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Forest Fire Protection System Based on LoRa Technology

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Abstract: At present, most forest fire prevention systems use 4G base station network communication. When encountering a fire, due to the weak signal of the mountain base station, data transmission cannot be quickly achieved, and the best rescue time for the fire is often missed. We have proposed our solution for this, a forest fire prevention system based on LoRa communication technology. Using various sensor technologies to accurately monitor and collect temperature and humidity, smoke concentration, flame value, etc. in the forest, the data is transmitted to the cloud management system through LoRa communication module networking. Once a fire is detected, the fire point can be accurately located based on the location of the deployed nodes, and the backend system alarm can be triggered. Forest firefighters can also be notified through apps, text messages, and other means.

1. Introduction

Since the emergence of forests on Earth, forest fires have accompanied them. On average, more than 200000 forest fires occur worldwide each year, accounting for over 1% of the world's total forest area. China experiences an average of over 10000 forest fires every year, burning hundreds of thousands to millions of hectares of forests, accounting for approximately 5-8% of the country's forest area. In May 1987, a huge forest fire occurred in Greater Khingan of Heilongjiang Province, covering 1.01 million hectares, of which 70% were forests.

Forest fires not only burn and burn trees, directly reducing forest area, but also seriously damaging forest structure and environment, causing a loss of balance in forest ecosystems, a decrease in forest biomass, reduced productivity, a decrease in beneficial animals and birds, and even causing human and animal casualties. High intensity fires can damage the chemical and physical properties of soil, reduce soil water retention and permeability, and cause the groundwater level of certain forest and low-lying areas to rise, leading to swamping; In addition, due to the carbonization and warming of the soil surface, it can also accelerate the drying of the burned land, leading to the overgrowth of positive weeds, which is unfavorable for forest regeneration or causes the replacement of low value forests that are tolerant to extreme ecological conditions.

According to incomplete statistics, the world has suffered multiple forest fires, with massive forest fires causing the destruction of billions of hectares of forest. On average, up to 13 billion tons of additional carbon emissions in the global atmosphere each year come from forest fires, exceeding 1/4 of the global annual net carbon increment. Forest fires cause an increase in soil temperature, causing serious damage to the soil. At the same time, the longer the fire lasts, the larger the burning area, and the greater the damage to the ecological environment, seriously damaging biodiversity. The longer the time required to extinguish forest fires, the more manpower, material resources, and financial resources consumed, and the more serious the impact on industrial and agricultural production, which may cause a large number of casualties and affect social stability and development.

Two forest fires have occurred in Liangshan Prefecture, Sichuan, China, resulting in a total of 50 deaths. At around 15:00 on April 13, 2023, Wang Mouwei, a resident of Xiajia Community in Huangwu Street, Yantai, cleared weeds on the contracted land in Beishan after drinking alcohol. During this period, he ignited a fire and caused a wildfire in Yantai.

These fires always remind us that forest fire prevention is urgent!

2. Project Background

The existing forest fire prevention systems in the market collect surrounding environmental data through sensors, and use 4G networks to transmit the data to the gateway (data centralization device). The gateway then sends the data to the local management platform for fire analysis and warning. [1] The Figure 1 is the schematic diagram of forest fire prevention system networking.

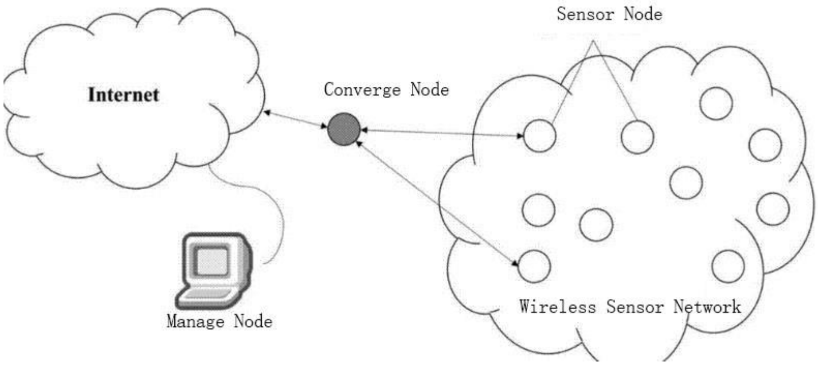

Figure 1: Schematic diagram of forest fire prevention system networking.

2.1. Problems with the System

When deploying and installing the system, some problems were encountered: the operator's 4G network relies on base stations on the mountain, but the base station signal is poor, the network is unstable, paid for traffic is purchased, there is delay, and nodes cannot achieve full coverage.

At present, the forest fire prevention system does not have 5G network equipment and mostly uses 4G base station network communication. In the event of a fire, due to the weak signal of the base station on the mountain, data transmission cannot be quickly achieved, and the best rescue time for the fire is often missed. [2]

At present, big data analysis technology is still not used in forest fire prevention work in many places. In addition, there is no information exchange platform between local government agencies and forest fire prevention authorities, making it difficult to accurately understand local fire hazards and sources.

2.2. Market Analysis

We analyzed several mature forest fire prevention system products from both inside and outside the province. As shown in Table 1, most of which use GIS geographic positioning, base station communication, and camera monitoring of fire points. The GIS system requires high usage costs, and the bandwidth requirements for base station communication are high. The use of intelligent cameras to capture fire images has visual blind spots.

Table 1: Comparison table of existing forest fire protection systems

Typical fire protection system cases	Core technology	Disadvantage
Forest fire warning system of Jinan	Infrared thermal imagers can accurately detect high-temperature objects and locate them using GIS geographic information systems.	The fees are high, and generally require software and authorization fees of 100000 to 200000 yuan based on the platform and system calculation
Intelligent forest fire warning platform of Yantai	Using sensors to detect flames and smoke, transmitting information based on communication towers.	The base station signal is poor and cannot meet the high bandwidth requirements of wireless devices for monitoring points.
Heyuan forest fire remote video monitoring Project of Guangdong	Visible light cameras and thermal imaging cameras.	A large number of intelligent cameras need to be deployed, which is costly. Due to the obstruction of large trees, the cameras have blind spots for monitoring.

3. Project Solution

3.1. Technical background

We have proposed our solution for this: a forest fire prevention system based on LoRa communication technology.

LoRa is a mature wireless communication technology that is low-power, long-distance, and has a wide coverage range. A single node can cover a range of several kilometers; And his communication frequency band is free to use; LoRa nodes can form their own networks to transmit data without the support of operators (such as 4G and 5G).

LoRa, as an unauthorized spectrum based LPWAN wireless technology, has a more mature industrial chain and earlier commercial application compared to other wireless technologies such as Sigfox and NWave. After global promotion by LoRa Alliance international organizations such as Semtech, Cisco, IBM, KPN Telecom of the Netherlands, and SK Telecom of South Korea, LoRa technology has become an important foundational support technology for new IoT applications and smart city development.

As one of the LPWAN technologies, LoRa has the characteristics of long distance, low power consumption, low cost, easy deployment, and standardization. The following shows the key features and corresponding advantages of LoRa technology. [3]

- Low power consumption and long-distance

The biggest characteristic of LoRa is that it can propagate farther than other wireless methods under the same power consumption conditions.

- Wide coverage

The advantage of LoRa lies in its technical long-distance capability. A single node can cover several kilometers, and LoRa Link budget is superior to any other standardized communication technology.

- License free

The communication frequency band used by LoRa is a free wireless frequency band of 433MHz.

According to the key characteristics of LoRa technology, it can be seen that LoRa is very suitable for IoT applications that require low power consumption, long distance, large capacity, and location-based tracking, such as intelligent meter reading, intelligent parking, vehicle tracking, pet tracking, smart agriculture, smart industry, smart cities, smart communities, and other applications and fields.

Currently, the LoRa network has been piloted or deployed in multiple locations worldwide. According to the latest released relevant data, 16 countries around the world are deploying LoRa networks, and 56 countries are starting pilot projects, such as the United States, France, Germany, Australia, India, etc. KPN Telecom of the Netherlands and SK Telecom of South Korea deployed LoRa networks covering the whole country in the first half of 2016, providing IoT services based on LoRa. Compared to the rapid development of LoRa technology abroad, the application of LoRa in China is slightly indifferent. The currently visible public application is the LoRa network (smart waterway) construction carried out by domestic AUGTEK company on the Beijing Hangzhou Grand Canal. It is reported that the full coverage of the Jiangsu section has been completed. In fact, there are not many domestic manufacturers engaged in the development of LoRa modules and solutions. In addition to AUGTEK, there are also many companies such as Zhousi IoT, Sichuang Huilian, Putian Tongda, NPLink, Mensi Technology, Lierda, Tonggan Microelectronics, Shanghai Yongmin, Wuhan Tuobao, Boda Guangtong, Zonghang Technology, Weichuan Technology, Sanfan Information, and so on. With the explosive development of the domestic wide area Internet of Things and the active promotion of LoRa applications by CLAA organizations, more and more pilot projects based on LoRa applications in China will be deployed in various industries to provide high-quality and efficient IoT services.

3.2. Design Scheme

We have designed a forest fire prevention system solution based on LoRa wireless communication technology. Encrypt during transmission, resist interference, and achieve long-distance secure data transmission.

As shown in Figure 2, the specific implementation process of our plan is to first use various sensor technologies to accurately monitor the temperature and humidity, smoke concentration, flame value, etc. in the forest. The second step is to network the data (like playing checkers) to a centralized node (gateway) through the LoRa communication module carried by the node, and then use a wired network to transmit the data to the cloud management system. Once a fire is detected, the fire point can be accurately located based on the location of the deployed nodes, and the backend system alarm can be triggered. Forest firefighters can also be notified through apps, text messages, and other means. [4]

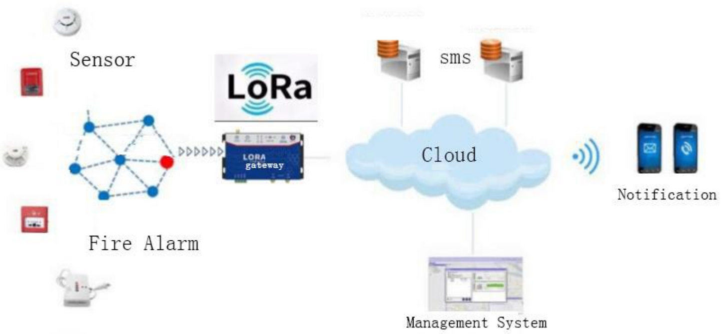

Figure 2: System structure diagram

We simulated the forest fire prevention system using existing laboratory equipment. After the flame sensor collects the fire information, it will be displayed on the screen, and the data will be transmitted to the management system platform through the LoRa communication module through the network, triggering an audible and visual alarm.

3.2.1. Design process

We design hardware circuit diagrams as shown in Figure 3,and develop software programs for sensor nodes as shown in Figure 4, which are powered by solar energy. The core control microcontroller adopts the STM32L151 series chip, coupled with sensor sockets, buttons, indicator lights, and OLED screens, which can display the collected sensor data on the screen and transmit it through the LoRa communication module network.

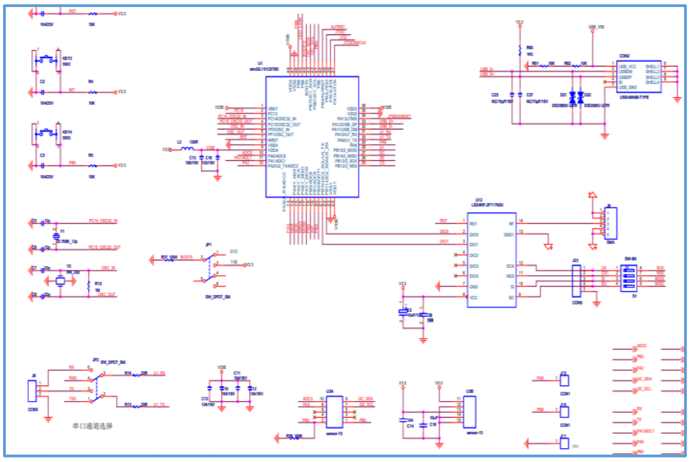

Figure 3: LoRa sensor node schematic diagram

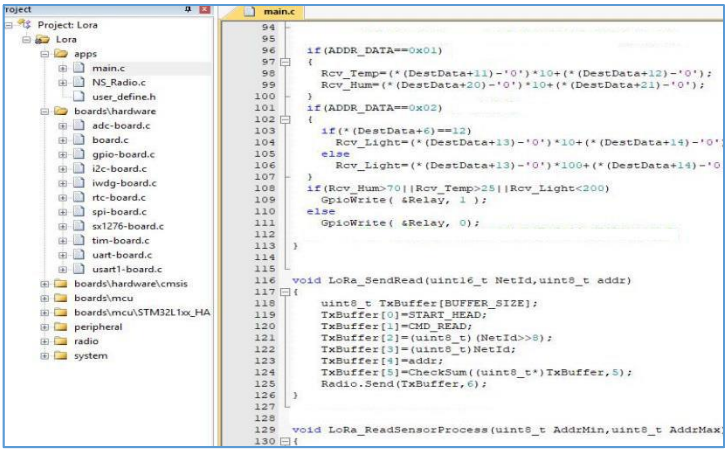

Figure 4: Programming interface

Due to limitations in research and development technology, we have chosen mature products in the market for the gateway. We have designed wiring for the wired connection from the gateway to the cloud platform.

As shown in Figure 5, forest environmental monitoring data can be updated and displayed in real-time on our self-developed monitoring cloud platform, and timely warnings can be given in case of fire. Through the image of the cloud platform below, we can see environmental information such as temperature, humidity, flame, lighting, smoke concentration, etc. Once the threshold value we set is exceeded, an alarm will be triggered, the alarm light will light up, and forest firefighters will be notified through APP and SMS.

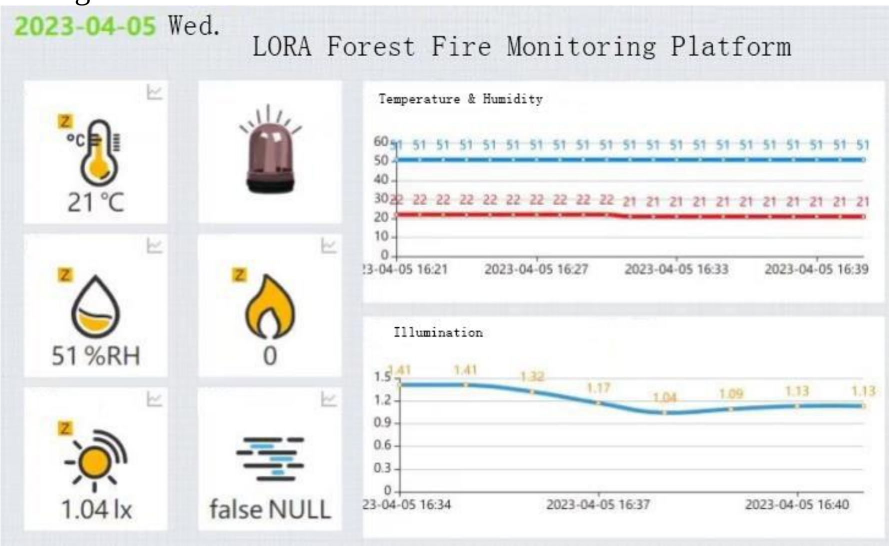

Figure 5: Forest fire prevention monitoring cloud platform

4. System Testing

After simulation testing on campus, setting up 10 nodes can achieve forest wide coverage communication. When the LoRa node collects fire data, it will display the fire information on the node screen and transmit it to the LoRa gateway node through remote wireless communication. After receiving the information, the gateway node will transmit it to the cloud platform for display. At this time, the fire alarm light will light up and notify the forest firefighter through SMS. [5] Figure 6 is about campus simulation testing.

Figure 6: Campus simulation testing

5. Project Advantages

The LoRa forest fire prevention system utilizes sensing technology and wireless communication to detect and identify fires, and obtains specific data for data analysis and early warning. The LoRa forest fire prevention system can detect fires 24/7 and accurately locate the ignition point. Compared to 4G base station network communication, it has wider coverage, higher timeliness, lower propagation delay, lower cost, and less functional consumption. The LoRa forest fire prevention system is less affected by environmental and geographical factors, and has marketing differentiation compared to other forest fire prevention monitoring equipment, with a wider market. Our market advantage is the ability to remotely manage at anytime and anywhere with the help of cloud platform advantages, with high security, small geographical factors, wide coverage, precise positioning, lower costs, and lower power consumption.

6. System Cost Analysis

The sensor nodes used in the project are powered by solar energy, combined with sensors and LoRa communication modules. The selling price of each node is around 3000 yuan, and the net profit of each node is around 1000 yuan excluding the cost price.

- Analysis of the total investment cost of a fire prevention system
- Procurement and installation of sensor modules
- Product development, online testing, and later improvement
- Product promotion and promotion
- Employee salaries and benefits

7. Risk Analysis

We have market competition with many emerging technology fire prevention projects. In response to this situation, we will leverage our market advantages, gain public opinion support through publicity, continuously update technology, expand the market, and operate flexibly. Our market operation faces issues such as high initial investment, seeking downstream partners, and increasing management and operational costs. In response to this situation, we will do a good job in market research, find partners locally, develop a reasonable budget plan and Marketing plan, actively promote and actively contact businesses, do a good job in communication and cooperation, and constantly improve technology.

Therefore, we have developed a financial risk management plan to address these issues:

▪ 1) We need to raise more funds and increase project budgets and funding by seeking sponsorship, donations, and other means.

▪ 2) We need to optimize expenses. We conduct optimization analysis on project expenses, identify existing waste and redundant expenses, and optimize and reduce these expenses.

▪ 3) To improve efficiency, we can learn to introduce more advanced financial planning models. At the same time, we continuously update our technological level and expand our advantages compared to other competitors.

8. Program Code

8.1. LoRa gateway Code

```
void LoRa_GateWay_AutoCTL(uint8_t *DataBuf,uint16_t len)
{
  uint8_t *DestData =NULL;
  #define HEAD_DATA       *DestData
  #define CMD_DATA        *(DestData+1)
  #define NETH_DATA       *(DestData+2)
  #define NETL_DATA           *(DestData+3)
  #define ADDR_DATA       *(DestData+4)
  #define ACK_DATA        *(DestData+5)
```

```
#define LEN_DATA         *(DestData+6)
#define DATASTAR_DATA *(DestData+7)

DestData =ExtractCmdframe((uint8_t *)DataBuf ,len,START_HEAD );
if(DestData !=NULL )
{
    if((DestData - DataBuf )>(len-6)) return;
    if(CMD_DATA !=CMD_READ ) return;
    if(CheckSum((uint8_t  *)DestData  ,6+DestData[6])  !=(*(DestData+6+(*(DestData+6)))))
return;
    if(((((uint16_t)NETH_DATA )<<8)+NETL_DATA ) !=MY_NET_ID ) return;
    char OledBuf[32];
    memset(OledBuf    ,' ',30 );
    memcpy(OledBuf,&DATASTAR_DATA,(LEN_DATA-1)>30?30:(LEN_DATA-1));
    OLED_ShowString(0,4,(uint8_t *)OledBuf);
    USART1_SendStr((uint8_t *)DestData,LEN_DATA+7);
}

// User added code: LoRa gateway data parsing and logical control start
if(ADDR_DATA==0x01)
{
    Rcv_Temp=(*(DestData+11)-'0')*10+(*(DestData+12)-'0');
    Rcv_Hum=(*(DestData+20)-'0')*10+(*(DestData+21)-'0');
}
if(ADDR_DATA==0x02)
{
    if(*(DestData+6)==12)
        Rcv_Light=(*(DestData+13)-'0')*10+(*(DestData+14)-'0');
    else
        Rcv_Light=(*(DestData+13)-'0')*100+(*(DestData+14)-'0')*10+(*(DestData+15)-'0');
}
if(Rcv_Hum>70||Rcv_Temp>25||Rcv_Light<200)
    GpioWrite( &Relay, 1 );
else
```

```
        GpioWrite( &Relay, 0);
  // LoRa gateway data parsing and logical control completed.
}
```

8.2. Sensor node code

```
void LoRa_ReadSensorProcess(uint8_t AddrMin,uint8_t AddrMax)
{
  static uint16_t time=1000;
  static uint8_t addr=1;
  if(User0Timer_MS >time )
  {
        User0Timer_MS =0;
        time=randr(1000,4000);
#ifndef TRANSPARENCY
        printf("Read network ID is 0x%04x,address is %d 的 sensor node\r\n",MY_NET_ID,addr);
#endif

        char StrBuf[32]={0};
        memset(StrBuf ,'\0',32);
        sprintf(StrBuf ,"ID:%04X,Addr:%d",MY_NET_ID,addr );
        OLED_ShowString(0,2,(uint8_t *)StrBuf);
        memset(StrBuf ,' ',32);
        OLED_ShowString(0,4,(uint8_t *)StrBuf);
        LoRa_SendRead(MY_NET_ID,addr++);
        if(addr>AddrMax)
              addr=AddrMin;
        GpioToggle(&Led1 );
  }
}

// Communication protocol: checksum
uint8_t CheckSum(uint8_t *buf,uint8_t len)
{
  uint8_t temp =0;
```

```
  while(len--)
  {
        temp +=*buf;
        buf++;
  }
  return (uint8_t )temp;
}

// Communication protocol: communication frame header parsing
uint8_t *ExtractCmdframe(uint8_t *buf,uint8_t len,uint8_t CmdStart)
{
  uint8_t *point = NULL;
  uint8_t i;
  for(i=0;i<len;i++)
  {
        if(CmdStart ==*buf )
        {
              point = buf;
              return point;
        }
  buf++;
  }
return NULL;
}

// Communication protocol: Command frame parsing.
void LoRa_DataParse(uint8_t *LoRaRxBuf,uint16_t len)
{
  #if defined(LORA_GATEWAY)
        LoRa_GateWay_AutoCTL(LoRaRxBuf,len);
  #endif
  #ifdef LORA_NODE_TEHU
        uint8_t *DestData =NULL;
        #define HEAD_DATA     *DestData
```

```
#define CMD_DATA        *(DestData+1)
#define NETH_DATA       *(DestData+2)
#define NETL_DATA               *(DestData+3)
#define ADDR_DATA         *(DestData+4)
#define ACK_DATA          *(DestData+5)
#define LEN_DATA        *(DestData+6)
#define DATASTAR_DATA       *(DestData+7)
DestData =ExtractCmdframe((uint8_t *)LoRaRxBuf ,len,START_HEAD );
if(DestData !=NULL )
{
    if((DestData - LoRaRxBuf )>(len-6)) return;
    if(CMD_DATA !=CMD_READ ) return;
    if(CheckSum((uint8_t *)DestData ,5) !=(*(DestData+5)) ) return;
    if(((((uint16_t)NETH_DATA )<<8)+NETL_DATA ) !=MY_NET_ID ) return;
    if(ADDR_DATA    !=MY_ADDR ) return;
    uint8_t RspBuf[BUFFER_SIZE]={0};
    memset(RspBuf ,'\0',BUFFER_SIZE );
    RspBuf[0]=START_HEAD ;
    RspBuf[1]=CMD_READ ;
    RspBuf[2]=(uint8_t)(MY_NET_ID>>8) ;
    RspBuf[3]=(uint8_t)MY_NET_ID ;
    RspBuf[4]=MY_ADDR ;
    RspBuf[5]=ACK_OK ;
    sprintf((char *)(RspBuf +7),"tem:%dCe,hum:%d%%",temperature,humidity);
    RspBuf[6]=strlen((const char *)(RspBuf +7))+1;
    RspBuf[6+RspBuf[6]]=CheckSum((uint8_t *)RspBuf,6 +RspBuf[6]);
    Radio.Send(RspBuf ,7 +RspBuf[6]);
    GpioToggle(&Led1 );
}
#endif
```

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