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Bob Heile Chairman, Zigbee Alliance



What is the ZigBee Alliance?

- A rapidly growing, worldwide, non-profit industry consortium consisting of
 - Leading semiconductor manufacturers
 - Technology providers
 - OEMs
 - End-users
- An Organization with a mission to define reliable, cost-effective, low-power, wirelessly networked, monitoring and control products based on an open global standard





The ZigBee Alliance Solution

- Targeted at home and building automation and controls, consumer electronics, PC peripherals, medical monitoring, and toys
- Primary drivers are simplicity, long battery life, networking capabilities, reliability, and cost
- Alliance provides interoperability, certification testing, and branding





How is ZigBee related to IEEE 802.15.4?

- ZigBee takes full advantage of a powerful physical radio specified by IEEE 802.15.4
- ZigBee adds logical network, security and application software
- ZigBee continues to work closely with the IEEE to ensure an integrated and complete solution for the market





Why do we need ZigBee technology

- ONLY standards-based technology that
 - Addresses the unique needs of most remote monitoring and control and sensory network applications
 - Enables the broad-based deployment of wireless networks with low cost, low power solutions
 - Provides the ability to run for years on inexpensive primary batteries for a typical monitoring application







Who is supporting the ZigBee Alliance now?

- Six promoter companies
 - Honeywell, Invensys, Mitsubishi, Motorola, Samsung and Philips
- A rapidly growing list (now almost 60 participants) of industry leaders worldwide committed to providing ZigBee-compliant products and solutions
 - Companies include semiconductor manufacturers, wireless IP providers, OEMs, and end users
- ZigBee's membership continues to grow as additional companies realize the market need for and benefits of standards-based interoperable wireless products





The Wireless Market



LOW < ACTUAL THROUGHPUT > HIGH





Wireless Network Evolution

Point to Point

- Simple wire replacement
- Direct Connection between devices
- Limited communication



Point to Multi-Point

- Centralized routing and control point
- Examples include: Wi-Fi, GSM, Bluetooth
- All data must flow through "base station"



- Full RF redundancy, with multiple data paths
- Self Configuring / Self Healing
- Distributed Intelligence





Frequencies and Data Rates







Basic Network Characteristics

- 65,536 network (client) nodes
- 1 fully functional network coordinator (master)
- Optimized for timing-critical applications
 - New slave enumeration: 30 ms (typ)
 - Sleeping slave changing to active: 15 ms (typ)
 - Active slave channel access time: 15 ms (typ)



- Network coordinator
- **Full Function node**
- **Reduced Function node**
- ··· Communications flow
- ••• Virtual links





Initial Enumeration







Bluetooth Coordinator









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Topology Models



Traffic types

Periodic data

- Application-defined rate (e.g. sensors)
- Intermittent data
 - Application-defined rate or determined by external stimulus (e.g. light switch)
- Repetitive, low-latency data
 - Allocation of time slots (e.g. mouse)





Protocol Stack Features

- 8-bit microcontroller (e.g. 80c51)
- Full protocol stack <32 k
- Simple node-only stack ~4k
- Coordinators require extra RAM
 - Node device database
 - Transaction table
 - Pairing table









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Venkat Bahl Marketing Chair, Zigbee Alliance

What is the Alliance about

Value Proposition:

- "Wireless Control that Simply Works"

Mission Statement:

 To enable reliable, cost-effective, low-power, wirelessly networked, monitoring and control products based on an open global standard.





Applications



Case Study of Mom's House

- Easily create networks
- Add devices to networks
- Merge applications
- Extend range





Mom's House September 2004



- Son installs a retail two-pack ZigBee lamp controller and lamp module
- Mom likes it, allows her to stay warm in bed without having to get up to turn out lamp



Mom's House October 2004



- Son worried about her health, so adds wearable panic button and phone line connection
- New PAN coordinator assumes coordination master function from lamp module; network auto-reconfigures for star topology



Mom's House December 2004



- Mom likes it, son worried about her neighborhood, so adds door and window security sensor
- PAN Coordinator locates these new devices and adds them
- PAN Coordinator offers to alert police via phone line if window sensor is tripped, turns on lamp by bed



Mom's House February 2005



- Mom now worries about mail being stolen from roadside box, so wants to know when mailman delivers mail
- Son buys ZigBee Mailbox Alert

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 finds that range is exceeded, purchases ZigBee Range Extender, finds it also allows her Panic Button to work outside in the garden



Mom's House December 2005



- For Christmas, Mom gets new computer with ZigBee Human Interface Devices (HID)
- Comes with software to allow her to automate her house via ZigBee





Application of products - Residential



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Application of products – Convenience Convenience Store Store



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International

Application of products – Supermarket



Internationa

Application of products – Commercial Buildings



Heating and Cooling HVAC Air-Handling Unit Heating and Cooling Pumps Fans **Energy Control** Fan Coils/ VAV **Utility Monitoring** (Elec./Water/Gas/Oil







Flexima

General





Product Pull Through





Why ZigBee?

- Reliable
- Mesh networking
- Low data-rate applications
- Very long battery life
- Secure
- Scalable
- Low cost

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Global applicability



What is the advantage of the ZigBee solution over proprietary solutions?

• Main advantages

- Product interoperability
- Vendor independence
- Expectation of increased product innovation as a result of the industry standardization of the physical radio and logical networking layers
- No more having to invest resources to create a new proprietary solution from scratch every time
- Companies now can leverage these industry standards to instead focus their energies on finding and serving customers





A Primer to ZigBee And 802.15.4

Jon Adams

Director, Technology Strategy Motorola Wireless and Mobile Systems Tempe, Arizona





Introduction to the IEEE 802.15.4 Standard

- IEEE 802.15.4 standard released May 2003
 - Semiconductor manufacturers
 - Sampling Transceiver ICs and platform hardware/software to Alpha Customers now
 - Users of the technology
 - Defining application profiles for the first products, an effort organized by the ZigBee Alliance





IEEE 802.15.4 Basics

- 802.15.4 is a simple packet data protocol for lightweight wireless networks
 - Channel Access is via Carrier Sense Multiple Access with collision avoidance and optional time slotting
 - Message acknowledgement and an optional beacon structure
 - Multi-level security
 - Works well for
 - Long battery life, selectable latency for controllers, sensors, remote monitoring and portable electronics
 - Configured for maximum battery life, has the potential to last as long as the shelf life of most batteries





Frequencies and Data Rates







Direct Sequence and Frequency Agility



Over the Air

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After DS correlation





IEEE 802.15.4 standard

- Includes layers up to and including Link Layer Control
 - LLC is standardized in 802.1
- Supports multiple network topologies including Star, Cluster Tree and Mesh
- Low complexity: 26 primitives versus 131 primitives for 802.15.1 (Bluetooth)
- ZigBee is developing the upper layers of the Stack and application profiles





IEEE 802.15.4 MAC Overview

- Employs 64-bit IEEE & 16-bit short addresses
 - Ultimate network size can reach 2⁶⁴ nodes (more than we'll probably need...)
 - Using local addressing, simple networks of more than 65,000 (2^16) nodes can be configured, with reduced address overhead
- Three devices specified
 - Network Coordinator
 - Full Function Device (FFD)
 - Reduced Function Device (RFD)
- Simple frame structure
- Association/disassociation
- AES-128 security
- CSMA-CA channel access
- Optional superframe structure with beacons
- GTS mechanism





IEEE 802.15.4 Device Types

- Three device types
 - Network Coordinator
 - Maintains overall network knowledge; most sophisticated of the three types; most memory and computing power
 - Full Function Device
 - Carries full 802.15.4 functionality and all features specified by the standard
 - Additional memory, computing power make it ideal for a network router function
 - Could also be used in network edge devices (where the network touches the real world)
 - Reduced Function Device
 - Carriers limited (as specified by the standard) functionality to control cost and complexity
 - General usage will be in network edge devices
- All of these devices can be no more complicated than the transceiver, a simple 8-bit MCU and a pair of AAA batteries!





System Simplicity and Flexibility







MAC Options

- Two channel access mechanisms
 - Non-beacon network
 - Standard ALOHA CSMA-CA communications
 - Positive acknowledgement for successfully received packets
 - Beacon-enabled network
 - Superframe structure
 - For dedicated bandwidth and low latency
 - Set up by network coordinator to transmit beacons at predetermined intervals
 - » 15ms to 252sec (15.38ms*2n where $0 \le n \le 14$)
 - » 16 equal-width time slots between beacons
 - » Channel access in each time slot is contention free
 - Three security levels specified
 - None
 - Access control lists
 - Symmetric key employing AES-128





ISM Band Interference and Coexistence

- Potential for interference exists in every ISM band, not just 2.4GHz
- IEEE 802.11 and 802.15.2 committees are addressing coexistence issues
- ZigBee/802.15.4 Protocol is very robust
 - Clear channel checking before transmission
 - Backoff and retry if no acknowledgement received
 - Duty cycle of a ZigBee-compliant device is usually extremely low
 - It's the "cockroach that survives the nuclear war"
 - Waits for an opening in otherwise busy RF spectrum
 - Waits for acknowledgements to verify packet reception at other end





ZigBee and Mesh Networking





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ZigBee and Bluetooth

Comparison Overview

	Bluetooth	ZigBee
AIR INTERFACE	FHSS	DSSS
PROTOCOL STACK	250 kb	28 kb
BATTERY	rechargeable	non-rechargeable
DEVICES/NETWORK	8	2^16
LINK RATE	1 Mbps	250 kbps
RANGE	~10 meters (w/o power amp)	~30meters (w/o power amp)
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Transceiver Comparisons

- Instantaneous Power Consumption of ZigBee Transceivers are "similar" to Bluetooth without protocol
 - ZigBee
 - OQPSK with shaping -- Max data rate 128kbps over the air
 - -90 dBm sensitivity -- 40ppm xtal
 - Bluetooth
 - FSK -- Max data rate 720kbps over the air
 - -85dBm sensitivity -- 20ppm xtal
- Bluetooth's frequency hop makes it extremely difficult to create extended networks without large synchronization cost





Protocol Makes the Difference

•Bluetooth

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- Moderate duty cycle, secondary battery operation where battery lasts about the same as master unit
- Wire replacement for consumer devices that need moderate data rates with very high QoS and very low, guaranteed latency
- Quasi-static star network structure with up to 7 clients (and ability to participate in more than one network simultaneously)
- Generally used in applications where either power is cycled (headsets, cellphones) or mains-powered (printers, car kits)



Protocol Makes the Difference

•ZigBee

- Very low duty cycle, very long *primary* battery life applications
- Static and dynamic star and mesh network structures with potentially a very large number (>>65534) of client units, low latency available but not necessary
- Ability to remain quiescent for long periods of time without communicating to the network

ZigBee Protocol was developed to serve very different applications than Bluetooth and leads to tremendous optimizations in power consumption



Security Mechanisms

IEEE 802.15.4

- Standards based algorithms
- AES 128-CTR
- CCM/CBC-MAC
- Authenticity

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• Replay Attack resistant (freshness check)

Bluetooth

- Proprietary algorithms
- Safer+
- CRC (error control)
- No authenticity
- Replay attack susceptible (no freshness check)



Comparison of key features of complementary protocols

Feature(s)	IEEE 802.11b	Bluetooth	IEEE 802.15.4
Power Profile	Hours	1 Week	1Year+
BOM	\$9	\$6	\$3
Complexity	Complex	Very Complex	Simple
Nodes/Master	32	7	64000
Latency	Enumeration upto 3	Enumeration upto 10	Enumeration 30ms
	seconds	seconds	Endmeradori Soms
Range	100 m	10m	70m
Extendability	Roaming possible	No	YES
Data Rate	11Mbps	1Mbps	250Kbps
Security	Authentication Service Set ID (SSID)	64 bit, 128 bit	128 bit AES and Application Layer user defined

HVAC control in building automation





Conclusion

- Bluetooth and ZigBee transceiver physical characteristics are very similar
- Protocols are substantially different and designed for different purposes
- ZigBee designed for low to very low duty cycle static and dynamic environments with many active nodes
- Bluetooth designed for high QoS, variety of duty cycles, moderate data rates in fairly static simple networks with limited active nodes





More Information

ZigBee Alliance web site <u>http://www.ZigBee.org</u>

IEEE 802.15.4 web site http://www.ieee802.org/15/pub/TG4.html

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