Research and Implementation of Large Telescope Control System Based on Wireless Smart Sensors

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ABSTRACT

Telescope Control System (TCS) becomes more and more complexity, especially the large telescope control system of force actuators for deformed mirror and position actuators for modifiable degrees of mirrors. It is very difficulty to connect thousands of sensors, actuators and controller with wired link. This paper presented a large telescope control system based on wireless smart sensor (WLTCS), connecting wireless sensors and controllers with wireless link, employing the TCP/IP protocol as communication protocol. Polling access can overcome contention and guarantee every sensor to communicate with controller in time; using intelligent control methods when some channels are interfered, multi-hop wireless paths can improve throughput and performance. The analysis and simulation indicate that WLTCS can greatly reduce complex of implementation and improve communication performance.

Keywords: Telescope Control System, TCS, WLTCS, wireless smart sensors

1．INTRODUCTION

Large Telescope Control System (TCS) is a complicated system, which may contain thousands of actuators and sensors. In current telescope control systems are Distributed Control System (DCS) which are based on wired network (as Ethernet, CAN, etc.), connecting actuators, sensors and controllers with wired channel. Especially, the application of active optic control advanced the speed of large telescope. It is a challenge for large telescope control system. Traditional TCS includes thousands of cables which result in difficult-to-manage, occupy signification space and lack of system flexibility.

In recent years Wireless Local Area Network (WLAN) and Wireless Sensor is a rapidly emerging field of activity in data and control networks. This paper describes a wireless smart sensor networks telescope control systems (WLTCS). Large telescope control system based on wireless smart sensors is a wireless local area network, include main controller, access points (AP), wireless smart sensors and actuators. Main controller communicates with sensors by wireless link, employing the TCP/IP protocol as communication protocol. WLTCS allows for easy expansion, it is a scalable and

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flexible system. WLTCS decreases costs of design, operating and maintenance, which drastically reduced the number of measurement channels.

It is well known that there are several problems with WLAN. The wireless media is more prone error and higher bit error rate than wired networks. The WLAN can not provide large bandwidth like wired networks. In order to improve performance of WLTCS, we use TCP/IP protocol to connect AP and wireless sensors, use PCF access mode, intelligent control methods and multi-hop wireless paths when some channels are interfered. Simulation shows WLTCS is suited for large telescope control systems.

This paper is organized as fellow: section 2 provides a brief description of DCS. Section 3 presents smart sensor networks. Section 4 presents the implementation of Wireless Smart Sensor Networks Telescope Control System. The simulation results are demonstrated in section 5. Finally, the paper is concluded in section 6.

2 . DISTRIBUTED CONTROL SYSTEM

Distributed Control System (DCS) is a control system method that is spread, or distributed, among several different unit processes. As shown in figure 1:

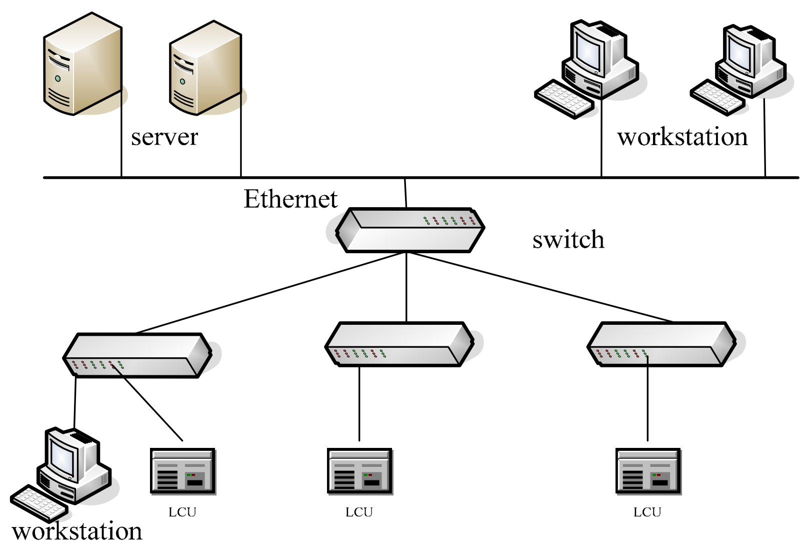

Figure 1 Distributed Control system

DCS use decentralized elements or subsystems to control distribute processes or complete manufacturing systems. DCS consist of a remote control panel, communications medium, and central control panel.

The DCS is typically a hard-wired system and exists with finite boundaries, such as a process plant or within a factory. Wired systems are reliable and well suited for the typical process environment where flexibility is not an issue. Wireless systems are starting to become popular and hold the promise of improved flexibility in both physical and logical layout of the facility.

3．SMART SENSOR NETWORKS

Traditional data and control networks like LANs (Local Area Networks) originally using wired Ethernet have been enhanced or replaced with wireless networks. Sensor networks tend to application specific and are typically hard-wired to perform a specific task efficiently. The main attraction of wireless sensors network include: cost effectiveness, convenience, flexibility, tetherless access to the information infrastructure. Likewise, wireless network control systems also provide added flexibility, reduced infrastructure costs, and greater convenience.

A sensor networks can be used for different application areas (e.g. health, home, industry control). A sensor network is composed of a large number of sensor nodes that are densely deployed either inside the phenomenon or very closed to it [1]. The sensor nodes, which are intended to be physically tiny and inexpensive, consist of sensing, data processing, and communicating components. Wireless sensor networks generally consist of a data acquisition network and a data distribution network, monitored and controlled by a control center. The sensor networks cannot work in complete isolation. Generally, there are three ways for connecting the sensor networks to an existing network such as a TCP/IP networks. TCP/IP has become the de-facto standard for communication. TCP provides reliable full-duplex stream transmission. IP records the address of the sender and the receiver.

The commonly way to connect the sensor networks with a TCP/IP networks is to deploy a special proxy server between two kinds of networks. The proxy acts as a relay or a frond-end.

Delay Tolerant Networking (DTN) architecture aims to address the desire to provide interoperable communications between and among a wide range of networks which may have exceptionally poor and disparate performance characteristics [2]. DTN is proposed for unpredictable and potentially high bit-error rates environments. DTN is a “overlay” architecture, which can operate above the existing protocol stacks in various kinds of networks. DTN can provide a gateway function between TCP/IP and sensor networks. Their interconnection could be done by using a DTN overlay on top of the networks.

Adam Dunkels etc. discuss the way of connecting wireless sensors network with TCP/IP [3]. They have also showed that a full TCP/IP stack indeed can be run on sensors [4]. Directly employing TCP/IP stack in wireless sensors network would enable seamless integration of the wireless sensors network and any TCP/IP network. The general architecture of wireless sensors network with TCP/IP is shown in Figure 2.

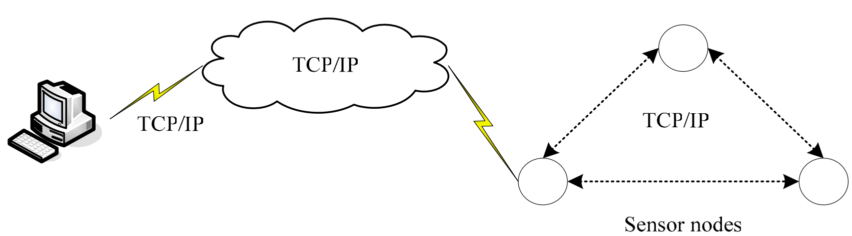

Figure 2 wireless sensors network with TCP/IP

A smart sensor is a sensor that provides extra functions beyond those necessary for generating a correct representation of the sensed quantity [5]. Wireless smart sensor node is made up of several basic components, as shown in figure 3: a sensing unit, an actuating unit, a data processing unit, a storing component, communicating components (transceiver), and a power unit.

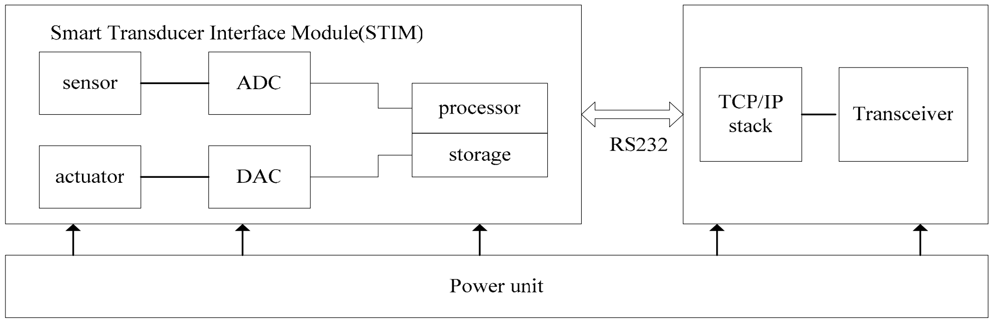

Figure 3 the components of smart wireless sensor node

It is necessary to build up a highly advanced network with many sensor nodes. Today the master computer polls many slave sensors. Each sensor is a separate unit which works independently and provides useful information. Smart sensor connects the digital sensor to a micro-controller capable of doing more advance calculations. The micro-controller can also be connected to input devices and to output devices.

4 . WIRELESS SMART SENSOR NETWORKS TELESCOPE CONTROL SYSTEM

Telescope Control System maybe contains thousands of actuators and sensors. Deploying wireless smart sensors in TCS will perform a specific task efficiently. Wireless Smart Sensor Networks Telescope Control System (WLTCS) is a wireless local area network, include main controller, access points (AP), wireless smart sensors and actuators. Main controller communicates with sensors by wireless link, employing the TCP/IP protocol as communication protocol. When main controller sends a command transmitted by AP to a sensor, then the sensor forwards to the actuator. Vice versa, sensors send the result that the actuator executed to main controller.

4.1. **IEEE 802.11 MAC protocol**

The IEEE 802.11standard MAC protocol includes the distributed coordination function (DCF) and the point coordination function (PCF) [6].The fundamental DCF is CSMA/CA that allows for automatic medium sharing between compatible PHYs. Each station generates a random backoff interval using a binary exponential random backoff algorithm before transmission. For a STA to transmit, it will sense the medium to determine whether it is idle. If the medium is not busy, the transmission may proceed. If the medium is busy, the STA will defer until the end of the current transmission. The STA will implement random backoff algorithm and shall decrement the backoff interval counter while the medium is idle.

In order to support real-time traffic, the IEEE 802.11 MAC incorporates an optional access method called a PCF. The PCF is based on a centralized polling protocol where a point coordinator (PC) located in an access point (AP) providing contention-free services to the wireless station associated with a polling list. The PC performs the role of the polling master.

The DCF is suited for asynchronous data transmission, but the performance will rapidly fall when a lot of wireless stations access to an AP in the 802.11 WLAN. The PCF is designed for real-time tasks. Large telescope control system maybe contain thousands of actuators, it is suited to adopt PCF.

4.2. WLTCS architecture

Large telescope control system based on wireless smart sensors (WLTCS) is a wireless local area network, as shown in figure 5, include main controller, access points (AP), local control units(wireless sensor networks). Main controller communicates with sensors by wireless link, employing the TCP/IP protocol as communication protocol. When main controller sends a command transmitted by AP to a sensor, then the sensor forwards to the actuator. Vice versa, sensors send the result that the actuator executed to main controller. LCU is mainly composed of wireless sensor networks. A wireless sensor networks is composed of lots of smart sensor nodes. As shown in figure 2, a wireless smart sensor consists of a sensor unit, an actuator unit, a wireless communication unit, etc.

WLTCS maybe contain thousands of wireless smart sensors. 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 smart 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.

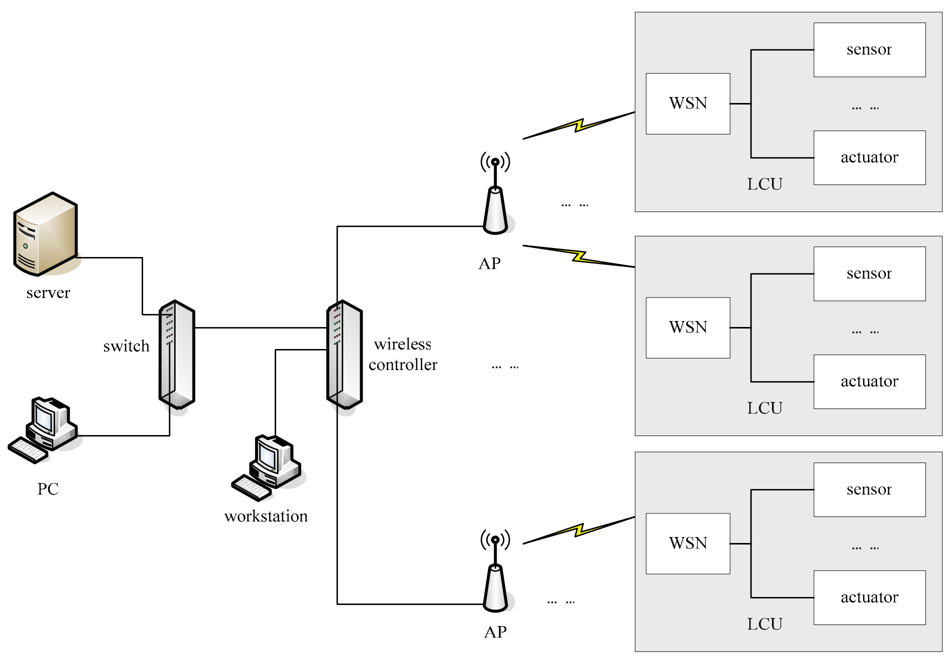

Figure 4 WLTCS Architecture

TCP/IP has become the de-facto standard for network. Directly employing the TCP/IP protocol suits as the communication protocol in the sensor network would enable seamless integration of the sensor network and any TCP/IP network. Because of the limitations of sensor network, using a number of optimization methods to achieve better performance and data throughput [7]. Standard header compression methods in [8] can be used. In WLTCS, all sensor nodes are deployed in a local area, and are devised to operate a special task. For this reason, Full IP head is not used, we defined IP address by (x, y) format, x denotes the number of submirror, y denotes the number of sensor. Other compression techniques can be used.

Wireless communication has the reputation of being notoriously unpredictable. The quality of service depends on the environment. Wireless communication is characterized by limited bandwidth, high latencies, high bit-error rates and temporary disconnections. Using intelligent control methods to resolve long-term network anomalies to guarantee communicate between controller and wireless sensors. Multiple hops may degrade performance of data transport than a single hop. AP directly communicates with each sensor node in WLTCS. When a wireless link is disconnected or interfered badly, some adjacent sensors will act as a route or proxy in the network. AP will poll others sensor when didn't receive acknowledge from the sensor exceeded the set threshold. AP selects a free adjacent node to retransmit command to the sensor. Then multi-hop wireless paths achieved communication between AP and sensor. It is show by analysis and simulation which can improve throughput and performance.

5 . SIMULATION

OPNET provides a comprehensive development environment supporting the modeling of communication networks and distributed systems. OPNET model is divided to three layers of network, node and process. Network concerned with the specification of a system in terms of high-level devices called nodes, and communication links between them. Node model is made up of protocol model and connections, each model corresponds one or more process model. Process concerned with the specification of behavior for the processes that operate within the nodes of the system. Fully general decision making processes and algorithms may be specified by C program [9]. WLAN models are part of the standard OPNET Modeler library, which include [10]: Wireless Workstation, Access Point or Wireless Router, BSS, etc.

Two sets of simulation are executed. First scenario with 11 identical WLAN stations, parameter configuration shows in TABLE 1. We employed 20 identical WLAN stations in second scenario, which parameter configuration is the same with the first. The topology structure of WLAN is showed in figure 5.

Table 1 Parameter configure of workstation

Inter arrival Time(seconds)	0.01(exponential)
PCF Functionality	enable
Rts Threshold(bytes)	256
Data rate(Mpbs)	11
Physical Characteristics	Direct sequence

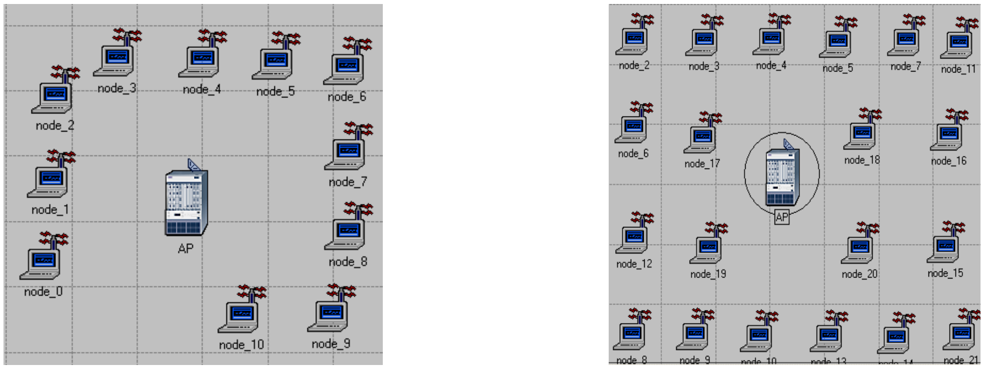

Figure 5 Topology structure of WLAN

Simulation results indicate that the throughout of workstations in PCF is larger than in DCF with larger number of stations. The figure 6 shows throughout of scenarios (first scenario contains 11 stations, second scenario contains 20 stations). The figure 7 shows the media access delay of wireless workstations. It is known that throughout will decrease and media access delay will increase in DCF access mode from the simulation results. Because PCF can void the collision, it enhances the data transmission rate greatly, especially WLAN contains larger workstations. CP polls workstations in the polling list, so the delay is a constant in PCF, but the delay in DCF maybe not known. The performance of PCF is higher than DCF in larger number of wireless workstations network.

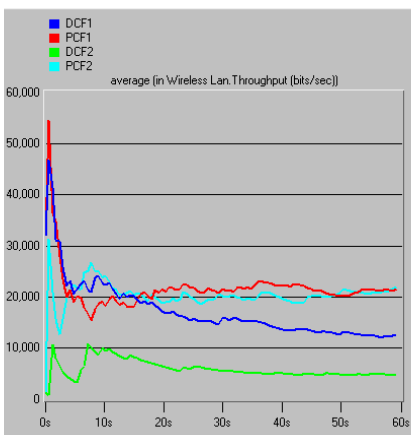

Figure 6 Average throughout of workstation

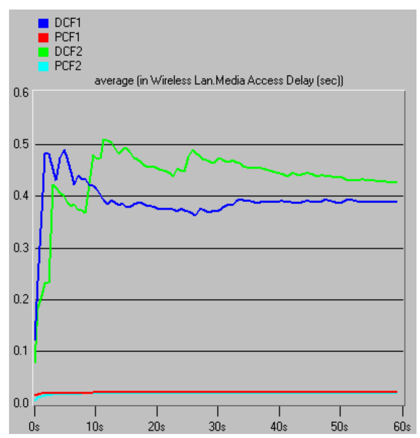

Figure 7 Average media access delay

6． CONCLUSION

This paper proposed a wireless telescope control system based on smart sensors (WLTCS), which can offer flexibility, robustness and is suited for large telescope control system. We connected wireless sensors and access points (AP) by wireless link, employing the TCP/IP protocol as communication protocol. Performance will be enhanced if use PCF access mode, intelligent control methods and multi-hop wireless paths when some channels are interfered. Finally, we use simulation to simulate the performance of PCF and DCF in the control system. The simulation results indicate performance of PCF is higher than DCF in larger number of wireless workstations network.

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