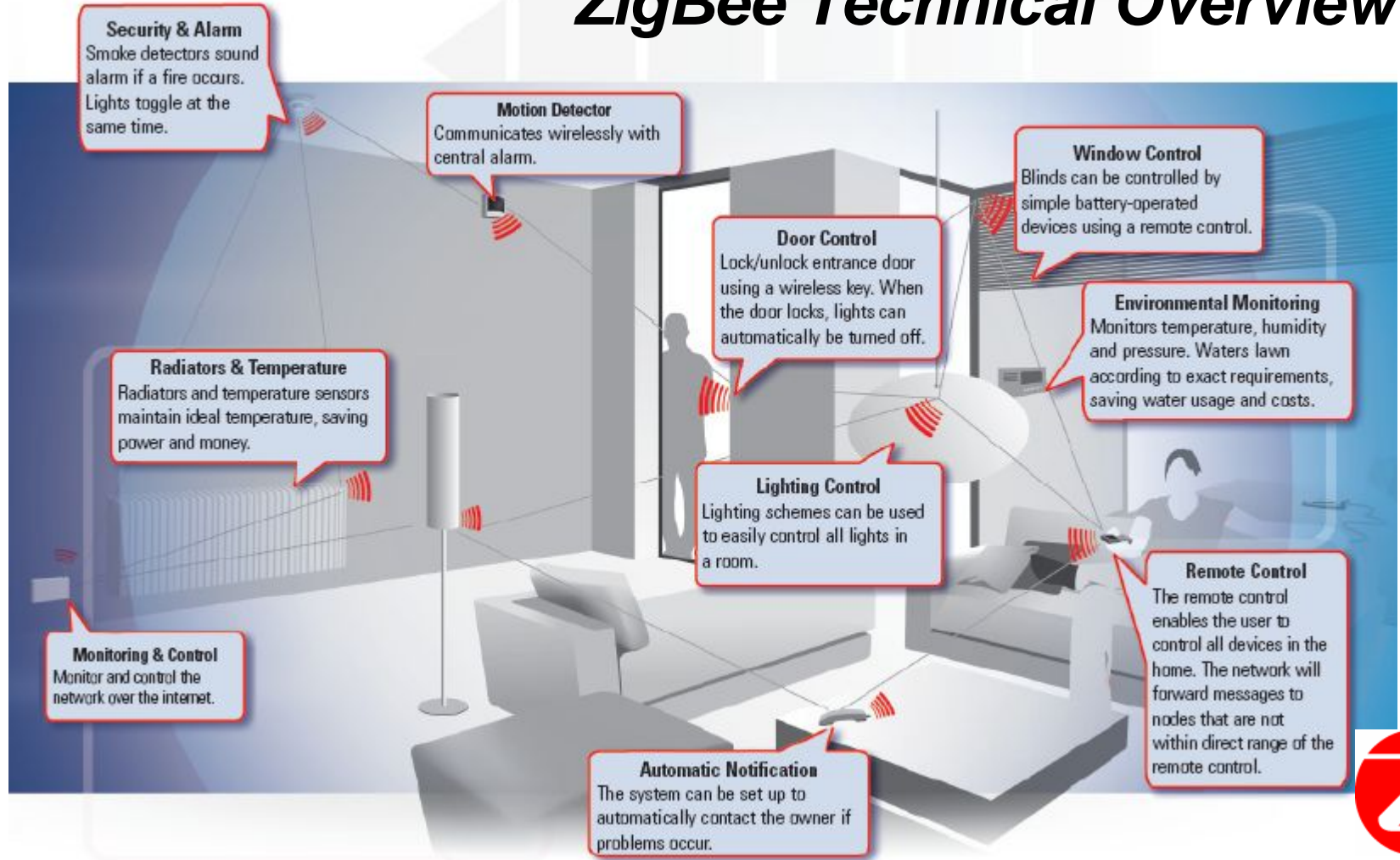


TI Low Power Wireless

ZigBee Technical Overview



Overview

ZigBee overview

Hardware

Topology and routing

Stack and application profile

Design process

Certification

Requirements

ZigBee Alliance

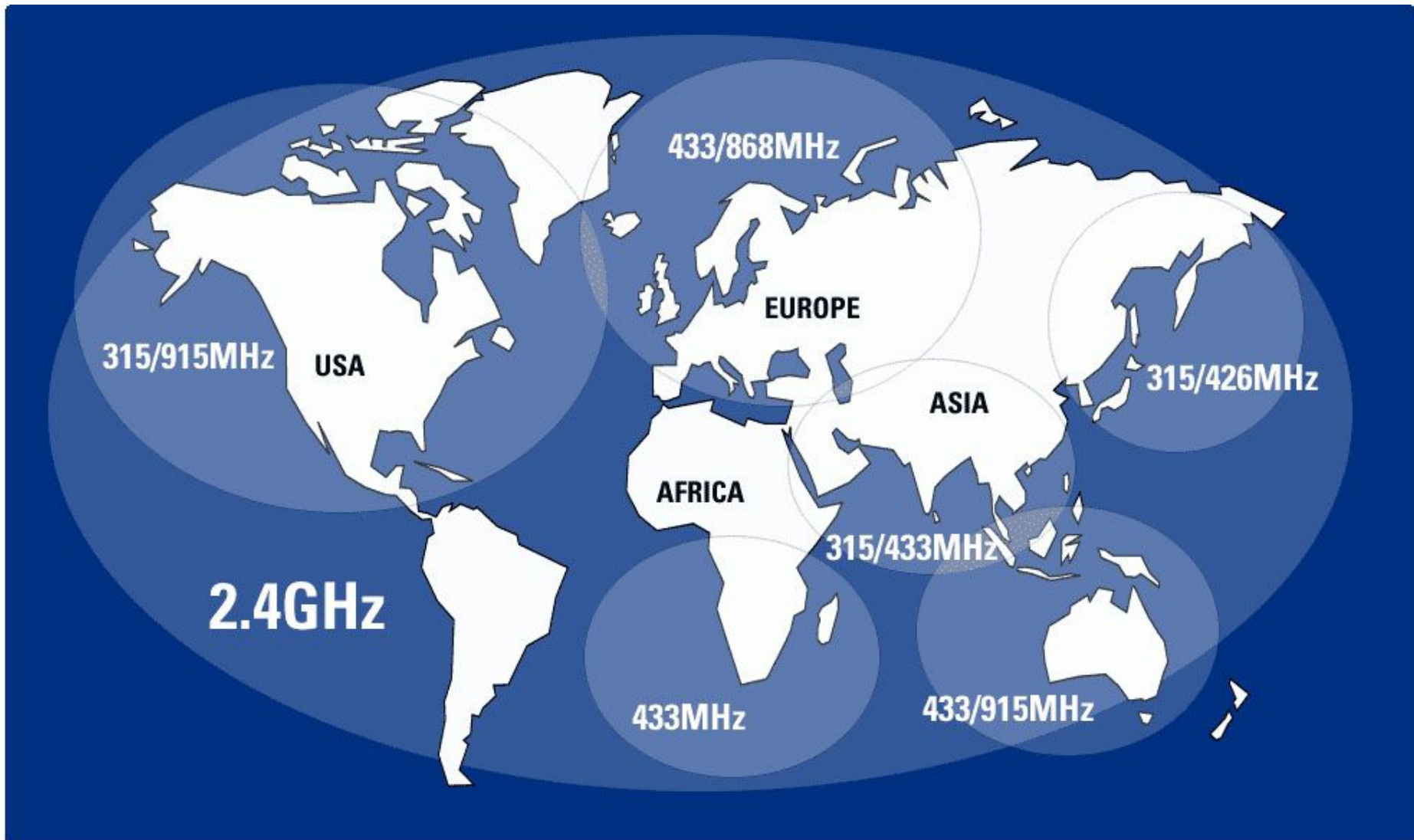
“The ZigBee Alliance is an association of companies working together to enable reliable, cost-effective, low-power, wirelessly networked monitoring and control products based on an open global standard”

Source: ZigBee Alliance homepage

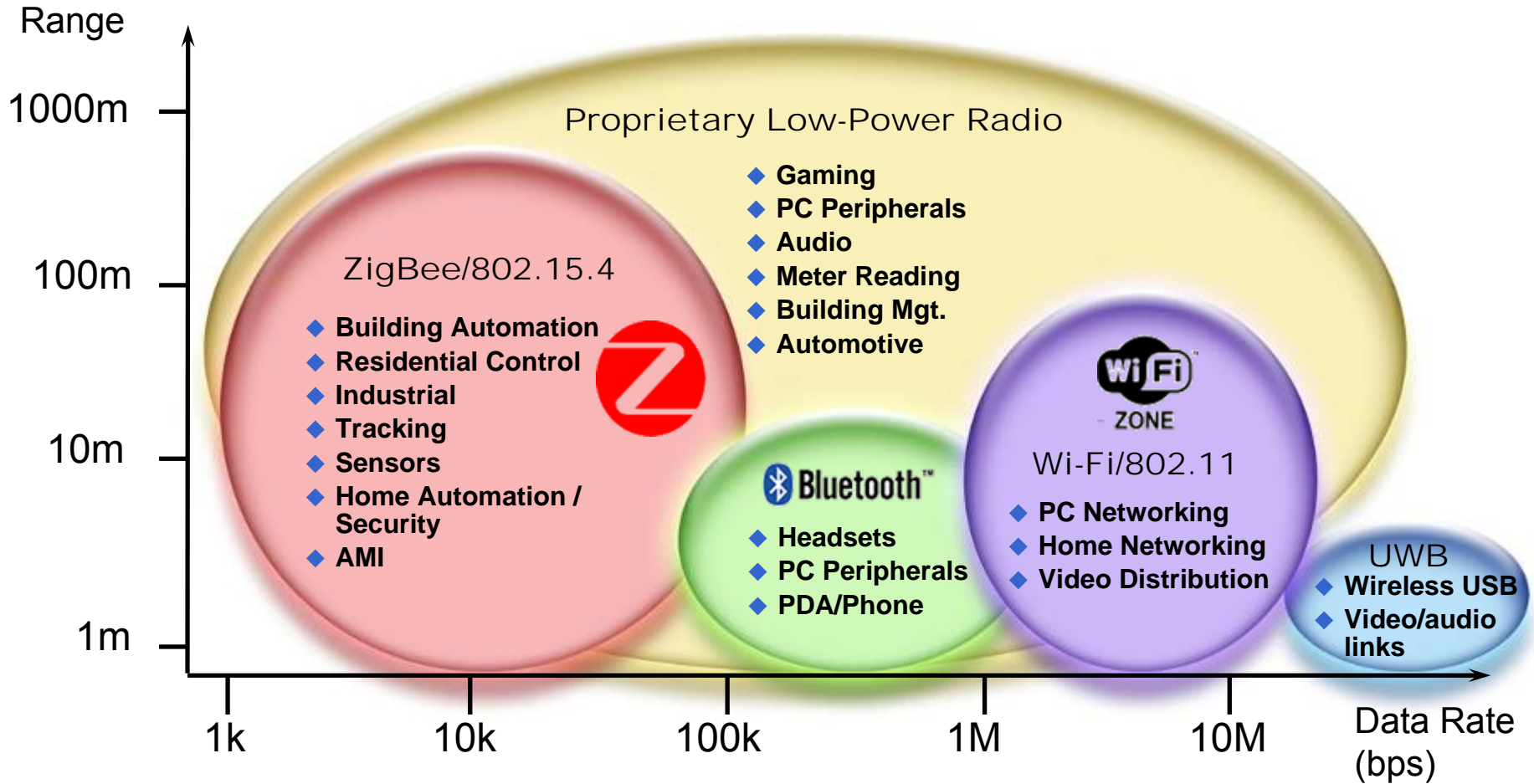
Promoters of the ZigBee alliance are:



Global Frequencies



Short Range Wireless



Application Examples

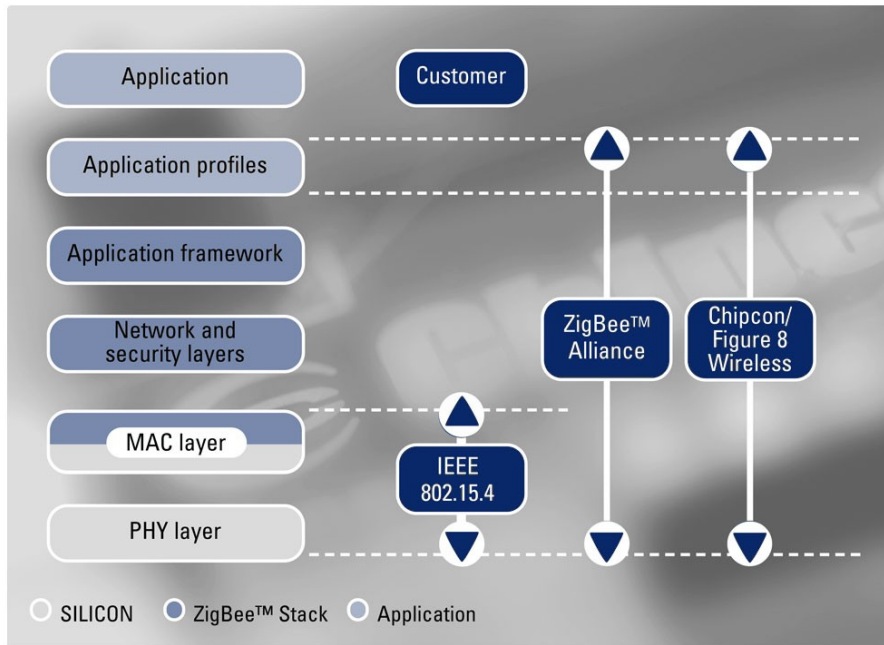
HOME AND BUILDING AUTOMATION

CONSUMER ELECTRONICS



AND MORE: MEDICAL, ENVIRONMENTAL MONITORING, ASSET TRACKING, ...

ZigBee™ Overview



- Application
- ZigBee™ Stack
 - Network functionality
- IEEE 802.15.4
 - Physical layer/Radio
 - Standardized point to point link

- Self healing (Mesh networks)
- Very long battery life (many years on AA batteries)
- Low node cost
- Easy to deploy (low installation cost)

- Supports large networks (hundreds of nodes)
- Intended for monitoring & control applications
- Standardized protocol (interoperability)

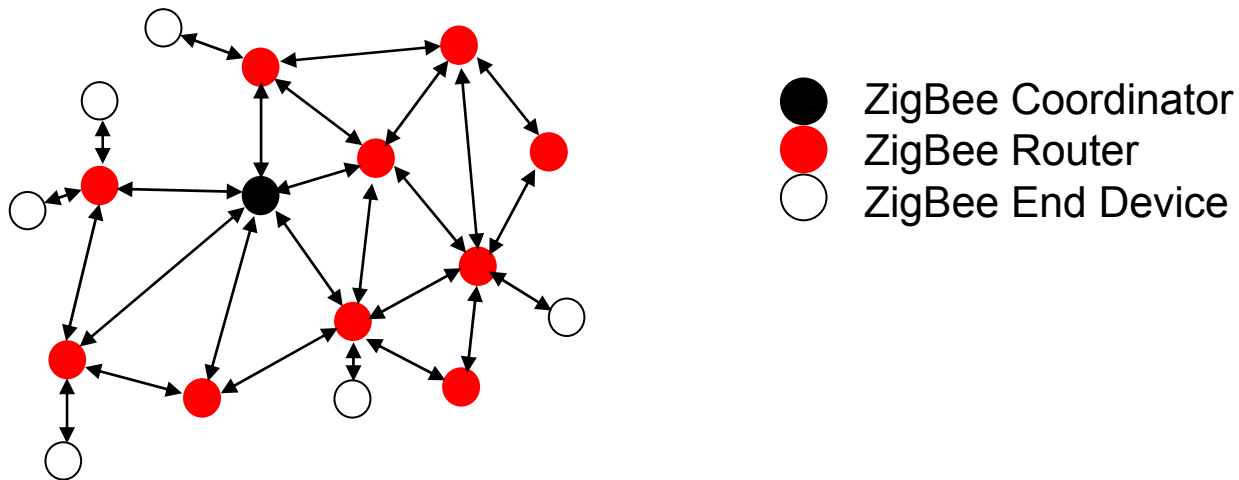
Alliance Roadmap

- IEEE 802.15.4-2003 defines PHY/MAC
- ZigBee-2006
 - Product shipping today
- ZigBee-2007
 - Two stack profiles: ZigBee and ZigBee PRO
 - 3 golden units have passed certification
- Profiles
 - Home Automation (HA)
 - Profile released and tested
 - Advanced Metering Infrastructure (AMI)
 - Profile released. Testing to complete in by Q2 '08
 - Commercial Building Automation (CBA)
 - Under development. To be finalized by end '08.

ZigBee-2006

Benefits to Consider

- Extremely well tested by a variety of companies
- Base of products and networks on market and in use today!
- Many certified stacks and silicon providers available
- Simple = less code & less overhead



ZigBee-2007: ZigBee and ZigBee PRO

- ZigBee
 - Based on proven 2006 feature set plus frequency agility and optional fragmentation
 - Basic features require less memory
- ZigBee PRO
 - Enhanced features optimize performance and RAM utilization under select scenarios
 - Feature enhancements based on identified limitations of ZigBee-2006 for specific network deployments
- Profiles
 - HA and AML are defined to work with ZigBee and ZigBee PRO
 - CBA is specified to work for ZigBee PRO
- Interoperability
 - PRO devices will operate as End Devices (EDs) on a ZigBee network, and vice versa

Note: TI has ZigBee and ZigBee PRO Solutions available based on your needs

ZigBee-2007 Feature Set

ZigBee

- Tree Addressing
- AODV Routing
- Backup Tree Routing
- Fragmentation
- Frequency Agility
- Basic Group Addressing
- Security

ZigBee PRO

- Stochastic Addressing
- AODV Routing
- Many to One / Source Routing
- Asymmetric Link Handling
- Fragmentation
- Frequency Agility
- Basic Group Addressing
- Limited Broadcast Addressing
- Security
- High Security

Overview

ZigBee overview

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Topology and routing

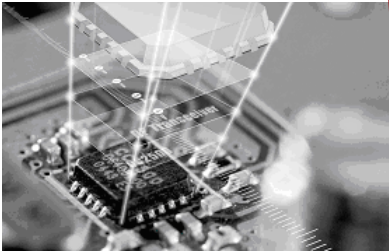

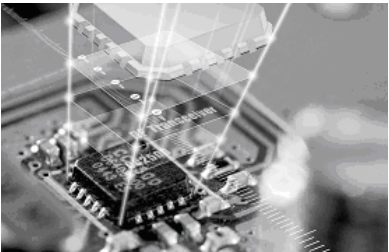
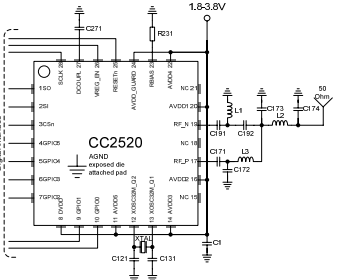
Stack and application profile

Design process

Certification

Requirements

Three paths to ZigBee

	<p><i>Small footprint High integration Available today</i></p>	<p><i>Z-Accel is flexible, easy to use and will reduce time to market</i></p>	<p><i>Ultra low power Available today</i></p>
Application & Profile	CC2430	Any Processor	MSP430
ZigBee stack - Z-Stack		ZigBee Processor – CCZACC06	
Radio			CC2520
			

CC2430 / CC2431

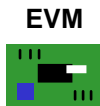
Low-Power IEEE 802.15.4 and ZigBee® SoC

Features . . .

- 32 MHz single-cycle low power MCU
- CC2430 has different flash sizes 32/64/128 KB
- Hardware AES encryption engine
- Industry leading ZigBee® protocol stack
- Excellent selectivity and blocking performance
- CC2431 includes a hardware location engine

Applications

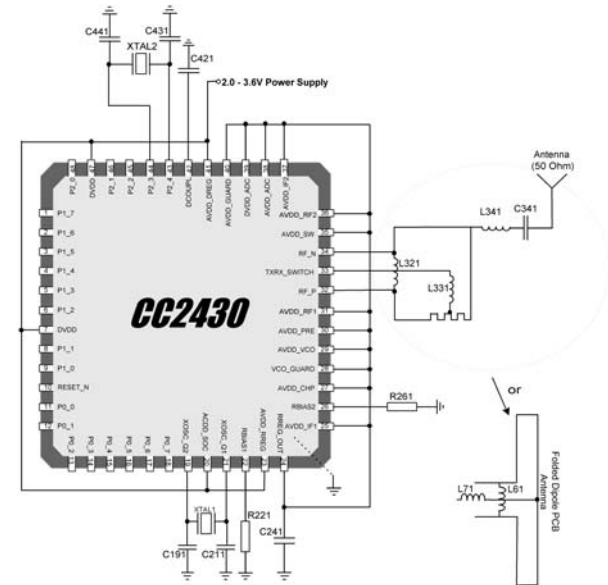
- Home and building automation
- Industrial monitoring and control
- Sensor networks
- Asset tracking / patient monitoring



CC2430DK
CC2430ZDK
CC2431DK
CC2431ZDK

. . . Benefits

- Ideal for battery operated systems
- Suitable for proprietary and ZigBee® systems
- Supports high security systems
- Standardized, robust mesh network
- Excellent co-existence with Bluetooth and WiFi
- Easily add support for locationing awareness
 - Accuracy 3-5 meters

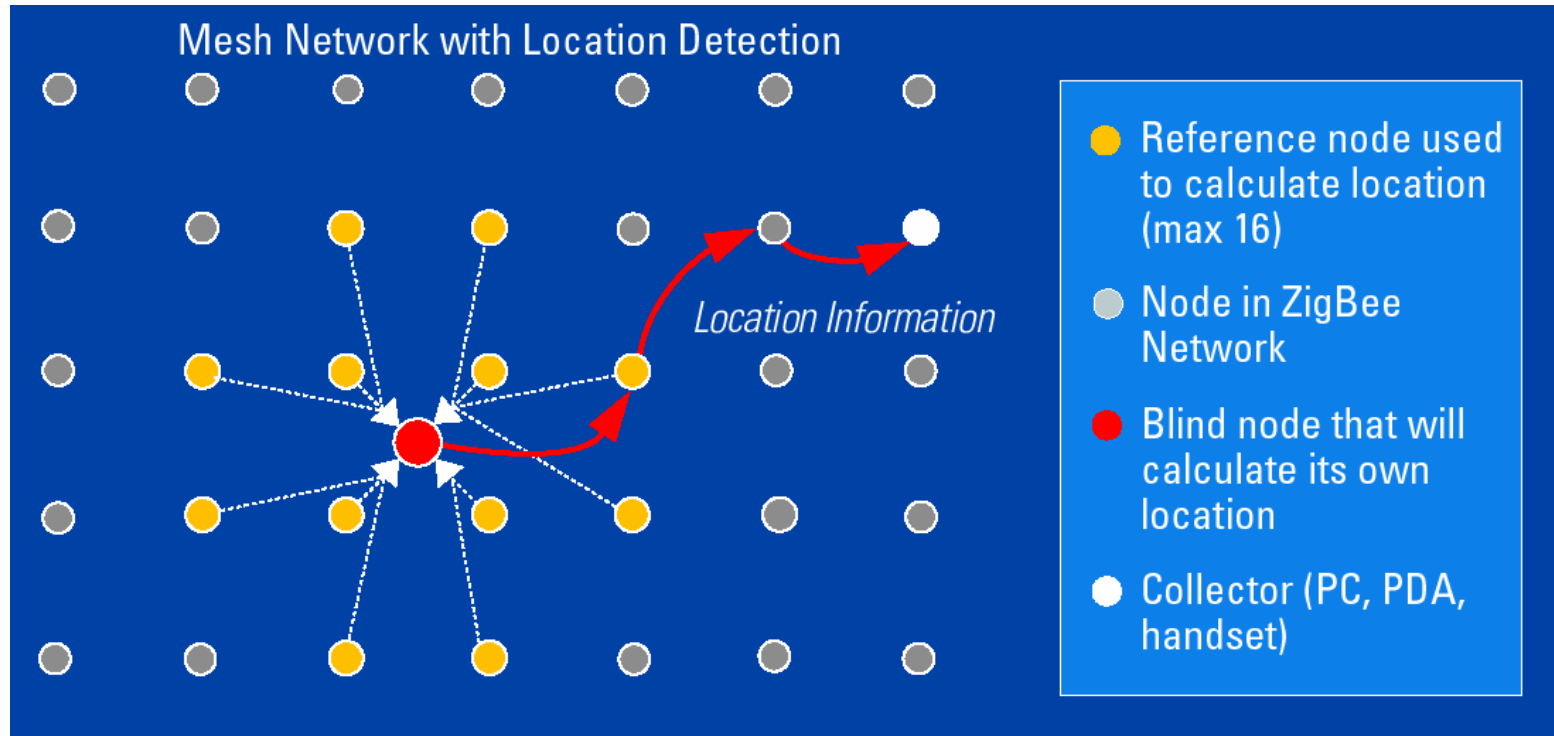


CC2430/CC2431 System on Chip



- Excellent performance
 - Low current consumption, short transition times
 - Selectivity/Co-existence
- Supported by Z-Stack
 - Supported by TI's industry leading ZigBee stack
 - Z-Stack is golden unit as TÜV Rheinland
- Well known core (8051)
 - Supported by well known development environments, e.g. IAR
 - Lots of source code available for this platform
 - Few external components, only one crystal needed
 - Many useful peripherals including USARTs, ADCs, timers etc.
 - IEEE 802.15.4 hardware support including AES128 security engine
- CC2431 - adds location functionality

Mesh Network w/ Location



Reference Node (Yellow)

- ◆ CC2430 or CC2431
- ◆ Used for locating
- ◆ Placed at known static location
 - ◆ One node for each 100 m²
- ◆ Provide signals for blind nodes

Blind Node (Red)

- ◆ CC2431
- ◆ Collects RSSI and coordinates
- ◆ Calculates its own position

Improving accuracy of CC2431

- To improve accuracy the implementor can:
 - Take an average over several RSSI readings
 - Remove obviously incorrect values (E.g. remove min and max values)
 - Add more reference nodes (3-16 can be used)
 - Filter on coordinates (Max velocity for node often known)
 - Use antennas with well known performance
 - Include output power information to reference nodes' beacons (can be done during production testing)
- Using the above mentioned suggestions an accuracy of down to 5 m could be achieved in good RF environments

CC2520

Second generation 2.4 GHz ZigBee®/IEEE 802.15.4 RF transceiver

Features

- Best-in-class co-existence and selectivity properties
- Excellent link budget (103dBm)
- Extended temperature range
- AES-128 security module
- CC2420 interface compatibility mode

Applications

- IEEE 802.15.4 and ZigBee based products
- Industrial monitoring and control
- Home and building automation
- Low power RF sensor networks
- Set-top boxes and remote controls

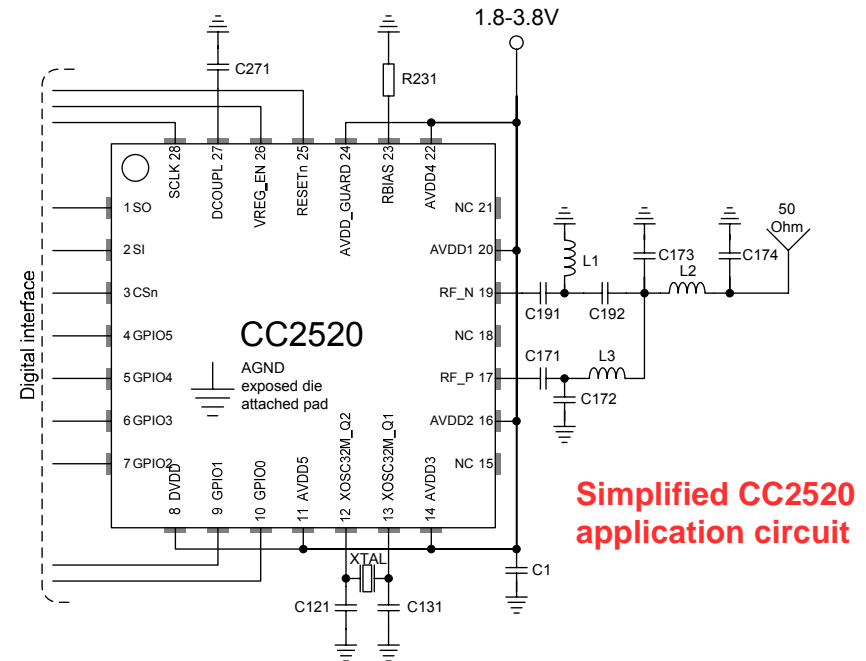
EVM



- CC2520DK

Benefits

- Reliable RF link with interference present
- 400m line-of-sight range with the development kit
- Ideal for industrial applications
- No external processor needed for secure communication
- Easy upgrade for existing CC2420 customers



Simplified CC2520 application circuit

SmartRF05

Development Platform

SmartRF05 is the next generation development platform from Low Power Wireless

- Designed to operate with MSP430 plug-in boards
 - CCMSP-EM430F2618
- Base board and plug-in Boards support TI LPW radios
 - CC2420, CC2430
 - CC1110, CC2510
 - CC2500, CC1100, CC1101
 - CC2520



CCZACC06A1

Z-Accel 2.4 GHz ZigBee[®] Processor

Features ...

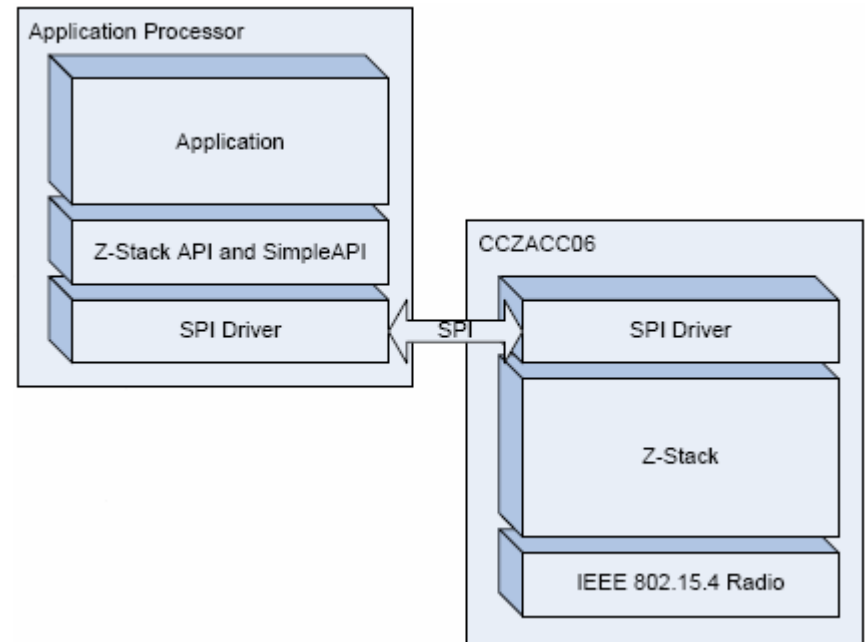
- Standard SPI or UART interface
- ZigBee Compliant Stack
- Configurable device type and network settings
- Industry leading ZigBee[®] protocol stack
- Excellent selectivity and blocking performance
- Simple API makes development easy

Applications

- Home and commercial building automation
- Industrial monitoring and control
- Sensor / actuator networks
- Asset tracking

... *Benefits*

- Flexibility to choose a host processor
- Simplify and shorten product development time
- ZigBee certified stack
- Ideal for battery operated systems
- Standardized, robust mesh network
- Excellent co-existence with Bluetooth and WiFi



EVM



eZ430-RFZACC06 Demo Kit

What is Z-Accel?

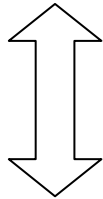
Z-Accel is a ZigBee Network Processor solution where a host microcontroller communicates with TI's CCZACC devices over SPI or UART

CCZACC06 is the first generation ZigBee certified network processor in the Z-Accel family

Z-Accel makes it SIMPLE to add ZigBee to new or existing products, and allows customers to work with their favorite microcontrollers for application development.



Host microcontroller (4kB+) for your application code



SPI or UART communication between the Host and CCZACC



CCZACC06 runs the certified ZigBee compliant Z-Stack

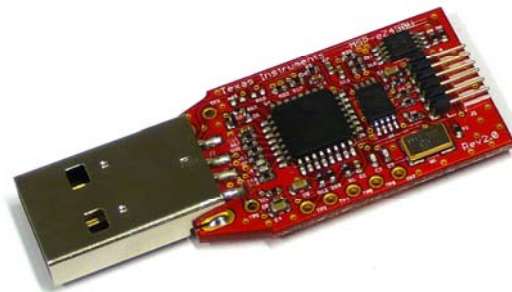
eZ430-RFZACC06 Demonstration Kit

Evaluate Z-Accel Today!

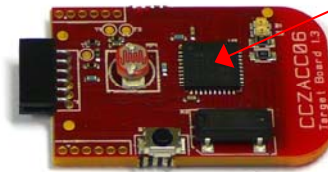
The eZ430-RFZACC06 Demo Kit

- Allows fast evaluation of Z-Accel in action
- Interfaces an MSP430F2274 to the ZigBee Processor (CCZACC06)
- Demonstrates the Simple API command interface to CCZACC06
- Available March '08

USB or Battery Powered



ZigBee Processor



MSP430F2274
(backside)

Note: Chip antenna optimizes packaging at the expense of RF performance

Overview

ZigBee overview

Hardware

Topology and routing

Stack and application profile

Design process

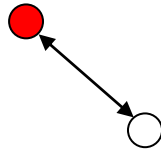
Certification

Requirements

ZigBee logical device types

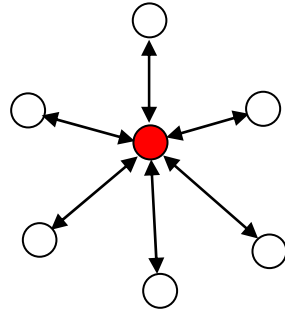
- Coordinator (IEEE 802.15.4 FFD)
 - In addition to Router functionality the coordinator should
 - Start the network
 - Act as security trust center (optional in ZigBee 2006)
 - Handle keys
 - Perform indirect binding (optional in ZigBee 2006)
 - Coordinator remembers what devices that are bound
- Router (IEEE 802.15.4 FFD)
 - Route packets
 - Handle associations
- End Device (IEEE 802.15.4 RFD or FFD)
 - Sleeps when not communicating

IEEE 802.15.4 based Networks



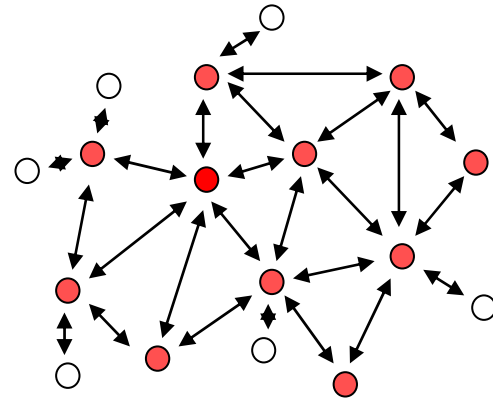
Point to Point

Proprietary or
IEEE 802.15.4
PHY + MAC



Star Network

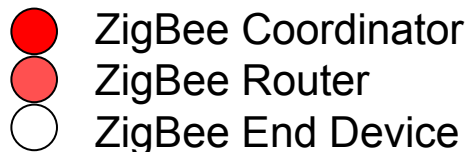
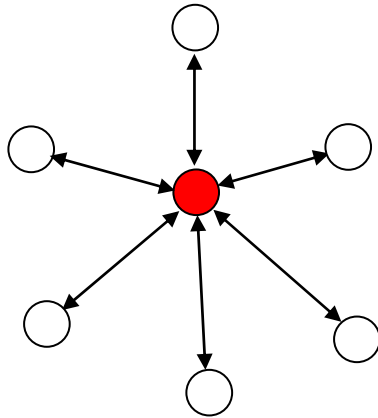
IEEE 802.15.4
PHY+ MAC



Multihop – Mesh Networks

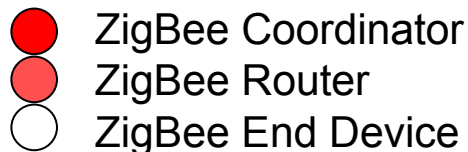
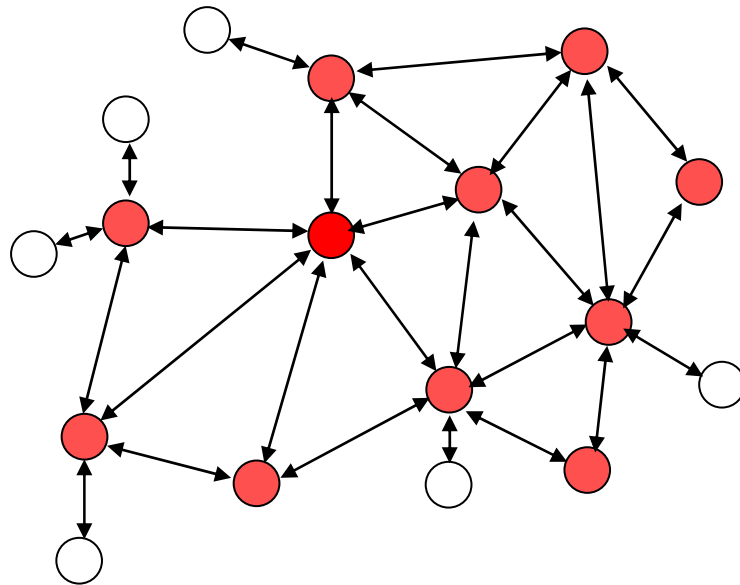
ZigBee or based on ZigBee
technology

Star Network



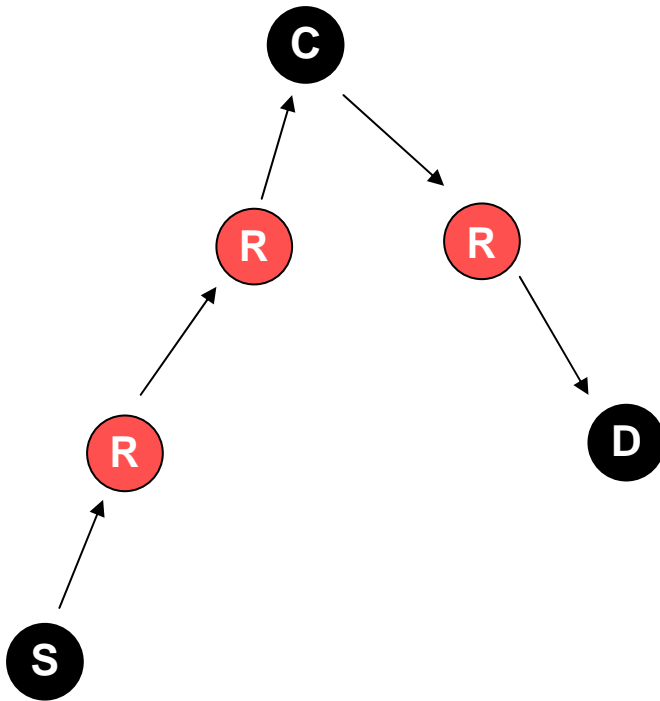
- *Pros*
 - *Simple architecture*
 - *Can be battery powered through use of beacons*
- *Cons*
 - *Not extendable (range)*
 - *End devices can only communicate through coordinator*
 - *Battery powered coordinators can not be ZigBee certified*
- *Example*
 - *Security systems*
 - *Medical*

Mesh Network



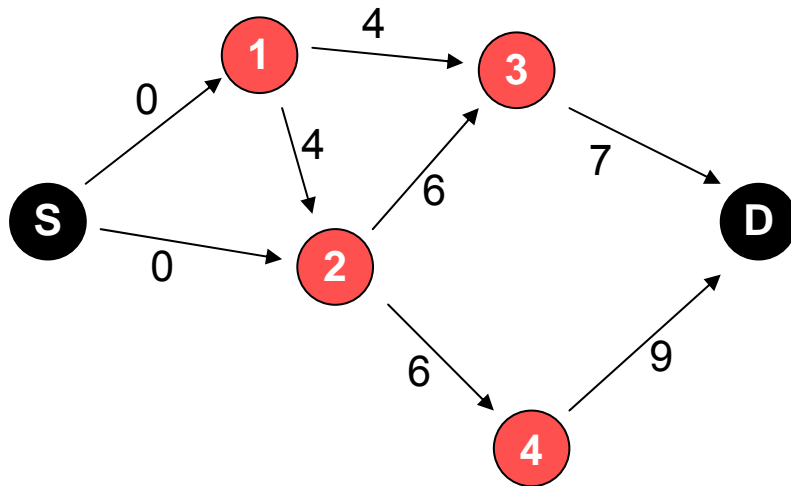
- *Pros*
 - *Self healing*
 - *Easily extendable through multiple hops*
 - *End devices can be battery operated*
 - *Easy to deploy*
 - *Can be ZigBee certified*
- *Cons*
 - *Router nodes needs to be mains powered*
- *Example*
 - *Lighting applications*
 - *Building Automation*

Tree routing - Mesh



- Routing is based on addresses
- No routing table needed
- Can cause sub optimal routes in some cases

Table routing (simplified) - Mesh



In this example the selected route will be:
S-1-3-D (link cost 7)

- Requesting device
 - Sends Route Request
- Routing device(s)
 - Adds link cost depending on LQI
 - Selects request with lowest link cost
 - Forwards the Route Request
 - Stores the information
- Requested device
 - Selects lowest link cost
 - Sends Route Response
- Routing device(s)
 - Uses stored information to route the response back

Overview

ZigBee overview

Hardware

Topology and routing

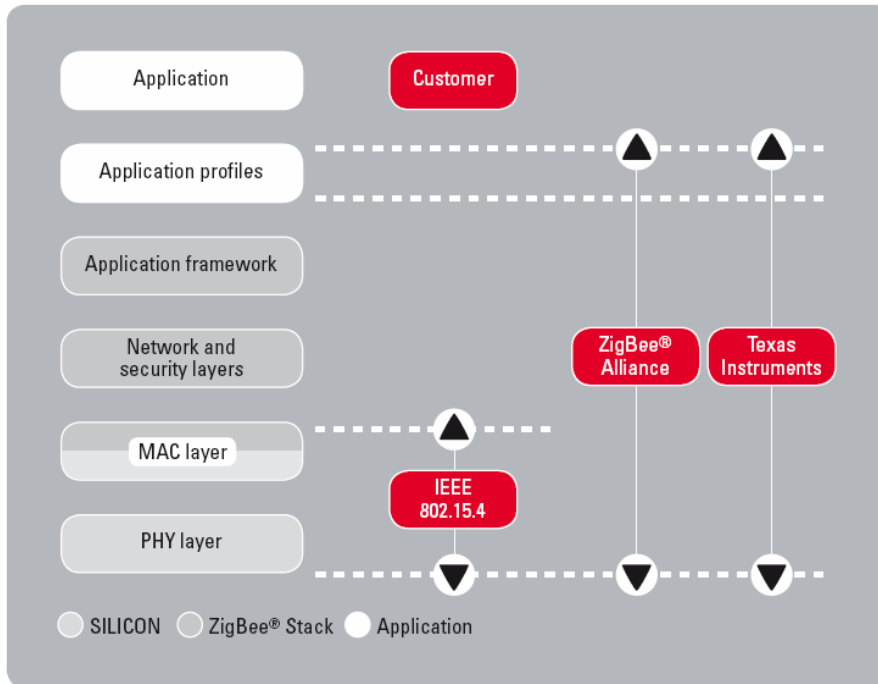
Stack and application profile

Design process

Certification

Requirements

ZigBee™ Overview



- ZigBee™ Stack
 - Application
 - Application Profiles
 - Stack Profile
 - Application Framework
 - Network & Security
- IEEE 802.15.4
 - MAC - Medium Access Layer
 - PHY – Physical Layer

Stack Profile

- What is included in a Stack Profile?
 - Topology
 - Addressing scheme
 - Routing algorithm
 - (Everything that is common to multiple applications)
- Stack Profiles available
 - ZigBee
 - ZigBee PRO (released in Q1'08)

Application Profile

- An Application Profile is used on top of a stack profile
- Example: Home Automation Application Profile based on ZigBee Stack Profile
- There are three different types of application profiles
 - Public – Approved by the alliance
 - Published – Information available but not approved
 - Private – No information is revealed about the profile
- The ZigBee Alliance distributes profile IDs

ZigBee Specification

	ZigBee 2004	ZigBee 2006	ZigBee 2007
Stack profiles	•Home Controls	•ZigBee	•ZigBee •ZigBee PRO
App profiles	•Home Controls Lighting	•Home Automation •etc	•Home Automation (HA) •Commercial Building Automation (CBA) •Advanced Metering (AMI)
Z-Stack	≤ 1.3.X	1.4.X+	2.0.X+
Available	2005	2006	March 2008

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SimpleAPI for Z-Stack

SimpleAPI has only 10 API calls to learn, which drastically simplifies the development of ZigBee applications

- Simple API simplifies:
 - Device configuration
 - Commissioning of networks
 - Binding of devices
 - Sending and receiving data
- Advanced API can still be used if needed
 - ~90% of all applications can be done with SimpleAPI

*API = Application Programming Interface (software interface)

Benefits of using SimpleAPI

- Use all the benefits of ZigBee
 - without extensive ZigBee knowledge
- Shorten time from idea to launch
 - Simple but flexible API
- Shorten learning curve
 - Documentation less than 30 pages
- Examples included with Z-Stack

ZigBee Design Process

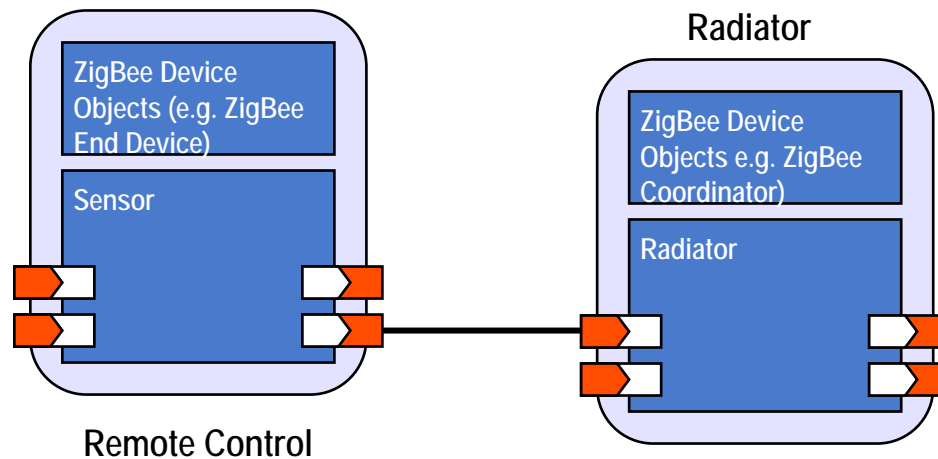
- In this example we will create a Heating application.
- It will have the following functionality:
 - Radiator that can be remotely controlled
 - Temperature sensor that is battery operated
 - Remote control that is battery operated and can be used to acquire the current temperature and adjust it

Define Devices

- Define devices in the system
 - E.g. Radiator, temperature sensor and remote control
- Map to Logical Devices
 - Radiator – Coordinator or Router
 - The radiator is most likely always mains powered
 - Temperature sensor/Remote control – End Device
 - The temperature sensor(s) and the remote control are most likely battery operated.

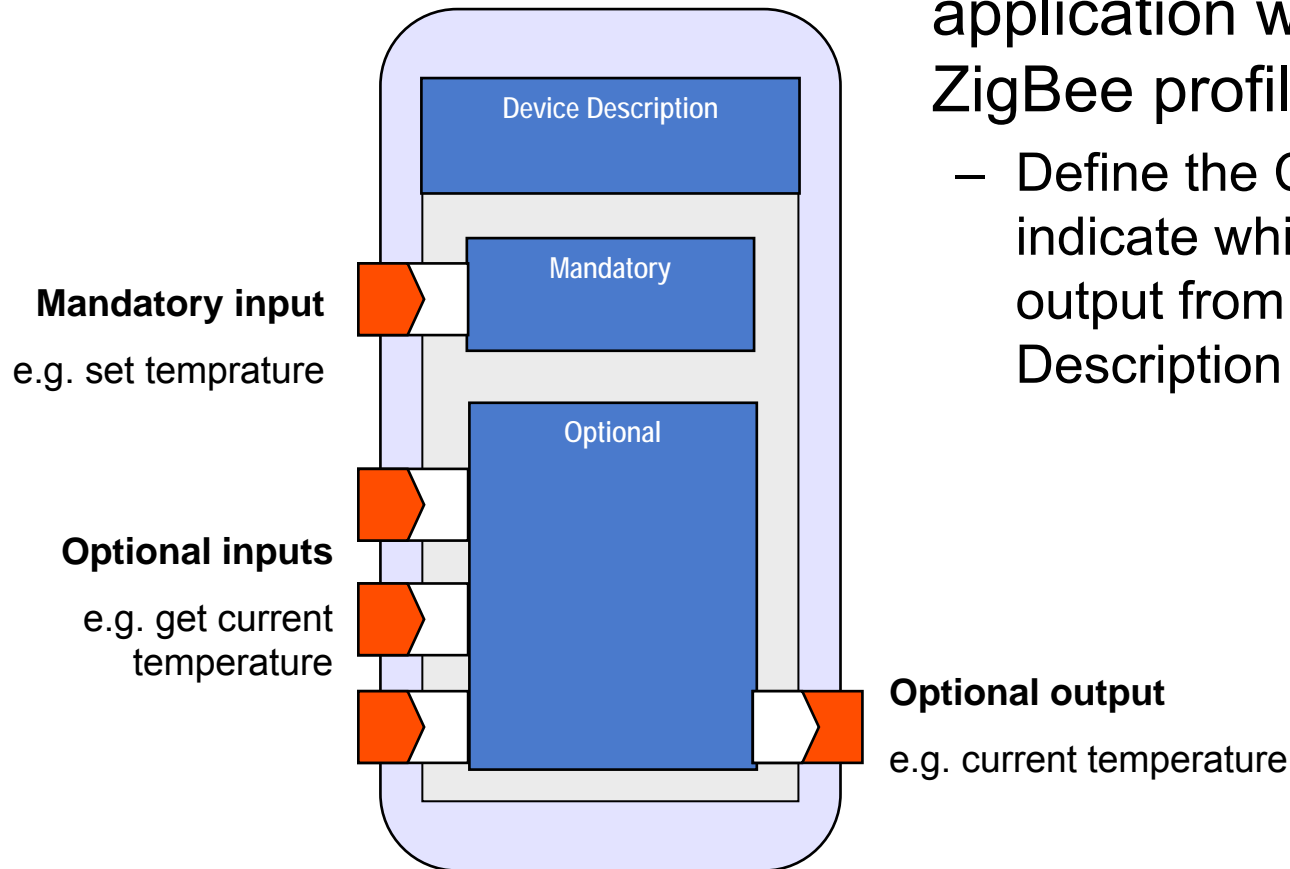
Define Profile

- Define the Profile by partitioning the devices
 - The Temperature sensor needs to be able to send its temperature to both the remote control and the radiator
 - The Remote Control needs to be able to request the temperature from the sensor and pass the requested temperature on to the radiator
 - Etc.....



ZigBee device example

- E.g. a new Heating application with no defined ZigBee profile
 - Define the Clusters and indicate which are input and output from each Device Description



Device Descriptors

- Define the Device Descriptions within each Profile
 - Node Descriptor (mandatory - one per device)
 - Logical Device Type, Frequency Band, MAC Capability, Buffer Size
 - Power Descriptor (mandatory - one per device)
 - Power mode, source and level
 - Simple Descriptor (mandatory - one per active endpoint/interface)
 - EndPoint Number, Profile ID, Input and Output Cluster Number
 - Complex Descriptor (optional - one per device)
 - Language, Mfg Name, Model and Serial Number
 - User Descriptor (optional - one per device)
 - User defined strings

Commissioning - Methods

- No commissioning tool:
 - Preconfigured
 - Defined during production
 - Self configuring network
 - Defined during start-up
 - User configured
 - Button presses, Dip switches, LCDs, LEDs etc.
- Commissioning tool:
 - Professional
 - Laptop/PDA
 - USB/SD/Compact Flash etc.
 - Commissioning tool
 - Commercial
 - All types of PCs

Commissioning

- Pre-configured networks
 - Set up during production
 - Channel, PAN ID, Security etc.
- Non pre-configured networks
 - Defining a list of channels for your application
 - Select from 1 up to 16 channels
 - Search channels
- How do I associate to the "right" network (commissioning)?
 - Pre programmed security settings
 - Specific PAN ID
 - Proximity (minimize range to select the right network)
 - Dip-Switches for Channel and PAN ID
 - Filtering on MAC addresses
 - Search for specific device after association
 - If not found try next network
 - Combination of the methods above
 - Have a button on the coordinator that allows associations on the network

Access and Security

- Who should have access to your network?
 - Allow only own nodes
 - Filter on MAC address
 - Use pre-defined key for security
- Security
 - MAC layer security
 - Point-to-point links
 - NWK layer security
 - Stack profile interoperability
 - Application layer security
 - For strict security requirements

Coordinator/Router Failure

- What happens if a coordinator/router fails?
 - Previous routes using this node will be updated upon failure
 - An End Device associated to the coordinator will have to select a new parent
 - If the device has been used to store bindings these will be lost and the device would have to be re-configured
 - Can/should be avoided by not using indirect bindings
 - Binding cache can be used instead
 - If the coordinator is the security trust center it can not send out keys
 - Can be avoided by distributing keys differently
- All critical data can be stored so that the network can work after a power down

SimpleAPI functions and callbacks

- `zb_SystemReset`
 - Resets network
- `zb_StartRequest`
 - Starts network
- `zb_PermitJoiningRequest`
 - Allow nodes to join network
- `zb_BindDevice`
 - Establish a binding (connection)
- `zb_AllowBind`
 - Allow binding request
- `zb_SendDataRequest`
 - Send data
- `zb_ReadConfiguration`
 - Read configuration parameters
- `zb_WriteConfiguration`
 - Write configuration parameters
- `zb_GetDeviceInfo`
 - Get current address, PAN ID etc
- `zb_FindDeviceRequest`
 - Search for a device on the network
- `zb_StartConfirm`
 - Network start up callback
- `zb_AllowBindConfirm`
 - Accepted bind request callback
- `zb_SendDataConfirm`
 - Send data status callback
- `zb_ReceiveDataIndication`
 - Incoming data callback
- `zb_FindDeviceConfirm`
 - Search results callback
- `zb_HandleKeys`
 - EVM key push callback
- `zb_HandleOsalEvent`
 - Operating system callback

For more details see the SimpleAPI for Z-Stack documentation in the Z-Stack documentations folder

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Compliance and Certification

- ZigBee Qualification Group (ZQG) is responsible for:
 - Establishing an independent test house program
 - Selecting test houses
 - National Technical Systems of Culver City, California
 - TÜV Rheinland of North America of Pleasanton, California
 - Write Protocol Implementation Conformance Statement (PICS)
- ZigFest
 - ZigBee Alliance Interoperability testing events
 - Participating in a ZigBee Alliance interoperability testing event is mandatory for compliancy

What can be tested?



- ZigBee Compliant Platform
 - IEEE 802.15.4 PHY and MAC
 - ZigBee network, security and application layer functions
 - TI ZigBee development kits are based on ZigBee Compliant Platforms
- ZigBee Compliant Product
 - Product based on a ZigBee Compliant Platform
 - Can use the ZigBee name and logo
 - Can co-exist with other ZigBee systems
 - Interoperable if a public profile is used

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Development cost for ZigBee

- Development kit: e.g. CC2430 ZigBee DK
 - Kit (9 boards + Tools + packet sniffer)
 - For price please see: <http://www.ti-estore.com/>
- Compiler from IAR (\$2395/seat)
 - 30+60 day evaluation version included in the kit
 - Volume prices available. Please contact IAR directly: <http://www.iar.com/>
- Regulatory certification (FCC, ETSI, ARIB etc.)
 - Price determined by the local test house
 - Same as for non-ZigBee products
- ZigBee certification (TÜV or NTS) ([Certification FAQ](#))
 - Price decided by test houses (~\$3k-10k/product)
- IEEE addresses
 - \$1650 for all the addresses you will ever need (2^{40})

Additional costs for ZigBee

- ZigBee alliance membership (Benefits)
 - Adopter (\$3500/year)
 - Additional \$1500/product for certification to the Alliance
 - Participant (\$9500/year)
 - Early access to specification
 - No additional cost for certification to the Alliance

Questions?

Please send questions or comments about this presentation to: lpw_pme_zigbee@list.ti.com

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