ZigBee has attracted significant attention largely due to its promise to deliver a global specification for reliable, cost-effective, low power wireless communications. In just a few years time, the ZigBee Alliance has made significant strides in advancing ZigBee’s position in today’s wireless device market. The Alliance has grown to include over 200 member companies. ZigBee chipsets and stacks have become readily available from a variety of vendors. And, last year saw the emergence of the first ZigBee-certified end products in the market.

By carefully defining the network and application layers in the ZigBee specification, the ZigBee Alliance hopes to enable independent device manufacturers to develop unique end products that can interoperate with each other. Members anticipate a high demand for ZigBee chipsets, which should reduce the cost to OEM developers. This, in turn, will yield lower-cost end products for systems integrators and end users.

**ZigBee networks**

ZigBee defines three node types – a co-ordinator, routers, and end devices. The co-ordinator can start a ZigBee network by selecting the operating channel and personal area network identifier (PAN ID) of the network. Once the network is started, routers and end devices can join the network. Both the co-ordinator and routers can send and route data through the network, and allow other routers and end devices to join to them. End devices do not participate in routing data and can therefore sleep when they are not transmitting or receiving data.

When a device joins a ZigBee personal area network (PAN), a parent-child relationship is formed between the device that joined (child), and the device that allowed the join (parent). A simple ZigBee network is shown in Fig. 1.

**ZigBee addressing**

ZigBee devices support two address types: a 64-bit IEEE address and a 16-bit network address. The 64-bit address is unique among all ZigBee devices and contains a unique 24-bit manufacturer-specific organisational unique identifier (OUI) assigned by the IEEE. When a device joins a ZigBee PAN, it receives a 16-bit network address from the device to which it is joined (its parent). The network address is intended to be unique within the PAN. Network addresses are used in data transmissions and packet routing. Routing tables, which are used to route data packets, store the network addresses of each destination device and the next hop device. It is therefore essential that network addresses are known and unique among devices in a PAN to ensure data reaches the correct device.

**ZigBee routing**

ZigBee includes a basic framework for ad-hoc on-demand distance vector (AODV) mesh routing. If a device must transmit data to another device, it can first discover a route to reach the destination device. Mesh routing allows paths to be dynamically created, repaired, or replaced to help maintain a reliable path between devices.

In addition to mesh routing, however, the ZigBee specification frequently relies on tree routing. In tree routing, data is strictly routed from parent to child, or child to parent, across the “tree” from the source device to the destination.

Tree routing can be problematic in applications where nodes can move or go down. If a single node fails part-way through a route, tree routing will be unable to get around the point of failure. Mesh networking, on the other hand, has the ability to discover a new route if an existing route fails.

ZigBee stacks built around the ZigBee 1.0 specification regularly used both tree and mesh routing. The interaction between the two was quite complicated and varied between stacks. However, the Enhanced ZigBee specification (2006) recently added a nwktUseTreeRouting attribute that can disable tree routing entirely, and a network layer management (NLME) route-discovery-request primitive to force route discovery as needed. These features can remove the problems associated with tree routing and allow developers to take full advantage of mesh routing.

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**Fig. 1: Simple ZigBee network.**
ZigBee interoperability

The ZigBee specification includes provisions that can be used to define various types of networks. The developer can easily configure parameters such as:

- Number of routers and/or end devices in their target system
- Level of security
- Routing table and neighbour table sizes
- Maximum network depth (join depth from the co-ordinator to the most distant descendent device)
- Maximum number of child routers and end devices that a co-ordinator/router parent will allow

The ZigBee Alliance has developed public profiles that establish common settings for these different stack-settable parameters. The profile also defines interfaces called cluster IDs to accomplish common tasks within the profile (i.e. the home controls stack profile defines cluster IDs to turn on, turn off, or toggle a light).

End products must be designed around the same profile to be interoperable. Thus, an application developer must set their stack parameters to match the specified values of a public profile to ensure interoperability with other solutions that use the same profile. Alternatively, the developer can freely modify the stack parameters to fit their own design by implementing a private (custom) profile. Cluster IDs defined within the scope of a private profile will not be interoperable with public profile-based devices.

Since developers have flexibility in selecting a profile, not all ZigBee devices are interoperable. This flexibility in the specification, while it may cause some initial market confusion, allows developers to decide if their application should interoperate with products from other vendors, or not. In cases where interoperability is not required, powerful ZigBee solutions can be developed around a private profile, tailoring the stack parameters to fit the specific needs of an application.

ZigBee applications

There is a wide and varied range of applications for which ZigBee is suitable. These include residential, commercial and industrial applications. ZigBee modules have been used for lighting controls, smoke and CO2 detectors, HVAC controls, home security, and automatic utility meter readings in residential and commercial use. Other examples include monitoring of medical equipment, building and industrial automation, environmental controls, and even communicating between a remote control and a digital set-top box.

These examples are only a sample of the virtually limitless applications of ZigBee modules. This is thanks to ZigBee’s small size and low level of power consumption, permitting wireless to be added to many devices that would have been impractical using other wired or wireless technologies.

Summary

While ZigBee faces some significant issues in the future, the ZigBee Alliance has great momentum, experienced leadership, and a large pool of talented designers contributing to the advancement of the standard. Even in its infancy, important groundwork has been laid in the ZigBee specification that provides a strong networking layer and application flexibility for the designer.

With a strong consortium of leaders in the embedded device space, ZigBee is on its way to becoming a big player in the embedded device market. Provisions are currently being discussed by the ZigBee Alliance to add greater value and address many of the remaining unresolved issues in the ZigBee specification. Modules and networking stacks are beginning to emerge that are ZigBee certified, that offer powerful mesh solutions, and that effectively address many, if not all, of the current ZigBee limitations. With more ZigBee platforms, tools, and certified end products entering the market, now is the time to begin developing reliable, low power, cost-effective ZigBee-based solutions.

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