ZigBee
A Case Study

ZigBee – An Introduction

There has been tremendous growth in the field of wireless communication during the last decade. The wide acceptance of 802.11 standards for wireless local area network (WLAN) and cellular phone networks have proved that low cost wireless solutions are feasible and acceptable. There are many applications that require low cost, low data rate, low power and inexpensive solution to network within a small area thus requiring a low rate wireless personal area network (LR-WPAN).

There are many proprietary solutions that address these needs, but they are expensive and incompatible between manufacturers. The IEEE 802.15.4 is a new standard for LR-WPAN providing a low cost and less complicated solution. The expected applications are home/office automation, industrial sensors and control, distributed sensor networks and environment monitoring. The ZigBee networking standard has slowly but surely taken up an important share of the wireless market. Vendors of ZigBee products are increasing, and more and more types are coming out.

The ZigBee alliance, an association of companies working together to develop ZigBee standard based products for monitoring and control, has led to the increased adoption of the IEEE 802.15.4 standard. The ZigBee standard defines upper layer that are built on the IEEE 802.15.4 standard. The aim of the ZigBee alliance is to replace every switchbox, electrical outlet and various sensors in a building by wireless nodes that communicate with each other even though manufactured by different manufacturers. This standard is being widely adopted by the industry and the numbers of products based on the standard are increasing exponentially. The ZigBee alliance is forecasting that in the next few years time, there could be 50 ZigBee devices per home and eventually as many as 150.

Network Topologies

In order to enable efficient data exchange in large-scale networks ZigBee standard utilizes topologies enabled by data IEEE 802.15.4 transfer models and extends them by specifying tree and mesh network topologies. A ZigBee network can adopt one of the three topologies: Star, Tree and Mesh. These are illustrated below.

Figure 1

Star, Tree and Mesh Topology
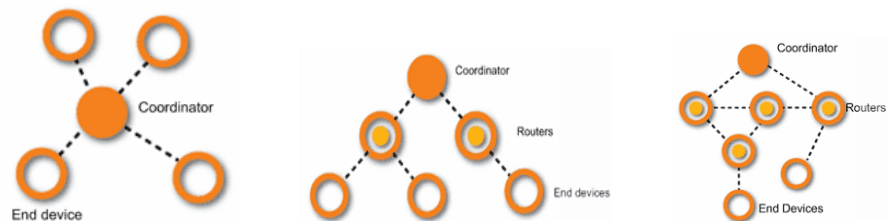
Device types

There are three different types of ZigBee devices

ZigBee coordinator (ZC): The most capable device, the coordinator forms the root of the network tree and might bridge to other networks. There is exactly one ZigBee coordinator in each network since it is the device that started the network originally. It is able to store information about the network, including acting as the Trust Centre and repository for security keys.

ZigBee Router (ZR): As well as running an application function a router can act as an intermediate router, passing data from other devices.

ZigBee End Device (ZED): Contains just enough functionality to talk to the parent node (either the coordinator or a router); it cannot relay data from other devices. This relationship allows the node to be asleep a significant amount of the time thereby giving long battery life. A ZED requires the least amount of memory, and therefore can be less expensive to manufacture than a ZR or ZC.
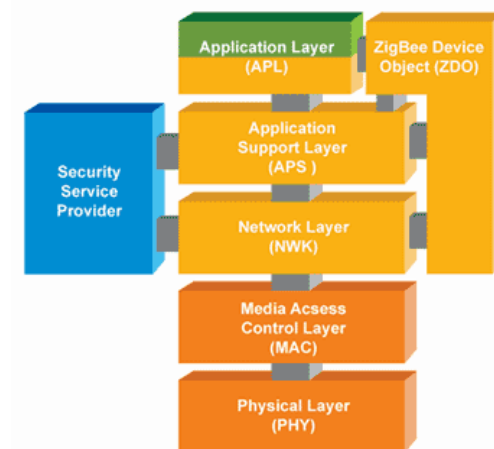
ZigBee Protocol Stack

Figure 2

ZigBee protocol stack

The ZigBee specification is a standard that defines a stack protocol enabling the interoperability of wireless devices in a low-cost, low-power consumption and low-data-rate network. The ZigBee stack is founded over the IEEE 802.15.4 standard, which defines the multiply accumulate (MAC) and physical (PHY) layers of the protocol. MAC and PHY layers define the RF and communications components of neighboring devices. ZigBee stack layers, on the other hand, include a network layer, an application layer and a security service provider (SSP).

Devices are defined by the profiles and are implemented as application objects. Each application object is connected to the rest of the ZigBee stack by an endpoint, which is an addressable component within a device. Communication is made from endpoint to endpoint and through data structures called clusters. Clusters contain a set of attributes needed to share information between application objects. Clusters used in a specific application are defined within its profile. Each interface can receive or send data in the form of a cluster.

There are two special endpoints: 0 and 255. Endpoint 0 is used for the configuration and management of the entire ZigBee device. Through this endpoint, the application can communicate with other layers of the ZigBee stack to initialize and configure them, attach points with data transmission, security and binding. Binding is the ability to match different but compatible devices together, such as a switch and lamp. The network layer enables devices to communicate with one another. It is involved in the initialization of the device within a network, routing of messages and network discovery. The application support sublayer also provides these services. The application can configure and access the parameters of the network layer through the ZDO.

Application Example – A Reference Design

This reference design describes the design of light dimming devices for light bulbs, based on Freescale's MC1321x microcontroller with an 802.15.4 RF modem and controlled by the MC33794 E-Field Imaging device. The communication is based on a low power 2.4 GHz radio frequency transceiver using Simple MAC (SMAC) based on ZigBee.
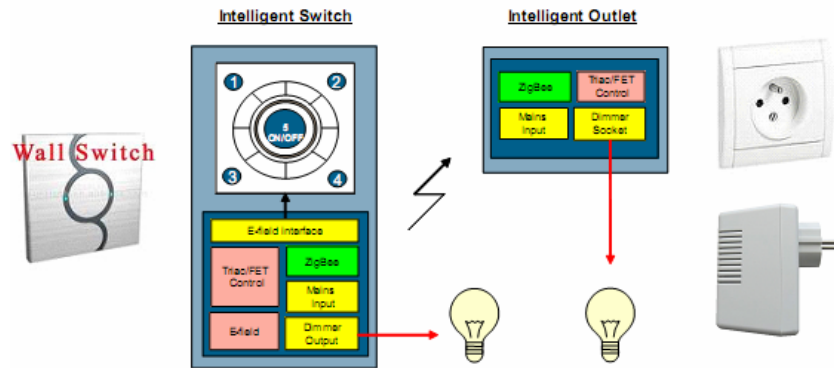

Figure 3

FreeScale reference design

The system consists of two kinds of applications:

▊ Intelligent switch is intended to replace a standard wall switch and provides dimming function on one phase of AC power. The control interface is an E-field contactless touch panel with various shapes of electrodes. The intelligent switch can also control four intelligent outlets through a 2.4 GHz radio frequency transceiver using SMAC.

▊ Intelligent outlets are intended to replace standard wall power outlets. The device needs the full AC power and dims the light in standard desk lamps and other portable devices. There are two versions of intelligent outlet boards, implementation in a wall outlet case and implementation in an adaptor case.
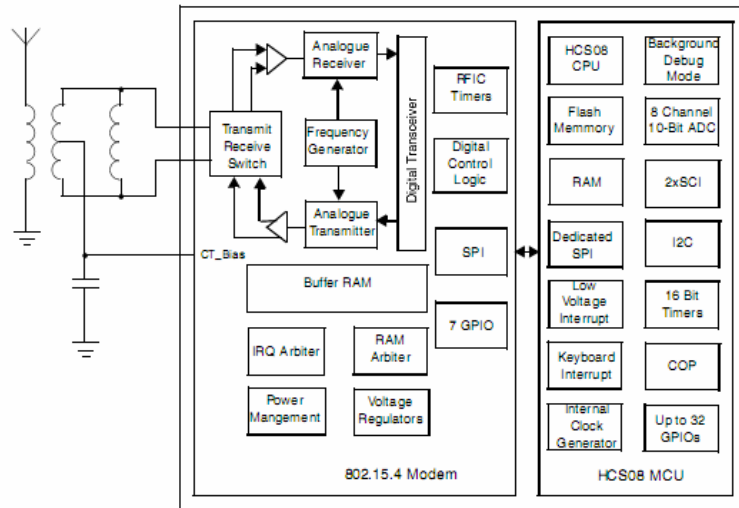
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Figure 4

System block diagram

MC1321x MicroController

The MC1321x family is Freescale's second-generation ZigBee platform incorporating a low-power 2.4 GHz radio frequency transceiver and an 8-bit microcontroller into a 9x9x1 mm 71-pin LGA package.

Figure 5

MC13213 block diagram

The MC1321x solution can be used for wireless applications from simple proprietary point-to-point connectivity to a complete ZigBee mesh network. The combination of radio and a microcontroller in a small footprint package allows for a cost-effective solution. The MC1321x contains an RF transceiver, which is an IEEE 802.15.4-compliant radio operating in the 2.4 GHz ISM frequency band. The transceiver includes a low-noise amplifier, 1mW nominal output power, PA with internal voltage controlled oscillator (VCO), integrated transmit/receive switch, on-board power supply regulation, and full spread-spectrum encoding and decoding. The MC1321x also contains a microcontroller based on the HCS08 family of microcontroller units (MCU) and can provide up to 60-Kbyte of flash memory and 4-Kbyte of RAM. The onboard MCU allows the communications stack and the application to reside on the same system-in-package (SiP).