Energy-saving mechanism design for 6LOWPAN wireless sensor network

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Abstract

Combined with the wireless sensor network and distributed multi IPv6, IEEE802.15.4 technology is introduced into the network design and wireless sensor network carries out seamless misaiming with the internet, finally a new 6LOWPAN wireless sensor network energy saving mechanism will be obtained, its mechanism combines with the comprehensive power of optical fiber line, wireless sensor network node distribution optimization multi distributed IP technology to design energy-saving model, and uses C language to program the algorithm. In order to test the effectiveness and reliability of energy-saving mechanism, the energy-saving wireless sensor network is built, and the integrated Contiki environment is developed, finally the use of Firefox browser with B/S architecture tests the energy-saving mechanism. Through the test, it can be found that when sending, receiving, idle and sleep in wireless sensor network, 6LOWPAN wireless sensor network can realize the network energy-saving effectively.

Keywords: 6LOWPAN network, distributed IPv6, IEEE802.15.4, C language, Contiki integration

1 Introduction

Wireless sensor networks are mostly local area network (LAN) of ad hoc network form, which can only access and process the monitored information in the dedicated control centre. IP network is widely used, if local area wireless sensor network can be accessed internet backbone network, it will bring more convenience to users [1, 2]. According to the complex gateway of internet protocol development, there are three main problems for wireless network access to the internet: firstly it needs a dedicated adapter; secondly the data package of existing internet format occupies large space with big power, which can’t meet the requirements of wireless sensor network terminal; finally when many embedded devices are accessed to IP network, due to the limited IP address of current version IPv4 protocol, they will face addresses shortage [3]. 6LoWPAN by virtue of its function advantage can solve these problems very well, which can reduce the network energy consumption. Based on this, the energy-saving mechanism of wireless sensor network is designed, and its mechanism is tested on network, finally realizes the energy-saving optimization design of wireless sensor network.

2 Overview of 6LOWPAN wireless sensor network energy-saving principle

With the development of computer network technology, more and more devices need to access network. The 6LoWPAN working group of the internet engineering task force will be dedicated to apply IPv6 in IEEE 802.15.4, so as to realize the seamless connection between wireless sensor network and IP network [4]. The formation of energy-saving mechanism in 6LOWPAN wireless sensor network is related to network configuration and sensor terminal energy-saving. Combined the two aspects, a new energy-saving mechanism is established.

2.1 MAIN ENERGY-SAVING MODE OF 6LOWPAN WIRELESS SENSOR NETWORK

The wireless sensor network based on 6LoWPAN is a joint product of wireless sensor network technology, IPv6 technology and network technology, its energy-saving way is realized mainly by network configuration and wireless sensor terminal energy-saving.

2.1.1 Network configuration

6LoWPAN technology solves the internet accessing problem of perception layer and wireless sensor node, and realizes the IP implementation of wireless sensor terminal [5, 6]. The wireless sensor network is built by using 6LoWPAN technology, and it is shown in Figure 1.

Figure 1 shows the schematic diagram of 6LOWPAN wireless sensor network energy-saving mechanism that is built by distributed network node [7]. The distributed network uses Ipv6 distributed network system, and the use of boundary router connects the sensor network with Ipv6 network system, using 6LOWPAN router between nodes realizes node information exchange and energy saving.

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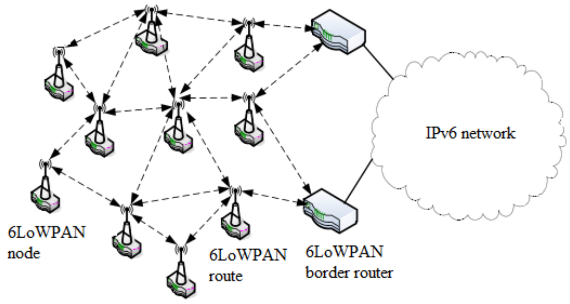

FIGURE 1 The schematic diagram of distributed network energy-saving mechanism

2.1.2 Sensor terminal

Sensor terminal energy consumption is also one of the main energy consumption in 6LOWPAN wireless sensor network, and the design of low power consumption can be realized by mainly using two kinds of sensor terminal solar cell, including monocrystalline solar cell and polycrystalline solar cell.

(A). Monocrystalline solar cell. Monocrystalline solar cell uses monocrystalline silicon to produce battery, its basic structure is shown in Figure 2.

FIGURE 2 Monocrystalline solar cell

Monocrystalline cell has stable power performance, and it is one of the most used solar cells. Compared with polycrystalline silicon battery, it has higher efficiency of solar energy conversion, but it has high requirements for material, so the production cost is also higher.

(B). Polycrystalline silicon solar cells. Compared with monocrystalline silicon solar cells, the advantage of polycrystalline silicon solar cells is saving material, and its disadvantage has lower transformation efficiency.

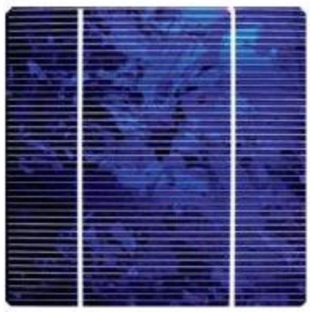

FIGURE 3 Polycrystalline silicon solar cell

As shown in Figure 3, polycrystalline silicon solar cell mainly uses the production process of chemical gas phase deposition, it is easy to manufacture with low cost, and its performance is higher than monocrystalline silicon solar cells, so it has been widely applied in the solar energy-saving battery.

2.2 OVERVIEW OF 6LOWPAN WIRELESS SENSOR NETWORK ENERGY-SAVING MECHANISM

Wireless sensor network can be divided into different types according to the different applications, however the nodes of wireless sensor network is basically consistent, in which it has mainly four modules, including power supply module, wireless communication module, processor module, sensor module [8]. The specific frame is shown in Figure 4.

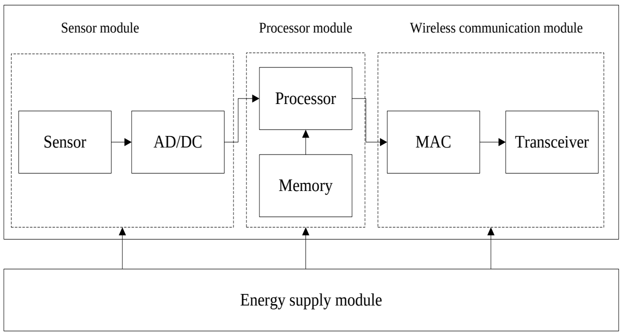

FIGURE 4 Architecture of the sensor node

Among them, the energy supply module is the essential part of all electronic systems, it is the power centre of the whole node network, which is responsible for providing the necessary energy, and the main energy consumption is the three big modules [9]. Using 6LOWPAN technology, it can achieve energy saving from the following two aspects:

2.2.1 Multi task kernel driven by event

6LOWPAN uses the Contiki integrated development environment, this driver model can make multiple tasks share one stack without occupying independent stack for each task, and each task only occupies a few bytes of RAM, greatly saving storage space, and it is more suitable for wireless sensor network.

2.2.2 Low power wireless sensor network protocol stack

Contiki provides a complete IP network and the low power wireless network protocol stack [10]. For the IP protocol stack, it supports IPv4 and IPv6 versions, including some simplified web tools, Telnet, HTTP, web services and so on; these integrated environment reduces network energy consumption.

3 Mathematics model and algorithm of 6LOWPAN wireless sensor network energy-saving mechanism

The establishment of wireless sensor energy-saving mechanism can greatly reduce energy consumption, saving computer hardware/software and network communication resources, which have an important significance for the design of wireless sensor network.

3.1 ENERGY CONSUMPTION OF 6LOWPAN WIRELESS SENSOR NETWORK

In order to improve the transmission efficiency of 6LOWPAN, the optical fiber transmission will be used in wireless network communication line [11]. In the optical fiber line, the power consumption of network signal transmission is mainly related to optical system loss and dispersion, in which the maximum effective transmission distance of optical loss is shown in Equation (1).

$$g = \frac{G_m - G_n - G_c - 2K_p - L_p}{\lambda_a - \lambda_b} . \quad (1)$$

Among them, G_m is the luminous power for completely loss; G_n is receiving sensitivity without security loss; Y_n is the luminous flux rate; λ_a and λ_b are respectively the light loss coefficient; K_p is loss at the interface; L_p is the maximum communication rate of cable, in which the dispersion limited expression is shown in Equation (2).

$$L = \frac{S}{k} . \quad (2)$$

Among them, L is the dispersion limited distance; S is the largest dispersion; k is dispersion coefficient. In the actual construction process, the erection of optical fiber lines needs to consider the maximum effective transmission distance and dispersion limit, so the maximum effective range is shown in Equation (3).

$$\widehat{L} = \max(g, L) . \quad (3)$$

In Equation (3), it can effectively calculate the energy consumption of 6LOWPAN wireless sensor network in the actual building process, which provides the mathematical basis for the establishment of energy-saving mechanism.

3.2 6LOWPAN WIRELESS SENSOR NETWORK NODE OPTIMIZATION

In the design of 6LOWPAN wireless sensor network, the processing of network nodes is also improving network performance, which reduces the one of the main factors of network energy consumption [12]. The mathematical model of independent nodes is established by using the least square method, assuming that the independent sequence of 6LOWPAN network nodes is $(x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n)$, there is:

$$y_i = \lambda + n x_i + X_{\sigma i} . \quad (4)$$

In Equation (4), the independent node sequence can be optimized by using the least square method, in which the estimated value of least squares is shown in Equation (5).

$$\hat{n} = \frac{\sum_{i=1}^{m} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{m} (x_i - \bar{x})^2} . \quad (5)$$

Among them,

$$\bar{x} = \frac{1}{m}\sum_{i=1}^{m} x_i , \ \bar{y} = \frac{1}{m}\sum_{i=1}^{m} y_i . \quad 6$$

Then the maximum likelihood estimation values of 6LOWPAN network independent nodes energy consumption in X_σ can be expressed as:

$$\psi = \sqrt{\frac{1}{m}\sum_{i=1}^{m} {x_{\sigma i}}^2} \quad (7)$$

And the optimization distance of 6LOWPAN independent network nodes can be expressed as:

$$f(S_d) = \frac{1}{\psi\sqrt{2\pi}} e^{\frac{-[S_d - (P_f + Z_f + Z_j - S_l - S_{d0})]}{2\psi^2}} . \quad (8)$$

Among them, S_d is expressed as optimization distance; ψ shows the covariance; S_{d0} shows the distance function. When $S_d \ge S_{d0}$, the performance and the energy-saving state of 6LOWPAN wireless networks will achieve optimal, so its state can carry on the design of network transmission line.

3.3 IP MULTIPLE DISTRIBUTION MATHEMATICAL MODEL OF 6LOWPAN WIRELESS SENSOR NETWORK

Multi distributed network can realize the transmission of high capacity information, in which its core technology is the application of IP multi distribution technology [13]. In order to optimize multiple distributed, it needs to design the space distribution of IP network nodes. Assuming that the distance of multiple distributions IP network node is y, its expression is shown in Equation (9).

$$\int_{t_1}^{t_2} \sqrt{\left(\frac{du}{dt}\right)^2 + \left(\frac{dv}{dt}\right)^2} dt = y . \quad (9)$$

So, it can use the generalized function to calculate the extreme point of node distribution, it is

$$y(u,v) = \frac{1}{2}\int_{y_1}^{y_2}\left(u\frac{du}{dt} - v\frac{dv}{dt}\right)dt. \quad (10)$$

By using the function variation principle, if

$$J(u) = Hu^2 - 2fu \quad (H > 0). \quad (11)$$

Among them, H and f are real constants, the use of multiple function variation principle can solve the minimum value point as shown in Equation (12).

$$J(\vec{u}) = J(u_1, u_2, \cdots, u_n) = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}u_i u_j - \sum_{i=1}^{n} b_i u_i. \quad (12)$$

In the multi distribution IP network system, network node supports super nodes. This function can search better performance of node in the area, and then the use of DHT algorithm can form an overlay network, forming subnet system of super nodes [14]. The super node can also choose the standby node after a selected super node is in failure, it can choose another node as a backup node, so as to save node resources and network energy consumption as shown in Figure 5.

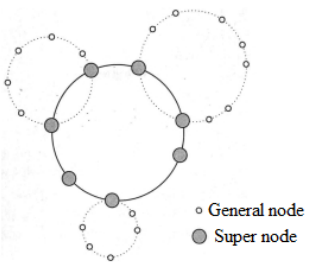

FIGURE 5 Schematic diagram of the novel IPv6 wireless sensor network node.

As shown in Figure 5, the use of distributed IPv6 network can greatly improve the utilization rate of network nodes, forming the wider range of wireless network area, which can effectively reduce the energy consumption, and it can be applied in 6LOWPAN network energy-saving mechanism.

4 Study of 6LOWPAN wireless sensor network energy-saving experiment

In order to verify the effectiveness and reliability of energy-saving mechanism mathematical model for 6LOWPAN wireless sensor network designed in section second, and combined with the wireless sensor network and IPv6, IEEE802.15.4 technology is introduced into the network design, to carry on seamless splicing experiment between wireless sensor networks and internet.

FIGURE 6 Wireless sensor network layout

In order to verify the energy-saving effect of 6LOWPAN wireless sensor network, this paper sets up a wireless sensor network as shown in Figure 6. The wireless sensor network terminal uses polycrystalline silicon solar cell, the bottom layer uses IEEE802.15.4 and MAC layer, the system adds 6LOWPAN adaptation layer between network layer and IEEE protocol, and the transport layer uses the UDP protocol and CoAP protocol [15]. The use of HTTP gateway can use CoAP protocol to read, delete and modify the source data.

4.1 THE DEVELOPMENT CONTIKI INTEGRATED ENVIRONMENT

The experiment uses developed kit by Mei Xin Lin Ke Company, which are developed on Contiki platform. The kit supports IEEE802.15.4 physical transmission protocol and IPv6 development environment. The experimental hardware part of 6LOWPAN wireless sensor network is mainly composed of transmission node, transmission module, and transmission gateway, and its software part is mainly composed of Contikistudio integrated development platform [16]. The Contiki integrated development environment is a multitask operating environment system, which has better portability and open source performance, and occupies less memory in the process of operation, so it is very suitable for application in wireless sensor networks and embedded operating system.

Contiki uses C language program with lower hardware requirements, so it is suitable for use in a variety of microcomputer, computer and PC SCM. Based on 6LOWPAN wireless network, the data transmission procedure is developed, in which sensor end gets main program data as follows:

```
private void get temperature()
{
Sql Connection con = new Sql
Connection(DBHelper.connString.ToString());
con.Open();
string sql = "select a.url,a.port,b.mid,b.uri from sh_mote as
a,sh_typemote as b where
a.mid = b.mid and a.flag = '1' and b.flag='1' and
b.tflag='3'";
SqlCommand cmd = new SqlCommand(sql, con);
```

Inserting the collected wireless sensor data into the internet database, the procedure is as follows:

```
private void insertdatatemperature(int mid, string str,
DateTime nowtime)
{
Sql Connection con = new
SqlConnection(DBHelper.connString.ToString());
con.Open();
string sql = string.Format("insert into
sh_temperature(mid,temperature,nowtime)
values('{0}','{1}','{2}')", mid, str, nowtime);
SqlCommand cmd = new SqlCommand(sql, con);
SqlDataReader sdr = cmd.ExecuteReader();
sdr.Close();
con.Close();
}
```

Database data needs to be sent to wireless gateway in CoAP data packets, the program is:

```
RESOURCE(light, METHOD_GET, "light");
Void light_handler(REQUEST* request, RESPONSE*
response)
{
char buf[32];
int16_t light = NULLDATA;
light = sensor_light_get();
sprintf(buf, "%d", light);
char etag[4] = "ABCD";
```

4.2 WIRELESS SENSOR NETWORK TEST FOR 6LOWPAN ENERGY-SAVING MECHANISM

In order to test the effect of 6LOWPAN energy-saving mechanism, the system uses the Firefox browser. The Firefox browser uses the B/S frame, in which its frame structure is shown in Figure 7.

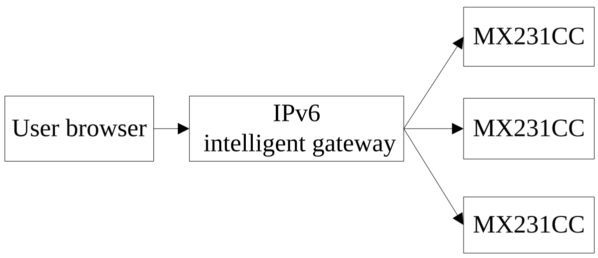

FIGURE 7 Structure diagram of 6LOWPAN with B/S architecture

As shown in Figure 7, it represents the schematic diagram of Firefox browser testing system, this system is composed of browser, web server, IPv6 intelligent gateway and MX231CC nodes. The browser access uses the HTTP protocol to directly access the web, and nodes goes through IPv6 gateway and CoAP protocol to carry on communicate, so as to access the sensor data resources.

TABLE 1 The communication design between the two 6LOWPA

ID:1	**Rime started with adress 0.18.116.10.1.1.1**
ID:1	MAC 00:12:74:01:00:01:01:01 Contiki-2.6 started.Node id is set to1.
ID:1	CSMA ContikiMAC,channel check rate 8Hz,radio channel 26
ID:1	Tentative link-local IPv6 address fe80:0000:0000:0000:0212:7401:0001:0101
ID:1	Starting "UDP client process"
ID:1	fe80::212:7401:1:101
ID:1	Created a connection with the server fe80:212:7402:2:202 local/remote port 3001/3000
ID:1	Client sending to:fe80::212:7402:2:202(msg:Hello 1 from the client)
ID:1	Client sending to:fe80::212:7402:2:202(msg:Hello 2 from the client)
ID:2	Server received:"Hello 2 from the client"from fe80::212:7401:1:101
ID:2	Responding with message: Hello from the server!(1)
ID:1	Responding from the server:"Hello from the server!(1)"
ID:1	Client sending to:fe80::212:7402:2:202(msg:Hello 3 from the client)
ID:2	Server received:"Hello 3 from the client"from fe80::212:7401:1:101
ID:2	Responding with message: Hello from the server!(2)

In order to verify the normal of network communication, the use of integration software simulates the communication between two 6LOWPAN wireless sensor network nodes, and then the use of IPv6 sends and receives UDP data packets. As shown in Table 1, for two nodes, one is as a server function, and the other is as a Client. After the establishment of digital connection, node 1 uses UDF data mode that does not stop to node 2 to send data, it means that can carry out UDP data transmission as IPv6 the same host between two 6LOWPAN sensor nodes.

TABLE 2 Wireless sensor network routing test protocol

497	**ID:2**	**Rime started with address 0.18.116.10.2.2.2**
509	ID:2	MAC 00:12:74:01:00:01:01:01 Contiki-2.6 started.Node id is set to2.
521	ID:2	CSMA ContikiMAC,channel check rate 8Hz,radio channel 26
543	ID:2	Tentative link-local IPv6 address fe80:0000:0000:0000:0212:7401:0002:0202
547	ID:2	Starting "UDP client process""collect common process"
558	ID:2	UDP client process started
558	ID:2	Client IPv6 address:aaa:212::7402:2:202
564	ID:2	fe88:212::7402:2:202
572	ID:2	Created a connection with the server ::local /remote port8775/5688
643	ID:1	Rime started with address 0.18.116.10.1.1.1
655	ID:1	I am sink!
667	ID:1	UDP server started

This test simulates a complete course of 6LoWPAN wireless sensor network that is established by two 6LoWPAN wireless sensor nodes through neighbour discovery protocol, this network uses RPL routing. By tests, it can be found that the wireless sensor network node 2 can realize the environmental data acquisition, and then the 6LoWPAN wireless network sends to node 1, this node 1 saves data in the form of UDP, so as to verify the stability and reliability of network communication.

The nodes of wireless sensor network are composed of four parts, except the power supply unit, the other is energy consuming unit, and the wireless communication unit is the largest energy consumption unit [17]. The energy consumption results of each function unit are obtained by using 6LOWPAN test, the energy-saving data statistics are shown in Figure 8.

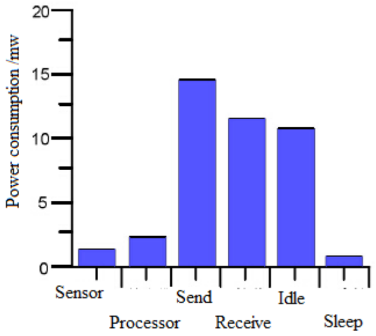

FIGURE 8 Each unit energy-saving for the node

In general, the node wireless communication unit has four states: send, receive, idle and sleep. In order to display the energy-saving situation of nodes directly, the obtained energy-saving data will be listed table as shown in Table 3.

TABLE 3 The statistics of 6LOWPAN wireless sensor network energy-saving

Test items	Common wireless sensor network energy consumption (mV)	6LOWPAN sensor network energy consumption (mV)	Network energy-saving (mV)
Sensor	4.64	3.12	1.52
Processor	5.04	2.11	2.93
Send	26.73	12.52	14.21
Receive	23.07	10.21	12.86
Idle	21.62	9.52	12.10
Sleep	2.53	1.32	1.21

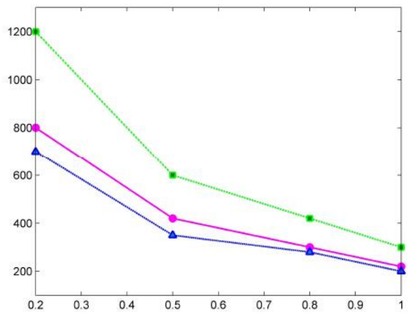

FIGURE 9 The average delay of nodes

In Table 3, it can be seen that when receiving and sending data, the energy consumption of the node will be the largest; when the device is in idle, monitoring channel is still in working condition, so the energy consumption will be also relatively larger, and will be relatively low at other time [18]. From the energy-saving effect, it can be seen that in the links of more energy consuming, the energy-saving effect of 6LOWPAN is more obvious, and its maximum energy-saving can reach 14.21mV, it indicates that the 6LOWPAN can maximize use internet resources to reduce its energy consumption, which can improve the efficiency of network communication and transmission.

Figure 9 shows the tested three nodes in 6LOWPAN wireless sensor network, the average delay simulation curve is obtained. From the chart, it can be seen that with the increase of multi distribution IP area, the network average delay gradually reduces, so as to verify the validity and reliability of multi distributed IP 6LOWPAN energy-saving mechanism.

5 Summary

The mathematical model of optical fiber line power, wireless sensor network node optimization and multi distributed IP are designed, and after the model is programmed by using C language program, finally a new energy-saving mechanism model of wireless sensor network is obtained.

Combined with the distributed IPv6 technology and IEEE802.15.4 protocol, a new 6LOWPAN wireless sensor network energy-saving mechanism is designed, which realizes the seamless splicing energy-saving effect between wireless sensor network and internet, and develops Contiki integrated environment of wireless sensor network energy-saving test.

The effect of energy-saving mechanism is tested by using B/S architecture Firefox browser. Through the test, it can be found that between wireless sensor network two nodes. They can effectively realize UDP data sending and receiving, and through the seamless splicing between IPv6 gateway and internet. It can complete data collection and transmission, finally through the power consumption, simulation. Its results showed that in accepting, transmission and idle periods, the wireless sensor network can save energy effectively, which reduces the splicing cost of internet and wireless sensor network, and provides the technical reference for the design of wireless sensor network.

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