

Implementation of ZigBee-VLC system to support light control network configuration

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Abstract—In this paper, ZigBee-VLC Transmitter and Receiver are designed, implemented and tested. By utilizing the ZigBee-VLC Transmitter and Receiver, commissioning procedures for light control network configuration are simplified and commissioning time is drastically reduced. With this configuration, lighting control network configured to use a maximum of 2^{16} lighting is possible. As a result of this research, the transmitter is complete with ZigBee-VLC features implemented in the Single MCU without rising production costs and the 1-board solution receiver including a ZigBee and VLC functions are implemented. In addition, as a result of the test work using the light control app, dramatically shortening commissioning time, easy lighting control is possible was confirmed.

Keywords—ZigBee-VLC, ZigBee Commissioning, LED, MCU, Light Control

I. INTRODUCTION

Depending on the ratio grows to replace the traditional lighting with LED lighting, the VLC technology that take advantage of the LED light on the wireless communication, have been continuously studied[1-2].

VLC is one of the communication methods using LED. By utilizing semiconductor characteristics of the LED transferring the information stream that want to send in the form of On/Off the LED light source. This type of modulation is called Intensity Modulation. Photodetector using the light-receiving element receives signal, this method is called direct detection. If VLC communication speed is equal to or less than 200 Hz, Flashes of light are perceived as the human eye, Flicker is that the eye of the person in the blink of the light source is generated. Thus, flicker-free condition must be satisfied in order to VLC[3].

The VLC signal transmission and dimming support that the basic features required for LED lighting should be possible at the same time. ETRI holds the VPPM standard patent. With the VPPM technology it can simultaneously support communication and Light dimming control[4].

In recent years, depending on the use of smart devices grows, Interest in the location-based services of BLE and VLC technology base are increasing. In the case of VLC technology base location-based services It provides a small positioning error as compared to the RF-based location-based services such as BLE. For this reason, VLC is applicable to a variety of applications that require precise location service.

In addition, wireless lighting control market is expanding gradually. The Wireless lighting controls does not require building a separate facility for lighting control. ZigBee technology is fulfilling the great axis technology for wireless lighting controls.

In spite of the many advantages, during the initial installation, there is two drawbacks that Long time spent on commissioning for ZigBee lighting control network configuration and low light recognition. In this study to overcome the above drawbacks and as an additional location-based service provider was studied using a VLC technique.

II. ZIGBEE LIGHT CONTROL NETWORKS

ZigBee wireless lighting control lights each have a unique ZigBee MAC ID. For configuration of ZigBee Light control network, it must go through the commissioning procedures for collecting the unique ZigBee MAC ID during the initial light installation.

A. ZigBee Only Commissioning Procedure

The conventional commissioning procedures for using only ZigBee network is as follows:

- The coordinator starts the commissioning process.
- The coordinator broadcasts a message request to join a wireless lighting control network to the lights in the zone.
- In this case, each light can avoid collision by rotating the regular back-off algorithm, and Network Join Messages is sent to the coordinator.
- The coordinator will be allowed to join the network of the End Device has the highest RSSI value during the network Join messages arrives within a certain period of time.

Until all of the area lights join the network, performs the above steps repeatedly.

However, the radio transmission characteristics, light is far away from the coordinator, the current algorithm for selecting the light received with the highest RSSI is hard to be selected. For this reason, the coordinator is to repeatedly broadcast the network join request message, a time required for commissioning is exponentially.

The commissioning procedures that use only ZigBee is shown in Figure 1.

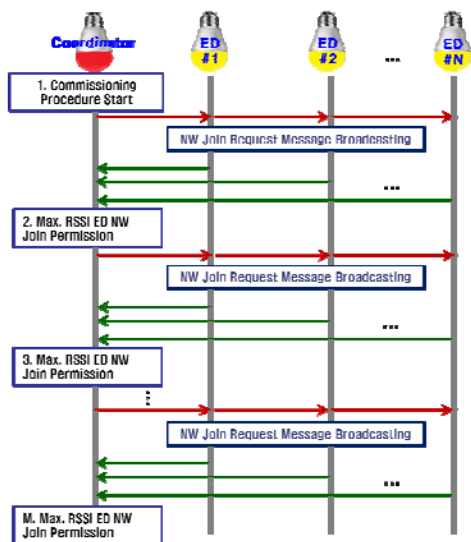


Figure 1. Commissioning procedures that use Only ZigBee for ZigBee Light Control Network Configuration

B. ZigBee-VLC Commissioning Procedure

VLC technology application areas for expansion and significantly reduce commissioning time, ZigBee wireless commissioning the lighting control for the network configuration has been studied how to apply VLC techniques.

The proposed commissioning procedure that using ZigBee and VLC technology is as follows:

- The coordinator starts the commissioning process.
- It receives the MAC ID that is sent to the VLC ZigBee-signal lights, and then completes the commissioning process of the light.

Repeat as much as the number of light, the commissioning procedure is completed. Simple and intuitive configuration is possible and the ZigBee lighting control network. For this reason, the installation and maintenance costs of wireless lighting will be considerably reduced.

Summarizing the commissioning time is conceptually shown in Figure 3.

The detailed design of ZigBee-VLC commissioning procedure is shown in Figure 4.

It demodulates the data received from the VLC signals, Check the lighting environment commissioning has been completed. If the light is commissioning its incomplete state, check that the ED with the ZigBee MAC ID in the End Device DB owned a coordinator there. If the ZigBee MAC ID is not present in the End Device DB, the coordinator Register the received information and the allocation information in the DB at the same time, and then transmits the Command for commissioning completion to the End Device via the ZigBee link. If the ZigBee MAC ID is present in the ED DB, it corresponds to the case before a command is not performed normally. The coordinator re-transmits the Command for commissioning completion to the End Device via the ZigBee link.

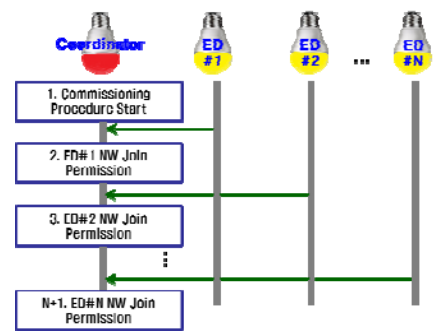


Figure 2. Commissioning procedures that use ZigBee with VLC for ZigBee Light Control Network Configuration

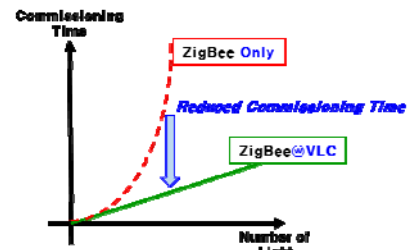


Figure 3. Compare Time of the Commission Methods

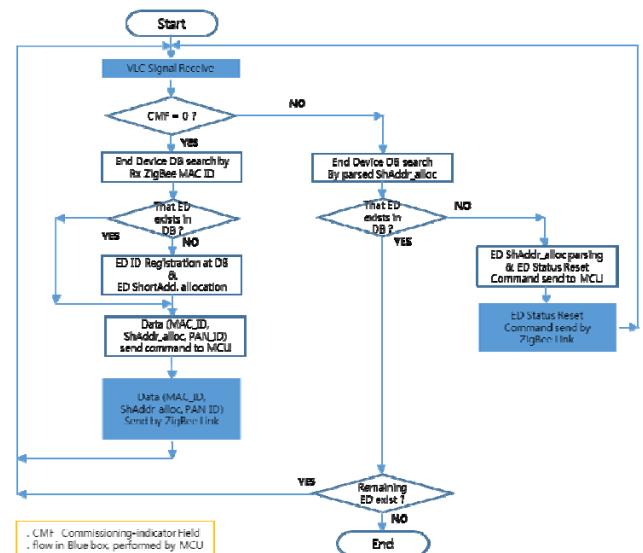


Figure 4. Detailed design of ZigBee-VLC commissioning procedures

III. ZIGBEE-VLC FRAME FORMAT

The frame format used in the ZigBee wireless lighting control network configuration using a VLC technique frame format divided into ZigBee / VLC data frame format. ZigBee frame is to be transferred to the lights from the coordinator, it is classified as a light control frame and sending the frame to the VLC data transmission of the 64-byte variable length.

The VLC frame to the coordinator is transmitted to the visible light in a light. The same frame format is separated with a data that includes, it is classified two groups. One group transmits the ZigBee MAC ID. And the other group transmits the 64 bytes length variable data. The ZigBee frame consists of a header and variable-length data payload. The

payload length is determined by the specified field value of a header.

A. ZigBee data Frame Format for Light Control

The data frame format for ZigBee wireless link is shown in Figure 5.

According to the value of the ZigBee frame header fields, it varies the nature of the ZigBee frame. It is classified into three types:

- Commissioning-related commands
- Lighting dimming control command
- The frame containing the variable data and variable data change instruction to change at the same time

B. ZigBee data Frame Format for variable VLC data upload

When the ZigBee frame header field has a specific value, it means that the Variable data change request command and variable data to change the transmission of the VLC data are passed through the ZigBee link.

The maximum length of VLC data in variable-implemented system is 64 bytes.



Figure 5. ZigBee data frame format

C. VLC data Frame Format for Commissioning Service

The data frame format for VLC link is shown in Figure 6.

On initial installation, VLC data frame format is in the form suitable for use in commissioning service.

According to the value of the VLC frame header fields, it varies the nature of the VLC frame. It is classified into three types:

- Commissioning completion status of the ED and Assigned short address communication
- VLC transmission data changed by receiving the VLC light control value
- VLC transmission data is changed to the variable data received via the ZigBee link

When a command requesting a transition to the commissioning status received over the ZigBee link, the payload of the VLC frame is filled with 2-byte length short address and dummy data.

After completion of commissioning, only the VLC frame for transmitting short address assigned can be utilized such as location-based services.

D. VLC data Frame format for variable data services

After completion of commissioning, various application services something like URL message, short message, etc. can be provided.

VLC frame format for variable data services is shown in Figure 6.



Figure 6. VLC data frame format

IV. IMPLEMENTATION OF ZIGBEE-VLC SYSTEM

A. ZigBee-VLC Transmitter

The behavioural design of ZigBee-VLC Transmitter is shown in Figure 7. The ZigBee-VLC Transmitter is implemented in the TI CC2530 MCU with an 8051 CPU core. By using the I/O interface of the MCU to provide the LED light source, VLC FEM module is included separately. ZigBee-VLC Transmitter is supplied with power from the SMPS board modules are included for supplying power to the LED light source.

In order to implement ZigBee-VLC Transmitter within a single MCU, the MCU resources distribution optimization was performed. Compared to traditional implementations that use the full resources of the MCU to a VLC Transmitter, it processes the ZigBee communication interrupt is important. In addition, by reducing the maximum ZigBee interrupt processing time, and focused on maximizing the VLC communicable time. Figure 8 shows a design concept for MCU resource optimization.

When a frame is received with the ZigBee data format described in Section III, The ED is parsed the header fields of the data frame. If the received frame is a frame lighting control, modify the dimming value of the light and restart the VLC sent. There are restrictions in use of MCU resources, the light dimming control resolution is limited to 5%.

If the received frame is a variable VLC data, the exchange of data values themselves that are passed through the VLC and, VLC frame is newly generated, and restarts the VLC transmission.

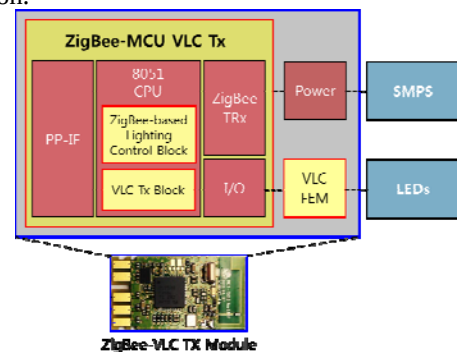


Figure 7. ZigBee-VLC Transmitter Behavioral Design

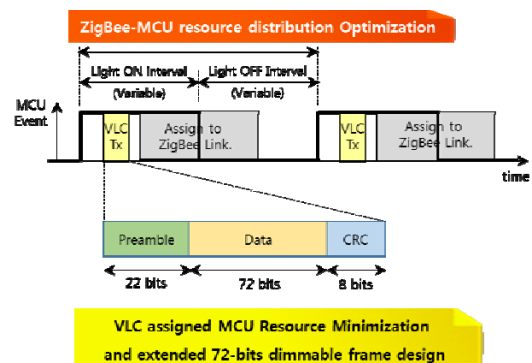


Figure 8. ZigBee-VLC data generation algorithm design for the MCU resource distribution optimization

B. ZigBee-VLC Receiver

VLC receiver is implemented in the form of one board solution. The board includes one MCU and one FPGA. More particularly, ZigBee communication part Smart Device Interface part is implemented in the TI CC2531 MCU with an 8051 CPU core. The VLC FEM Interface module and VLC receiver module is implemented in Xilinx FPGA. In addition the smart device apps for Operation Commissioning the prototype testing and demonstrations were made. The behavioural design of the receiver is shown in figure 9.

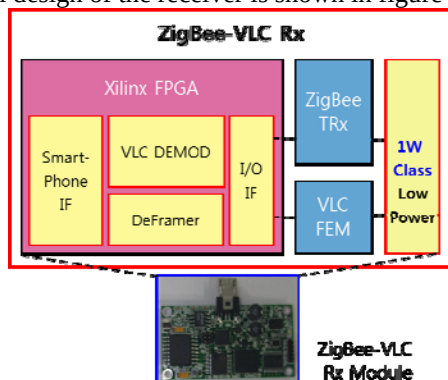


Figure 9. Behavioral design of ZigBee-VLC Receiver

V. CONCLUSIONS

In this paper, ZigBee-VLC Transmitter and Receiver are designed, implemented and tested. By utilizing the ZigBee-VLC Transmitter and Receiver, commissioning procedures for light control network configuration are simplified and commissioning time is drastically reduced. With this configuration, lighting control network configured to use a maximum of 2^{16} lighting is possible.

As a result of this research, the transmitter is complete with ZigBee-VLC features implemented in the Single MCU without rising production costs and the 1-board solution receiver including a ZigBee and VLC functions are implemented. In addition, as a result of the test work using the light control app, dramatically shortening commissioning time, easy lighting control is possible was confirmed.

In addition, using the VLC variable data service capabilities developed in this study is predicted to be applicable to in more areas, It hopes to contribute to the activation of the domestic LED lighting market.

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Tae-Gyu Kang, Ph.D. has been LED Communication Research Section Director at ETRI for 23 years (or since 1989) with responsibility CCS No. 7 Intelligent Network, responsibility Voice over Internet Protocol, system lighting and responsibility LED Fusion technology Visible Light Communications. Visible Light Communication is a technology that LED illumination switches on and off repeatedly according to wireless communication media and its modulation schemes. System Lighting is a lighting that has system capabilities with wireless connection ZigBee, wired connection DALI, multi-sensor, active cooling, and processing/driving. He has been contributed international and domestic standard specification of Visible Light Communication as chairman of IEEE 802.15.7 VLC regulation subcommittee, chairman of TTA visible light communication service Working Group, and editor of TTA VLC roadmap. He is interested in fusion technologies: Visible Light Communication, Intelligent Information Technology LED illumination, system lighting, and networking protocols between LED lamps.