

CONNECTED LIGHTING SYSTEM WITH ZIGBEE CONTROL BOARD AND PWM

¹Aishwarya Chandrasekhar, ²Mohammad Yasin, ³S Nivash

¹Mtech, Embedded System Technology, ²Product Architect, ³Assistant Professor,

^{1,3}Department of Electronics and Communication,

SRM Institute of Science & technology Chennai, India.

²Controller Software – Indoor, Philips Lighting, Bengaluru, India.

Abstract: In order to achieve high energy savings, there are various smart lighting control methods comprising network solutions and smart controllers. This paper aims to support a network-based lighting control solution using Zigbee protocol that incorporates communication between various system components for lighting control. It creates an emphasis on development of a wireless system where a network is created and connected to LED luminaire through PWM driver which uses the average current controlling design which redirects to the control of brightness and intensity of luminaire forming an interoperability with all the required network devices.

Keywords: PWM Led driver, WCB, Zigbee, ZCL, ZLL

1. Introduction

Indefinite standard lighting protocols are used for communication and network management of lighting systems, the most important ones use low rate Personal Area Networks and the set of operations are defined by IEEE 802.15.4 standard. The IEEE 802.15 group specifies the MAC for wireless personal area networks which concentrates on affordable cost devices communication. Each layer in this carries out different operations and routing to next layer as shown in Fig.1.

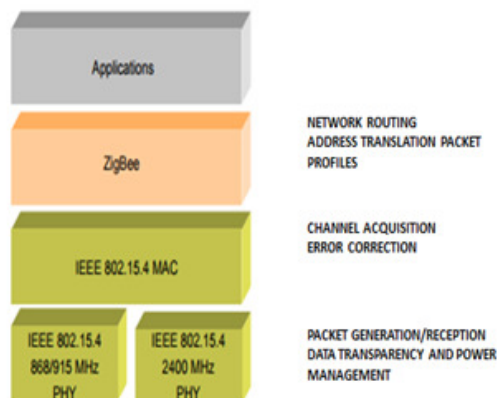


Figure 1. 802.15.4/Zigbee Architecture

This provides a peer-peer network model and supports full functional and reduced functional devices which provides reliability and security by using certain algorithms. As heterogenous networks are expected to join in a network there are preferences to have a Modbus-Zigbee gateway which has mapping techniques assigning unique id to a device [5]. The nominal range of control voltages is from 0 to 10 volts positive which is also a front end driven method for controlling equipment and seen in the entertainment applications and architectural systems including controllers and dimmers. To achieve a wireless connectivity there's no need for an end device to act as remote controller instead a router controller can send and receive messages which has same functions as that of normal remote controller and can also be used in energy saving mode [2].

2. Proposed Method

Any Energy Efficient technology is evolved for developing an automated system that integrates wireless network consists of an end device, a controller, router and PC which handles and records the required and updated data as displayed in Fig.2.



Figure 2. Representation of a wireless automated system

In designing a specific lighting system, the requirements may vary like here it consists of a wireless control board(WCB), PWM driver, a Zigbee

coordinator, a load and a cloud/pc. A cloud records all the information and the energy metrics of the luminaire and sometimes required for controlling WCB during testing and maintenance. Led light is preferred instead of fluorescent luminaire as its specific for low cost applications and can be easily installed holding high ease of reliability and maintenance [3]. Zigbee is used because of the less power that is being consumed by the end-devices. An End Device is also maintained here in the test setup which has no specific responsibility to maintain the network structure instead a router controller takes the responsibility when the equipment joins the network. This coordinator will allocate a 16-bit network address which is unique and in further used in device identification and transfer of information. Router routes the traffic between nodes where as an end device doesn't route traffic and a coordinator is a special router in addition to form a network. The setup can involve use of multiple WCBs to control multiple loads as in Fig.3. Communication between PC/Cloud and coordinator is established by a standard RS232COM port through which the network topology of Zigbee can be scanned.

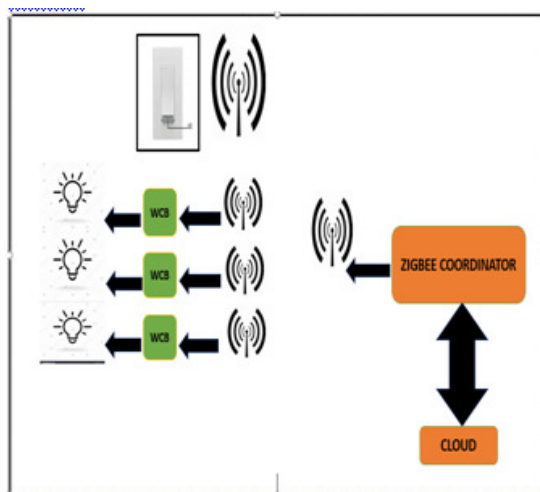


Figure 3. Proposed Design Setup

Different test scenarios were quoted and tested for all the cluster variants. The final setup and the customer product evolves through development, testing and maintenance phases. Development process includes certain additional setup which includes Debug Board designed by Philips that has the application of a debugger board for Atmel MCU. This forms a connection between the PC and wireless control board (WCB) and forms a help in discovering the MCU and used for debugging. This process also includes Atmel ICE which is a powerful development tool for debugging and programming, generally it is used for

ARM Cortex M based Atmel SAM microcontrollers with On Chip Debug capability supporting JTAG and PDI interfaces. It's connected to the debug board for sending and receiving the signals and passes them to the driver.

A. Wireless Control Board (WCB)

This controller basically consists of Atmel MCU units ATSAMR21E18A and ATSAMR21E19A. It also contains a manual switch which is programmed to have set and reset options for example a long manual press for a time instant can reset the WCB board. Generally, this reset is done for few seconds which makes WCB join the open network. WCB is connected to a PWM driver which extends connection to the LED or Luminaire. The two MCU's unitedly control the receiving commands from the pc and forwarding them to PWM driver to control the luminaire. Atmel ATSAMR21E18A, which offers best performance in low power operating up to 48MHZ and has three 16bit timer/counters supporting 60 channels, which identifies its best part of application in wide range of home automation and industrial applications. It supports 1.62V to 3.63V power supply and happens to easily migrate to SAMR21G and SAMR21J devices. On the other side, Atmel ATSAMR21E19A, is an IEEE 802.15.4 compliant single chip combines an ARM Cortex-M0+ based 32-bit microcontroller and best-in-class 2.4 GHz RF transceiver which offers an excellent RF performance. These D21 and R21 chips are erased and flashed accordingly using batch(.bat) files. An integrated development environment is provided by IAR Embedded Workbench and this manages complete application projects for embedded systems. The environment has tools that are used to permits one to develop and meant for linking, compiling and debugging and they comprise complete end target support.

B. PWM Led Driver

Besides the usage of Linear controllers which dissipate heat while delivering expected power output, this type of injecting PWM pulses into LED is preferred as it doesn't deliver power at all. This driver is connected to a power supply board which in turn controls the existing LED. This technique for controlling LED is done with full amplitude pulses of current and the width of the pulses is varied to control the apparent brightness. Fig.4 displays the Load control through WCB. The LED/Luminaire tests were performed with different clusters which are defined in Zigbee Cluster Library [8]. This type of dimming calculates the amount of light focused on human eye as the average light generated in pulses.

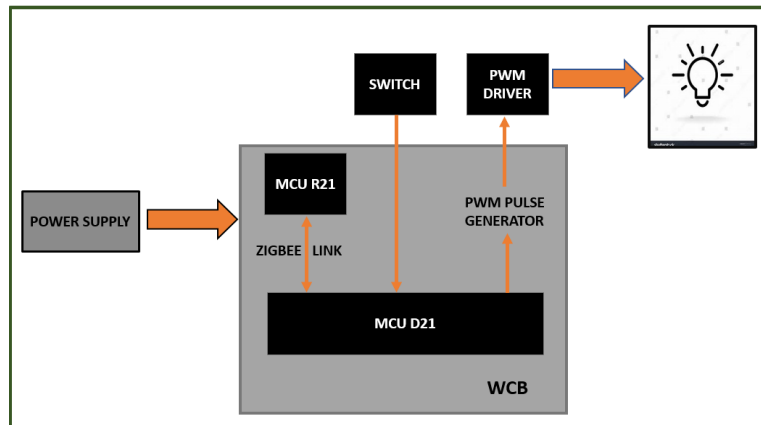


Figure 4. LED Load Control through WCB

C. ZigBee Network Joining Process

The Network basically consists of Coordinator/gateway, end device which is usually WCB which handles device joining process. When a network is being formed, gateway searches for an available open channel, starts a network by creating a PAN (Personal Area Network) id to the network. Gateway configures itself and then gets

ready to respond to queries from other devices those wishes to join the network. Fig.5.Explains Auto Join process that includes opening the Network in Coordinator and power on the WCB. WCB immediately starts the Auto join where it starts searching for the available network every 5 seconds. If any open network, it joins the network, else it searches there network every 5 min.

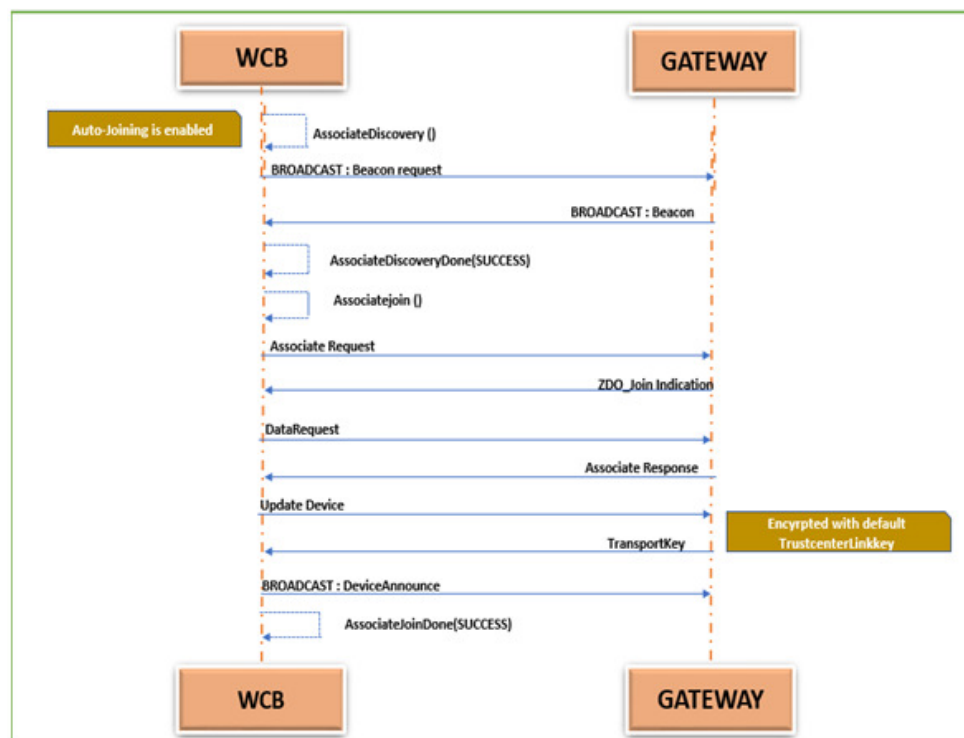


Figure 5. Autojoin Process in WCB

D. ZigBee Cluster Library

ZigBee Cluster Library (ZCL) is the Alliance that has defined number of standard clusters and these can be associated with all functional area. Its structure defines a header and payload that are inside the Protocol Data Unit (PDU) used for messages transmission and reception. It also defines attributes like read and write to indicate success or failure. This ZigBee Application link generally includes Smart energy, Home Automation and ZigBee Light Link (ZLL) [4]. The clusters of ZCL include those listed in the following Table.1.

Table 1. Classification of Different clusters in ZCL

General Cluster	Cluster ID
Basic	0x0000
Power Configuration	0x0001
Identify	0x0003
Groups	0x0004
Scenes	0x0005
On/Off	0x0006
On/Off Switch Configuration	0x0007
Level Control	0x0008
Alarms	0x0009
Time	0x000A
Binary Input (Basic)	0x000F
Commissioning	0x0015
Door Lock	0x0101
Thermostat	0x0201
Thermostat User Interface Configuration	0x0204
Colour Control	0x0300
Illuminance Measurement	0x0400
Illuminance Level Sensing	0x0401
Temperature Measurement	0x0402
Relative Humidity Measurement	0x0405
Occupancy Sensing	0x0406
IAS Zone	0x0500
IAS ACE (Ancillary Control Equipment)	0x0501
IAS WD (Warning Device)	0x0502

The contribution of different clusters depends on the type of application we are using. In involvement of Lighting System, we use only On Off, Basic, Identify, Groups, Scenes, Level Control and Commissioning [10] as displayed in Fig.6.

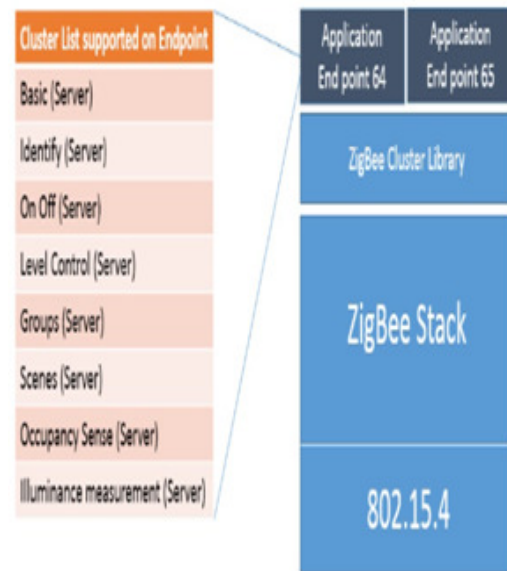


Figure 6. Clusters supported at Application layer

Time Synchronization of devices in a Zigbee network is must so for these conditions we use alarm and time clusters whenever possible. There are certain attributes which can be written by local application which allows ZCL to respond to that commands related to those attributes which are externally compiled to an application and which are enabled separately for both client and server as described in Fig.7. Whenever a request signal is sent by a device, it waits for certain timeout to get the response code. ZCL Fundamentals and features describe shared device structures capturing the attributes. Each time the device sends a request for different clusters in different appearance considering needs of the requirement; contrastive responses are needed to identify the successful communication between end devices or master and devices.

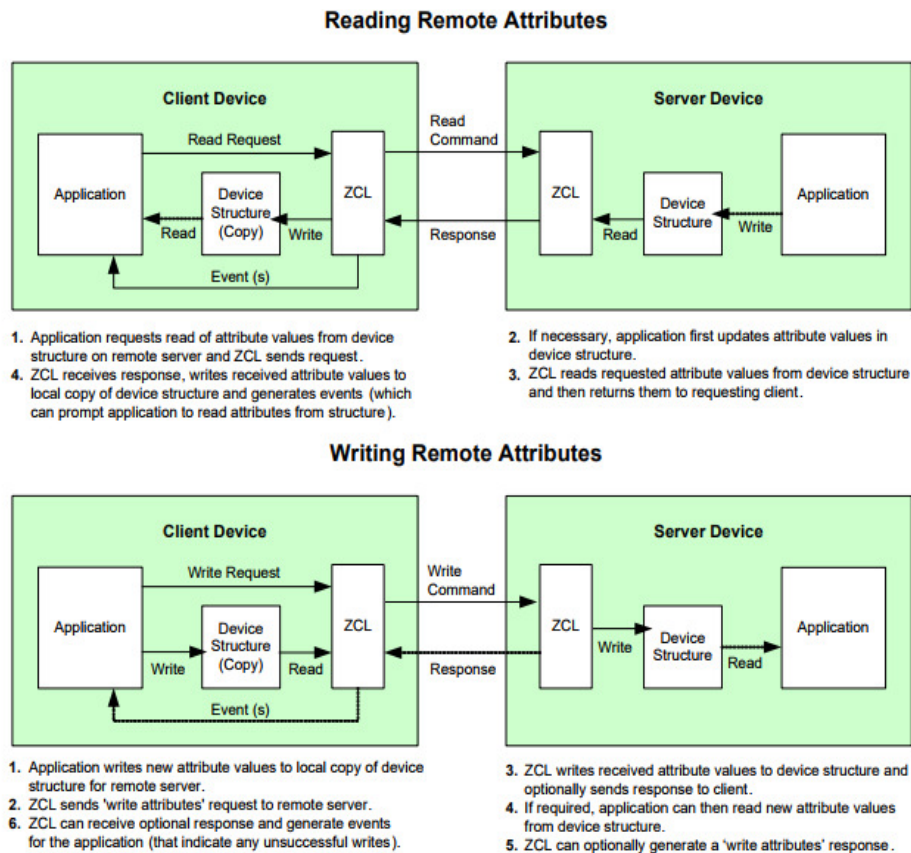


Figure 7. Comparison of Read/Write attributes

The best knowledge in making the result is made by developing different test scenarios for all the clusters that are existing with all factors of constraints like on/off at different time instants, switching, control, dimming at different hex levels and then testing is done to check for the expected needs before the product is handled to the users.

3. Results and Discussion

E. Usage of Zigbee

In this implementation of a Network-based lighting control solution, dependency happens to be on a robust network which discovers easy way to consumer-focused lighting applications. Modern Illumination systems using controllers can be preferably produce more cost-effective solutions in a Home Automation system. The comparison of why Zigbee is considered preferred than other techniques can also be shown

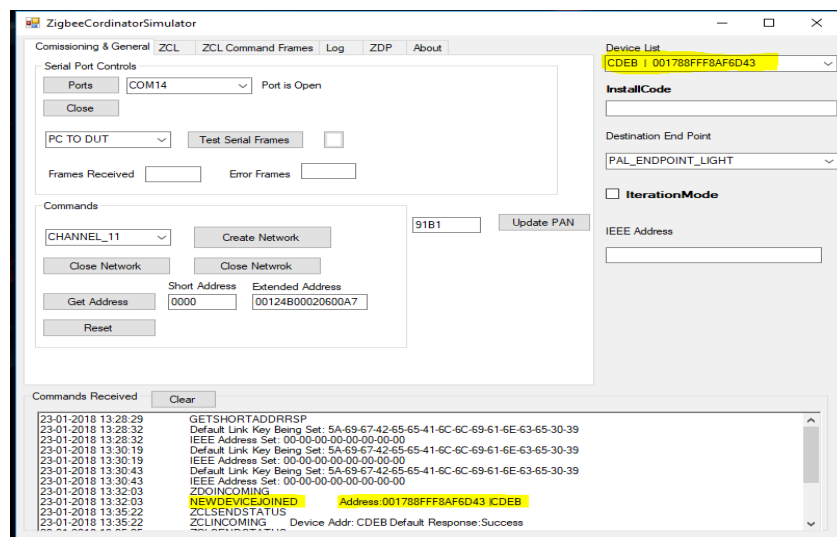
practically as in Table.2. This comparison drives a major thought of having connected from an end-device to another end-device through a router and a coordinator using a single PAN id connecting many devices at a time. The benefit of Zigbee is that when 'n' number of devices are connected as in a mesh kind of network where the parent node is not directly connected to the child node the switching on of other devices connected in chain happens automatically from the influence of each devices co-ordination and there's no need of separate power supply device at each point of connection in the whole network. The manufacturer can opt for Zigbee Coordinator tool if a smart RF is added to the setup. As soon as simulator tool recognizes the device with corresponding IEEE address it acknowledges with a message that a new device is joined. According to the MAC/IEEE address that is recorded, we can recognize the device which is connected.

Table 2. Illustration of different technologies with comparison

Market Name	ZigBee™	---	Wi-Fi™	Bluetooth™
Standard	802.15.4	GSM/ GPRS/ CDMA	802.11b	802.15.1
Application Focus	Monitoring & Control	Wide Area Voice & Data	Web, E-mail, Video	Cable Replacement
System Resources	4KB- 32KB	16MB+	1MB+	250KB+
Battery Life (days)	100- 1,000+	1 – 7	5 - 6	1 - 7
Network Size	Unlimited (26+)	1	32	7
Bandwidth (KB/s)	20 - 250	64- 128+	11,000+	720
Transmission Range (meters)	1 - 100+	1,000+	1- 100	1 - 10+
Success Metrics	Reliability, Power, Cost	Reach, Quality	Speed, Flexibility	Cost, Convenience

The additional benefit of using this solution is that it makes sure that it's perfect while operating with Home Automation Systems when limited channels that are provided for communication and control. As a part of this technologies its reliability makes it bit affordable in usage. As we consider ZLL, they are specifically used in Lighting applications and this optimized approach of

ZLL increases its capability in implementing different color levels and brightness in different atmosphere settings which results in maximum convenience and efficient energy result. The manufacturer can choose any of the requirements and come up with a complete automation system.

**Figure 8.** ZigBee Coordinator tool displaying a device joining process

Once the network is joined, we can check for the address matching in simulator tool as displayed in Fig.8. Then, we can make use of ZCL clusters and their

corresponding commands broadcast for controlling load. This illustration is shown in Fig.9.

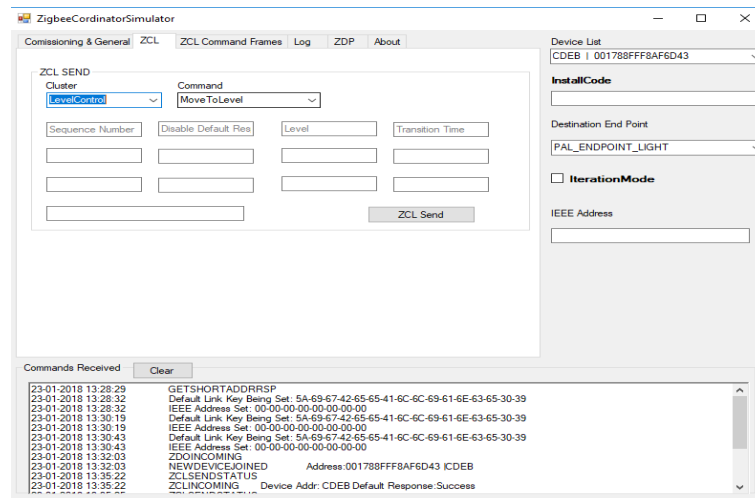


Figure 9. ZCL clusters and commands in coordinator tool

ZCL includes the clusters that are set up for Smart Home Lighting applications as they define a set range of standard devices on which controlling relies upon.

The Attributes in simulator tool can be defined as in Fig.10, ZCL command frames according to the cluster and type of configuration needed.

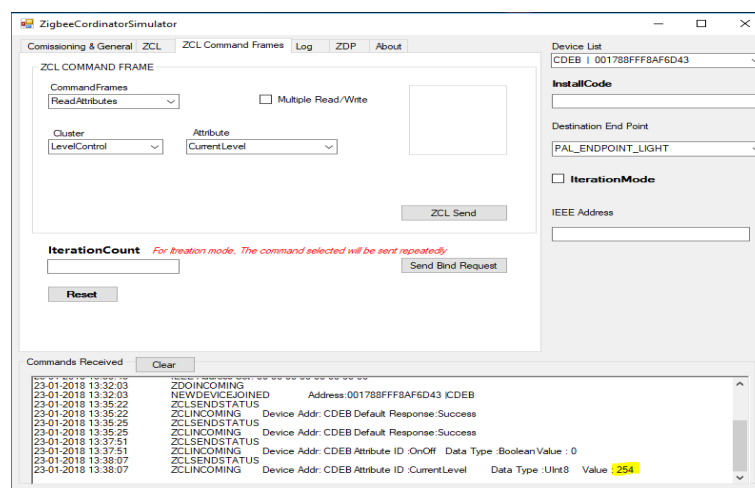


Figure 10. ZCL attributes and command frames in coordinator tool

Advanced features can also be added to ZCL like different color loop and scene control and settings which can be used by designers.

F. PWM LED Dimming

Apart comparing many analog and digital lighting control methods that are tested and implemented, this is a common digital method used as its efficient in power saving and speed of operation. Many markets spread out for the use of this technique in all luminaire control methods they manufacture, and they follow distinct

protocols for their usage as some follow using of a controllable ballast which can act as a PWM protocol. The ballast is a firmware unit that acts as support for controlling elements. The controlling is done in such a way that the signal is inverse to the dimming, i.e. the voltage is directly proportional to brightness of the lamp. This method when included with a MCU based solution makes the use of reduced components and proved that it has the capability of varying the duty cycle and frequency which is controlled by software that creates low impact on using power and is a best example of energy efficiency.

4. Acknowledgment

I would like to thank Mr. Suresh Satyavolu, R&D Group Manager Digital Systems Engine, Controller Software Global Systems, Philips Lighting, Bengaluru, for providing guidance and all required facilities. I am thankful to Philips Lighting Pvt. Ltd., Bengaluru, India for providing the resources for this work.

References

- [1] Mohammad Tahan and Tingshu Hu(2017) "Multiple String LED Driver with Flexible and High-Performance PWM Dimming Control", 2017, IEEE Transactions on Power Electronics.
- [2] Yao, J., Zhang, Z., Dong, P., and Holtman, K. (2014). "A Zigbee controlled lighting system with improved resistance to wireless interference." 2014 IEEE Asia Pacific Conference on Wireless and Mobile, 219–225 (Aug).
- [3] Ji, H., Zhao, Q., Wang, X., and Sun, Q. (2013). "Zigbee-based led intelligent lighting control system." 2013 10th China International Forum on Solid State Lighting (Chi- naSSL), 252–254 (Nov).
- [4] Kamoln Kaemarungsi, Rachasak Ranron and Prasit Pongsoon(2013) "Study of received signal strength indication in ZigBee location cluster for indoor localization" Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2013 10th International Conference.
- [5] Hsiao, R.S., Lin, D.B., Lin, H.P, Chung, S.C. (2012)." Integrating Zigbee lighting control into existing building automation systems' International Conference on Information Science and Control Engineering 2012 (ICISCE 2012), 1–5 (Dec).
- [6] Lavric, A., Popa, V., Males, C., and Finis, I. (2012). "A performance study of Zigbee wireless sensors network topologies for street lighting control systems." 2012 Inter- national Conference on Selected Topics in Mobile and Wireless Networking, 130–133 (July).
- [7] Siddiqui, A. A., Ahmad, A. W., Yang, H. K., and Lee, C. (2012). "Zigbee based energy efficient outdoor lighting control system." 2012 14th International Conference on Advanced Communication Technology (ICACT), 916–919 (Feb).
- [8] Hung, C. H., Bai, Y. W., and Tsai, R. Y. (2011). "Digital control for home lighting systems with Zigbee communication." 2011 IEEE International Conference on Consumer Electronics (ICCE), 763–764 (Jan).
- [9] Jun, Y. and Wei, W. (2010). "Led lighting control system based on the Zigbee wireless network." 2010 International Conference on Digital Manufacturing Automation, Vol. 1, 892–895 (Dec).
- [10] Zigbee Cluster Library Specification, Revision 6, Draft version 1.0.
- [11] S.V.Manikanthan and D.Sugandhi " Interference Alignment Techniques For Mimo Multicell Based On Relay Interference Broadcast Channel " International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) ISSN: 0976-1353 Volume- 7 ,Issue 1 –MARCH 2014.
- [12] T. Padmapriya and V.Saminadan, "Handoff Decision for Multi-user Multiclass Traffic in MIMO-LTE-A Networks", 2nd International Conference on Intelligent Computing, Communication & Convergence (ICCC-2016) – Elsevier - PROCEDIA OF COMPUTER SCIENCE, vol. 92, pp: 410-417, August 2016.

