ZigBee Technology Development for Smart Home Appliance Application

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Abstract

The U.S takes a major role in the area of Smart Appliance Home Control Network technology for decades. The most popular solutions for this technology at this time include wired and wireless. Today, the benefit of remove control system in the house has been enjoyed. As the fast growth of wireless technology, a convergence of sensor devices and home appliances, wireless system is now a movement toward our daily life. This paper depicts the development procedure of smart appliance using wireless technology, Zigbee network. An example of developing a wireless network sensor will be given.

Key Words：Smart Appliance、Home Control Network、Wireless Sensor Network、ZigBee

1、Introduction

During the past few years, wireless systems seem to the breeding of life. The market demand for “Smart Home Appliance Control Network” device is increasing. Some sensors are developed with Bluetooth, a consumer oriented technology that is designed to eliminate computer cables. Others are implemented with IEEE 802.11b, or Wi-Fi’s IEEE 802.11g, these standards are proposed for the wireless LAN technology used in offices and increasingly in airports, hotels, and restaurants. In a home security system, for example, wireless sensors would be much easier to install than sensors that need wiring. This article will focus on the HomeRF technology and ZigBee is considered as the appropriate solution to implement this system.

ZigBee arrived in the 2.4GHz band, joining the now IEEE 802.15 (Institute of Electrical and Electronic Engineers: IEEE) which has two well-established substandards, Bluetooth and UWB (Ultra Wideband: UWB). ZigBee looks rather like Bluetooth but is simpler and cheaper. It has a lower data rate and spends most of its time in sleep mode. ZigBee is considered as reliable, low-power consumption and cost-effective advantages while implementing wireless systems. This characteristic means that a ZigBee network should be able to run for three months and up to one year on a pair of AAA batteries. The target of building home automation, sensor control, security and consumer electronics as the main application makes technical sense.

The remainder of this paper is organized as follows. In section two, an overview of the IEEE 802.15.x Standard for WPAN (Wireless Personal Area Network: WPAN) and the ZigBee Network Architecture will be given.

Table 1、 IEEE 802.15.4 Physical Layer

Frequency Band	2.4GHz	868 (915) MHz
Geographical Region	Japan; Europe; USA	Europe; USA
Data Rate	250 kb/s	40 kb/s
Chip Rate	1 Mc/s	300 (600) Kc/s
Data	16-ary orthogonal modulation	Differential BPSK
Channel	16 Channels; 5MHz Channel separation	1(10) Channels; 2MHz Channel separation@915MHz
Sensitivity	-85dBm	-92dBm
Max. Conductive Power/Radiated field limit	10dBm (10mW); 20dBm (100mW); 30dBm (1000mW)	14dBm (25mW); 30dBm (1000mW)

Table 2、 IEEE 802.15.4 Data Frame Format

			Frame Control	Sequence Number	Address Info	Payload	Frame Check Sequence
MAC Sub layer			MAC Header (MHR)			MAC (MSDU)	MAC Footer (MFR)
			Octets: 2	1	0-20	Variable	2
			MAC Protocol Data Unit (MPDU)				
PHY Layer	Synchronization Heard		PHY Header	PHY Payload			
	Preamble	Start of Frame Delimiter	Frame Length	PHY Service Data Unit (PSDU)			
	4	1	1	0-127			
	PHY Protocol Data Unit (PPDU)						

Afterwards, the processing procedure of a ZigBee network, the core of this wireless system, will be shown. Also, the illustration of the development environment including hardware and software will be given. Section four, the home sensor network application development of the complete system is provided. The final section presents discussions and conclusions of the wireless network and its future challenges.

2、Overview of Wireless Network

The ZigBee standard operates in 2.4GHz band or the 868MHz or 915MHz ISM (Industrial, Scientific and Medical: ISM) bands used in Japan, Europe and US respectively. The date rates are 250kbps at 2.4GHz and 20kbps to 40kbps in the lower frequency bandwidth. The transmission range is about 10 meters indoor and around 75 meters outdoor. In Table 1, the comparison of analyzing IEEE 802.15.4 Physical Layer with different frequency Bands is given.

2-1、IEEE 802.15.x Standards

IEEE 802.15.x Standard provides wireless connectivity among devices in a personal operating space. The 802.15.x WPAN family include 802.15.1 (Bluetooth)、802.15.2 (Bluetooth)、802.15.3 (UWB) and 802.15.4 (ZigBee) protocol for wireless networks.

Bluetooth is an open standard for short-range digital radio wireless connectivity. It is a small, cheap chip to be plugged into computers, printers, mice, monitors, mobile phones, and so on. UWB brings the convenience and mobility of wireless communications to high-speed interconnects in devices throughout the digital home and office. UWB is designed for short-range WPANs, enabling wireless connection of multiple devices for transmission of video, audio and other high-bandwidth data. The ZigBee is reliable, cost-effective, low power consumption. The benefit of a Zigbee system is to achieve monitoring and controlling aims based on an open global standard. This wireless communications solution will be embedded in consumer electronics, home and building automation, industrial controls, PC peripherals, medical applications, and electronic toys and games.

2-2、IEEE 802.15.4 Standard

ZigBee is the integration of network, security, and application services layers, which includes the physical layer (Physical Layer: PHY) and medium access control (Medium Access Control: MAC: MAC) layers of the IEEE 811.15.4 radio. Wireless medium access control MAC and PHY are the specifications for low-rate wireless personal area network. It provides a standard for ultra-low complexity, ultra-low cost, ultra-low power consumption, and low data rate wireless connectivity among inexpensive devices. It will be secure for lightweight wireless communication among sensors and building automation. Table 2 is the IEEE 802.15.4 data protocol format.

In the Figure 1, all of the device types within a Zigbee system, there are network coordinator, full function device (Full-Function Device: FFD) and reduced function device (Reduced-Function Device: RFD). There are three types of Zigbee network topologies, Star、Mesh and Cluster.

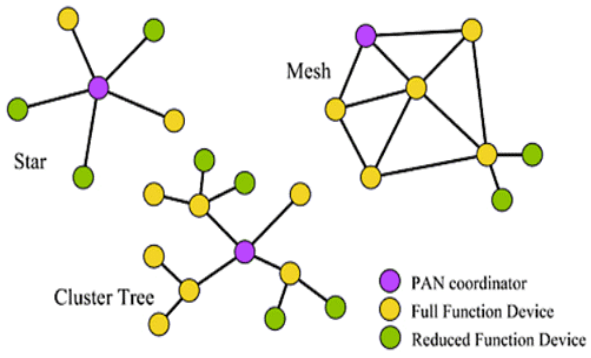

Fig.1 ZigBee network

2-3、ZigBee Network Layer of Architecture

IEEE 802.15.4 working group defined the lower layers of protocol stack as MAC and PHY. First version standard was released on December 1st, 2003. Furthermore, ZigBee alliance defined the upper layer of protocol stack from network to application include application profile. Figure 2 is the Architecture of ZigBee network.

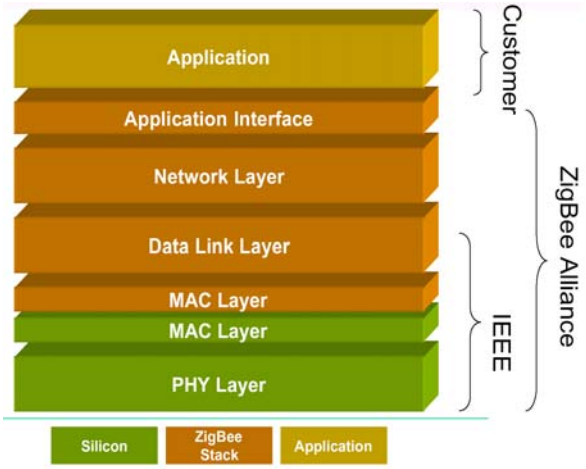

Fig.2 ZigBee network of Architecture

3、ZigBee Development of Environment

Zigbee module is consisting of the MCU (Microprocessor Control Unit: MCU), RF IC (Radio Frequency Integrated Circuit: RF IC), and antenna circuit. In the following Section, each development environment will be presented with more details. (Figure 3)

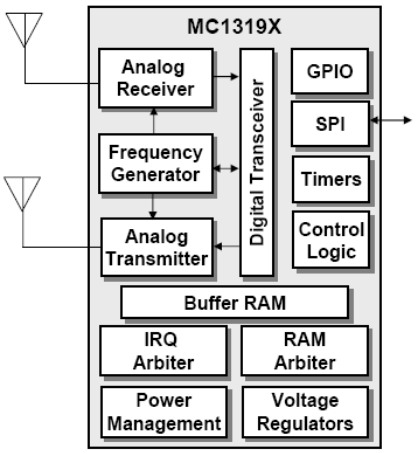

Fig 3. ZigBee 2.4 GHz Transceivers Block

3-1、Hardware Requirement

RF transceiver is a wireless technical that is fully compliant to the IEEE 802.15.4 PHY specification. It is targeted at IEEE 802.15.4 proprietary or standards based solutions. IEEE 802.15.4 MAC is a communication protocol used for short range, low power, and low data rate wireless applications. ZigBee network supports the

Table 3、 RF Transceiver

Function	Specification
Network Topology	Peer-to-Peer, Star and Mesh
Transfer Mode	Packet and Streaming
Throughput	250Kbps O-QPSK DSSS
Low Power Modes	Hibernate, Doze and Idle
Sensitivity	-92dBm
Operating Voltage	2.0V to 3.4V
MCU Support	Optimized for 8-bit HCS08 Family
MCU Interface	SPI Interface to MCU
Power Output	-16.6dBm to +3.6dBm(software selectable)
Operating Temp	-40 to +85ºF Operating Temperature
Package	5x5 QFN-32 (Meets lead-free requirements)

beaconed, star, cluster-tree and mesh networks. Moreover, RF IC supports the guaranteed time slots (Guaranteed Time Slots: GTS) includes the AES 128-bit Encryption and uses the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance: CSMA/CA) algorithm for co-existence mitigation. A ZigBee node that uses CSMA/CA is essentially taking a listen-before-talk approach to see if any radio traffic is already underway. The RF functions are supported by the development environment with object code, and the designers can target only at the 8-bit HCS08 MCU,

which is a relatively cheap and powerful MCU as it can achieve buffered transmit and receive data packets. Low component count reduces complexity and cost. The RF transceiver and MCU hardware design requirement will be illustrated in the Table 3 and Table 4.

3-2、Association the ZigBee Network

Each ZigBee network needs at least one FFD as a controller, but most network nodes can be RFDs**.** RFDs can talk only with FFDs, not to other RFDs, but they contain less circuitry than FFDs, and little or no power-consuming memory. (Figure 1)

Every PAN has a unique 16-bit ID and a single ZigBee coordinator. For ZigBee, merging PANs after they have formed is not possible without re-commissioning the two systems. The ZigBee coordinator has a special 16-bit network address of 0x0000.

Table 4、 MCU Requirement

Item	MC9S08GT60
CPU	HCS08
Serial Communications	2× SCI, SPI IIC
Voltage Regulator	On-Chip
General Purpose I/O	Up to 36
Debug	BDM On-Chip
FLASH	60k Bytes
RAM	4k Bytes
Analog-to-Digital	8-Channel, 10-Bit
Timer	4-Channel, 16-Bit
Clock Generator	Frequency-Locked Loop

Every device has a unique 64-bit MAC address. Upon association, every device receives a unique 16-bit network address. Only the 16-bit network address is used to route packets within the network. Devices retain their 16-bit address if they disconnect from the network, however, if the leave the network, the 16-bit address is re-assigned. Network broadcast is implemented in the MAC:

- Network address 0xFFFF is the broadcast address
- Special algorithm in network to propagate the message
- “Best Effort” or “Guaranteed Delivery” options
- Radius limited broadcast feature

3-3、ZDO Binding API

Wireless network builds and sends ZDO (ZigBee Device Object: ZDO) binding requests and responses. All binding information (tables) is kept in the ZigBee Coordinator. Hence only the ZigBee Coordinator can receive binding requests. Binding manager establishes resource size for the binding table, processes bind requests, and supports bind and unbind commands from external application.

3-4、Z-Stack incoming data

A company named Figure 8 offers a set of development tool that contains Z-Stack (ZigBee Protocol Stack Package) and Z-Tool (ZigBee Protocol Stack Test Tool). This tool contains the complete communications software solution for easily integrating ZigBee wireless technology onto embedded systems. Figure 8 ensures that the Z-Stack is fully compliant with

the ZigBee protocol specification. Z-Stack is fully configurable, extremely portable, robust, reliable, and easy to maintain on every embedded platform.

Z-Stack architecture has multiplexing incoming data to endpoints. Application Framework provides 2 service types the Key Value Pair (KVP) and Message (MSG). Z-Stack supports applications on Endpoints from 1-255 over APS. Structure section defines the data objects used in SET and GET commands. Two messaging service types are defined the KVP commands Service and the MSG commands Service.

4、Application Development

Generic Application Profile – Z-stack provides a single device description template and has the capability to define simple descriptions to advertise interfaces to support device discovery, service discovery and binding and utilizes all standard ZigBee platform features.

4-1、ZigBee Profile

Profile Builder is a development system that can be used to create user defined ZigBee application. It generates profile code. Accordingly, the ZigBee coordinator, routers and end devices need to follow the ZigBee Alliance standard. One reason for optimism about ZigBee adoption for home automation and security is its ease of use. the home controls sensor profile is listed below:

- Dimming Load Controller
- Switching Load Controller
- Dimming Remote Control
- Switching Remote Control
- Occupancy Sensor
- Light Sensor Monochromatic

Home Controls Lighting Profile – In the Z-stack provides 6 device descriptions, each has its own sample application. This profile can be used as the sample application for designer's development reference.

4-2、ZigBee Market Future

In figure 4, it is estimated that the scale of the global market for low-speed communication will reach 570 million in 2005 in advance, ZigBee can make heavy occupation rate of market more when the time comes, this represents the space that it can grow for sizable potentiality. The sales of 802.15.4 nodes and chipsets will increase from essentially zero to 165 million units by 2010 by depiction. Not all of these units will be coupled with ZigBee, but most probably will be reach firmly on the World predicts of 465 million wireless sensors RF modules by 2010.

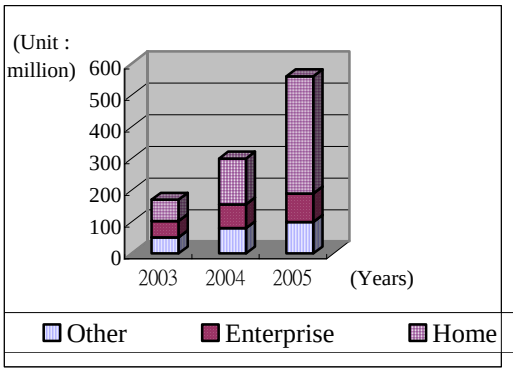

Fig 4 .The global low-speed communication uses the market

(Source from：ABI，Dataquest，Adcon Telemetry AG，Taiwan ITRI ITIS，2003/01)

5、Conclusion

ZigBee is designed for high reliability, low-cost, low-power, low-data rate and highly secure wireless applications. ZigBee is built on the global, robust IEEE 802.15.4 radio standard. Large ZigBee ecosystems are made available today which equates to fast time to market. ZigBee, based on the HomeRF technology, is also starting to receive attentions for sensor implementation.

This paper has reviewed the popular home automatic technologies, wireless sensor networks of ZigBee technologies. It is found that a wireless smart sensor network is the most important part in our life. The found gives future direction of research and development of wireless and smart sensor structures using Zigbee. It is estimated the ZigBee Network will be

applied to a large amount in the home appliances, sensor network systems in the future.

Acknowledgement

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