White Paper

ZigBee™ Wireless Transceiver Engineering Options

RFM

Realizing this new standard's automation benefits – and there are many – requires navigating your engineering options

Overview

ZigBee offers unique advantages for wireless applications, including low-cost radios, mesh networking, a basis in standards, and low power consumption. But with a technology this new, realizing a successful ZigBee implementation requires understanding its architecture and operation, assessing design options at the chip and module level, and weighing practical considerations relative to specific application needs.

This white paper provides a developer's overview of ZigBee, presenting key aspects of ZigBee's architecture and certification requirements as they relate to implementation options. It then examines the strengths and challenges of each primary option to help the reader decide which path is best suited to specific application and business needs.

The ZigBee Basics

ZigBee is the product of the ZigBee Alliance, an organization of manufacturers dedicated to developing a new networking technology for small, ISM-band radios that could welcome even the simplest industrial and home end devices into wireless connectivity. The ZigBee specification was finalized in December, 2004, and products supporting the ZigBee standard are just now beginning to enter the market.

ZigBee is designed as a low-cost, low-power, low-data rate wireless mesh technology. The ZigBee specification identifies three kinds of devices that incorporate ZigBee radios, with all three found in a typical ZigBee network (Figure 1):

- a **coordinator**, which organizes the network and maintains routing tables
- **routers**, which can talk to the coordinator, to other routers, and to reduced function end devices
- **reduced function end devices**, which can talk to routers and the coordinator, but not to each other

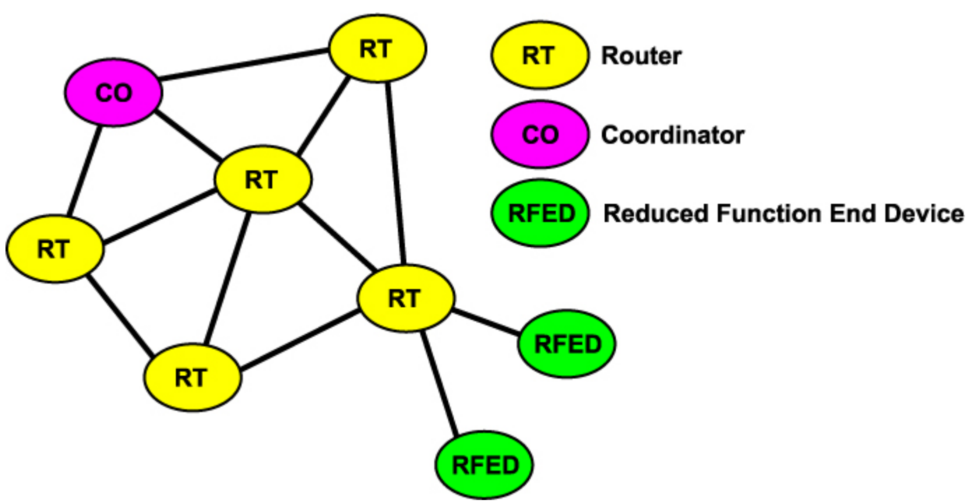

Figure 1: ZigBee networks incorporate coordinators, routers, and reduced function end devices in a variety of topologies (mesh topology shown)

To minimize power consumption and promote long battery life in battery-powered devices, end devices can spend most of their time asleep, waking up only when they need to communicate and then going immediately back to sleep. ZigBee envisions that routers and the coordinator will be mains powered and will not go to sleep.

To illustrate how these components interrelate, consider ZigBee networking in office lighting. Several manufacturers are currently developing inexpensive sensors for fluorescent tubes that let lights be turned on and off by battery-powered wall switches, with no wires between switch and fixture. The light switch is the end device, powered by a button cell battery that will last for years; the switch wakes up and uses battery power only when flipped on or off to transmit the new state to the fluorescent tubes' routers which, as they are already connected to the mains, are not concerned with battery conservation. Any one of the fluorescent tubes can contain the coordinator. The implications are enormous for new office construction – no more electrical runs for lighting, and the ability to reconfigure lighting controls at almost zero cost.

ZigBee extends similar benefits to a wide range of industrial automation and control applications.

ZigBee Benefits

In all of its uses, ZigBee offers four inherent characteristics that are highly beneficial:

- **Low cost**
  The typical ZigBee radio is extremely cost-effective. Chipset prices can be as low as $12 each in quantities as few as 100 pieces (while the 802.15.4 and ZigBee stacks are typically included in this cost, crystals and other discrete components are not). Design-in modules fall in the neighborhood of $25 in similar quantities. This pricing provides an economic justification for extending wireless networking to even the simplest of devices.

- **Range and obstruction issues avoidance**
  ZigBee routers double as input devices and repeaters to create a form of mesh network. If two network points are unable to communicate as intended, transmission is dynamically routed from the blocked node to a router with a clear path to the data's destination. This happens automatically, so that communications continue even when a link fails unexpectedly. The use of low-cost routers can also extend the network's effective reach; when the distance between the base station and a remote node exceeds the devices' range, an intermediate node or nodes can relay transmission, eliminating the need for separate repeaters (Figure 2).

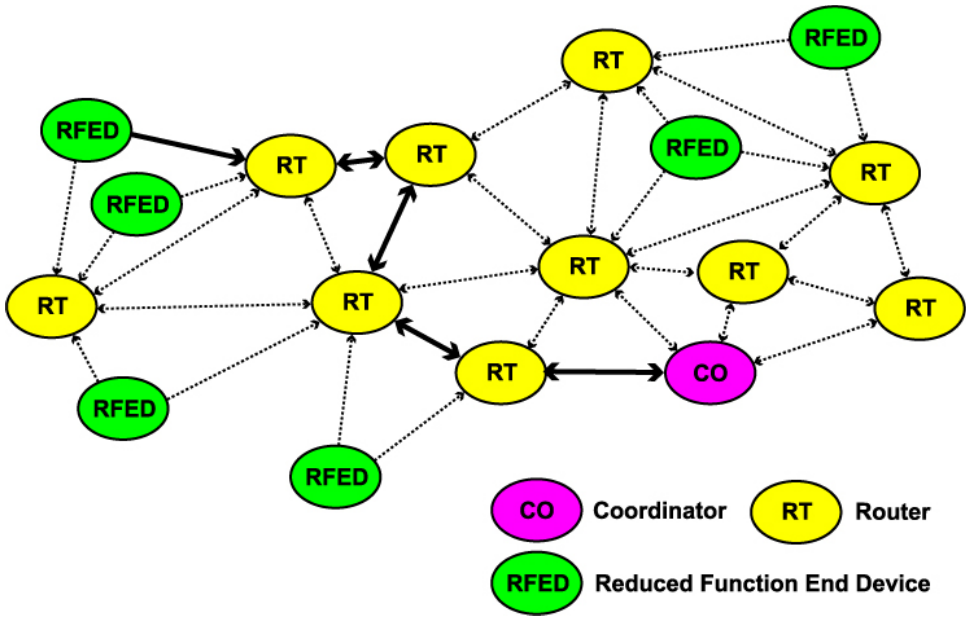

Figure 2: Heavy lines show a signal from a reduced function end device passing through multiple routers to reach a gateway functioning as a coordinator; lighter lines show possible alternative signal paths

- **Multi-source products**
  As an open standard, ZigBee provides customers with the ability to choose among vendors. ZigBee Alliance working groups define interoperability profiles to which ZigBee-certified devices must adhere, and certified radio will interoperate with any other ZigBee-certified radio adhering to the same profile, promoting compatibility and the associated competition that allows the end users to choose the best device for each particular network node, regardless of manufacturer.

- **Low power consumption**
  Basic ZigBee radios operate at 1 mW RF power, and can sleep when not involved in transmission (higher RF power ZigBee radios for applications needing greater range also provide the sleep function). As this makes battery-powered radios more practical than ever, wireless devices are free to be placed without power cable runs in addition to eliminating data cable runs.

ZigBee Architecture

For purposes of this discussion, there are three areas of architectural responsibility in a ZigBee engineering effort (Figure 3).

- The physical and MAC layers take full advantage of the physical radio specified by IEEE 802.15.4. The 802.15.4 specification describes a peer-to-peer radio using Direct Sequence Spread Spectrum. The specification also calls out the data rates, channelization, and modulation techniques to be employed.

- The ZigBee Alliance specifies the logical network, security, and application software, which are implemented in a firmware stack. It is the ZigBee networking stack that creates the mesh networking capability. Each microcontroller/RF chip combination requires its own ZigBee stack due to the differences in micro-controllers and RF chips. Typically, the ZigBee stack is included with either the microcontroller or RF chip. The stack may belong to the chip vendor, be provided by the chip vendor from a third party source, or be provided by a third party source for a specific microcontroller/RF chip combination.

- The application layer is defined by profiles, of which there are two types: *public profiles* are those certified by the ZigBee Alliance for interoperability purposes, and *private profiles* are for use in closed systems.

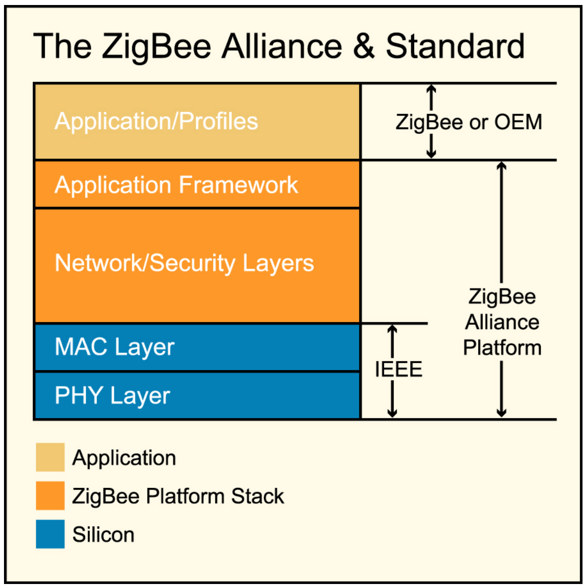

Figure 3: The ZigBee firmware model

A word about the ZigBee Alliance: The following discussion includes options that require access to intellectual property available only to members of the ZigBee Alliance. There are three types of membership; all companies that plan to release products incorporating ZigBee technology must become at least adopting members, an entry-level membership that provides such benefits as access to specifications and developer conferences/ workshops. For information, visit www.zigbee.org.

ZigBee Implementation: Hardware and Firmware Considerations

In investigating ZigBee development resources, you'll want to visit the ZigBee Alliance at www.zigbee.org. Members of the ZigBee Alliance offer ZigBee-compliant platforms, in either the chipsets themselves or design-in modules developed on them. There are three basic options for ZigBee hardware implementation:

- **Chipset reference designs**
  ZigBee chipmakers offer reference designs which, to be relevant for as many different applications as possible, are very broad. Using a reference design may

mean giving up real estate and incurring cost for capabilities you don't need, but you'll avoid the time and expense of a custom design.

- **Chipset custom designs**
  You can save space and recurring product expense by building a custom design around a chipset. Be sure to work with a chipset you know well; as all current sets consist of an RF chip paired with a microchip, you'll need both RF and digital design engineering capability.

- **Design-in modules**
  There are a number of OEM module manufacturers, including Cirronet, whose products incorporate ZigBee-compliant chipsets. With any module solution, the RF work is already complete, often with optimization for particular types of applications, and typically including FCC and ETSI certification as a module. You may or may not find a module that supports your application in the optimum manner, but if you do, you'll get to market very quickly and greatly reduce development costs. Because module manufacturers aggregate demand from a number of customers, they often will be building modules in such large quantities that the price of a module may even be less than the cost of a chipset solution.

ZigBee Implementation: Profile Considerations

The chipset and the stack are incomplete without a profile, which defines the module application. As mentioned previously, there are public profiles and private profiles. For public profiles, ZigBee Logo Certification is available; private profiles are not intended to interoperate and therefore cannot be certified.

At this point, the simple fact is that there is only one ZigBee public profile, and that's for lighting. If you are developing a ZigBee solution for any other type of application, and can't wait for the development of an appropriate public profile, you'll need to go with one of the private profiles that have been developed, or develop your own.

Some chipmakers have created private profiles that are integrated into their stacks, typically general-purpose serial UARTs. Module manufacturers are more likely to offer application-specific private profiles, and may offer something suitable to your needs.

Implementing profiles, either public or private, is no small undertaking. In addition to the need to license development tools from the stack providers and attending a training class, be prepared to spend a fair amount of time studying the various firmware components that constitute the ZigBee stack. Also make sure that your firmware engineers are familiar with the microcontroller used in the platform. While none of these items is insurmountable, they do add to development costs and time to market.

If you decide to use a third-party ZigBee module, you can still develop your own profile. Most module manufacturers can provide the hardware abstraction libraries, which reduces the effort. Some module manufacturers offer services to create a custom profile for their customers. While this is not a free service, it can simplify the development effort and shorten time to market.

A word about profiles and gateways: While every ZigBee network needs a coordinator, not all need a gateway. In the lighting example, the ZigBee network doesn't interface with another network. For most sensing and monitoring applications (and many other industrial/commercial applications), the ZigBee network will need to interface to another network, either Modbus or Ethernet. When that's the case, you'll want to make sure that your solution is available with a compatible gateway that implements the same profile.

ZigBee Implementation: Certification and Testing

Once you have engineered your product with the necessary hardware, firmware, and profile, it's now time to start testing. First there is the FCC and ETSI tests. Then there are the ZigBee tests, but before you can run these tests, you must join the ZigBee Alliance. By joining the ZigBee Alliance you gain access to the IP embodied in the ZigBee technology. Without joining the Alliance, your legal ability to use the ZigBee technology can be called into question.

Any ZigBee product you market must first pass one of two testing levels, either ZigBee Friendly (for private profiles) or ZigBee Logo Certified (for public profiles). Each requires that ZigBee Compliant Platform testing be successfully completed first.

ZigBee Compliant Platform (ZCP) testing may be completed by a chipset manufacturer or a module manufacturer and passed through to their customers. This testing is concerned primarily with compliance testing at the stack profile (different from the application profiles). As long as the ZigBee implementation uses the stack profile used for the ZCP testing, it does not need to be repeated. If, however, a different stack profile is needed for your device and that stack profile was not tested by the chipset or module manufacturer, you will need to repeat the ZCP tests.

ZigBee Friendly testing assures that products with private profiles won't cause problems for other nearby ZigBee networks. If a chipset or module manufacturer has passed ZigBee Friendly testing, a product incorporating its device does not need to be retested *as long as the profile used in the testing is used unchanged.* If any changes are made to the profile, the product with the modified profile must be submitted for ZigBee Friendly testing. Module configuration settings are not considered changes to the profile.

ZigBee Logo Certification is testing performed on a ZigBee Compliant Platform using a public profile. This testing is concerned with interoperability with other device manufacturers' products and is the highest level of testing. Once this testing has been passed, the product may carry the ZigBee logo along with the icon relating to the application profile (Home Control/Lighting for example). A bit of a Catch-22 with this testing is there must be at least three vendors with products implementing the application profile. So when a profile is made public, until there are three vendors that have implemented the profile, none of the vendors can get ZigBee Logo Certification.

Summing It Up: Choosing the Best Options for You

In the end, decisions regarding ZigBee hardware/firmware, profiles, and certifications depend on practical decision points that must balance what you want of your product with what's available today.

- Ultimate control over product details is achievable with a custom design around a ZigBee-compliant chipset. This method carries high up-front costs in RF and digital engineering, plus investments in test equipment and test fees, and will typically encounter the longest time to market. It may also yield the lowest recurring per-unit cost; if manufacturing quantities are sufficiently high, and if time to market is not critical, this is an advantageous method.

- The use of a chipset reference design will provide faster time to market, eliminating much of the engineering cycle of a custom design. This option still incurs costs in development, test equipment, and testing, and will likely mean a higher recurring per-unit cost than a custom design due to the broad nature of reference designs. But if time to market is important, and if projected manufacturing quantities are sufficiently high, this is a good choice.

- The use of a design-in module will generally provide the shortest time to market and the lowest up-front cost. It may represent the most economical choice of all, especially if manufacturing quantities are modest or uncertain. If you can locate a module with a profile that meets your needs, you'll really have smooth sailing – in this case, you'll avoid not only much of the engineering costs, but the investment in test equipment and test fees as well.

There are many specifics to be considered among the product resources available to you, and they and the dynamics that govern engineering choices will change as the ZigBee standard matures. To help make the best informed decisions, you are encouraged to visit www.zigbee.org for further discovery.