# ZigBee FAQ

*When I started to get interested in ZigBee I felt that some kind of FAQ document for beginners was missing. The ZigBee Alliance web site provides some very high level description of the technology, which may not be sufficient for someone willing to understand it better but not having the time to dig into the full specification. I also noticed that several questions seemed to be recurrent concerns (e.g., interference at 2.4 GHz, role of the ZigBee coordinator, etc.), often with unsatisfactory answers.*

*By no means is this document exhaustive. It is a collection of typical questions I have either been asking myself or been asked to answer in the past months. I included additional insights gathered through reading articles or attending conferences. These contribute, in my view, to a livelier understanding of the topic.*

*My intention is to update it from time to time. Contributions (questions, corrections, additions) are welcome to be posted at g.thonet@ieee.org.*

## ZigBee Alliance

### What is the ZigBee Alliance?

The ZigBee Alliance is a non-profit industry consortium of leading semiconductor manufacturers, technology providers, OEMs and end-users worldwide. Members aim at defining a global specification for interoperable, cost-effective, low-power wireless applications based on the IEEE 802.15.4 standard. Current membership is about 200 and includes both heavyweights (such as Siemens and Texas Instruments) and small startups.

The ZigBee Alliance's web site is www.zigbee.org.

### What is the goal of the ZigBee Alliance?

The goal of the ZigBee Alliance is to create an open specification defining mesh and tree network topologies with interoperable application profiles for wireless control systems. Its focus is clearly on standards-based, low-cost, low-power, and low-data rates applications. Means to certify products are also within the scope of the ZigBee Alliance.

### Who is supporting the ZigBee Alliance today?

Industry leaders worldwide have committed to providing ZigBee-compliant products and solutions. Member companies include 13 promoters (BM Group, Ember, Freescale, Honeywell, Huawei, Mitsubishi Electric, Motorola, Philips, Samsung, Schneider Electric, Siemens, STMicroelectronics, and Texas Instruments) and participants that comprise semiconductor manufacturers, wireless intellectual property providers and OEMs.

Until recently the ZigBee Alliance used to be dominated by semiconductor manufacturers and technology providers. Since 2006 large OEMs like Siemens and Schneider Electric have joined the Board of Directors. They are expected to bring to the Alliance a more application-centric focus, which will be instrumental in achieving the promise of product and vendor interoperability.

Although the ZigBee Alliance used to be so far very US-centric, membership has significantly grown in Europe and Asia. Supporting companies are now spread all over the world.

### What are the typical applications promoted by the ZigBee Alliance?

Since its inception ZigBee technology has been designed as a general-purpose low-data rates, low-power wireless solution. Contrary to competing technologies (such as Z-Wave, which focuses on home control), ZigBee has a very wide application scope. Typical examples include home automation (lighting, heating, closures, security, access to set-top boxes), building automation (lighting, HVAC, smoke detection, access control), industrial monitoring, automatic meter reading, environmental data collection, and medical sensing.

**Which ZigBee Alliance members are active in residential and building automation?**

Control4, Danfoss, Eaton, Grundfos, Hitachi, Honeywell, Hubbell, Invensys, Johnson Controls, Legrand, Marlin Controls, Mitsubishi Electric, Nice, Niko, Philips, Schneider Electric, Siemens, Trane, Urmet Domus, Vantage Controls, Viconics, and Yamatake.

**Which ZigBee Alliance members are active in industrial automation?**

Crane, Eaton, Grundfos, Hitachi, Honeywell, Invensys, Legrand, Mitsubishi Electric, Omron, Schneider Electric, Siemens, Yamatake, and Yokogawa.

**Which ZigBee Alliance members are active in automated metering?**

Holley Metering, Itron, and Schneider Electric.

## ZigBee Standard

**What does the ZigBee standard include?**

The ZigBee standard specifies a full protocol stack for enabling wireless control applications (*Figure 1*). The lower layers (physical and medium access) comply with IEEE 802.15.4. On top ZigBee specifies a network layer (for managing network formation, addressing, routing) and an application layer (for managing device models, application bindings, application objects). Standardized device activation and configuration procedures are provided by a commissioning framework.

Functionality and interoperability of the protocol stack are governed by a set of rules called stack profile. A stack profile specifies, for instance, which addressing mechanism is used and which level of security the application shall implement.

At the application layer, interoperability is ensured through public application profiles, i.e. collections of device descriptions specified by the ZigBee Alliance and that collectively form a distributed application. Product manufacturers can also choose not to share their device descriptions and make use of private application profiles, which means they will not be interoperable with other vendors.

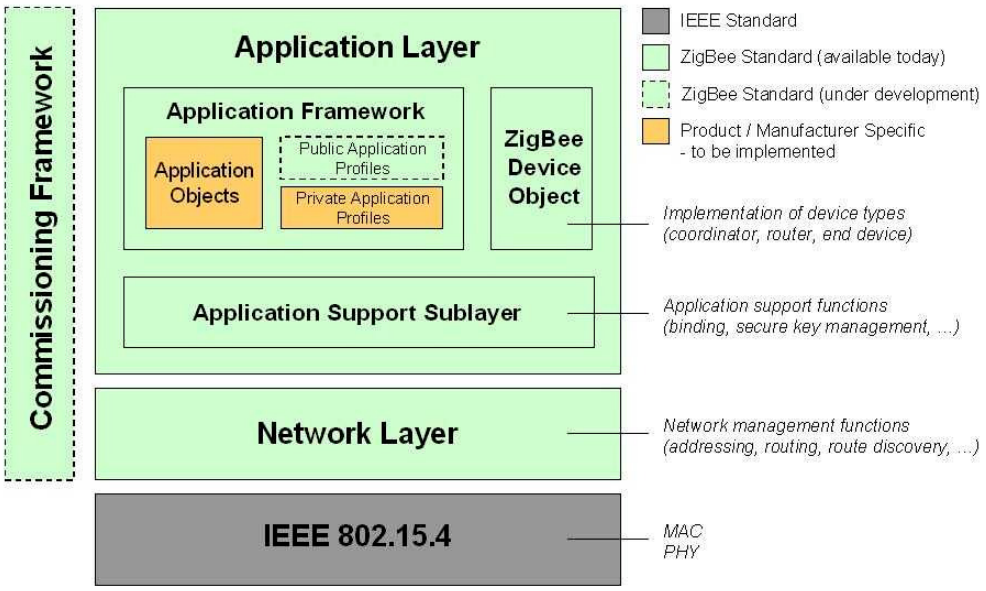


*Figure 1 - ZigBee Protocol Stack*

### Are there several ZigBee versions?

Currently, the public revision of the specification is ZigBee 1.0 (dated December 2004). It includes the network layer, the application layer, and the 'Home Controls, Lighting' (HCL) application profile (which will be superseded by a new profile in the next revision). ZigBee 1.0 does not include any commissioning recommendations, nor does it specify any particular stack profile since only tree addressing is defined.

The next public revision of ZigBee is 1.1, which should be available by end 2006. It will include advanced features allowing to depart from current limitations imposed by tree addressing and centralized binding. New application profiles, along with corresponding commissioning frameworks, will also be released.

Some vendors, such as Ember, provide ZigBee stacks that are ahead of the current specification. Advanced features are then often brought to the ZigBee Alliance to be included in the next official revision.

### What are the various ZigBee stack profiles?

ZigBee 1.1 will include two stack profiles:

- 'ZigBee' (formerly 'Home Controls') targets simpler, smaller networks that typically operate in a residential environment. Addressing is performed in a tree fashion, security implementation is fairly simple, and application bindings take place in the coordinator in a centralized manner. The corresponding specification is now complete.
- 'ZigBee Pro' (formerly 'Commercial, Industrial and Institutional') targets larger and more sophisticated networks. Addressing and routing are more scalable, security is more robust, and advanced features such as multicast are included. Also, 'ZigBee Pro' aims at providing minimal reliance on the coordinator through distributed application bindings. The corresponding specification should be complete by end 2006.

### What are the various ZigBee application profiles?

ZigBee 1.0 includes the 'Home Controls, Lighting' (HCL) application profile, which provides basic definitions for simple residential lighting applications.

ZigBee 1.1 will include additional application profiles:

- 'Home Automation' (HA) replaces and expands HCL. It relies on 'ZigBee' stack profile and defines a set of devices for use in home environments: switches, thermostats, window shades, radiators, etc. The corresponding specification is almost complete.
- 'Commercial Building Automation' (CBA) targets large building systems and relies on 'ZigBee Pro' stack profile. The specification includes device descriptions for lighting and HVAC management, for instance. It should be available by end 2006.
- 'Industrial Plant Monitoring' (IPM) includes device definitions for sensors and actuators used in industrial control: temperature, pressure, infrared, etc. The corresponding specification should be complete by end 2006.

Other ongoing initiatives cover additional applications within the scope of ZigBee:

- 'Wireless Sensor Applications' (WSA) will provide features for decreasing power consumption in router devices and allow them to be in sleeping mode.
- 'Telecom Applications' (TA) will address new scenarios around the use of mobile phones in residential or tertiary environments.
- 'Automatic Meter Reading' (AMR) targets metering applications but is today on hold.

### What is the ZigBee Cluster Library (ZCL)?

The ZigBee Cluster Library (ZCL) is a significant addition to revision 1.1. In ZigBee, a cluster is a message or collection of messages pertaining to a given application domain. Some devices (such as on/off switches) have the same definition and functionality whatever application profile is used. The idea behind creating the ZCL was to provide cluster reusability by abstracting clusters across several application domains and placing them in a library organized according to functional domains (e.g., lighting, closures, HVAC).

### What is the ZigBee Commissioning Framework (ZCF)?

The purpose of the ZigBee Commissioning Framework (ZCF) is to specify standardized ways of forming and configuring ZigBee networks. This includes the definition of general commissioning modes (fully automatic, with or without commissioning tool) and consistent procedures to activate ZigBee devices. The ZCF will be available in revision 1.1 and comes together with HA and CBA application profiles.

### What are the various ZigBee certification mechanisms?

The ZigBee Alliance has defined three certification levels:

- The ZigBee Compliant Platform (ZCP) certification is available today for hardware and software technology providers. So far 13 vendors have had their ZigBee platform certified.
- The ZigBee Network Capable (ZNC) certification targets products that make use of a private ZigBee application profile in addition to a compliant platform. The policy is being designed to allow easy self-certification and the use of a logo.
- The ZigBee Certified Product level provides interoperability with other vendors since it requires the use of a public ZigBee application profile in addition to a compliant platform. A specific test plan comes along each public application profile released by the ZigBee Alliance.

## Technical Issues

### Is it possible to deploy ZigBee networks in sub-GHz bands?

Yes, it is. ZigBee can use IEEE 802.15.4 physical interfaces transmitting at 868 MHz or 915 MHz. Data rates are reduced to 20 kbps and 40 kbps, respectively. The rest of the protocol stack is the same as in ZigBee implementations at 2.4 GHz.

### What is the typical communication range of ZigBee?

Range depends on a number of factors including the surrounding environment, transceivers' characteristics, antenna design, output power, etc. Some of these parameters can be optimized to increase the range in specific propagation conditions. Using today's off-the-shelf ZigBee radios at a nominal output power of 0 dBm, typical values are 10 to 50 m indoor and about 100 m outdoor, more in case of perfect line-of-sight.

### Does WiFi represent a significant risk of interference for ZigBee?

In the 2.4 GHz band WiFi may interfere with ZigBee. When physical distance and frequency separation between WiFi and ZigBee devices are small enough, the quality of ZigBee links can deteriorate and entail errors and retransmissions. Experimental results (see for instance wireless.industrial-networking.com/articles/articledisplay.asp?id=765) suggest that the ZigBee packet error rate never reaches 100%, even in worst-case traffic load conditions (WiFi FTP or media streaming).

One mitigation technique is to permit ZigBee devices to switch to another frequency channel whenever an interferer has been detected. This feature is foreseen to be part of revision 1.1. Another solution is to enforce appropriate deployment rules. Additional experiments (check for instance www.freescale.com/files/rf_if/doc/app_note/AN2935.pdf) suggest to have at least 2 m and 30 MHz offset between ZigBee and WiFi transceivers.

### Is multipath fading a chief concern for ZigBee?

Multipath fading impacts all wireless transmissions. Resulting radio signals reach the receiving antenna by several paths, leading to signal interference and phase shifts that can cause errors and affect the link quality. This phenomenon tends to be overlooked in mesh networks since data packets can travel through alternative routing paths in case of communication failure. While multipath fading may not be a concern for densely meshed ZigBee networks, it surely is for single point-to-point links.

### What is the typical battery lifetime of ZigBee end devices?

Battery lifetime is a function of many parameters such as battery type, capacity, duty cycling and end-use application. Different radios and micro-controllers feature different levels of power consumption, which ultimately affect battery lifetime. Today's off-the-shelf ZigBee components operating under low duty cycles allow for typical lifetimes comprised between 5 and 10 years. Applications like automatic meter reading that require even sparser transmissions may exceed 10 years.

Further improvements in power consumption are foreseen with the increasing availability of single-chip ZigBee solutions (integrating the radio and the micro-controller on the same chip).

### Is it possible to have battery-powered ZigBee routers?

ZigBee routers are today assumed to be mains-powered. The low-power router functionality is expected to be part of the ZigBee specification in the near future. This initiative is driven by the 'Wireless Sensor Applications' (WSA) work group.

### Does the ZigBee coordinator represent a single point of failure?

All ZigBee networks require a coordinator, which is responsible for network formation. In ZigBee 1.0 and in 'ZigBee' stack profile, the coordinator additionally hosts the binding table and this way becomes a weak point. Mechanisms to deal with coordinator breakdowns (such as duplication of the binding table) are implementation issues and out of the scope of revision 1.0.

ZigBee 1.1 will host mechanisms to deal with coordinator failures and manage decentralized binding tables. The coordinator will not be anymore at risk of becoming a single point of failure.

### How is addressing performed in ZigBee?

In ZigBee 1.0 and in 'ZigBee' stack profile, nodes are logically organized as a tree. Routers branch out in a tree-like manner from the coordinator, with end devices typically being sleepy devices. Addressing is performed hierarchically by following the tree structure.

In 'ZigBee Pro' stack profile, there is no logical tree structure. Network addresses are randomly attributed, with potential address conflicts resolved subsequently.

### How is routing performed in ZigBee?

In ZigBee 1.0 and in 'ZigBee' stack profile, routing is initially performed deterministically, along the branches of the tree structure. Tree routing means that resulting routes are sometimes indirect and assumes that the network topology is static. As a second step, table routing can be used to shortcut the tree and discover new routes.

In 'ZigBee Pro' stack profile, only table routing is allowed. Along a route, each intermediate node uses its own routing table to forward the packet to the next node, until the packet reaches its destination. For a particular destination, each node stores the next-hop information in its routing table.

### Are ZigBee networks scalable?

ZigBee's addressing scheme can support up to 65'535 nodes per coordinator, and multiple coordinators can be linked together to increase the overall size. This limit obviously is theoretical and does not guarantee proper operation of such a large network. Scalability will highly depend on the application requirements in terms of density, traffic load and acceptable latency.

With little experimental material available for very large networks, it is however safe to assume that such big networks will be adequately organized into geographical clusters. Building on the ongoing ZigBee Alliance's work regarding IP gateways, one can also imagine linking several ZigBee networks through high-speed IP backbones that already exist in many environments.

### Are ZigBee networks secure?

The ZigBee specification includes provisions for security and data integrity based on access control lists, packet freshness timers and 128-bit AES encryption. It is fairly safe to expect that these are adequate for residential and most commercial and industrial applications.

### Is ZigBee compatible with IP?

As of today the ZigBee specification does not include any IP layer. Connection to IP-based networks can be achieved in two different ways:

- Implementation of dedicated gateways. Enhancements to the protocol stack are currently being designed within the ZigBee Alliance to facilitate interfacing ZigBee networks to the IP world.
- Insertion of a specific IP layer in the protocol stack, in a similar manner as in the 6LoWPAN initiative (www.ietf.org/html.charters/6lowpan-charter.html). Work ongoing in the ZigBee Alliance aims at enabling the transmission of IPv6 packets over ZigBee networks.

### Does ZigBee have a transport layer?

No, the ZigBee specification does not define a transport layer. Since most ZigBee data exchanges target simple and small messages, the question of ensuring end-to-end data delivery has been left to the product vendor. The latter can choose to include that capability as part of its application.

Some stack vendors, such as Ember, provide an additional transport layer that guarantees reliable end-to-end messaging and simplifies application development. This feature is however not specified in the standard and will therefore be used in combination with private application profiles.

### Will products based on different ZigBee stack profiles be interoperable?

No, they will not. 'ZigBee' and 'ZigBee Pro' stack profiles do not rely on the same addressing and routing schemes, which prevent interoperability.

## Market Acceptance

### Is ZigBee a competitor for Bluetooth?

ZigBee and Bluetooth have been developed to serve different application spaces. Bluetooth targets higher data rates and better QoS to transport richer media (typically voice signals). ZigBee conveys much simpler messages across more scalable networks that require very low duty cycling without close synchronization.

### Is ZigBee a competitor for WiFi (IEEE 802.11b/g)?

ZigBee and WiFi clearly address very distinct application requirements. Cost and power consumption patterns of WiFi cannot fit wireless control needs, whereas ZigBee's bandwidth is by far too low to transmit large data flows.

### Is ZigBee a competitor for Z-Wave?

ZigBee competes with Z-Wave in the home automation space. As a technology focused on the home control segment exclusively, Z-Wave has been faster than ZigBee in bringing its protocol stack to the market. While Z-Wave is a single-source technology, ZigBee enjoys multi-sourcing and relies on an IEEE standard. In addition, ZigBee provides higher data rates and operates in both 2.4 GHz and sub-GHz unlicensed bands.

# ZigBee FAQ

**Are there yet ZigBee products on the market?**

Yes, there are. Some implement an actual ZigBee stack while others feature a ZigBee-ready platform like EmberNet.

Examples in the residential space include Control4 (lighting), Eaton (home automation), Golden Power Manufacturing (sprinklers and thermostats), Hawking Technology (home gateways), Kalirel (heating), Mija (fire extinguishers), Nice (shutters), and TSC Systems (home automation).

Examples in the commercial space include Mija (fire extinguishers), Philips (lighting), Siemens (building automation), and TAC (building automation).

**Which companies have performed ZigBee interoperability tests?**

The vast majority of ZigBee Compliant Platform (ZCP) providers have participated in such events called ZigFest. So far, an average of 12 companies has been involved in ZigFest meetings every quarter.

**Is there any risk related to third-party intellectual property?**

I am not aware of any particular risk. If you are, let me know.