Starswave

Intelligent Street Lamp System

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Windows Embedded Student ChallengE

Final Report

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The amount of electric power consumed by public lighting is tremendous, which accounts for about 32% of the whole lighting system consumed. Since most of the street lamps are on from 23:00 to 7:00 next morning, this wastes a lot of energy. We realize that some kinds of recent sensors are not only of stable performance but also cheap, and that some modern existing LEDs already have the advantages of long lifetime and brilliant illumination (100--200 lm/w), so they can be comparable to or even exceed the conventional high-voltage sodium lamps as street lamps. What was described above led us to the idea of designing a system to solve all these problems. Here comes our Starswave!

Just imagine that in one pitch-dark night, there is a brilliant light wave along the lonely road and that when one brightens, another dims out. And the very center of which is you! That is what Starswave intends to bring to you. The Starswave can supply sufficient light in some definite area in front of you by the combination of sensors and EBox, while keeping the rest of lamps on the road in the least electricity-consuming state. Also through the Internet, The Starswave can determine the switching time of street lamps in the whole year according to the information on the sunrise and sunset, and the illumination in an abominable environment (such as fog or rainstorm) based on the weather information. In addition, The Starswave, making good use of the sensors, can provide the present traffic flow and the traffic jam information on adjacent roads for people who want it.

On the whole, Starswave mostly have five merits as following:

- **Saving electricity:** By controlling lamps, it is ensured that they can automatically just lighten the definite road vehicles or passersby are about to pass by and by the use of LEDs, the Starswave could save about 50% electricity for the whole public lighting system, meanwhile reducing the light pollution.
- **Saving lives:** By downloading the weather forecast through the Internet, when abominable weather occurs, such as fog and rainstorm, the lamp can automatically light to avoid the accident.
- **Saving time:** Drivers can get the information about traffic flow to determine to take an expedite way.
- **Valuable information:** The Starswave offers useful traffic information. At the same time it can facilitate the management and maintenance of lamps.
- **Anti-polluting:** Unlike the other popular lamps that emit harmful substances when they are broken, the LED would be a better choice.

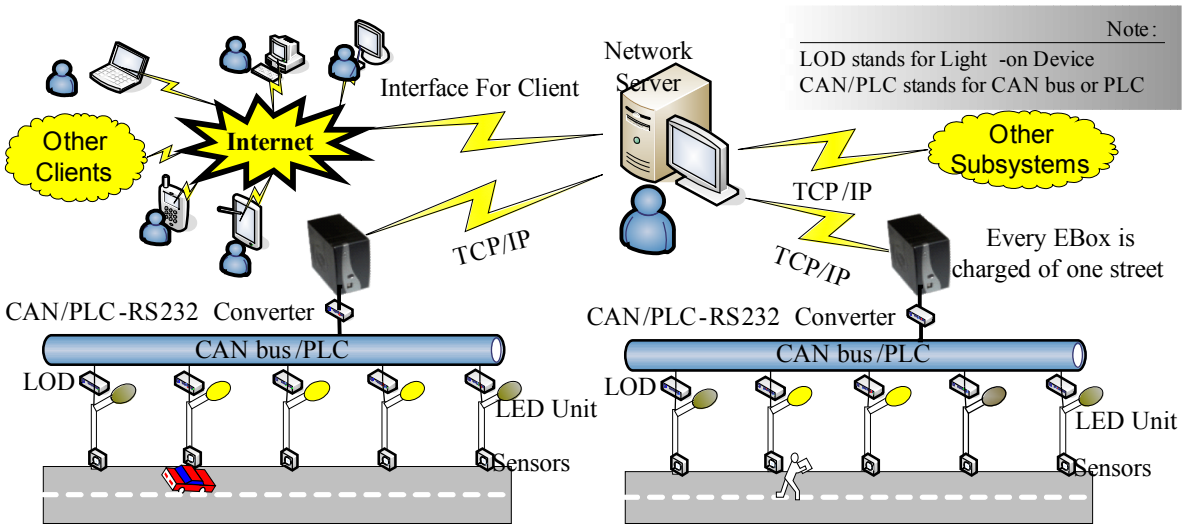


Figure 2.1 Starswave System Overview

EBox is responsible for collecting detected signals of Sensors and sending out control command real-timely. And it can report the exception of system and lamps and transmit to the Network Server the traffic information gained by the frequency of collected detected signals. Meanwhile it can receive the control commands, weather forecast from Network Server and also upload the traffic information.

CAN/PLC-RS232 Converter accomplishes the conversion between the serial port protocol and CAN (Control Area Network) or PLC (Power Line Communication) protocol, which offers a uniform interface to EBox (including software & physical).

LOD (The Light-On Device) is designed to collect signals from Sensors and output the control voltage for LED Unit. Also it can receive the command from EBox and upload the relevant information such as the node number and the status of the lamp.

Sensors have two modules. Infrared module can obtain a signal when moving vehicle blocks infrared. Pyroelectric module could judge whether there are people passing by.

LED Unit composes of a LightAdjusting module and an array of high lightness LEDs.

The Network Server transfers the weather forecast and control commands to the EBox and receives the traffic information from EBox. Also it offers an interface to the people who need the information of traffic flow or lamp state via Web Page.

Idea Innovation: Most of the existing popular street lamp systems are controlled by time or light, which can't just give each entity the appropriate light as they need. And with many redundant lamps being on at night, they seriously waste the electricity. Starswave differs greatly from those. By adjusting lightness, Starswave can make the necessary lamps being illuminated well when vehicles or people pass by and synchronously let the other unnecessary lamps being off, thus saving energy and reducing the light pollution. In addition, Starswave utilizes weather forecast to intelligently control lamps in abominable weather. It can also detect the traffic flow and raise traffic efficiency.

Algorithm Innovation: With a simple algorithm, Starswave can efficiently send out the control command in a short time to meet the requirement of real time and it almost can work well in all instances no matter how complex it is. And the most exciting thing is that the input of the algorithm are just some simple integer representing the position of the target (by node number) and it is tolerant of small mistakes, which greatly simplifies the implementation of hardware.

The Choice of LED: As a highlight of Starswave, we chose high power LED with high lightness for illuminating in the light of the low power consumption, low light attenuation, high lightness, long life-span and the low electric consumption when start-up.

Lightness Adjusting: The main advantage of a PWM circuit over a resistive power controller is the efficiency, at a 50% level. In contrast, resistive controller at 50% load power would consume about 71% of full power. Except that, adopting PWM can also offer a digital interface and facilitate the control of the MCU.

Communication (PLC/CAN): Since the applied environment of Starswave often have the character of long distance, large number of nodes and high interference. We contrive two solutions for communication: CAN and PLC. CAN bus have the advantage of high anti-interference and high speed, and also it can fulfill the requirement of real time. CAN is mostly suited to system with a high request for performance; PLC can make good use of the existing power line and save time and money. It will be a good choice for ameliorating the old lamp system. In contrast, we give up RS-485 bus in view of the distance and the lamp number. Also we don't introduce wireless communication considering of cost.

During the development of Starswave, we had consulted the people in the Street Lamp Department and they showed great interests in our system. They think that Starswave could at least save 50% consumed amount of electricity of recent public lighting and it is really low-cost. The cost of each lamp with high performance is about $180. At the same time, Starswave can help to abate the pressure of electric supply and lessen the environment pollution. So Starswave is of great value in business market.

After the scope of the problem is carefully studied, the Extreme Programming strategy is chosen as our Software Engineering method. This decision helps us design a good embedded system in a reasonable time. First, two of us will make a fixed group to practice the Pair Programming to improve the efficiency of programming. And the other person will make an investigation from the practical and potential Starwave users. Second, since the time is limited, we will make a small number of iterations dynamically to adapt the change of requirement. Third, the interface of the system will be designed first to enhance the adaptability of the program. Finally, we will use the XML as a set of implementations that allow software to run on disparate operating systems and running in different environments.

Our team is organized well and we will work closely together on all parts. We divided the work in order to activate each member's potential. Li Wenbo is mostly responsible for LED Unit & Sensors. Zhang Shaofu is in charge of the CAN& PLC. Cheng Mingming handles the EBox and algorithm and Qiu Ling is responsible for the Network Server and algorithm.

Starswave, designed for green illumination of the city, is a modularized system which has high dependability, flexibility and real-time character. The system is comprised of the following components:

3.1.1 EBox

EBox is the core module of Starswave system which is a control software running on WinCE platform. One of its tasks is to receive data through Serial port. (These data are collected by transducers installed along roads and converted into the Serial port data format which will be transmitted to EBox module through CAN-RS232 or PLC-RS232.). Also it can send the control commands for the street lamp immediately through Serial port, which will finally reach the hardware and be executed. It is also responsible for sending traffic condition information to the Network Server. Another important function is that it can receive the control information from Network Server and changes the operation parameter and operational mode dynamically.

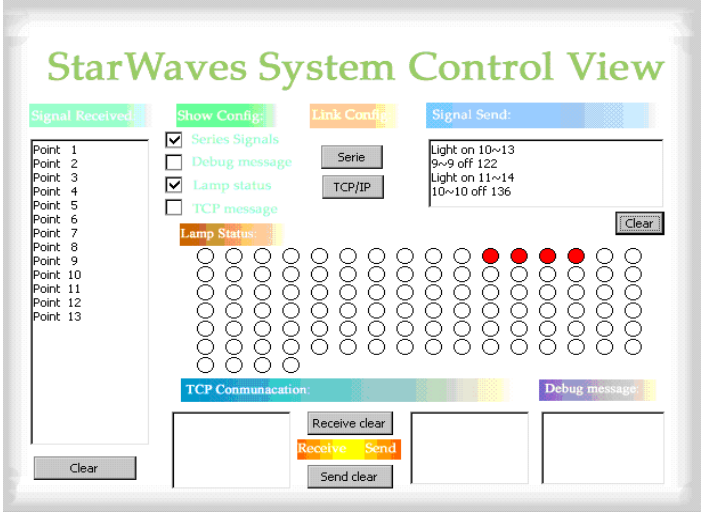


Figure 3.1 Starswave System Control View

- **General Composition**

MainControl: When data arrive, the read thread of Serial port will start OnSeriesRead method of MainControl in the form of call-back function. Then MainControl is responsible for organizing Algorithm module to accomplish the task of turning on/off the light. It is also responsible for monitoring and recording the data received, collecting the traffic information and regularly triggering the Algorithm module to finish turning off the light at the same time. In special conditions, for example while debugging, if the corresponding function is chosen, MainControl will display dynamically data stream information and operation information of system.

Algorithm: Algorithm module is a very innovative module in the whole system. It is responsible for generating range of lamps which should be on/off and analyzing unusual situation. This part will be discussed in detail in the following content.

Serial port: The Serial port module is mainly responsible for Serial port communication. For improving the efficiency of the whole system, we used two relatively thread with higher PRI to finish the function of reading and writing Serial port respectively. When data arrive, it can notify MainControl and transmit the entry address and the length of data received to MainControl. We can also conveniently submit the entry address and the length of data

writing into Serial port. Then this module will transmit writing messages and these parameters to the writing thread.

TCP: The organization and function of TCP module is very similar to that of Serial port module. It also gets two threads independent to finish the task of reading and writing .The difference is that the PRI of the two threads are relatively low since the task don't have a request for real time.

InformationRecord: The record of wrong information, the estimation of the flow of the traffic and some important systematic parameters were written into the corresponding data files and config files by InformationRecord module. It is also responsible for writing/reading, erasing the files and something like that.

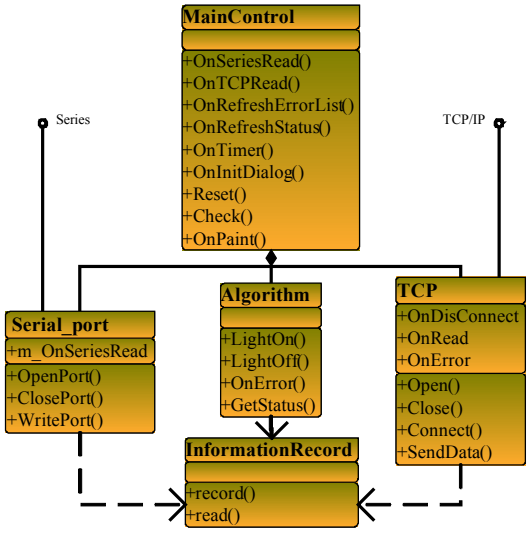


Figure 3.2 EBox Module Class View

- **Operational Mode**

The whole system can work under two modes according to the road condition. When the traffic is heavy, it works under the information gathering mode and under the control mode when vehicles and people passing-by are just a few. In addition, based on the weather forecast, when abominable weather (such as fog or rainstorm) occurs, Starswave can automatically change the operation parameter to get into the emergency state and turn on all the lamps to offer enough lighting.

Control Mode: Between midnight and 6:00 am, the whole system mainly works under the control mode. At this time, the system is mostly responsible for controlling lamps, reporting errors or exceptions and collecting traffic information.

Information Collecting Mode: Under this mode, Starswave mainly collects the traffic information and all the lamps are of the same state. And the exact state of lamps is lied on current time and config files of the system, which is determined by the detailed situation of each place and can be altered by administrators though Internet.

- **Interface Protocol**

Protocol for Serial port

Preamble code	Node NO. (High Byte)	Node NO. (Low Byte)	Status of light	Reserved	Reserved	Reserved	IsTarget

Figure 3.3 The protocol for Serial port (each rectangle stands for a byte , to EBox)

Node NO. : The number of the lamp sending this signal.
Status of light: on\off state of the current lamp.
IsTarget: It's 0XFF if there are people or vehicles passing by , otherwise it's 0X00.

Preamble code	Start NO. (High Byte)	Start NO. (Low Byte)	Number of lamps	Lightness Value (High Byte)	Lightness Value (Low Byte)	Traffic Inquiry	Reserved

Figure 3.4 The protocol for Serial port(each rectangle stands for a byte , from EBox)

Start NO. : The number of the starting node in the process of turning on the lamps.
Number of lamps: The number of the lamps that should be turned on, counting from the starting node.
Lightness Value: It is sent to DAC7611
Traffic Inquiry: It's 0xFF if there is an inquiring command, and it's 0x00 if there is a control command.

Definition of TCP Data Format

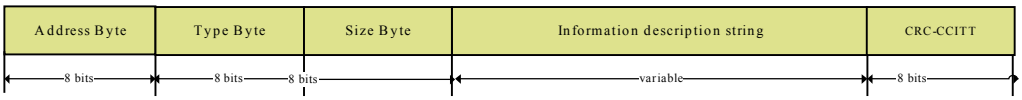


Figure 3.5 The protocol for TCP

Address Byte shows the position of the signal. Type Byte shows the type of the signal. Size Byte shows the length of the signal. Information description string represents the detailed content of the signal. CRC-CCITT is for check.

3.1.2 LOD

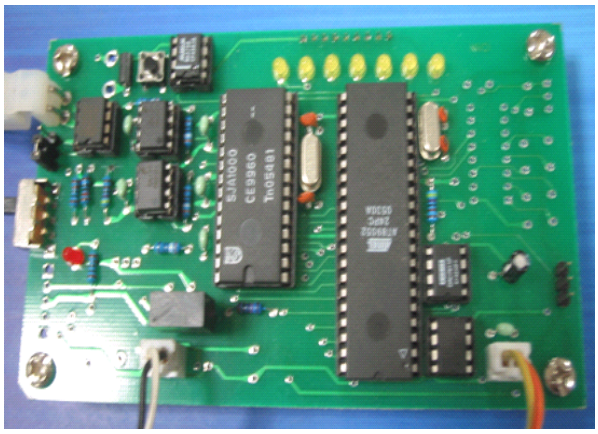


Figure 3.6 LOD adopting CAN

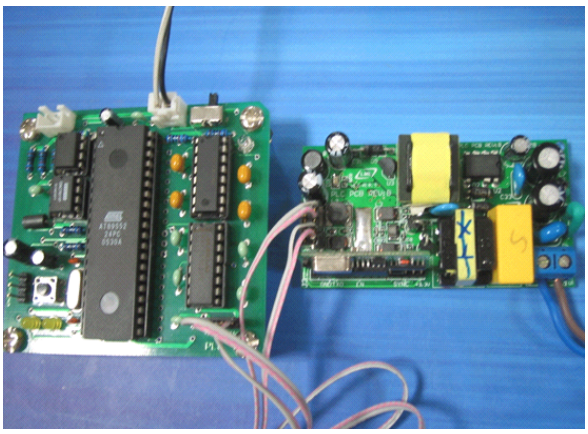


Figure 3.7 LOD adopting PLC

Each lamp uses one LOD as a node. Then we number lamps along a definite direction to use them as addresses of lamps, which are stored by EEPROM chip AT24C01A. The function of LOD is as follow:

- **Outputting Control Voltage to LED Unit**

Based on the value from EBox, LOD outputs the corresponding voltage to LED Unit to adjust the lamp lightness by a 12bit D/A chip DAC7611, which could achieve adjusting lightness up to 4096 levels.

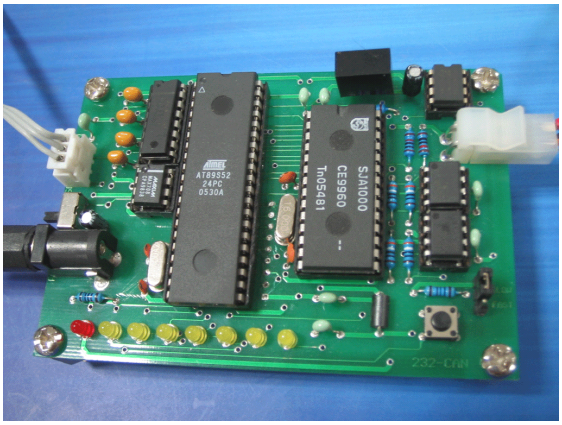
- **Detecting Signals from Sensors by Interrupt**

For obtaining reliability of detecting people and vehicles, we adopt multi-route sensors. With a 74HC11 chip, we implement the logic synthesis of all sensors detecting signals and ensure that an MCU interrupt in LOD must be triggered when any sensor detected passersby or vehicles. Once an interrupt of MCU is triggered, the lightness of the lamps will be illuminated for a certain time no matter whether the EBox sends a control command or not. In this case, we will avoid that some Lamps don't illuminate when people or vehicle comes by, because it hasn't received a command from EBox.

- **Uploading Signals and Receiving Command**

When an MCU interrupt is triggered, the information including the node number, the status of lamps and the information about vehicles and people will be transmitted to EBox via CAN or PLC. And when EBox sends out control commands, the MCU will determine whether it should adjust the lightness of some lamp or not according to the control information got from starting node number and the number of lamps that should be adjusted. When EBox want to ask for the information about the traffic flow and the lamp state, it sends out relevant data information.

3.1.3 CAN/PLC-RS232 Converter



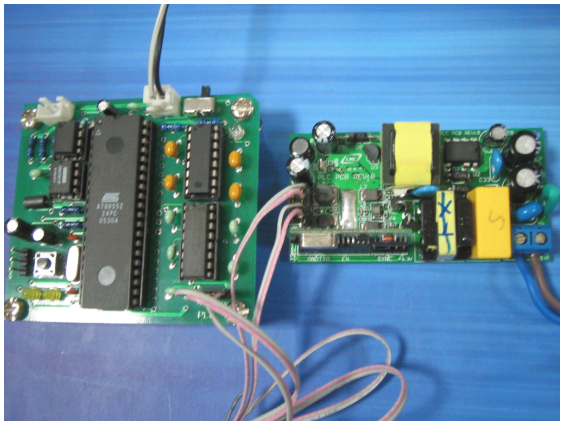


Figure 3.8 CAN-RS232 Converter Board **Figure 3.9** PLC-RS232 Converter Board

This module implements the conversion between CAN or PLC protocol and Serial port protocol, shielding the communication layer. Because we have two schemes for communication, there are two kinds of converter board.

- **CAN-RS232 Converter Board** uses AT89S52 as the main control chip and the CAN node is composed of SJA1000 and P82C250. And the application of PhotoCoupler 6N137 and 1000V islotaed DC/DC between SJA1000 and P82C250 greatly improves the reliability and the anti-interference of Starswave. Meanwhile direct connection to the Serial port on EBox could be achieved by using MAX232 which accomplish the conversion between TTL level and RS-232 level.

  Based on the CAN bus protocol, we defined our own CAN bus transmission protocol, using MCU to accomplish the conversion between the CAN protocol and the serial port protocol.

- **PLC-RS232 Converter Board** uses uPLM2200 manufactured by Leaguer MicroElectronics as the communication node and AT89S52 as the control chip. Similar to CAN-RS232 converter board, it achieves the conversion between PLC communication protocol and our RS-232 protocol, which makes it use the same protocol as CAN-RS232 Converter Board. However, uPLM2200 adopts LME2200C appropriative PLC chip which accomplishs reliable transmission by employing Multi-Carrier Fast Frequency Hopping Modulation-Demodulation to efficiently deal with time-varying interference and time-varying frequency response in low-voltage power line. In addition, the advanced technology of DSP and the inner forward error correcting code & decode further meliorate the bit error rate of data transfer. Compared with common chips, the

communication speed is improved greatly, which can be up to 2400bit/s. And for the communication data in our system is small, this baud rate could totally meet our requests.

3.1.4 Sensors

- **Detecting Vehicles by Infrared Module**

Infrared detecting has the advantage of the low-cost, the high sensibility and the small cubage. Also it can achieve the high anti-interference by using modulation signal, which makes it a good choice as a detector to detecting vehicles. In addition, by using the PLL (phase-locked loop) to lock the frequency of transmitting signal enhances the detecting sensitivity and eliminate the interference of sunshine.

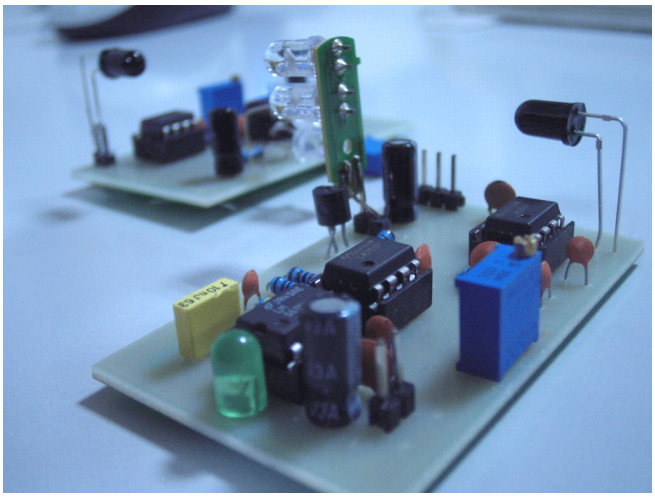


Figure 3.10 Infrared Module

Every node uses two infrared detectors with the same structure. And Automatic gain control (AGC) can adjust the gain to ensure the high sensitivity of sensors according to signal intensity.

Figure 3.11 Pyroelectric Module

- **Detecting People by Pyroelectric Module**

We use a special kind of body radiation detecting sensor, namely, the pyroelectric sensor.

Because this kind of sensor aims at body radiation, the pyroelectric components must be sensitive to the infrared radiation with the wavelength of about 10 micron.

In order to be only sensitive to body infrared radiation, its surface is covered with a special kind of Fresnel lens to efficiently control the environment interference.

Whenever people enter the detecting areas, the body infrared radiation focuses and is received by pyroelectric components. Then it triggers a signal.

- **Anti-interference**

Against Small Animals: When detectors are installed at proper altitude, small animals within detecting areas will not trigger signals.

Against Electromagnetism: The electromagnetic interference of common mobile telephone will not trigger signals.

Against Lighting: Detectors will not trigger signals during the range of ordinary sensibility when they are exposed to lighting out of 3 meter.

3.1.5 LED Unit

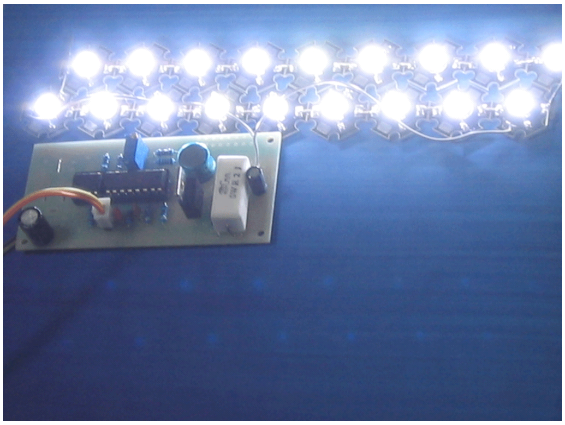


Figure 3.12 LED Unit (Brighter)

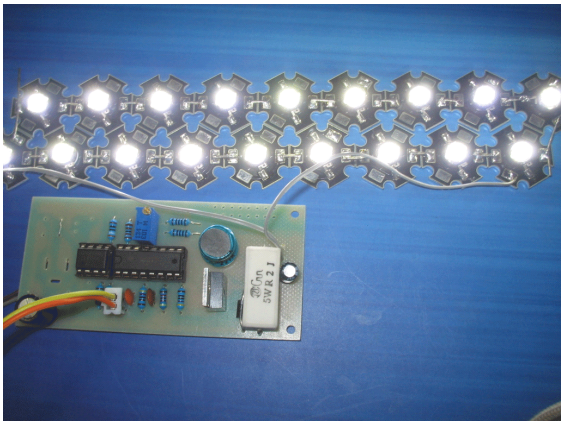


Figure 3.13 LED Unit (Dimmer)

- **High Light LED**

Each lamp consists of eighteen high light LEDs of 1W with great diffusivity, which is just for demonstration and is limited by our budget. In real life, according to the practical situation, we can use 3W or 5W LED and the number of the LED also can be changed.

- **LightAdjusting Module (PWM Module)**

We realize numerical control and constant current in the development of LightAdjusting Module by introducing PWM (Pulse Width Modulation). And the lightness of LED is proportional to the electric current.

■ **Constant Current**

By detecting the voltage across the small sampling resistance connected to LED in series and controlling the output voltage, the constant current could be achieved.

■ **Specifications**

PWM Frequency: 400 Hz
Max Current Rating: 3 A with an IRF521 FET
PWM circuit current: 1.5 mA when LED is off
The duty cycle can be tweaked, under closed-loop control, until the desired pressure is precisely achieved.

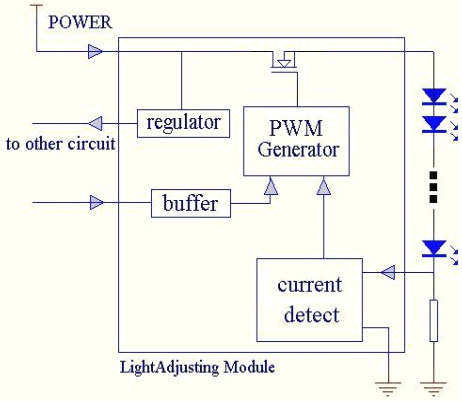


Figure 3.14 LightAdjusting Module

The compare of duty cycle in different lightness:

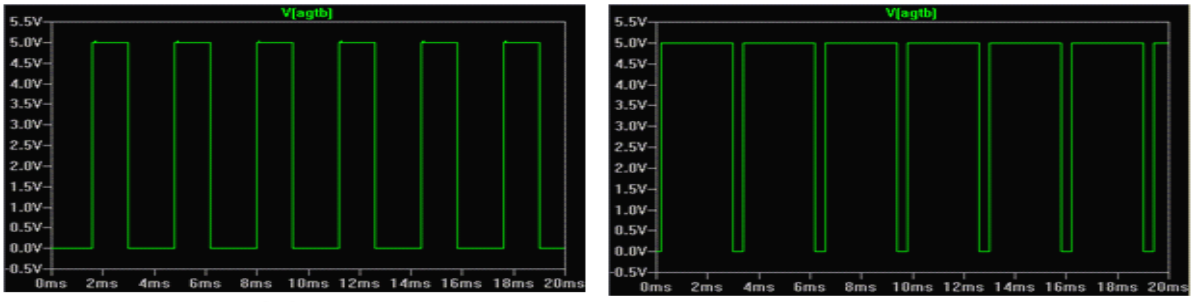


Figure 3.15 Relation of duty and lightness

The main Disadvantages of PWM circuits are the added complexity and the possibility of generating radio frequency interference (RFI), however, by employing some special kind of circuit, the interference can be reduced. Meanwhile PWM is economical and space saving.

3.1.6 Network Server

Starswave has a website that allows the common user to interact with the system for traffic information. The website allows the administrators to alter the system parameter and monitor the status of the system. The website is a collection of ASP pages coded in JScript and HTML. All the data consumed and produced by the ASP pages is stored in XML format.

Figure 3.16 Web site

We have a SQL Server database to support the website to implement functions mentioned above. And an application is designed to detect database and interact with EBox with TCP/IP.

- **Common Client**

Common client can check the traffic information by Web Page to take an expedite way to go.

- **Administrators**

1. Altering the System Parameter and the Operation Mode
2. Error Reporting and Maintenance

Through Internet, Administrators can get system information to facilitate system management and maintenance, which raises the efficiency of the system and saves resources.

- **Overall Goal**

The basic goal of the LampOn algorithm is to judge accurately which lamps should be turned on according to some position information (got through the node number) combined with the current time. The process of turning on the lamps must be efficient enough for the requirement that the lamps are employed to offer services to people and vehicles in motion. This algorithm will be in use in Control Mode. Its anticipated working environment is after midnight when the traffic is sparse. Therefore it is quite reasonable and effective to turn on several more lamps in some complicated situations. But it does not mean we can roughly judge which lights should be lighted at some certain moment. However which lights should be turn on? Our anticipated result is to turns on certain numbers of lamps ahead according to the velocity of the vehicles or passing-by. The number of the lamps to be lighted is

proportional to the speed of the vehicle at the same time it must be within a predefined range.

- **A Direct Way and Its Defect**

A direct way is: First detect the movement direction of the target, then its velocity. Decide the range of the number of lamps to be lighted according to the two parameters. However this solution has fatal defeat: when there are multiple targets that enter one certain region, it is too difficult to detect the direction and speed of the targets. And it will lead to the increase of the hardware cost. Also, there may be runtime error in some boundary situation.

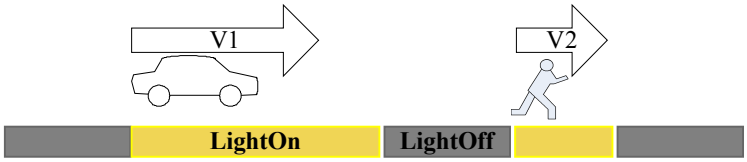


Figure 3.17 A direct way of judge which light to be turn on

- **Our Solution**

By a simple formula, we could determine the number of the lamps that should be illuminated in the direction the vehicles or people move. Linear functions ensure that the lighting scope in front of the vehicle is proportional to its speed. In formula L=A+B/|t[i] - t[i-1]|, t[i] represents the time when the ith sensor lastly gets data. And the parameter A and B can be exchanged to adapt different road requests. Also, by adding a restriction that the lighting scope has to be always of some proper interval with an up limit and a lower limit, we amend this formula to make it more reasonable.

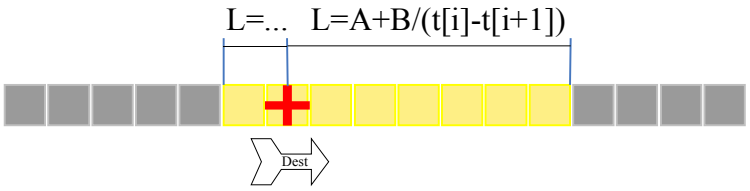


Figure 3.18 The way how we judge which light to be turn on.
(t[i] means the time when the ith sensor has signal)

- **Performance in Most Common Situations**

In most situations, the time difference of the current detecting point (DP) i and the previous DP i-1 is far less than that of the current DP i and the next DP i+1. So we can decide the length of the right lighted lamps with i and i-1, and the left with i+1 and i. In this way, we can achieve such an effect that there are a lighted region ahead whose length is proportional to the target speed and a black region behind with all lamps off.

- **Performance in Multiple Vehicles and Multiple Directions Situation**

In this occasional case, the detected time difference of two nodes will be shorter than it actually is due to the interference of other vehicles. In other words, there will be a few more lighted lamps than anticipated. Because the probability of this situation is small and there is a reasonable up limit to the illuminated lamp number, it would not result in much energy waste. And it is quite reasonable to light a few more lamps in some extreme situations.

- **In Situations with A Few Sensor Failure**

If one sensor goes wrong, at the time when the next signal of it should have arrived, the system will automatically recognize this disabled device and make an estimation of next arrival time of the signal from this device by employing liner matching method. Then the speed can be gained correctly. On the whole, there will be only one or two lamps less than anticipated. So it would not affect the whole effect much.

- **Requirements on Hardware**

The algorithms only need an integer which represents signal position, so what the hardware needs to do is only to collect some switch-status values. So the requirement on hardware is quite low, which means a very low cost of the system. And it becomes an inborn advantage for massive application and production.

- **Time & Space Complexity**

The time complexity and space complexity of the LampOn algorithm are both O (1). Its calculation and storage requirement do not increase with the scope of the problem (the number of sensors). And these processes have a high priority. All of this permits a high real time.

- **Boundary Situation Process**

When the target enters the road at the beginning, the sensors could not work due to the short of some necessary foregoing time records. We handle this problem by turning on the maximum number of lamps which is predefined. This method seems to have satisfied our requirement.

3.2.2 LampOff

- **Overall Goal**

Every lamp that should be turned off must be judged in high accuracy, and it allows a certain delay in time. That is to say, we cannot turn off the lamps which should be on for the moving target. However, it does not matter to allow a lamp on a litter longer after the target passed it.

- **Algorithms Statement**

Basic Algorithm: Due to the high accuracy requirement of this system, we set a counter for each lamp. During every successful process of illuminating lamps, the system makes the counter of this lamp the maximal value. Meanwhile every 1 unit time, the system subtracts 1 from the counter of each lamp if only it is bigger than zero. As long as we properly set the maximal value to make sure that before the next lighting process, the counter of the lamp that should be illuminated next time is bigger than zero, we could guarantee the high accuracy of our system.

Scan Acceleration: The method above has the problem of delay. We specially accelerate it by scanning. The details are as follows: Scan all the lamps in every time unit. We should turn off the lamp if a lamp is under the condition that the lamp on one side of it has been turned off and the last illuminating time of the one on the other side is later than that of the current considered lamp.

- **Correctness Analysis**

Correctness of the Basic Algorithm： If the counter of one lamp is below zero, it means the lamp is not in the lighted region in recent period of time. Otherwise, the value will become maximal when a target appears. Devising a proper maximum counting value will ensure the passage of the target before the lamp is turned off.

Correctness of the Scanning Algorithms: Because the time between two scanning is very short (we assume it 0.1s). And, basically every lamps that need not to be on will be turned off in time during the scanning, the lamps behind the target will be turned off in less than 0.1 s (lamps of both of the ends may be slower).

- **Efficiency Analysis**

Due to the short time interval of system scanning and the ability of the system to turn off the

light in time during every time interval, the lamps behind the target could be turned off in 0.1s (lamps in the end of the road may take a little bit longer time to turn off).

- **Analysis of Time & Space Complexity**

If the number of lamps of a road is n, the time & space complexity of the algorithms is O (n). For a road whose has a maximum of 400 or 500 lamps, the performance of EBox is quite enough.

3.2.3 Traffic Analysis

- **Requirement**

The traffic analysis needs to give a qualitative estimation of the traffic flow. We need not know the specific number of the vehicles at a certain moment, but an overall evaluation of the traffic flow. This process doesn't demand a high accuracy, nor does it demand a correct outcome at any moment. A correct evaluation at most situations will be OK.

- **Method and Expected Effect:**

We account the number of the consecutive sensors which frequently detect target signals and combine it with a table established according to the practical experience to estimate the traffic flow.

3.2.4 Hardware Fault Detecting

Under normal condition, the signal from a sensor can not be later than those from sensors on both of its two sides. Based on that, we can detect a hardware fault by judging the signals from adjacent sensors on both sides. If there is an abnormal situation, the system would make an estimation of the arrival time of corresponding signals by linear matching method. We record the fault information and regularly send it to the Network Server for some people to refer to.

3.2.5 Error Tolerance

- **Error Tolerance of Receiving Detecting Signals:** As we mentioned in the LightOn algorithm, once the hardware failure of sensors occurred, with our algorithm the accurate result can still be obtained, which is also true when the data loss happened during the signal transmitting.
- **Error Tolerance of Transmitting Control Signals:** For the problem of data loss in transmitting control signals, we introduce Timing Retransferring mechanism. During each fixed time, the algorithm module would retransfer Light Off command to lamps that should be turned off. Because the data transferred is too small, the system performance will not be influenced.

3.3 Testing Plan & Result

Our testing principle: first module testing, then system testing.

3.3.1 Small-Scale Entity Testing

During the development of Starswave, we make many small-scale testing for each completed hardware part. After all of them are implemented, by using Serial port debugging helper to simulate the control command from EBox we accomplish united debugging of communication link, LED Unit and Sensors. In the way, we fasten the system development and reduce the debugging time.

3.3.2 System Simulative Testing

Restricted by budget, we don't practically perform the large-scale testing to demonstrate the real effects. However, with a simulative program, we can demonstrate integrated effects by sending out signals which is of the same format as real signals and receiving control signals via serial port. And the whole process is transparent to the application in the EBox.

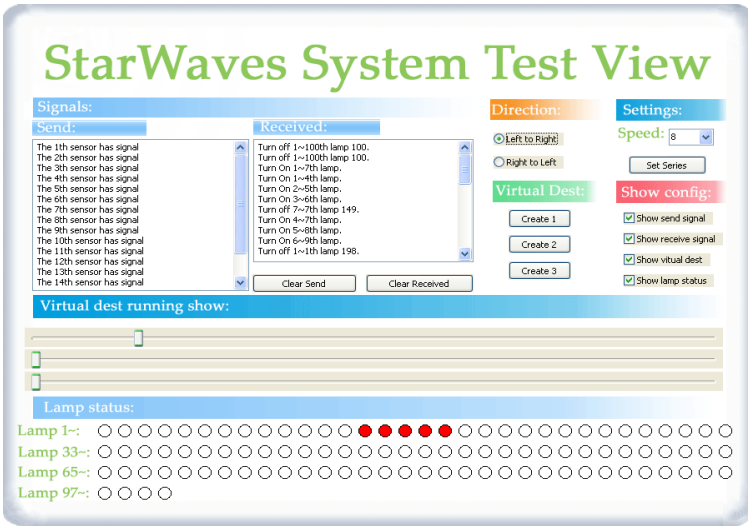


Figure 3.19 Test result of a simple case

According to the beginning direction and the prearranged speed parameter, the system determines the time when the entity gets to some certain lamp and send out a signal for the lamp on time. And this signal, which will be transmitted to EBox via Serial port, could be received by the simulative program and be processed. Then with the returning control signals, the result chart could be drawn. We execute this process under the circumstances of single vehicle, multiple vehicles whit same direction and multiple vehicles with opposite direction. And the result is shown in the following figure.

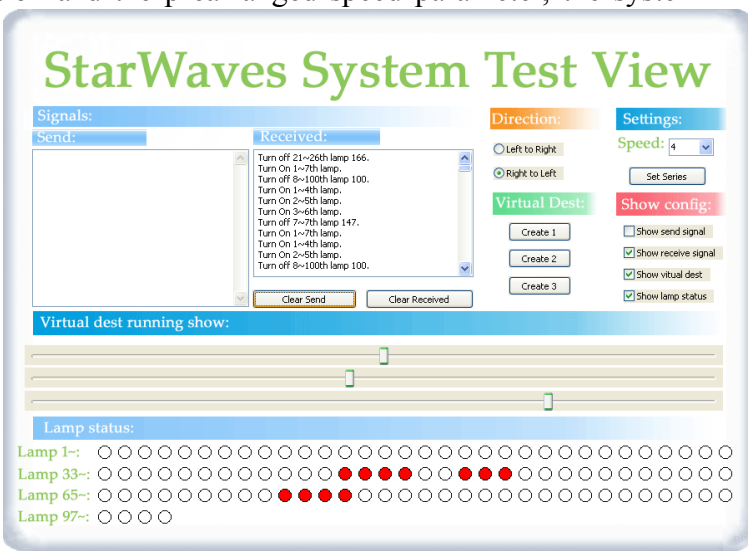


Figure 3.20 Test result of a complex case

Under the simple circumstance of single vehicle, the result is just as we expected. The higher the speed, the more lamps in front of the vehicle are turned on. And the result just accords with the prearranged expectation. In addition, the lamps behind the vehicle can turn off immediately.

We also made many comprehensive testing under the circumstance of multiple vehicles. And the results showed that the system could also work well. However there is still one small problem, which is that after two vehicle meet, the lamps behind both of them could not turn off in time. Since the probability of such situation is really small and a little delay is

acceptable, we are satisfied with these results.

3.4 Development Tools

Visio studio.net 2005: The control module on EBox and the data-receiving module from Network Server are completed by dotnet. And the reason we choose it is its good transplantation and especially dotnet 2005 basically accomplishes convenient development and debug in embedded platform the same as in the other general platform, which greatly fasten our development.
OneNote 2003: One Note is used by us to communication with each other, notify good idea and gather Web research!
DXP: The hardware design of LOD, CAN/PLC-RS232 Converter and LightAdjusting Module used Protel DXP, an EDA tool for developing circuit schematics and printed circuit board.
uVision 3: A MCU IDE produced by Keil Software. We complete the entire MCU program in C language including designing, debugging and emulating with it.
Microsoft Office Visio 2003: We use it to build UML module for its convenient operation.
SQL Server 2003;
Macromedia Dreamweaver MX 2004;

3.5 Cost

Cost of Starswave System				
	Device name	Price	Num	Total cost
Device for each lamp	Lightness Adjustor Module	$4	1	$148.85/$159.75
	Infrared Module	$2.5	2	
	Pyroelectric Module	$3.0	1	
	1W LED	$7.0	18	
	LOD(CAN/ PLC)	$11.85/$21.75	1	
Device for each rood	CAN /PLC -RS232	$8.1/$18.5	1	$8.1/$18.5

Table 3.1 Cost of Starswave System

The cost of Starswave in real application mainly rests with the high power LED, which will be greatly reduced as the technology advances. So Starswave has a brilliant prospect. By adopting CAN, each lamp needs a LOD (CAN) module and each street needs a CAN-RS23 Converter board. It is similar to the situation by adopting PLC.

We have been strictly following our plan. Up to now, we have completed the system development and accomplished all the system functions by and large as mentioned in Interim Report. In addition, we put forward a new exciting solution that we introduce PLC for communication. At present, after the module testing and the system linking and debugging, Starswave can efficiently work without people involved.

1、The time interval from EBox sending command to high-power LEDs lighting is less than 0.2s, which can totally satisfy the system requirements!

2、The time from sensors detecting signal to triggering an interrupt and illuminating the lamp is less than 400us. Meanwhile the signal takes less than 0.1s to be transmitted to EBox. In general, that is to say, the total time from discovering a target to lighting the lamp is less than 0.5s (via EBox).

3、Starswave implements transferring weather forecast from the Network Server and sending out corresponding command to control the switch time of lamps.

4、The client can log into our Network Server to check out the traffic information. Also the administrators can configure operation parameters of whole system via Web Page.

4.2 Future Work

1、Limited by transceiver, an CAN bus can support 110 nodes at most. So we are working on the development of CAN relay station.

2、EBox can download the traffic flow information from Network Server and display it through dot matrix LED. Then drivers can get valuable traffic information of the adjacent roads to pick up an expedite way, which will efficiently abate traffic congestion. The display module is now in the process of debugging.

3、Still there is an advisable solution that combines the merits of both CAN and PLC, namely LonWork. It has the advantage of high speed, high reliability and long-distance communication. Besides the transceiver which employs PLT-22 can make good use of current existing power line. If that could come true, it will be perfect!

- **Book:**

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2. Thomas H.Cormen, Charles E.Leiserson, Ronald L.Rivest and Clifford Stein. Introduction to algorithms. The MIT Press.
3. Ian Sommeriville. Software Engineering 6th Edition. Published by arrangement with Pearson Education.
4. Bing Wang, Cunbin Li, Peng Chen. EVC Advanced Programming and Application Development（Embedded Visual C++ Embedded Programming）
5. Sinan Si Alhir. Guide to Applying the UML. Springer Press Ltd.
6. Craig Larman. Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design, Prentice Hall Press, 1997.
7. Zhongmei Ma, Shunxin Ji, Kai Zhang andYan Ma. Microcontroller C language program. Peking University of Aeronautics and Astronautics Press
8. Wenlong Yang. Microcontroller Principle & Applications. Xidian University Press.
9. Zhengjun Li. Fieldbus Application Technology. China Machine Press.
10. Tiger Studio. Protel DXP Advanced Application. Posts &Telecom Press.
11. Yulin Zhou,Yang Ning,Guiqiang Lu.Windows CE.net kernel Customization and Application. Publishing House of Electronics Industry.
12. uVision2 User's Guide. Keil Software.
13. uPLM2200 User's Guide. Leaguer MicroElectronics

- **Datasheet:**

1. LME2200C Datasheet Leaguer MicroElectronics.
2. SJA1000 Datasheet Philips Semiconductors
3. P82C250 Datasheet Philips Semiconductors
4. 6N137 Datasheet Texas Instruments Incorporated
5. MAX232 Datasheet Maxim Integrated Products
6. MAX3232 Datasheet Maxim Integrated Products
7. DAC7611 Datasheet Burn-Brown Corporation
8. AT24C01A Datasheet Atmel Corporation
9. AT89S52 Datasheet Atmel Corporation
10. TL494 Datasheet. Texas Instruments Incorporated
11. LM567 Datasheet. National Semiconductor Corporation

- **Web site:**

1. http://msdn.microsoft.com
2. http://www.zlgmcu.com/philips/philips-can.asp A Web site about CAN bus.
3. http://www.yesky.com/SoftChannel/72340168526266368/20040908/1851586.shtml
This is a blog of a person who is expert in Win CE development. It's a Chinese web site.