Implementation of Advanced Modified PCF in Large Telescope Control System

Shuai Xiaoying[1,2] , Zhang Zhenchao[1] , Zhu Yongtian[1]

1. National Astronomical Observatories/Nanjing Institute of Astronomical Optics & Technology ,
Chinese Academy of Sciences , Nanjing 210042, China

2. Graduate School of the Chinese Academy of Sciences, Beijing 100049, China

Abstract

Large Telescope Control System (TCS) is a complicated system, which contains thousands of actuators. Wired TCS is inconvenient to point and track for a large telescope. This paper proposes a TCS based on IEEE 802.11 Wireless Local Area Network (WLAN), which provides flexibility, reduced infrastructure costs, and greater convenience. The IEEE 802.11 standard MAC protocol includes the DCF and the PCF. The DCF is designed for asynchronous data transmission, while the PCF is designed for real-time data. The performance of a WLAN with DCF will fall when the number of wireless station increase in a basic service set (BSS). An advanced modified PCF (APCF) is presented to poll data from the AP to stations and response data from stations to the AP in CFP. The analysis indicates that APCF can improve communication performance, and is very suitable for large TCS.

KeyWords: PCF, Telescope Control System, WLAN, APCF, TCS

1 . INTRODUCTION

Large Telescope Control System (TCS) is a very complicated system, which may contain thousands of actuators. In current telescope control systems are based on Ethernet or fieldbus network, connecting actuators, sensors and controller with wired channel. It is very difficulty to lay too many wires in a local area. And wired network is inconvenient for telescope to track and point, which is most important function of telescope.

In recent years Wireless Local Area Network (WLAN) is a rapidly emerging field of activity in data and control networks. Traditional data and control networks like LANs (Local Area Networks) originally using wired Ethernet have been enhanced or replaced with wireless networks. The main attraction of WLAN 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.

The performance of the wireless local area network is largely determined by MAC protocol. The major functions of a

[1] xyshuai@niaot.ac.cn, Dept. of Computer Science, Chizhou College, Anhui, China.

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MAC protocol are to provide a delivery mechanism for user data, fairly control access to the shared medium and to protect the delivered data. Therefore, it is important to have a MAC protocol that ensures efficiency and fair sharing of the channel. The IEEE 802.11standard MAC protocol includes the distributed coordination function (DCF) and the point coordination function (PCF) [1]. The DCF is designed for asynchronous data transmission by using CSMA/CA (carrier sense multiple access with collision avoidance) and must be implemented in all stations. On another hand, the PCF is optional and based on polling controlled by a PC (Point Coordinator).

It is well known that the performance will rapidly fall when a lot of wireless stations contest an AP in the 802.11 WLAN based on CSMA/CA. In order to realize real-time transmission in TCS, we presented an advanced PCF to poll data from AP to stations and deliver data from stations to AP in bounded time.

The work in [2] proposed a modified version of PCF called M-PCF, it can't resolve the hidden node and Null packet problem. An other modified PCF was introduced in [3], modified PCF reduces the channel under-utilization due to polling overheads and null packets that occurs in the standard PCF. A protocol called Superpoll was proposed in [4]. It contains a message that includes list of station that will be polled during a current CFP. But it still caused bandwidth to be wasted if a station has no data to send.

This paper is organized as fellow: section 2 provides a brief description of IEEE 802.11 MAC protocol. Section 3 presents a brief introduction of WLAN telescope control system. Section 4 presents the algorithm of APCF. The performance analysis is demonstrated in section 5. Finally, the paper is concluded in section 6.

2. IEEE 802.11 MAC PROTOCOL

2.1 Distributed coordination function (DCF)

The fundamental DCF is CSMA/CA that allows for medium sharing between compatible PHYs automatically. Each station generates a random backoff interval using a binary exponential random backoff algorithm before transmission [1]. 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 STA will implement random backoff algorithm and decrement the backoff interval counter while the medium is idle. The CSMA/CA can not solve the problem of hidden nodes and exposed nodes.

The virtual carrier sensing is provided by the MAC via a Network Allocation Vector(NAV) which shows the time of the medium is expected to be busy. The hidden node and exposed node problem are reduced by the use of RTS/CTS mechanism. When a STA wants to transmit data, it must sense the medium. If the medium is not busy in DIFS interval, then, the STA sends a RTS (request to send) frame. If the receiver receives the RTS, it sends a CTS (clear to send) frame to the sender. Each RTS and CTS frame contains a duration field whose value is expected to the time period for which the medium will be busy completing the current transmission.

2.2 Point coordination function (PCF)

In order to support real-time traffic, the IEEE 802.11 MAC adopts 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) provided contention-free services to the wireless station associated with a polling list [1]. Polling is the essential operation, the PC performing the role of the polling master.

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). PIFS is smaller than a DIFS period, but longer than the SIFS period. Beacon frame contains the information on the maximum duration of the CFP, beacon interval, and BSS identifier. All stations in BSS set their NAV and not to send any packet in the CFP after receiving a Beacon. During the CFP, each STA in the polling list is polled in turn. The PC sends a DATA+CF-poll frame or CF-poll frame to each station in its polling list. The station responds by sending a DATA+CF-ACK frame if it has data to send or a Null packet (CF-ACK) frame if it has no data to send at that time. If the PC receives a DATA+CF-ACK frame, it can send a DATA+CF-ACK+CF-Poll frame, or CF-ACK+ CF-Poll frame. If a station receives a CF-Poll from the PC, it can respond to the PC with DATA frame or a NULL frame. 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, but the performance will rapidly fall when a lot of wireless stations contest to access to an AP in the 802.11 WLAN. The PCF is designed for real-time tasks, but standard PCF can not resolve the problem of deliver data from stations to AP in bounded time, it is not suitable for the control system of large telescope.

3．WIRELESS LAN TELESCOPE CONTROL SYSTEM

Telescope Control System maybe contains thousands of actuators and sensors. Deploying wireless LAN in TCS will perform a specific task efficiently. Wireless Networks Telescope Control System (WTCS) is a wireless local area network control systems (WNCS), including main controller, access points (AP), wireless smart sensors and actuators. The basic distribute structure of the WLAN telescope control system is shown in Fig.1. WTCS make use of a wireless network for a real time communication [5]. Traffic between the telescope and controller is small control data. Telescope local control units send state of telescope and a response of local control unit to the controller, and controller commands actuators at regular interval. 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. To enhance the performance and real-time, WTCS adopt PCF access mode. AP polls each WLAN station in its polling list at regular interval.

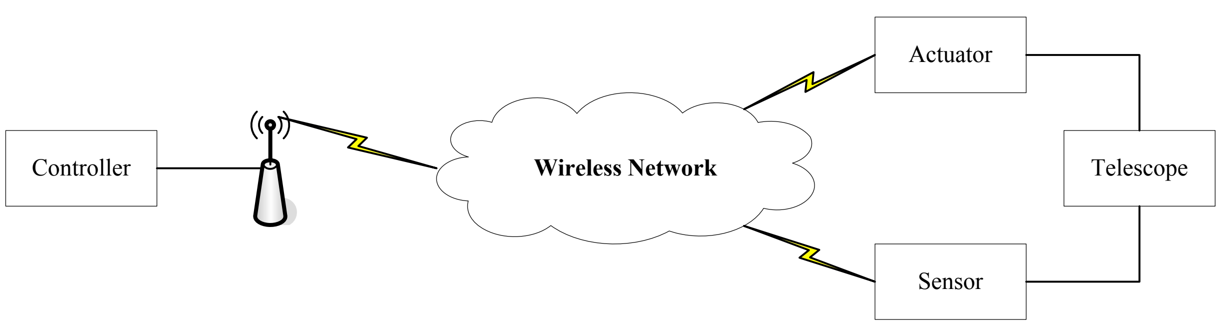

Fig.1 The general structure of WLAN telescope control system

4 . THE ADVANCED MODIFIED PCF(APCF)

We proposed an advanced modified PCF to improve the performance of WLAN and transmit data real-timely and stably, overcome the hidden problem, . As illustrated in Fig.2, during the CFP in the advanced modified PCF comprises two transmission periods: the downlink polling period and the uplink response period.

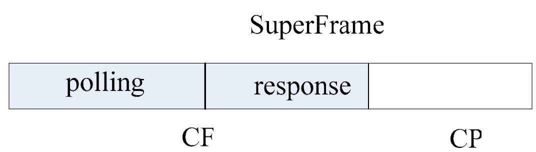

Fig.2 APCF Transmission Periods

There are two polling list queues in the CP. The poll-list stores the current stations that will be polled by listing order, the unack-list stores the stations in poll-list that didn't deliver the ACK to CP. In PCF polling period the CP polls the stations in the polling list by poll-list order. At begin, the CP send a beacon package to all station, notes the CFP begin. Then the CP transmits data to first station, after a SIFS, to second station, until to last one in the poll-list. The data contains the order of the station in the list. After the CP transmitted all data, stations start to deliver data to CP by the received order. The algorithm as follow:

```
If ( CFP_Duration < CFPMaxDuration )
{
   1) CP sends a beacon package;
   2) while (poll-list is not empty)
   {
 The CP sends data to the station by the poll-list order;
   Wait for SIFS;
        List next;
      }
3) while (! Last station)
   {
      Response data to CP by the received order;
      Wait for SIFS or slot time ;
      If (! Collision)
      {
         Next station;
       }
      Else
       {
          Collision Resolution;
         Data=Data+{collision list}
```

            }
        }
    }

4) If CP dose not receive the response data from a station, it store the order of the station in unack-list.

5) If CFP is not expired, the CP will poll the stations in the unack-list to retransmit data between the CP and stations; else retransmit next CFP.

Every station in the polling list maintains a counter, which is used to count the number of transmissions or the number idle period in the medium [4]. The initial counter value is the received order. The counter is decreased by one with every sensed transmission or idle slot time in the medium. When the counter equals one, the station sends data to AP. The process of up link response is following Fig. 3.

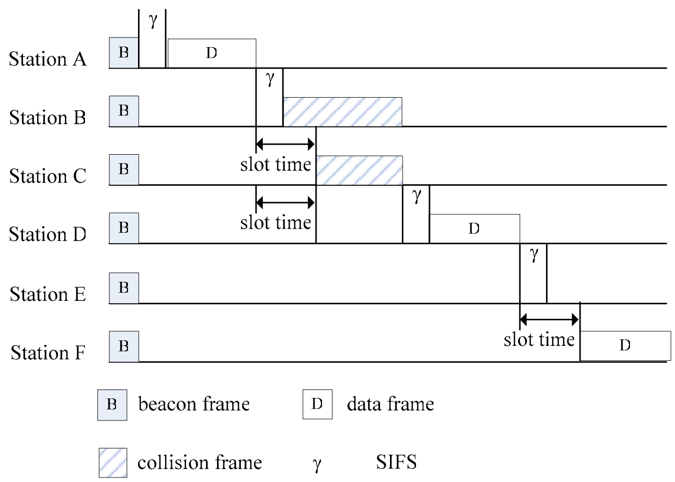

Fig.3 Procedure of Up Link

The hidden station problem occurs frequently in WLAN. From [4] we know a collision will occur in Fig.3. When station B is transmitting data, but station C cannot sense the transmission. After a slot time the station C starts to send data. When a collision occurred, PC and other station know the following station that will get the right to transmit. Therefore, we take the following means to resolve the collision between station B and station C in the list. After the transmission was over, PC and stations add station B and station C in the list rear. From station D resumes normal transmission. The wireless station D will broadcast the list of stations that have occurred collision, frame is as Data + {B, C}, in order to retransmit the collision frame. When the collision was occurred, we must compute the counter rightly. The algorithm is follow.

```
If ( idle time >σ or busy)
  Then counter=counter-1;
Else
  Waiting;
If (collision )
    Then counter =counter-1;
```

As mentioned earlier, each counter will decrease one when sense a transmission or idle over the slot time in the medium. If a collision was occurred, such as in Fig.3, the counter except station B and C will decrease once again.

5 . PERFORMANCE ANALYSIS

We first introduce the terminology used in the subsequent sections:

ρ : the probability that station j cannot hear the transmission from station i.

r: probability that a station has not data .

σ: slot time

T_{cf}: CFP duration

T_b: time of beacon package

T_d: time of data package

T_{dp}: time of data and poll package

T_{da}: time of data and ACK package

T_e: time of CF-end package

N: number of stations in the polling list

The system parameters are shown in table 1 [6].

Table 1 System Parameters

parameters	values
rate of PHY overhead	1 Mbps
data rate	11 Mbps
σ	20 us
Beacon size	35 bytes
Data size	40 bytes
PHY layer header	24 bytes
MAC layer overheader	28 bytes
ACK size	14 bytes
Poll size	52 bytes
SIFS	10 us

We assume the probability of every station has no data to transmit is r, and CFP interval is less than CFPMaxDuration. We assume that the CP generates a beacon package in a CFP interval, then, CP sends data to each station in the polling list one by one. After the down transmission was over, each station transmits data to CP in its order. When a station cannot receive data from the PC, the station will not send data to the PC. The time of a CFP of the standard PCF is

$$T_{cf}=T_b+T_e+(T_{dp}+2*SIFS+T_{da})*N \quad (1)$$

Since the interval in this modified advanced PCF consists of down and up link, we assume the data of down is equals the data of up, the time of this modified advanced CFP is

$$T_{cf}=T_b+T_e+(T_d+SIFS)*2N \quad (2)$$

From the Fig. 4 we can know the time of a CFP of APCF is less than the time of a CFP of PCF. The gap between the APCF and the PCF will increase with the increment of the number of stations in a BSS.

Then the channel efficiency of the standard PCF is

$$U_{PCF}=\frac{T_d+T_d(1-r)(1-\rho)}{T_{dp}+T_{da}(1-r)(1-\rho)+T_{null}*r+PIFS*\rho} \quad (3)$$

The channel efficiency of this modified advanced PCF is

$$U_{APCF}=\frac{T_d+T_d(1-r)(1-\rho)^N}{T_d+T_d(1-r)(1-\rho)+(\sigma+T_d)r\rho+\sigma(1-r)\rho} \quad (4)$$

The efficiency gain is given by

$$E=(U_{APCF}-U_{PCF})/U_{PCF} \quad (5)$$

The Fig. 5 depicts the efficiency gain in terms of group size for different values of ρ.

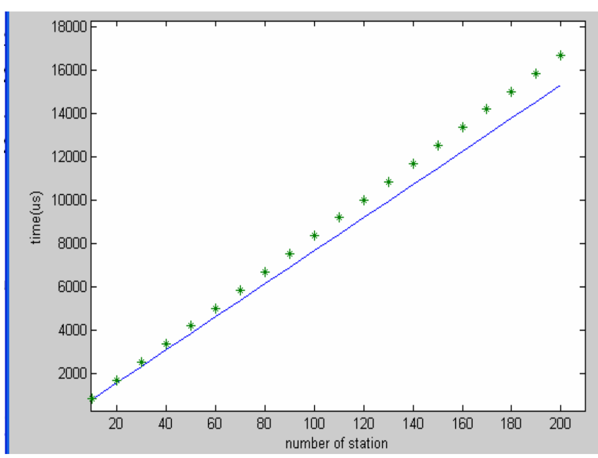

Fig. 4 The time of CFP

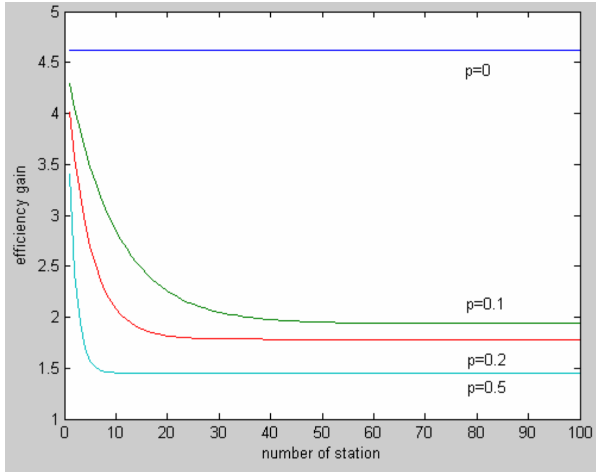

Fig. 5 Efficiency gain for different p

6 . CONCLUSIONS

This paper explores how an advanced modified protocol can be implemented in the IEEE 802.11 PCF. The analysis result shows that the proposed protocol has the potential to improve the IEEE 802.11 PCF support for real-time communication in large TCS. It can improve the performance of WLAN, decrease the costs and enhance the flexibility of TCS.

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