# FIBER POSITIONING CONTROL FOR LAMOST BASED ON ZIGBEE PRO

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**Abstract:** For observing thousands of celestial bodies simultaneously, 4000 nodes with an alveolate distribution on the focal plate of 1.75m in diameter are used in Large Sky Area Multi-Object Fiber Spectroscopy Telescope (LAMOST). In this paper, a novel fiber positioning control method based on ZigBee PRO was proposed for LAMOST fiber positioning. Compared with traditional control way of wire drive, it can reduce the number of external antenna more than 95%, furthermore, the difficulty of installation was minimized by saving the space on the back of focal plate. ZigBee PRO networking and data communication technology are analyzed and a mesh network is designed based on LM3S9B96, CC2520 and CC2530 to realize localization and reset for 4000 fiber positioning units. The fiber positioning control computer can make the further decision by employing of the feedback information of zero point.

**Keywords:** LAMOST; Fiber Positioning; ZigBee PRO; Mesh topology; LM3S9B96; CC2520; CC2530; Stepper motor

## 1 Introduction

As a super scientific project in China, LAMOST[1- 2] with lager field range of 21 square degree, effective masking aperture of 4 meter and focal distance of 20 meter is a meridian reflecting Schmidt astronomical telescope with a field of view of 5 degree, that is the observable field covers more than 20,000 square degree. The large focal plane of 1.75m in diameter should accommodate up to 4,000 optical fibers alveolate distributing on it, which can observe 4000 targets simultaneously. In order to move fibers to the desired astronomical targets, the fiber positioning unit with double rotation between a center rotation axis and an eccentric rotation axis is designed. Each unit has a central shaft and an eccentric shaft that are driven by step motors. The aggregate motion of the two equaling axles driven by stepper motor without reference position can realize optional positions on the range of observations. Different from the center rotation axis with angle of revolution 0~360 degree, the eccentric rotation axis is 0~180 degree illustrated in Figure 1, and the diameter of field controlled by every fiber is 33mm.

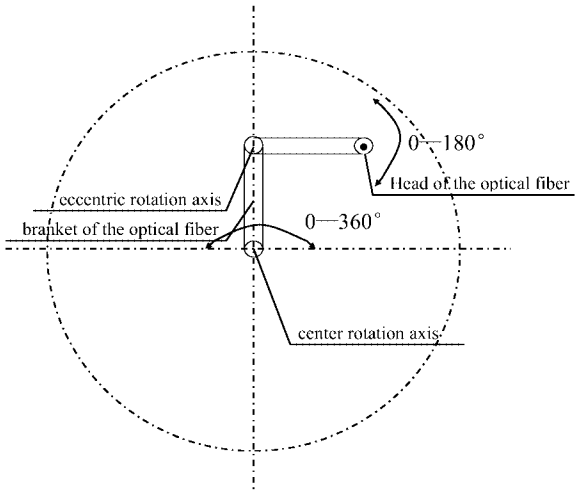


**Figure 1** Optical fiber positioning unit

4,000 fiber positioning[3-4] units need to be positioned precisely in LAMOST and every fiber positioning unit needs two stepper motors for its driven, so 8,000 stepper motors need to be controlled in the entire system. In the traditional long-term drive control mode, the lines in each positioning unit are more than ten, which include power lines, motor-driven cable and zero signal lines. There will be 50000 or so cable in the back of the focal plane, which would bring about great difficulties for units installation and focal plane movement. Combining with the character of low power, low cost and low data rate, the technology of ZigBee PRO, which follows the IEEE802.15.4 standard, is adapted on low cost equipment with low data rate, and it can meet the needs of most network topology models because of its all support of star network, cluster tree network and mesh network, et al. The task definition of fiber positioning, reset and wireless communication between nodes is designed based on ZigBee Pro control nodes, so that it can satisfy the requirement of single unit in fiber positioning for the project of LAMOST.

The above wireless communication mode is adopted to save the installing space on the back of the focal panel, and can save more than 95% external wires compared to the traditional cable control mode. In order to avoid excessive cable, in this paper, the stepper motor drive units is placed on the back of mechanical units and they

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are as a whole unit. Only two power lines are needed. This can save a lot of wiring space, but also facilitate the installation and maintenance for positioning units. Not only wireless data transmission [5-6] can be achieved, but also the step motor steps can be accurately controlled to achieve precise fiber positioning. This paper studies how to use the ZigBee PRO technology to group these 8000 nodes, explores the pros and cons of star network, tree network and mesh network in order to search the stars quickly and efficiently.

## 2 Scheme of fiber positioning control system for LAMOST

Now ZigBee network has been built successfully in LAMOST control system. The whole control system is shown in Figure 2, including the fiber positioning computer, the coordinator control nodes and drive nodes. The coordinator node communicate with the fiber positioning computer through the CAN/Ethernet protocol converter, through that data and control signal are transmitted, which causes the performance of the whole system more stable. The communication between the coordinator node and the drive node is through ZigBee PRO technology. 4000 fiber positioning units need to be controlled through this control system.

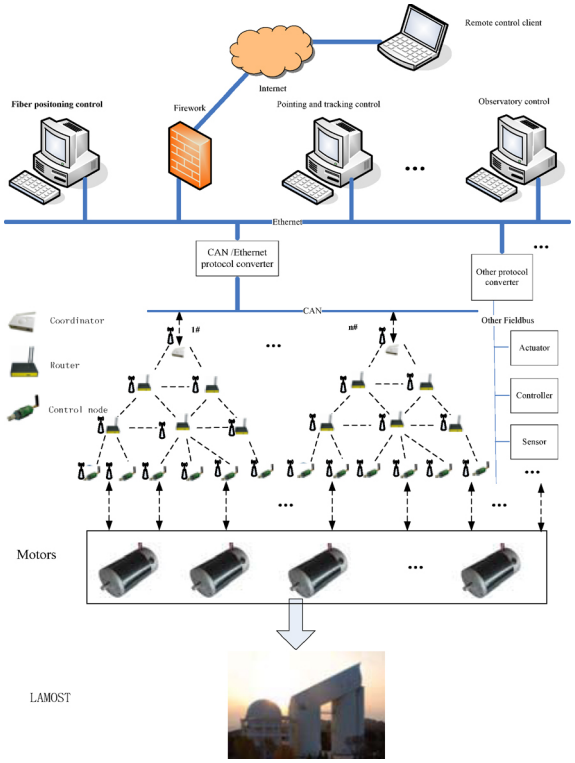


**Figure 2** The scheme of a fiber positioning control system for LAMOST

The coordinator node is the data transmission center between the fiber positioning computer and the drive node. The coordinator nodes receive data and commands sent from the fiber positioning computer, then the data and commands will be sent to all drive nodes one by one after being analyzed in the coordinator nodes. The coordinator nodes will check the working status of each drive node on a certain time interval, transmitting the error message and the drive node localization to the fiber positioning computer until the end of each drive node positioning. After receiving data and the command sent by the coordinator node, the drive node analyzes it, and then executes the command to drive the fiber to its certain position. After that, the drive node comes to the idle statue until receiving the coordinator node query. The ZigBee PRO network is designed as follows.

## 3 ZigBee topology

The ZigBee standard now stands along side Wi-Fi and Bluetooth as an established and critical wireless technology for an increasingly interconnected world. ZigBee's ability to simply and reliably form self-configuring, self-healing, mesh networks of low-cost, very low-power nodes is unique among these wireless standards sporting fanciful names.

The ZigBee Alliance had introduced an important update to the ZigBee specification leveraging the experience gained from the millions of ZigBee nodes deployed by multiple vendors since the specification was first published in 2004. The specification now includes two distinct Feature Sets— "ZigBee" and "ZigBee PRO"—that define key aspects of how a mesh network operates. The new ZigBee PRO [7] Feature Set offers significant improvements in network scalability, resiliency, security, and ease-of-use, especially for larger, more complex networks.

The ZigBee PRO standard provides a number of facilities that are not available in the standard ZigBee releases. ZigBee PRO provides additional capabilities that give additional functionality that may be required in more complex networks needed additional capability.

ZigBee PRO offers the star network, tree network, mesh network and other network topology to meet the needs of the most network. These are briefly described below.

The star topology consists of a coordinator and several end devices (nodes), as shown in Figure3. The coordinator is a central node, which is linked to all other nodes in the network. All messages travel via the central node. The operation of the star network depends on the coordinator of the network, and because all packets between devices must go through coordinator, the coordinator may become bottlenecked. Also, there is no alternative path from the source to the destination.

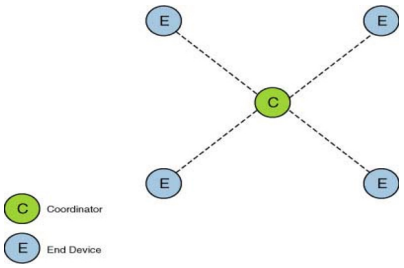


**Figure 3** Star topology

The tree network consists of a central node (root tree), which is a coordinator, several routers, and end devices, as shown in Figure 4. To reach its destination, a message travels up the tree (as far as necessary) and then down the tree. If one of the parents becomes disabled, the children of the disable parent cannot communicate with other devices in the network. Even if two nodes are geographically close to each other, they cannot communicate directly.

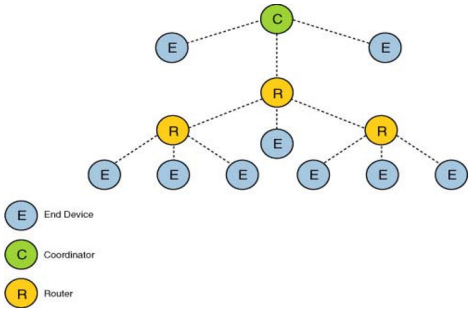


**Figure 4** Tree topology

Mesh topology, also referred to as a peer-to-peer network, consists of one coordinator, several routers, and end devices, as shown in Figure 5. The Coordinator selects the frequency channel to be used by the network (usually the one with the least detected activity), starts the network and allows other devices to connect to it (that is, to join the network).Mesh topologies need at least one Router. The Router relays messages from one node to another and allows child nodes to connect to it. The Coordinator is linked to a set of Routers and End Devices - its children. A Router may then be linked to more Routers and End Devices - its children. This can continue to a number of levels. End Devices are always located at the extremities of a network and can sleep in order to conserve power when not transmitting or receiving messages. These roles described above exist at the network level – a ZigBee node may also be performing tasks at the application level independent of the role it plays in the network. For instance, a network of ZigBee devices measuring displacement may have a displacement sensor application in each node, irrespective of whether they are End Devices, Routers or the Coordinator.

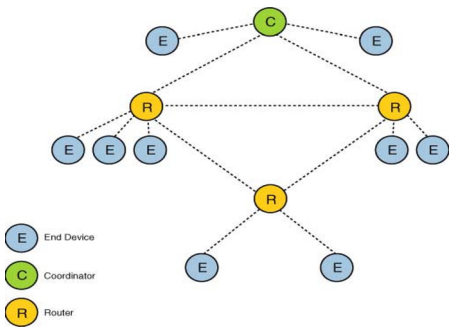


**Figure 5** Mesh topology

Compared with the above topology, a Mesh network has a tree-like structure in which some leaves are directly linked. Messages can travel across the tree, when a suitable route is available. A Router can be located anywhere that a message passing node is required. However, the communication rules are more flexible in that Router nodes within range of each other can communicate directly The Mesh topology gives rise to more efficient message propagation, and means that alternative routes can be found if a link fails or there is congestion. A "route discovery" feature is provided which allows the network to find the best available route for a message. A mesh topology is a multi-hop network; packets pass through multiple hops to reach their destination. Its range can be increased by adding more devices to the network. It can eliminate dead zones. A mesh topology is self-healing, meaning during transmission, if a path fails, the node will find an alternate path to the destination. Adding or removing a device is easy. Any source device can communicate with any destination device in the network. A mesh network is designed as follows.

## 4 Mesh network design

ZigBee PRO technology is a short distance, low-complexity, low power, low data rate, low-cost two-way wireless communication technology based on the IEEE 802.15.4 protocol. It based on standard Open Systems Interconnection (OSI): The 802.15.4 standard specifies the lower protocol layers—the physical layer (PHY), and the media access control (MAC). ZigBee Alliance defined on this basis, the rest layers such as the network layer and application layer, is responsible for high-level applications, testing and marketing. The network layer used here, based on ad hoc network [8] protocols, includes the following functions: construction and maintenance of the topological structure, nomenclature and associated businesses which involves addressing, routing and security and a self-organizing-self-maintenance functions which will minimize consumer spending and maintenance costs.

### 4.1 LM3S9B96+CC2520 coordinator

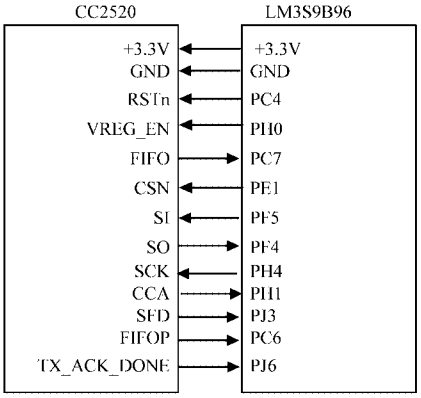


**Figure 6** LM3S9B96 and CC250 interface

### 4.2 Receive and send process of message in physical layer of CC2520

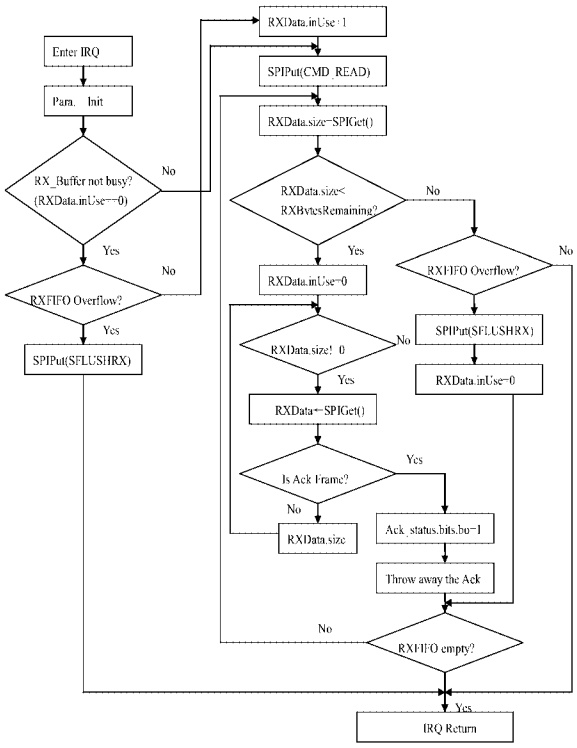


**Figure 7** Receive Process of Message

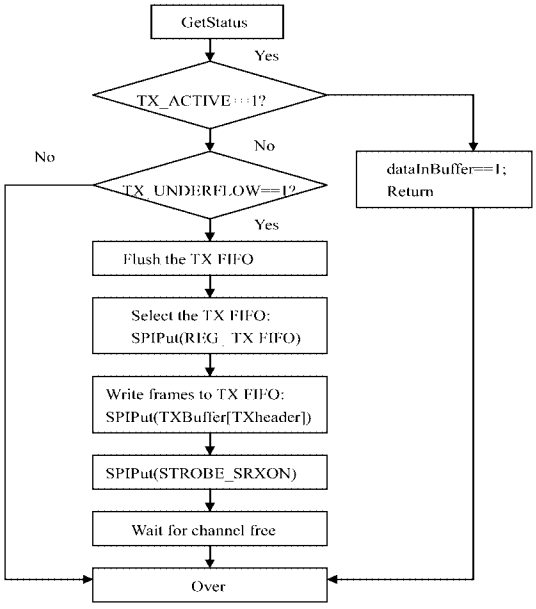


**Figure 8** Send Process of Message

### 4.3 Event process in the coordinator, routers and end devices

ZigBee uses the IEEE 802.15.4 2003 specification for its physical layer and MAC layer. The ZigBee standard has the capacity to address up to 65535 nodes in a single network. However, there are only three general types of node: Coordinator, Routers and End device.

#### 4.3.1 LM3S9B96+CC2520 coordinator's main codes

```
void zb_HandleOsalEvent (){
 unsigned char ucDeviceType;
 if (usEvent & ZB_ENTY_EVENT){
    DEBUG_PRINTF("Device starting\n");
    ucDeviceType=ZG_DEVIECETYPE_COORDINATOR;
    zb_WriteConfiguration(ZCD_NV_LOGICAL_TYPE, sizeof (ucDeviceType), & ucDeviceType);
zb_StartReques()}
 if (usEvent & MY_START_EVT){zb_StartRequest();}}
```

#### 4.3.2 MY_FIND_COLLECTOR_EVT main codes

```
viod zb_StartConfirm(){
 if (status==ZB_SUCCESS){
    …
osal_set_event ( sapi_TaskID, MY_FIND_COLLECTOR_EVT);}}
```

#### 4.3.3 CC2530 routers and end devices' main codes

```
void zb_HandleOsalEvent (){
 if ( event & ZB_ENTRY_EVENT){
    zb_StartRequest();}
 if ( event & MY_REPORT_EVT){
    if ( appState = =APP_REPORT){
     sendReport();
     osal_start_timerEx ( sapi_TaskID, MY_REPORT_EVT, myReportPeriod);}}
 if ( event & MY_FIND_COLLECTOR_EVT){
  if ( appState = = APP_REPORT){
   zb_BindDevice (FALSE, ACUTATOR_REPORT_CMD_ID, NULL);}
    appState = APP_BIND;
zb_BindDevice (TRUE, ACUTATOR_REPORT_CMD_ID, NULL);}}
```

## 5 Actuator and its wireless controller

The fiber positioning actuator controller as follows in ZigBee PRO network receives the orders from the fiber positioning control computer in Ethernet through the above protocols converter. As shown in Figure 9, the entire close-up control system of positioning actuator includes driver, wireless controller and feedback link based on the optical encoder. Integrating the controller [9] and driver achieves the closed-loop control of the stepper motor and improves the control accuracy greatly.

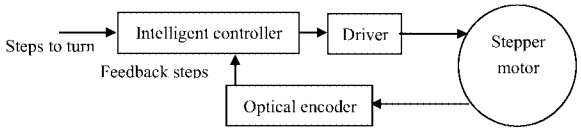


**Figure 9** Close-loop control of displacement actuator

The optical encoder built in a stepper motor detects the rotation angle of the stepper motor to make the driver with out-of-step detection and stall protection function.The wireless controller receives instructions from the fiber positioning control computer and judges and regulate step losses.

## 6 Conclusions

ZigBee technology is a short distance, low-complexity, low power, low data rate and low-cost wireless communication technology. It is widely used in the automation and sensor networks and it also has a successful application in LAMOST control system. In this paper, a novel fiber positioning control method based on ZigBee PRO was proposed for LAMOST fiber positioning, which can reduce the number of external antenna more than 95%, furthermore, the difficulty of installation was minimized by saving the space on the back of focal plate, comparing with traditional control way of wire drive. ZigBee PRO networking and data communication technology are analyzed and a mesh network is designed based on LM3S9B96, CC2520 and CC2530 to realize localization and reset for 4000 fiber positioning units.

## Acknowledgement

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