 2.5G and 2G Internet. It is typically used from mobile devices such as cell phones. It is a set of standards, or rules, that allow mobile devices to connect wirelessly to the Internet for surfing the web and making phone calls. What this event means for our control engineers is that it is possible to wirelessly monitor the performance of control system of LASs by a cell phone [7]. The preliminary test was done in 2006 in LAMOST design when a lab simulation carried out successfully with a normal cell phone. The result is very much promising and encouraging. One thing is for sure if it is adapted to new 3G cell phone the result could be better. Another IT event is that the concept of IOT is frequently and loudly covered by the media. IOT is a network of Internet-enabled objects, together with web services that interact with these objects. Also the problem of Internet Protocol Version 4 (IPv4) address exhaustion is much discussed. A possible solution is to make transition from IPv4 to IPv6. The implication of these big IT events for LAT controls system design is anticipated. So it is possible to get an IP address for each telescope object, which is Internet-enabled, together with web services that interact with these objects. With this vision in mind we control engineers are longing for the time to arrive.

5 Summary

For the past decades we have experienced dramatic advance by leaps and bounds in the network technology. Faster speed network comes into being, and so does the network load capacity. Modern society can not be in normal operation without Web. It is also true in the points of our discussion above. The LAMOST experience has shown fundamental transition in the way of designing for the LAT's control infrastructure as result of new era network-technology. Much more is anticipated in this regard. Full

remote automatic control, wireless control, robotic control, unmanned observation scheduling, virtual telescope, intercontinental or space operation and even moon-based telescope etc. are either already realized or on the table for discussion thanks largely to the epoch-making network-technology.. Control engineers must bear this in mind to keep with the pace of technology development for best possible designing control infrastructure.

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