Self-Configuration and Smart Binding Control on IOT Applications

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***Abstract*-The rapid development of wireless communication technology facilitates the realization of the Internet of Things (IOT). Self-configuration and smart connection system have become relative important issue in accordance with extensive applications of IOT, and the energy saving concepts. Therefore, this work presents the integration of 'Self-configuration and Wisdom Connection System' with Wireless Sensor Networks (WSN), IOT and ZigBee technology, to actualize self-configuration based on a received signal strength indicator Received Signal Strength Indicator (RSSI), lighting auto-configuration area, regional allocation, and sub-areas. The proposed 'Self-configuration and Wisdom Connection System' automatically configures different lightings to the same position within in the range -3dBm when the RSSI value varies only slightly. The system is configured to the same lighting site within the experimental environment when the sub-area range set -3dBm. This study presents a significant contribution to new configuration of objects in IOT, context awareness control, and optimization of network control platform.**

Keywords: ZigBee, IOT, Auto-configuration, Smart binding, WSN, RSSI.

I. INTRODUCTION

The initial rapid development of wireless communications technology was motivated by the need for military detection applications. Since then, ZigBee technology has been extensively used in a large range of fields, providing communications and sensing with low power consumption, high reliability, and multi-node networking. Today, this technology is extensively used in such applications as process monitoring in industry, consumer products for health testing, home electronic devices for monitoring or detecting intruders, medical sensing, elderly care, the collection of patients' information, such as blood pressure, heartbeat, and pulse, and environmental applications such as the detection of pollution water, air and soil using sensors. The popularity of smart devices has resulted in new applications of WSN, the new IOT and ZigBee technology [1].

With respect to the consumer market, ZigBee-related technologies have been available for a long time but not yet universally so. For example, the costs, installation and operational complexity of such technologies still affect the acceptance by consumers. Developments that make wireless technologies seamlessly bind to all types of home appliances; eliminate cumbersome setting, and cause users to feel that using a remote controller is as simple as using a cell phone may provide new opportunities in the IOT.

This paper proposes a 'Self-Configuration and smart Connection System' that integrates WSN, the IOT and ZigBee technology, and confirms its feasibility in both theory and practice. Lighting control systems with sensors are constructed with Self-configuration and smart lighting control. The system configures lighting based on RSSI information of reference points, and provides information about lighting RSSI for controlling devices, facilitating reference alignment. Moreover, this work proposes the concept of sub-area regional configuration, changing sub-area range by setting RSSI error, to increase controlling in lighting numbers and to enhance the effectiveness of automatic control.

This paper is organized as follows. Section 2 presents relevant background. Section 3 shows the architecture and functional design of the proposed system. Section 4 discusses the validation of the system and analyzes of its effectiveness. Finally, conclusions are drawn and ideas for future work are presented.

II. RELATED WORK

A. Wireless Sensor Network (WSN)

The rise of the WSN has involved the development of battery-powered WSN environments. In 2003, the MIT Technology Review identified the ten emerging technologies would soon change the fields of computing, medicine, manufacturing, transport and energy infrastructure [2]. Among all of them, wireless sensor networks were the most promising.

WSNs are widely used for controlling electronic consumer products, monitoring industrial processes, monitoring homes, monitoring medical conditions, environmental monitoring and other purposes. The increasing prevalence of smart devices in recent years has supported new applications of the IOT [1]. The application layer of IOT is composed of four sub-layers, which are the application layer, the cloud service layer, the network layer and the device layer [3]. In the IOT architecture, WSN is used in both the network layer and the device layer. In today's era of the cloud, the use of the Cloud (Sensor Cloud) with WSNs will become the mainstream [4].

B. ZigBee/IEEE 802.15.4

The hardware and software standards of ZigBee were mostly formulated by the IEEE 802.15.4 group and the ZigBee Alliance, respectively. ZigBee is extensively used for automatic control and remote control and can be embedded in various applications levels [5, 6]. ZigBee, which is used mainly for making short-range wireless connections, is a communication technology that is a hybrid of wireless marking technology and Bluetooth wireless technology. Consistent with the 802.15.4 standard, ZigBee performs communication among thousands of tiny sensors. With very high efficiency, these sensors deliver information to each other in a relaying fashion that consumes with very little energy. In short, ZigBee is a relatively inexpensive, low-power, short-range wireless network communication technology.

C. ZigBee IP

With the development of the Internet-of-Things, the ZigBee networking standard, which enables intelligent operation of networks, has become increasingly valuable. The Internet Engineering Task Force (IETF), affiliated with the ZigBee Alliance, has established various working groups to assess these sensing and control networks. The rapid depletion of the addresses of the fourth edition of the Internet Protocol (IPv4), IPv6 addressing, combined with existing IP agreements for low-power sensing and control of the Internet, seems to represent a reasonable way forward. Increasing the numbers of network and security layers as well as application architecture as required by the IEEE 802.15.4 standard, the ZigBee Alliance announced the ZigBee IP agreements concerning new IPv6 addressing technology in March 2013[7].

D. Received signal strength indication (RSSI)

In wireless location, two main types of methods are used to convert signals into distances. The first, in which the arrival time of the signal is converted, includes the time of arrival measurement method Time of Arrival (TOA) and the time difference of arrival method Time Difference of Arrival (TDOA) [8]. The second, in which the distance is calculated from the strength of the received signal, includes the use of the received signal strength indicator RSSI [9, 10]. RSSI is a simpler and easier method than TOA or TDOA for measuring distance, as it requires neither nanosecond-resolution equipment nor samples of long-term measurements, but it suffers from small errors associated with multipath interference and the fact that the strength of the received signal diminishes as distance increases. The received signal strength indication (RSSI) is calculated from the received signal strength (RSS), as in according to Equation 2-1 and 2-2. P_{RX} is the strength of signal that is received by the receiving node; P_{TX} is the energy intensity of the transmitting node; G_{RX} is the antenna gain of the receiving node; G_{TX} represents the antenna gain of the transmitting node; λ is the wavelength of the signal, and d is the distance between the antennas of two nodes and In a list of non-clauses, separate the items by commas, and the final two items by without a preceding comma. Substituting P_{RX} into Eq. 2-2 yields RSSI. Pref is a reference power and is 1mW.

$$P_{RX} = P_{TX} \cdot G_{TX} \cdot G_{RX} \left[\frac{\lambda}{4\pi d}\right]^2 \qquad (2-1)$$

$$RSSI = 10 \cdot log \frac{P_{RX}}{P_{ref}} \qquad (2-2)$$

$$RSSI = -(10n \, log_{10} \, d + A) \qquad (2-3)$$

RSSI is the transmission power from the sending node to the receiving node, which changes with the distance between the two nodes. According to the propagation model in Eq. 2-3, the received signal is converted into RSSI, in which A is the received RSSI value 1 m away from the receiving node; n is the signal propagation constant, which is also known as simply the propagation constant (propagation exponent), and d is the distance between the transmitter and the receiver in meters.

E. ZLL (ZigBee Light Link)

The ZigBee light link (ZLL) was designed for controlling LED lighting. LED lighting will become the main form of home lighting in the future. The lighting industry developed ZLL technology for the control of LED lights and submitted its specifications to the ZigBee Alliance to become the global standard. Osram (OSRAM), Philips (Philips) and Singular (GE) use products for lighting control that are developed by ZLL. The ZLL standard is expected to become the mainstream for lighting control applications, with the support of these three LED lighting manufacturers. The Interconnect Lighting Alliance (Connected Lighting Alliance) [11] adopted the ZLL standards in July 2013 as the common open standards for interconnected home lighting applications.

III. System architecture and functional design

Figure 1 presents the architecture of the Self-configuration and smart connection system; it is composed ZigBee devices, sensors, lights and other components. The system is operated using a ZigBee remote controller, tablet or mobile phone through an Ethernet or Wi-Fi.

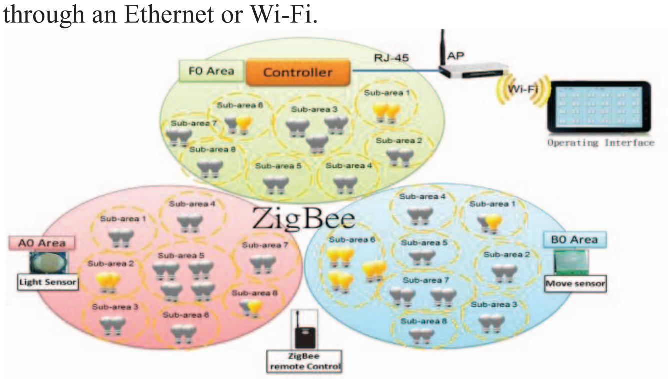

Figure 1 System Architecture

The system is divided into controller, light sensing area, and movement sensing area. They are three independent areas virtually, as follows.

- Controller
  1) The controller is coordinator at the center of the ZigBee network and is responsible for sending and receiving control commands. The coordinator communicates wirelessly with all ZigBee devices via the ZigBee interface.
  2) Software / Flash: The application program for ZigBee devices was developed using Z-Stack software and burned onto Flash memory. Flash memory provides archiving and records the parameters of lighting devices.
  3) The Ethernet interface is the external gateway to the ZigBee network. Users operate the self-configuration and smart connection system over Wi-Fi or the Internet interface.
- ZigBee lighting consists of a ZigBee device with two LED lights, of which both or one can be lit. Lighting sites are determined from the RSSI values of three reference points. ZigBee lighting includes a burning function and a Flash archive.
- The GUI Platform is a user-operated interface that is programmed by C#.NET/Microsoft .NET Framework.

The system includes three regions, each of which consists of eight sub-regions. A sub-region is the minimum instruction control unit and is modified by site allocation errors.

A. Software Development Tools

- Z-Stack, which was released by Texas Instruments (TI), is an industry-leading ZigBee protocol stack that has the gold standard of the ZigBee Alliance, as assessed by Rheinland Group (TUV Rheinland). (Z-Stack is used globally by ZigBee developers or ZigBee developers all over the world use Z-Stack).
- IAR Embedded WorkBench: IAR Embedded Workbench version 7.6 was applied to ZigBee program development. The IAR Embedded Workbench is a development platform that incorporates Assembler, C/C ++ and a debug tool. The IAR Embedded Workbench provides a complete set of integrated development programs, including project manager, editor and build tools, the C-SPY debugger, and others. Figure 2 presents the IAR Embedded Application Development platform screen.

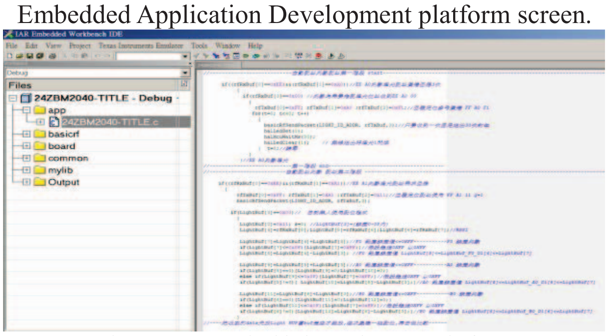

Figure 2 IAR Embedded Development Platform

- The SmartRF Flash Programmer is a burning tool that is used to compile and burn the system microcontroller on a TI chip, such as CC243x/CC253x Flash memory and supports the IEEE address (read and write) which must be used with the CC243x / CC253x burner. Figure 3.3 shows the operating screen.

B. Hardware Development Tools

The hardware includes two ZigBee wireless modules with high-tech sensors and LED lamps from the Chung-Kau Corporation.

- ZB2530-LAN (ZigBee wireless network module) is used as a controller. Figure 3 presents the ZB2530-LAN.
  1) Supporting RJ45 / RS232 external interface
  2) Receiving messages from ZigBee and connecting to a network or computer

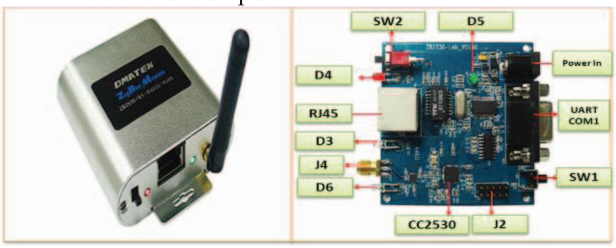

Figure 3 Exterior and interior of ZB2530-LAN

- The ZB2530-01 wireless communication module includes a TI CC2530 ZigBee standard chip which can be used in 2.4GHz, IEEE 802.15.4, ZigBee2007 / PRO and RF4CE applications. Based on this module, the proposed system also includes a light sensing module, a mobile sensing device, LED lamps and an analog remote control. Figure 4 shows the exterior of B2530-01 sensor.

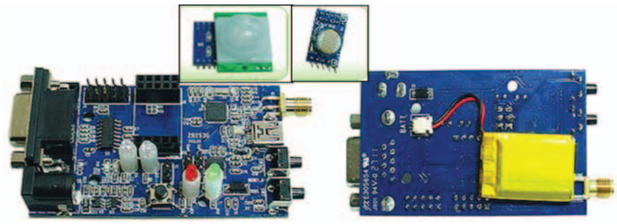
Figure 4 ZB2530-01 module

C. Packet Format

Figure 5 schematically depicts the sending and receiving of packets in the proposed system. The controller receives packets that are returned from ZigBee devices and sends the device status to operating interface, which then sends commands to ZigBee devices through the controller.

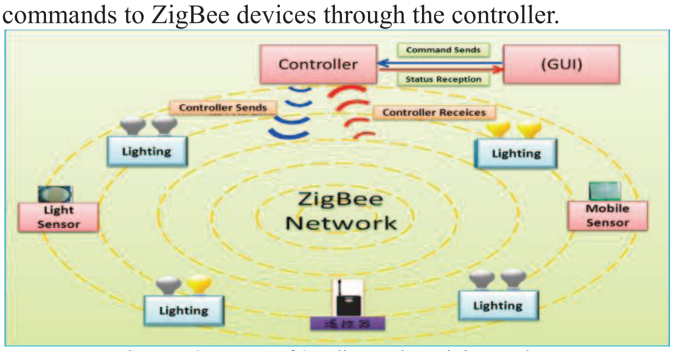

Figure 5 Structure of Sending and receiving packets

The controller receives wireless signals from lighting devices, sensors, and remote control backhaul. The fixed packet length is 10 bytes and packets are sent to the operating interface via the Ethernet interface. Figure 6 shows the format of the received packets.

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	Byte 9	Byte 10
Header	Header	Area Num	Device Num	Control Status	Connection Status	Scope Value	F0 RSSI	A0 RSSI	B0 RSSI

Figure 6 Format of received Packets

The controller sends commands wirelessly to lighting devices, sensors or the remote control device. The fixed packet length is 6 bytes. Figure 7 shows the transmission of the control commands.

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6
Header	Header	Area Num	Device Num	Control Inst	Connection Status

Figure 7 Transmission of Control Command

The controller or remote controller transmits site allocation commands wirelessly to lighting devices. The fixed packet length is 6 bytes. Figure 8 shows the transmission of site allocation commands.

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6
Header	Header	Area Num	Device Num	Config Inst	Error Range

Figure 8 Transmission of Site Allocation Command

D. Functional Development and Design

The self-configuration and smart connection system is developed to perform three major functions, which are lighting self-configuration, smart connection control, multi-functional remote control, based on the immediate collection of the RSSI and its distribution application. All equipment has an automatic saving mechanism. Table 1 presents the functional details, which are described in the following sections.

Table 1 Functions of Self-configuration

Function	Items
Self-configuration of lamps	1. Allocation sites of Setting new lamps (single / multi-lamp)
	2. Reallocation sites of lamps (single / multiple lamps)
	3. Clear lamp sites (single / multiple lamps)
	4. Allocation sites of area (single / multiple lamps)
	5. Query or delete site *location* record (single / full area)

The self-configuration adds and manages wireless lighting, sensing, or other devices to relieve the user setting problem. When performing site allocation, the system will determines the area in which the site will be, based on the RSSI values of the default reference points, and will save the records of the sited lighting devices. When the error range is preset to 0, only one lamp can be allocated to each sub-area. When the RSSI error range is applied to the site allocation process, the system compares the error range to the RSSI value of the sited lighting, and assigns the same lighting number. If the error range is within a single sub-area; therefore, the number of lighting devices in each sub-area is unlimited, and this scenario is called range site. The system can support 100 areas, each comprising eight sub-areas. The proposed system includes three areas, each of which consists of eight sub-areas. Figure 9 shows the procedure of site allocation.

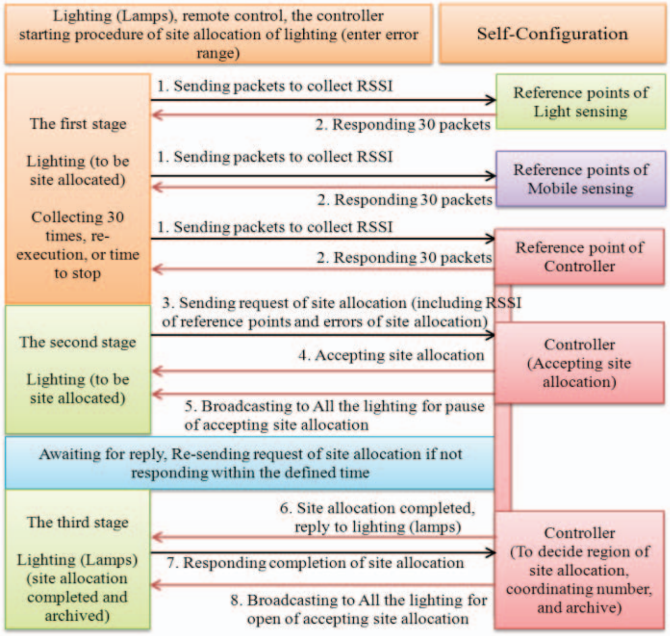

Figure 9 shows the procedure of site allocation

IV. system validation and performance analysis

The system is designed to perform all the functions in various environments. This section verifies the effectiveness of the system function in a real environment. The testing environment is a small conference room with the proposed system and wireless AP, but no other AP equipment, as presented in Figure 10.

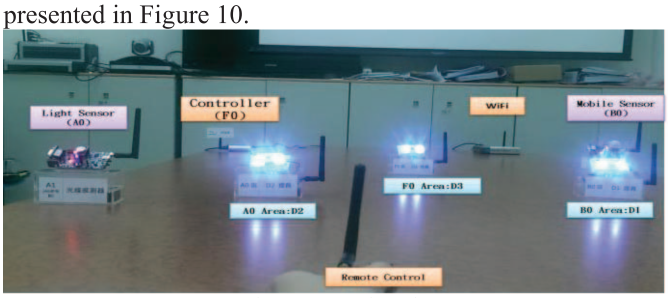

Figure 10 Testing Site

The required hardware includes the ZigBee device with simulated LED lighting (9V power supply), light sensors, mobile sensors and a ZigBee analog remote controller, as presented in Figure 11

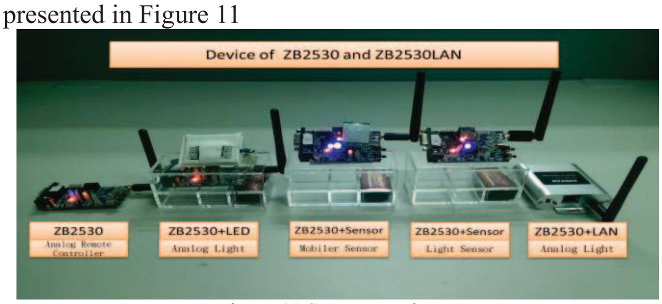

Figure 11 System Hardware

The GUI interface of the system software adopts the .NET Framework platform that was developed by Microsoft and written in C# programming language. System functions were firstly confirmed using the UDP software tool, and then converted into a GUI graphical user interface to improve the intuitiveness of the systems' operation.

A. *Verification of Project*

The verification of the system functions cover three major items, which are self-configuration of the lighting device, smart connectivity, and multi-function remote control, along with their sub functions. A description and screenshots related to the major functions follow.

- Self-configuration
    1) When a new lamp is added, the system detects the new lighting; displays the RSSI value of its reference point, and estimates the lighting configuration area.
    2) Click 'new site allocation' to activate self-configuration, which supports multi-lighting.
    3) The 'clear lighting function' restores initial value to lighting.
    4) Click 'site reallocation' to reallocate sites for all lighting or designated.
    5) In the 'lighting configuration state', records of sites in each area can be queried or deleted.
- Effectiveness Analysis of System

This section analyzes the performance of our system in the various experimental environments. The system performance analysis comprises the following.

- RSSI variation analysis
    1) Comparison of volatilities of RSSI values in various lighting position, and at different times in the same place.
    2) Comparing the difference between actual value and activating site allocation with averaging of 30 RSSI values.
    3) Analyzing RSSI variation and the influence to site allocation variation with two lighting placing closely in the same time.
- Research value analysis
    1) Technical differences between the proposed system and ZLL.
    2) Comparison of features of smart home products.

In embedded devices, fading that caused by signal reflection, scattering, diffraction and other multi-path phenomena, causes the received signal strength indicator (RSSI) in a particular location to vary. This experiment analyzes both the stability of the collected RSSI values and the effect of on automatic lighting configuration, for a TX Power device at 0dBm. The experimental procedure is as follows.

1) Analyze the RSSI variation of two lighting devices at fixed location over time. Compare the actual RSSI values with the average of 30 RSSI values of automatic lighting configuration by sampling the lighting return records every 30 seconds.
2) Analyzing the RSSI variation of lighting devices and its effect on site for two lighting devices that are placed close to each other.

The system adopts UDP software to collect RSSI values of lighting devices and reference points. Figure 12 shows the UDP received RSSI of lighting devices.

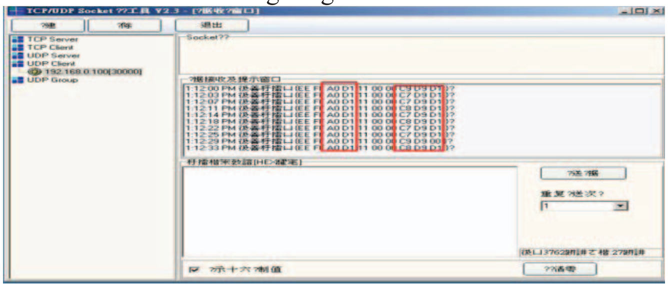

Figure 12 RSSI value of lighting device that is received by UDP

Table 2 presents a statistical analysis of the RSSI variation of lighting devices based on experimental data and charts. The following conclusions are drawn.

Lighting and Reference points RSSI Value (dBm)				
		F0	A0	B0
Light A	Max Value	-54	-38	-46
	Min Value	-56	-39	-47
Light B	Max Value	-54	-38	-46
	Min Value	-57	-40	-47
Max Variation of Lighting		-3	-2	-1
Securityof Error Scope		-3		

Table 2 Statistical Analysis of Variation of RSSI of Lighting

V. Conclusion

With respect to the consumer market in ZigBee-related technologies have existed for a long time but are not yet universally used. With regard to smart families as an example, costs, system installation and operational complexity affect consumer acceptance. The seamless binding of wireless technologies to all types of home appliances, elimination of the cumbersome setting, and causing users to feel that using a remote control is as simple as using a cell phone may provide new opportunities related to the IOT. In this work, the 'Self-configuration and Smart Connection System' is developed its feasibility verified. The results of verification of its major functions, Self-configuration, indicate that the system provides self-configuration for multi-lighting, with an RSSI value variation within -3dBm, and regional configuration in each sub-area validated.

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