



ZigBee tutorial



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Outline

- Introduction
- ZigBee frequencies
- ZigBee concepts
 - protocol Stack , Profiles, Clusters
- ZigBee application
 - Addressing
- ZigBee Architecture
 - ZC,ZR,ZED
- Practical part and ZigBee tools

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Introduction

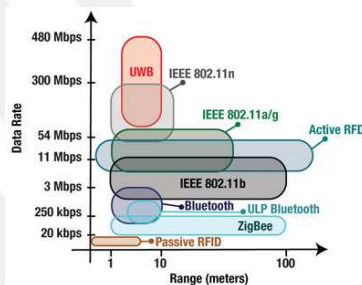
- **ZigBee** stands for “ **Z**onal **I**ntercommunication **G**lobal standard, where **B**attery life was long, which was **E**conomical to deploy, and which exhibited **E**fficient use of resources.”
- ZigBee stands over IEEE 802.15.4 PHY & MAC
- ZigBee aims:
 - Low data rate
 - Low power consumption
 - Small packet devices

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802.15.4/ZigBee Frequencies

- Operates in ISM radio bands:
 - 868 MHz **European** Band at 20kbps
 - 915 MHz **North American** Band at 40kbps
 - 2.4 GHz **Global** Band at 250kbps




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ZigBee and Other Wireless Technologies

Market Name	ZigBee™	---	Wi-Fi™	Bluetooth™
Standard	802.15.4	GSM/GPRS CDMA/1xRTT	802.11b	802.15.1
Application Focus	Monitoring & Control	Wide Area Voice & Data	Web, Email, Video	Cable Replacement
System Resources	4KB - 32KB	16MB+	1MB+	250KB+
Battery Life (days)	100 - 1,000+	1-7	.5 - 5	1 - 7
Network Size	Unlimited (2 ⁸⁰)	1	32	7
Bandwidth (KB/s)	20 - 250	64 - 128+	11,000+	720
Transmission Range (meters)	1 - 100+	1,000+	1 - 100	1 - 10+
Success Metrics	Reliability, Power, Cost	Reach, Quality	Speed, Flexibility	Cost, Convenience

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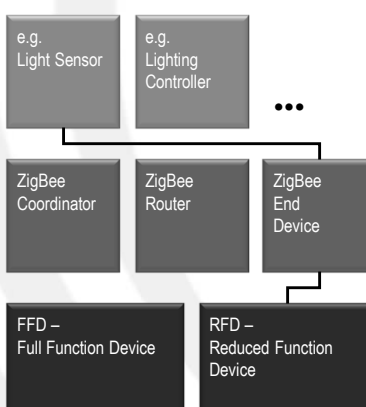


Application Device Type Model

Application Device Type

Logical Device Type


802.15.4 Device Type



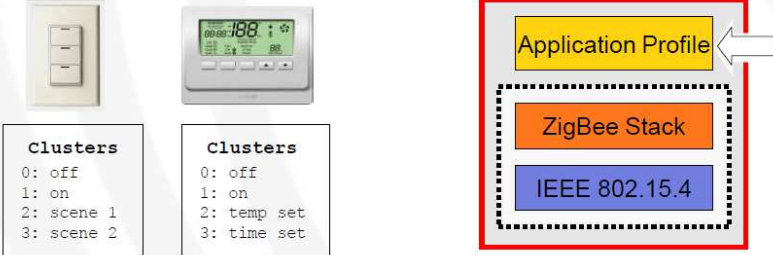
- Distinguishes the type of device from an end-user perspective
- Distinguishes the Logical Device Types deployed in a specific network
- Distinguishes the type of hardware platform

- ZigBee products are a combination of Application, Logical, and Physical device types
- Profiles may define specific requirements for this combination, but can also leave this up to manufacturers

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Application Profiles



- Application profiles define what messages are sent over the air for a given application
- Devices with the same application profiles interoperate end to end

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ZigBee Application profiles

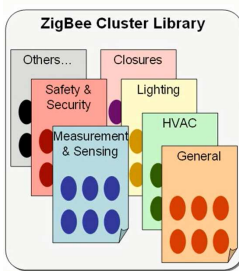
- Determines application-level features, protocol
- Defines device types with different capabilities (clusters)
 - 2 bytes "device ID" enumerates device type within the profile
- Inherits network-level features from stack feature set
- Identified by **2 bytes** application profile IDs
 - assigned by ZigBee Alliance
 - can request private profile IDs for custom applications or use one of ZigBee's published application profiles
- *Examples:*
 - Home Automation (HA) — based on ZigBee or Zigbee Pro
 - Commercial Building Automation (CBA) — based on ZigBee Pro
 - Smart Energy (SE) — based on ZigBee or ZigBee Pro
 - Manufacturer-Specific Profile (MSP) — anything proprietary

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ESD Elements Smart Device

ZigBee clusters

- A "cluster" is a set of message types related to a certain device function
- Enumerated by **2 bytes** Cluster ID
- Defines clusters for use in public profiles
 - Same cluster (and ID) can be used in multiple profiles
- Defines "attributes" and "commands" for a given cluster
- Groups clusters into "functional domains", e.g. Lighting, HVAC
- Uses "client" and "server" model of communication
 - Client sends messages to server: server maintains attributes



ZigBee Cluster Library

Others... Closures

Safety & Security Lighting

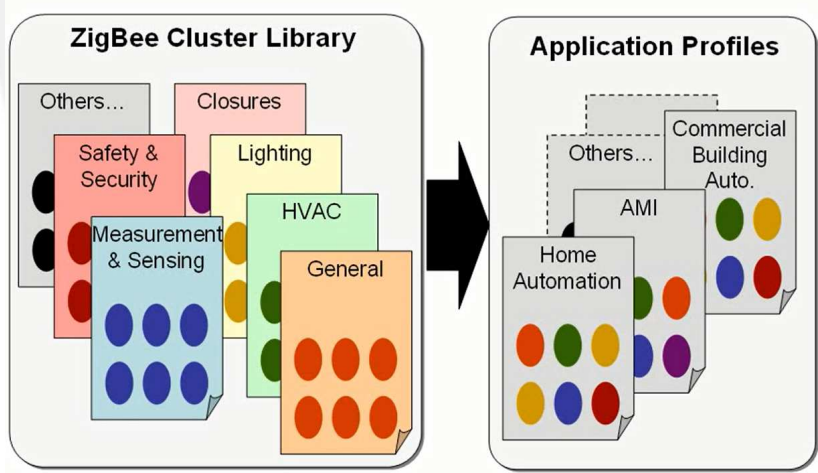
Measurement & Sensing HVAC

General

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ESD Elements Smart Device

ZigBee clusters



ZigBee Cluster Library

Others... Closures

Safety & Security Lighting

Measurement & Sensing HVAC

General



Application Profiles

Others... Commercial Building Auto.

AMI

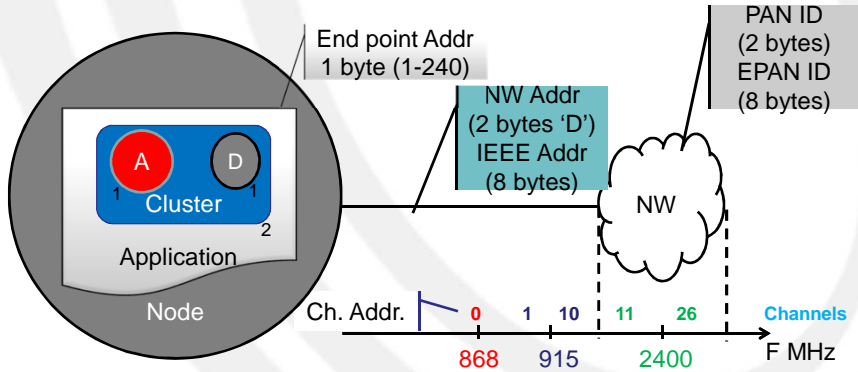
Home Automation

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ZigBee addressing

- Addressing is the way in which a message gets from one place to another in a network.



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ZigBee addressing

- For 2.4 GHz

Name	Range	Description
Channel	11-26	A physical portion of the RF spectrum
PAN ID	0x0000-0x3fff	The address of a network within a channel
NwkAddr	0x0000-0xffff	The address of a node within a network
Endpoint	1-240	The address of an application within a node
Cluster	0x0000-0xffff	The object within the application
Command	0x00-0xff	An action to take within the cluster
Attribute	0x0000-0xffff	A data item within the cluster

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ZigBee addressing

- The MAC address, also called IEEE address, long address, or extended address, is a 64bit number that uniquely identifies this board from all other ZigBee boards in the world

MAC Address: 0050C2 37B00C45F
PAN ID : 0000

MAC Address: 0050C2 37B00C453
PAN ID : 0001

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ZigBee architecture

- There are three different types of ZigBee devices:
 - ZigBee coordinator (ZC)
 - ZigBee Router (ZR)
 - ZigBee End Device (ZED)

Star

Tree

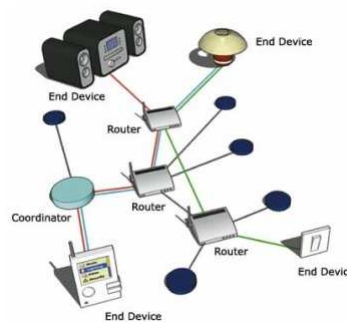
Mesh

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ZigBee Coordinator (ZC)

- only one in a network
- initiates network
- stores information about the network
- all devices communicate with the ZC
- routing functionality
- bridge to other networks

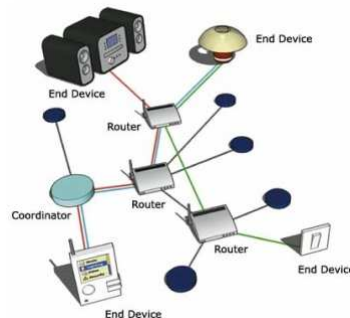


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ZigBee Router (ZR)

- optional component
- routes between nodes
- extends network coverage
- manages local address allocation/de-allocation

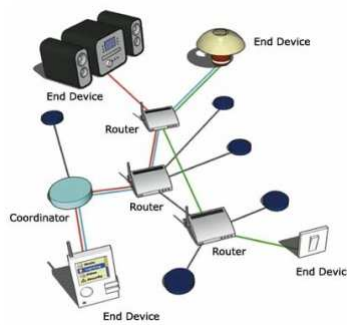


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ZigBee End Device (ZED)

- optimized for low power consumption
- cheapest device type
- communicates only with the coordinator via routers
- sensor would be deployed here



Summery for ZigBee device types

ZigBee Type	Notes
ZigBee Coordinator (ZC)	Special router that forms the network; only 1 per PAN
ZigBee Router (ZR)	No duty cycling available
ZigBee End Device (ZED)	Does not participate in routing; may be sleepy; requires ZC/ZR "parent" for network participation



ZC



ZR



ZED

IEEE 802.15.4 PHY Overview
Packet Structure

PHY Packet Fields

- Preamble (32 bits) – synchronization
- Start of Packet Delimiter (8 bits)
- PHY Header (8 bits) – PSDU length
- PSDU (0 to 1016 bits) – Data field

Preamble	Start of Packet Delimiter	PHY Header	PHY Service Data Unit (PSDU)
6 Octets			0-127 Octets

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IEEE 802.15.4 MAC Overview
General Frame Structure

		Payload		
		MAC Header (MHR)	MAC Service Data Unit (MSDU)	MAC Footer (MFR)
PHY Layer	Synch. Header (SHR)	PHY Header (PHR)	MAC Protocol Data Unit (MPDU)	
			PHY Service Data Unit (PSDU)	

4 Types of MAC Frames:

- Data Frame
- Beacon Frame
- Acknowledgment Frame
- MAC Command Frame

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IEEE 802.15.4 MAC overview

- Star networks: **devices** are associated with **coordinators**
 - Forming a PAN, identified by a PAN identifier
- Coordinator
 - Bookkeeping of devices, address assignment, generate beacons
 - Talks to devices and peer coordinators
- Beacon-mode superframe structure

The diagram illustrates the beacon-mode superframe structure and the communication sequence between a Coordinator and a Device. The superframe structure is shown as a horizontal bar divided into an Active period and an Inactive period. The Active period is further divided into a Contention access period (with green slots) and Guaranteed time slots (GTS) (with red slots). A Beacon is transmitted at the start of the Active period. The communication sequence is shown as a vertical stack of messages: Beacon (Coordinator to Device), Data request (Coordinator to Device), Acknowledgement (Device to Coordinator), Data (Coordinator to Device), and Acknowledgement (Device to Coordinator).

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ZigBee tools

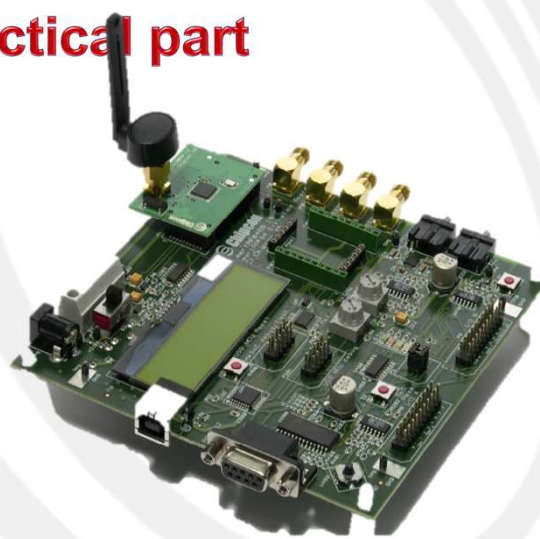
- Z-Stack™: is TI's ZigBee compliant protocol stack for a growing portfolio of IEEE 802.15.4 products and platforms
- IAR: is a development tools for testing and compiling Z-Stack based applications.
 - It incorporates IAR C/C++ Compiler for ARM Cortex-M3, assembler, linker, librarian, text editor, project manager, and debugger
- SmartRF™ Studio: is a Windows application that can be used to evaluate and configure Low Power RF-ICs from Texas Instruments.

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ESD Elements Embedded Systems Design

Practical part

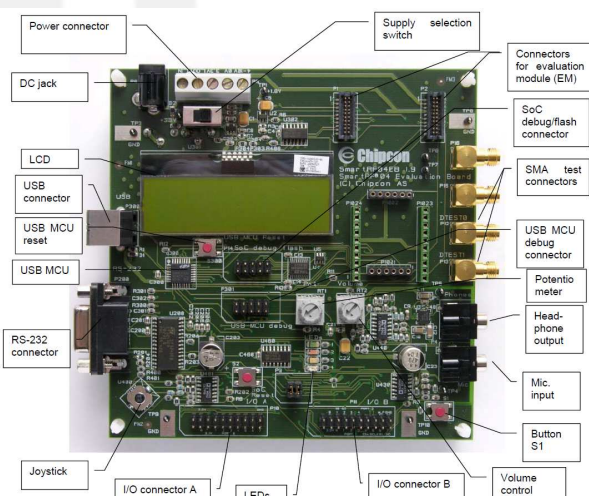
- Zigbee boards:
 - **Chipcon SmartRF04EB Evaluation Board with CC2430EM**



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ESD Elements Embedded Systems Design

Practical part



Labels for the board components:

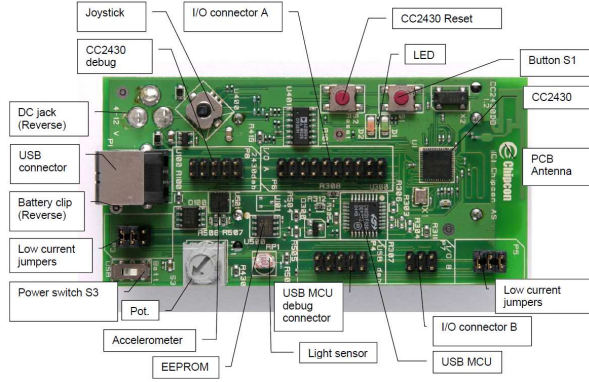
- Power connector
- DC jack
- LCD
- USB connector
- USB MCU reset
- USB MCU
- RS-232 connector
- Joystick
- I/O connector A
- LEDs
- Supply selection switch
- Connectors for evaluation module (EM)
- SoC debug/flash connector
- SMA test connectors
- USB MCU debug connector
- Potentiometer
- Head-phone output
- Mic input
- Button S1
- I/O connector B
- Volume control

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ESD Elements
Energy
Design

Practical part

- Zigbee boards:
 - Chipcon CC2430DB Development Board**



The diagram shows a green PCB development board with the following components labeled:

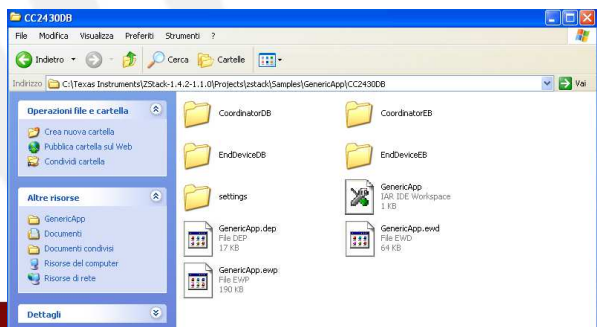
- Joystick
- I/O connector A
- CC2430 Reset
- LED
- Button S1
- CC2430
- PCB Antenna
- DC jack (Reverse)
- USB connector
- Battery clip (Reverse)
- Low current jumpers
- Power switch S3
- Pot.
- Accelerometer
- EEPROM
- Light sensor
- USB MCU debug connector
- I/O connector B
- USB MCU
- Low current jumpers

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ESD Elements
Energy
Design

Open example

- Open GenericApp example(Zstack & IRA tools) from example folder as shown bellow:
 - C:\TexasInstrument\Zstack-1.4.2.1.1.0\project\Zstack\samples\GenericApp\CC2430DB\GenericApp**



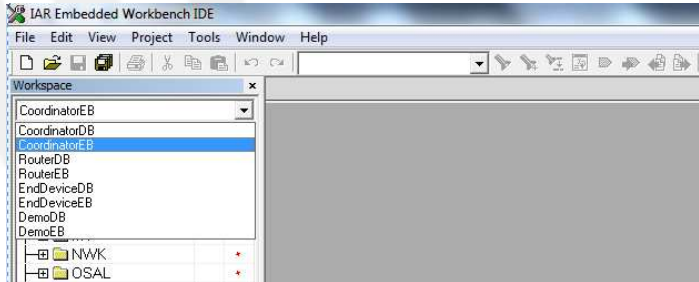
The screenshot shows a Windows File Explorer window titled "CC2430DB" with the address bar set to "C:\TexasInstrument\Zstack-1.4.2.1.1.0\project\Zstack\samples\GenericApp\CC2430DB". The left sidebar shows "Altre risorse" with "GenericApp" selected. The main pane displays the following files and folders:

- CoordinatorDB
- CoordinatorEB
- EndDevice00E
- EndDevice00B
- settings
- GenericApp (JAR IDE Workspace, 1 KB)
- GenericApp.dep (File DEP, 17 KB)
- GenericApp.evp (File EWP, 150 KB)
- GenericApp.evd (File EVD, 64 KB)

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Practical part

- Choose Coordinator or End device based on your board type (ED, DB) and ZigBee role (ZC,ZR,ZED)



The screenshot shows the IAR Embedded Workbench IDE interface. The 'Workspace' panel on the left lists several project templates: CoordinatorEB, CoordinatorDB, RouterDB, RouterEB, EndDeviceDB, EndDeviceEB, DemoDB, and DemoEB. Below these are folders for 'NWK' and 'OSAL'. The 'CoordinatorEB' project is currently selected and highlighted in blue.

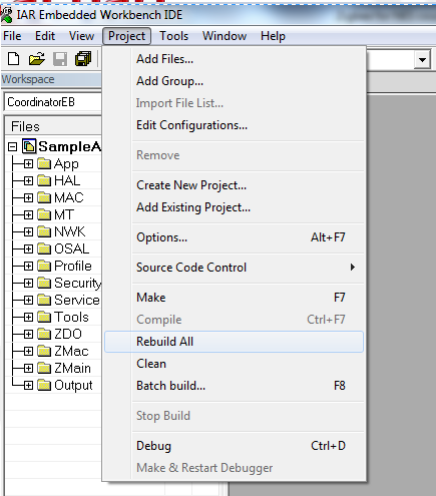
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Practical part

- then
 - Project-> buildall
 - Project->Debug (for configuration)

Reset zigBee kit from its switch.

- S300 for EB
- S2 for DB
- Repeat these steps to configure other devices



The screenshot shows the IAR Embedded Workbench IDE interface with the 'Project' menu open. The 'Rebuild All' option is highlighted. The menu also includes options like 'Add Files...', 'Add Group...', 'Import File List...', 'Edit Configurations...', 'Remove', 'Create New Project...', 'Add Existing Project...', 'Options...', 'Source Code Control', 'Make', 'Compile', 'Batch build...', 'Stop Build', 'Debug', and 'Make & Restart Debugger'. The 'Workspace' panel on the left shows the 'CoordinatorEB' project selected.

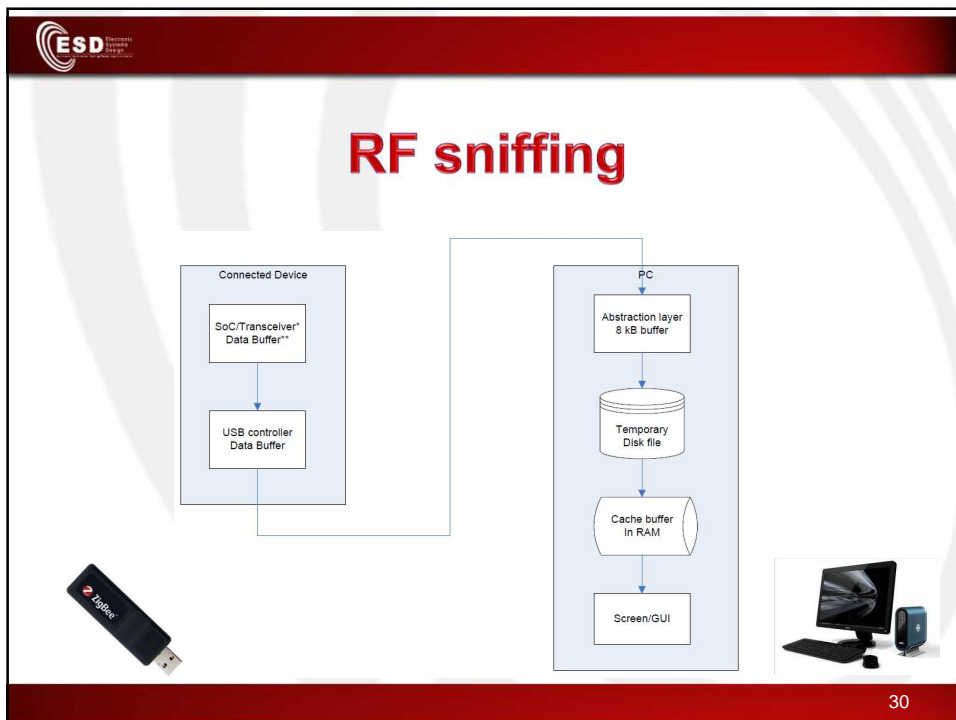
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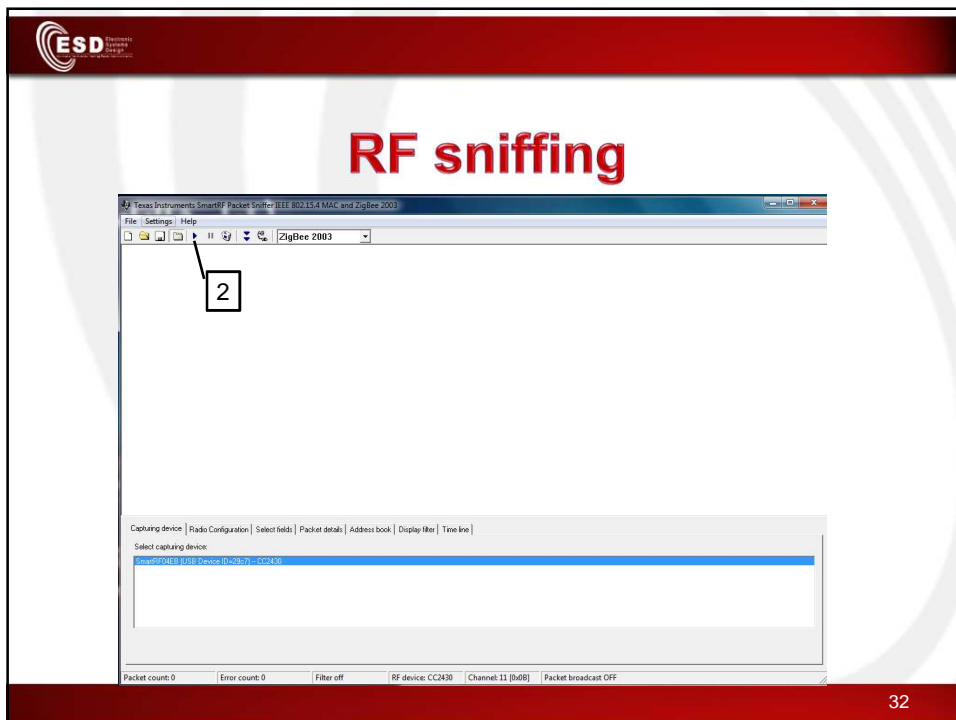
Practical part

- SmartRF tool
 - IEEE address 8 bytes (static)

1. Read
2. Change IEEE
3. Write

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RF TEXAS INSTRUMENTS SWRU187F

SmartRF Packet Sniffer: IEEE 802.15.4 MAC and ZigBee 2006

Packet	Time (ms)	Length	Type	Frame control field	Sequence number	Dest. PAN	Dest. Address	Source Address	MAC payload
179	=>	5	ACK	0 0 0 0 0	0x2C	0x74	0x		
180	=>	29	DATA	0 0 1 1	0x21	0x004C	0x0050	0x0038	13 07 00 00 11 07 00 00 07 10 10 01
181	=>	5	ACK	0 0 0 0 0	0x21	0x70	0x		
182	=>	27	DATA	0 0 1 1	0x2F	0x004C	0x0050	0x0038	40 00 01 00 00 10 00 00 00 01 01 00 10 0F
183	=>	5	ACK	0 0 0 0 0	0x2F	0x70	0x		
184	=>	10	CRC	0 0 0 0 0	0x7F	0xFFFF	0xFFFF		Request request
185	=>	24	SP	0 0 0 0 0	0x7F	0x004C	0x0050	00 50 0 0 0 0 0 0 0 0 0 0 0 1 1	Super frame specification
186	=>	10	CRC	0 0 0 0 0	0x7F	0xFFFF	0xFFFF		Request request

Packet count: 286 Error count: 6 Filter Off

Figure 12: Packet sniffer screenshot from the IEEE802.15.4/ZigBee protocols

Any questions?