Research of Large Telescope Control System

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ABSTRACT

With the development of active optics, control technology and computer, telescope control system (TCS) becomes more and more complicated. Large telescope control system contains thousands of controlled objects, and large telescopes are usually built in special location. These are challenge for control system. This paper research advanced control technique of TCS, presents the topology structure of wireless local area networks control, remote control based on satellites and wireless portable control and expatiates the real-time design of telescope control units.

Keywords: Telescope Control System, Wireless Networks Telescope Control System, Remote Control, Portable Control

INTRODUCTION

With the development of active optics, control technology and computer, the aperture of telescope become more and more large, and telescope control system (TCS) becomes more and more complicated. Large telescope control system contains thousands of controlled objects or more, especially adopted adaptive optics technology[1]. And large telescopes are usually built in special location where it is difficult for communication and traffic. These are challenge for control system. Utility of advanced technology can reduce the difficulties and complexity of TCS.

There are enormous controlled objects of TCS in narrow area. Traditional control systems don't satisfy the performance need of large telescope control system. Current, TCS adopts distributed control system (DCS), such as LAMOST (Large Sky Area Multi-object Fiber Spectroscopic Telescope) adopts distributed Ethernet control system[2]. Network control system (NCS) reduces collision domain and separates collisions through switcher. NCS improves the performance of the large TCS. As shown in Fig. 1, TCS based on NCS maybe include: remote control system, main control system and local control units.

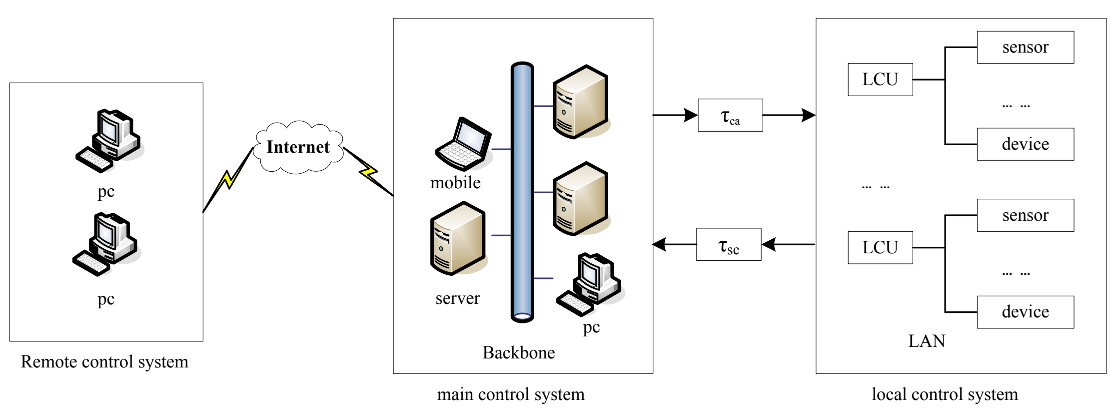

Figure 1. Telescope network control system

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Software and Cyberinfrastructure for Astronomy, edited by Nicole M. Radziwill, Alan Bridger,
Proc. of SPIE Vol. 7740, 774034 · © 2010 SPIE · CCC code: 0277-786X/10/$18 · doi: 10.1117/12.854114

Current large telescope control systems are based on wired network (as Ethernet, CAN, etc.), connecting actuators, sensors and controllers with wired channel. Traditional TCS includes thousands of cables which result in difficult-to-manage, occupy signification space and lack of system flexibility, especially in Antarctica Plateau and extra large telescope in the future. In recent years Wireless Local Area Network (WLAN) and Wireless Sensor is a rapidly emerging field of activity in data and control networks. Large telescope control system based on wireless networks (WLTCS) is a wireless local area network, include main controller, access points (AP), wireless local control units and actuators. WLTCS allows for easy expansion, it is a scalable and flexible system. WLTCS decreases costs of design, operating and maintenance, which drastically reduced the number of measurement channels.

The Antarctica Plateau has recently turned out to be the best place on the Earth to perform astronomical observations. We are going to devise telescope to build in the Antarctica. Remote control center transmits commands to local control units through satellites. LCUs connect the local server with wireless channel. To improve the communication performance, the special exchange format of data between remote control center and local control units must be designed.

To achieve the control of telescope at “Any Time, Any Where, Any Body”, proposed a telescope portable control system based on Java. The system adopted the J2ME-J2EE frame so that client can control the telescope in time through mobile terminal.

This paper is organized as fellow: section 2 provides a description of WLTCS. Section 3 presents remote control based on satellite. Section 4 presents the implementation of real-time Telescope Control System. The portable control system is demonstrated in section 5. Finally, the paper is concluded in section 6.

WLAN TELESCOPE CONTROL SYSTEM

1.1 Wireless local area network

WLAN has gained widespread acceptance in recent years. It provides user with relatively high bandwidth wireless data connectivity, and enabled low cost wireless connectivity. With the advent of the IEEE 802.11 standard for wireless LANs, the 802.11 has become the prevalent wireless network. The basic building block of WLAN is the BSS (Basic Service Set) which is composed of wireless stations. The wireless stations in the BSS can communicate with each other. The topology of WLAN contains two basic flavors: independent BSS (IBSS) and infrastructure BSS. Stations in an IBSS communicate directly with each other and thus must be within direct communication range. Two coordination functions are specified in the IEEE 802.11 MAC (Medium Access Control): the DCF (Distributed Coordination Function) is a basic multiple access technique; while the PCF (Point Coordination Function) is a polling scheme[3]. DCF is a contention-based access scheme utilizing CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). For a STA to transmit, it will sense the medium to determine whether it is idle. If the medium is idle for a DIFS, the transmission may proceed. If the medium is busy, the STA will defer until the end of the current transmission. The backoff procedure is used for collision avoidance. The STA will implement random backoff algorithm and decrement the backoff interval counter while the medium is idle. The PCF provides contention-free frame transmission in an infrastructure network by using the PC (Point Coordinator) in the AP. PC controls the medium by broadcasting a Beacon. At the beginning of every CFP, the PC sends a Beacon frame to all stations in the basic service area (BSA) after the AP confirms that the medium is idle for point-inter frame space (PIFS). During the CFP, each STA in the polling list is polled in turn. The PC continues to poll each station until it reaches the maximum duration of the CFP and the PC can terminate the CFP by sending a CF-End frame. The DCF is suited for asynchronous data transmission, while the PCF is designed for real-time tasks.

1.2 WLAN telescope control system

The main attraction of WLAN include: cost effectiveness, convenience, flexibility, tetherless access to the information infrastructure. Large telescope such as LAMOST, only active optics system there are 816 force actuators and 183 position actuators, 30-meter segmented mirror telescope there are thousands of actuators in the active optics system. It is very difficult for Wired NCS. Wireless Networks Telescope Control System (WTCS) as shown in Fig.2 is a wireless local area network control systems (WNCS), including main controller, access points (AP), wireless smart sensors and actuators. WTCS can provide added flexibility, reduced infrastructure costs, and greater convenience.

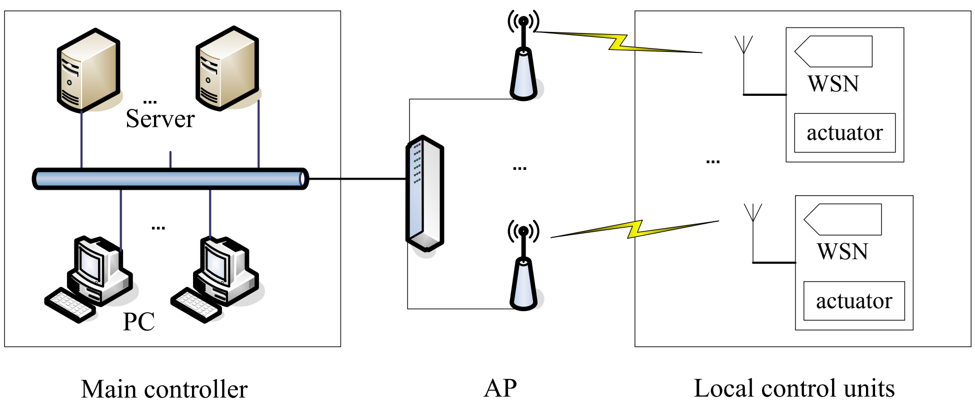

Figure 2. WLAN telescope control system

Main controller communicates with local control units by wireless link, employing the TCP/IP protocol as communication protocol. When main controller sends a command transmitted by AP to a wireless sensor of LCUs, then the wireless sensor forwards to the actuator. Vice versa, the send sends the result that the actuator executed to main controller. WTCS maybe contain thousands of wireless sensors and actuators. To reduce the collision among sensors and adapt for real-time control, AP polls wireless sensors in the polling list one by one. At first, AP polled the wireless sensor which would communicate with AP. The sensor answered the polling if it received the polling, then AP sent data to sensor, the transceiver received data and transmitted to actuator through RS232. Finally, sensor sensed the action and sent the result that the actuator executed to AP. The information being communicated in Telescope control system is typically state information and as such in normal operation. The required throughput of the control network is relatively low, but its reliability needs to be very high. To fairly assign resource to every actuator in a free contention system, devised polling protocol based on time-bounded time. Using two circular queues to store request message and acknowledge message, message that don't receive acknowledge exceeded a certain threshold to be retransmitted in next turn. In basis of the RTT and the number of request, adjust threshold and timeslice to improve performance.

REMOTE CONTROL BASED ON SATELLITES

Astronomers need large telescopes which need to be deployed on an excellent site to observe the far and faint celestial bodies. The Antarctic plateau holds many advantages such as: exceptional coldness, long periods of continuous observations, low wind speed; low infrared background; very dry, low sky brightness, is likely to be the best site for astronomical observing sites on earth[4]. All these advantages make the Antarctic plateau the most attractive site on earth for optical/infrared astronomy, and almost certainly the single best site for submillimeter and terahertz astronomy. In Oct. 2006, Chinese Center for Antarctic Astronomy worked out the project of Chinese Small Antarctic Telescope Array in Dome A which is used for observation of variable and transient astronomy[5]. We are going to devise large optical/ infrared telescope to build in the Antarctica.

The Antarctic environment requires robotic and remotely controlled operations for the telescope and its instrumentation, and imposes accurate insulation for all the equipment not working in warm rooms. The control system as shown Fig.3, remote control center transmits commands to local control units through satellites. LCUs connect the local server with wireless channel. The local control system is based on a embed system.

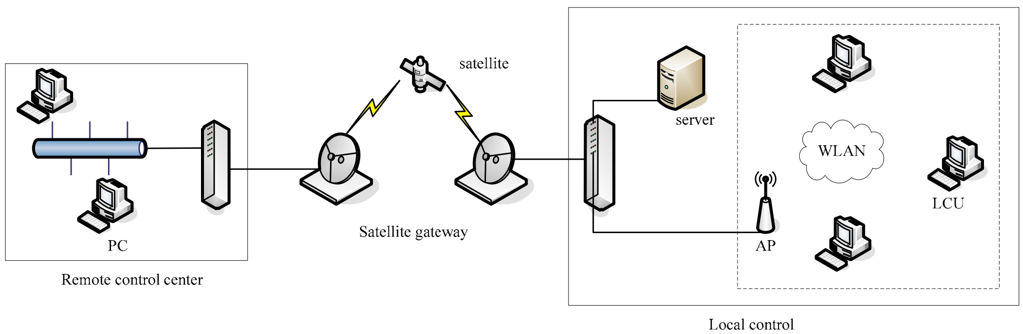

Figure 3. Remote control system based on satellites

LCU is based on embedded system which contains ARM processor, wireless transmitter and actuator with real-time Linux embedded operating system. The WLAN device in the LCU communicates with AP. To improve the communication performance, the special exchange format of data between remote control center and local control units must be designed.

REAL-TIME CONTROL

The large and extremely large ground-based optical telescopes are likely to involve a highly segmented primary mirror, such as: Giant Magellan Telescope (GMT), Thirty Meter Telescope (TMT), California Extremely Large Telescope (CELT) and European Extremely Large Telescope (E-ELT). The CELT includes 1080 segments in the primary mirror and 3240 primary mirror actuators. Extremely Large Telescopes adopted adaptive optics (AO) maybe contains thousands of actuators or more. The performance of ground-based telescopes has been limited by atmospheric turbulence. AO can further increase telescope sensitivity and allow the removal in real-time of much of the effect of atmospheric turbulence. Active optics and adaptive optics for large or extremely large telescopes represent many significant challenges such as: the control bandwidth should be increased as much as possible, the real-time computing requirements, and so on[6].

Telescope demands high real-time of star tracking and image quality correction during observation. The gravitation deformation of the telescope optical surface and thermal expansion and wind buffeting of the telescope disturb the quality of telescope, so the time of correct using active optical or adaptive optical system need minimum. In order to improve the performance of real-time in TCS, we adopted embedded system with real-time OS (Linux + RTAI) in local control system to satisfy the requirement of real-time computing. All interrupts are initially handled by the real time kernel and are passed to Linux only when there are no active real time tasks under RTAI (Real-Time Application Interface). RTAI was developed as a real-time operating environment[7]. Fig.4 shows Linux and RTAI system architecture. ADEOS (Adaptive Domain Environment for Operating System) is a nanokernal hardware abstraction layer that operates between computer hardware and OS that runs on it[8]. ADEOS can provide hard real-time support in Linux. Two domains could be implemented under ADEOS: one domain encompassing normal Linux and the other a real-time executive that provides hard real-time guarantees[9]. ADEOS implements a pipeline scheme which allows them to virtualise all what RTAI gathers into its HAL. RTAI offers typical switch times of 4uSec, 20uSec interrupt response, 100 KHz periodic tasks and 30 KHz one-shot task rates.

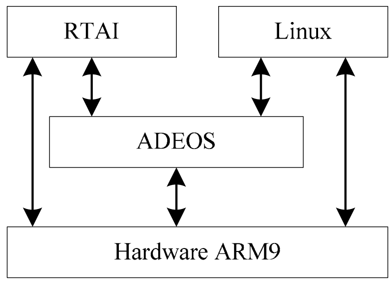

Figure 4. RTAI architecture

The transmitted data include: burst real-time data, periodic real-time data, and not real-time data. Burst real-time data were provided with the highest priority, periodic data took second place, not real-time data were deal with Linux kernel. We expand RTAI scheduler, and add RM schedule and EDF schedule. EDF scheduled burst real-time data, RM schedule periodic data. RTAI transmitted data to user interface with real-time FIFO.

PORTABLE CONTROL SYSTEM

To achieve the control of telescope at "Any Time, Any Where, Any Body", proposed a telescope portable control system based on Java. The system adopted the J2ME-J2EE frame as Fig. 5 shown, so that client can control the telescope in time through mobile terminal. Exploited telescope control client system on mobile terminal based on J2ME and server system based on J2EE. It achieved communication between client and server by XML format codes, and utilized PushRegistry to dynamically register inbound connection network[10]. The system gets over limitation of the remote, mobile and wireless control of telescope. The operators can get information from control system and maintain the telescope in real-time.

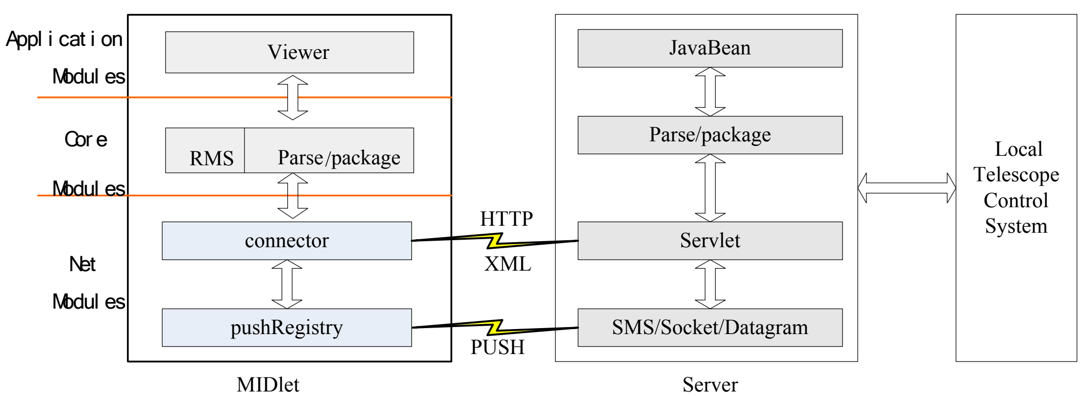

Figure 5. Portable telescope control architecture

Portable control system utilized pushResigtry to enable MIDlets to set themselves up to be launched automatically which received an inbound network connection. Inbound connections can be message-based (such as SMS), stream-based (such as TCP socket) or packet-based (such as Datagram). The MIDlets receive a push event, and get the address of the server. The MIDlets connect the server with http and exchange data with XML. The server connects the local telescope control system with fast Ethernet.

CONCLUSION

With the increase of aperture of optical telescope and infrared telescope, the telescope control system become more and more complicated. Large and extremely large telescope control system is a crucial field of telescope to study. WLAN has some advantages such as flexible arrangements and inexpensive cost which makes it be the first option among telescope control systems. Antarctic plateau is likely to be the best site for astronomical observing sites on earth. To achieve robust control of Antarctic telescope, a remote control system based on satellites is presented. Embedded control system with real-time Linux can improve the performance of TCS. The ELT of future contain thousands of controlled objects or more, so the design of the real-time control system is a challenge of telescope. Finally, this paper discussed portable control system of telescope. The portable control system can control telescope at "Any Time, Any Where, Any Body". Because of the complexity of large or extremely large telescope control system, the topology structure and the stability and real-time of must be researched in detail and in depth in the future.

ACKNOWLEDGE

This work was supported in part by a grant from National Important Project on Science-LAMOST and Foundation of Anhui Educational Committee-KJ2009B129.

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