Singapore Polytechnic
School of Electrical and Electronics Engineering
ET1205: Wireless Technology Applications

Experiment 05: Case study on Basics of ZigBee, ZigBee Wireless Personal Network System and Applications

Objectives:

Students will learn how to

- Identify different logical ZigBee devices, frequency channels, PAN ID, MAC addresses, ZigBee short address, etc… by using ZigBee software in Windows 7 laptops.
- setup a point-to-multipoint ZigBee cluster three network using ZigBee training kit on ZigBee software in Windows 7 laptops.
- monitor temperature, humidity and light by using sensor application.
- control LED lights by using switch & light application.
- perform a chat using the Serial Communication application.

Introduction

ZigBee, a specification for communication in a wireless personal area network (WPAN), has been called the Internet of Things (IoT). ZigBee targets the application domain of low power, low duty cycle and low data rate requirement devices.

ZigBee applications include:

- Home and office automation
- Industrial automation
- Medical monitoring
- Low-power sensors
- HVAC control
- Plus many other control and monitoring uses

This experiment provides an introduction to the various components of a ZigBee network. The ZigBee Training Kit consists of hardware and software that allows quick testing of the ZigBee Networking and offers a complete platform for development of ZigBee applications.

The ZigBee Training Kit includes the following components:

- 1 x ZigBee Coordinator Board
- 2 x ZigBee Router Board
- 2 x ZigBee End Device Board
- 2 x External Sensor Board
- 1 x USB Dongle for monitoring the packets transmission over the wireless channel

Figure 6.1 shows a block diagram of a ZigBee network with five nodes.

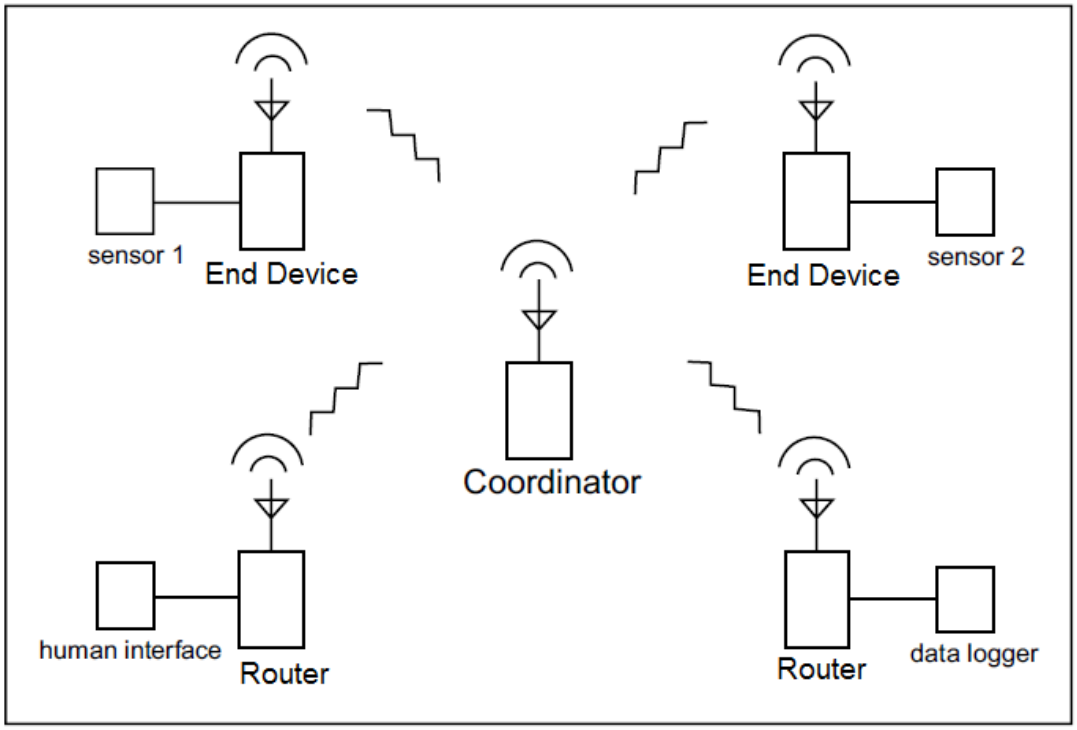


Figure 6.1 ZigBee Network

Components of ZigBee

In ZigBee technology, there are two basic hardware devices called full-function device (FFD) and a reduced-function device (RFD). Three logical devices (coordinator, router and end device) are required to setup a ZigBee network. A network shall include at least one FFD, operating as the PAN coordinator. PAN Coordinator owns the network and starts the network. It allows other devices to join the network and also provides binding and address-table services and saves messages until they can be delivered. It could also have input/output capability but mains powered. Routers are FFDs. They route messages but does not own or start network. It also scans to find a network to join and give a block of addresses to assign and usually mains powered depending on topology. End Device is an RFD. It communicates with a single device and does not own or start network but able to scans to find a network to join. It usually battery powered. An RFD is intended for applications that are extremely simple and do not need to send large amounts of data. An FFD can talk to RFDs or FFDs while an RFD can only talk to an FFD.

Wireless Network Topologies

IEEE 802.15.4 supports star and peer-to-peer topologies. The ZigBee specification supports star and two kinds of peer-to-peer topologies, mesh and cluster tree.
ZigBee-compliant devices are sometimes specified as supporting point-to-point and point-to-multipoint topologies. Figure 6.2 shows the Physical Network Topologies supported by ZigBee.

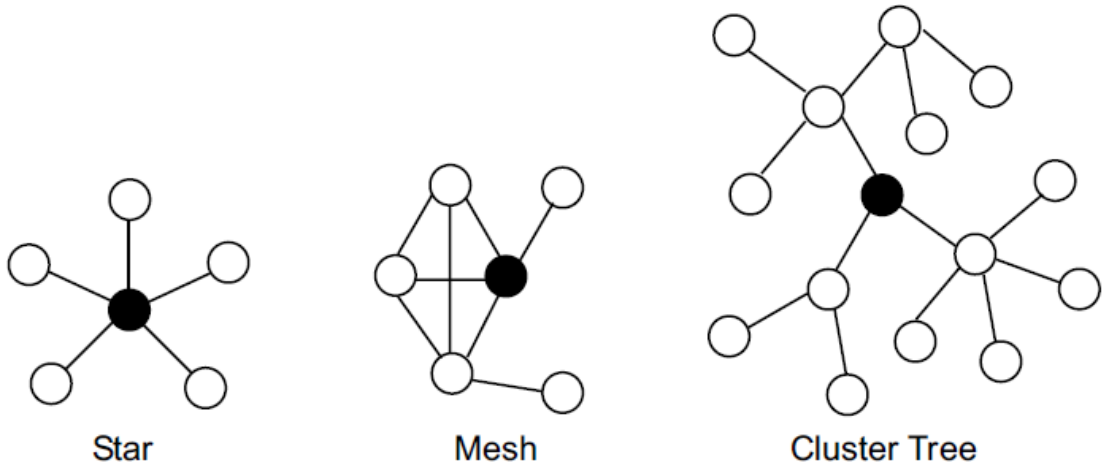


Figure 6.2 Physical Network Topologies supported by ZigBee

IEEE 802.15.4 ZigBee Standard

The following tables describe the summarized specifications of ZigBee standard.

ZigBee info and Parameters			
IEEE802.15.4	Physical/MAC layers		
ZigBee Alliance	upper layer stack and application profiles, compliance and certification testing, branding		
Range	Indoors: up to 30 m Outdoors (line of sight): up to 100 m		
ZigBee Hardware Device	Full Function Device (FFD)	Reduced Function Device (RFD)	
ZigBee Logical Device	Coordinator	Router	End Device
Physical layer protocol	DSSS (direct-sequence spread spectrum)		
Channel access mechanism:	Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA)		
Maximum number of nodes per network	64K		

Table 6.1

	ZigBee Wireless Parameter		
Frequency band	868.3 MHz	915 MHz	2.4 GHz
Frequency Range	868 – 868.6 MHz	912 – 928 MHz	2.405 – 2.480 GHz
Raw data rate	20 Kbps	40 Kbps	250 Kbps
Modulation Technique	BPSK	BPSK	O-QPSK
Number of channels	1 (Channel 0)	10 (Channel 1 to 11)	16 (Channel 12 to 27)
Bandwidth required	600 kHz	2 MHz	5 MHz

Table 6.2

Advantages of ZigBee

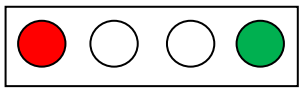
The advantages of using ZigBee are as follow.

- Easy deployment, self-forming
- Reliable and self-healing
- Supports large number of nodes up to 64K
- Easy to deploy
- Very long battery life
- Secure, Network and link keys can restrict access using 128bit Advanced encryption Standard (AES) security
- Low cost
- Can be used globally

Procedure:

Setting up hardware

1. Assume USB driver already installed and all serial switches are closed on the board. Plug USB Type A to B Cable to ZigBee Coordinator Board and laptop. LED4 (Green) is ON which means power is ON the board and then LED1 (Red) is ON that means it can establish ZigBee Network successfully.

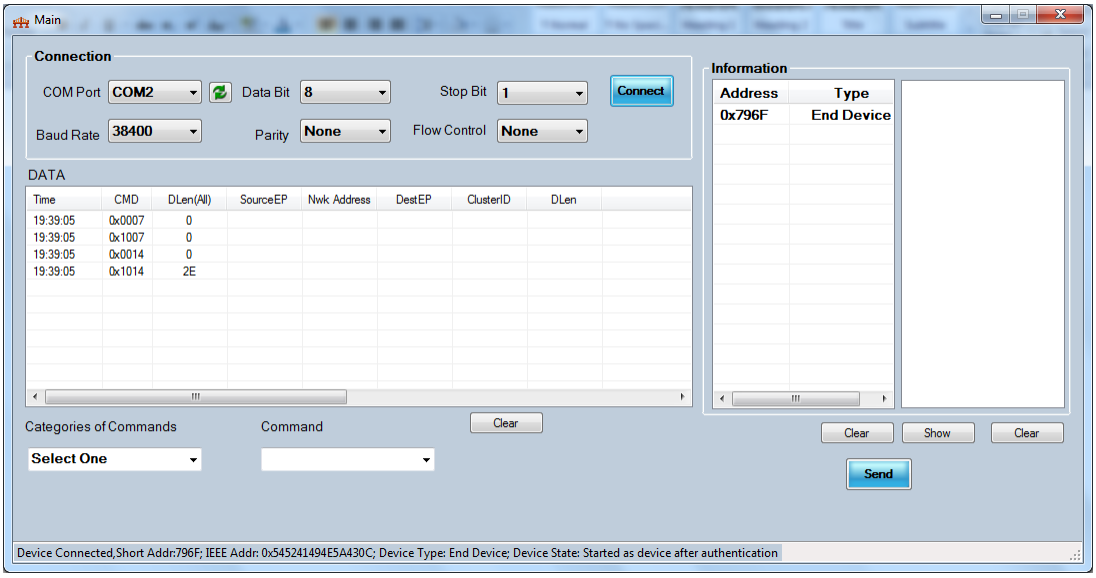


2. Do the same procedure 1 for two ZigBee Router Boards and two ZigBee End Device Boards. Here LED1 (Red) on these boards means they can join ZigBee Network successfully.
3. Plug phoenix connectors between External Sensor Board and ZigBee End Device Board. Make sure that pins ADIN0, ADIN1 and ADIN6 and 3V3 OUT, 5V OUT and GND from ZigBee End Device Board are connected with ADIN0, ADIN1 and ADIN6 and 3V3 IN, 5V IN and GND from External Sensor Board.
4. Do the same procedure 3 for ZigBee Router Board.

Setting up ZigBee training kit software

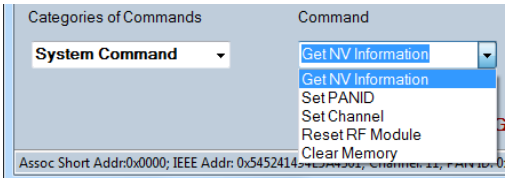
Since the ZigBee training kit software is designed to fully control from PC, the user is not needed to touch anything on the board.

1. Launch the ZigBee training kit Main Interface window by double clicking on the icon at the desktop or to Start ➔ Program ➔ Select ➔ ZigBee Training Kit.

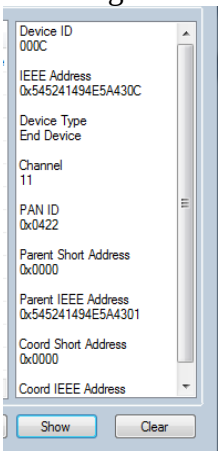


ZigBee Training Kit Main window

2. Select serial com from COM Port Drop down list. If associated COM port can't be seen, green-arrow button can be used for refresh. Use default data. (Data bit = 8, Stop bit = 1, Baud Rate = 38400, Parity = None, Flow = Control None) Click "Connect"  button. The information can be seen at the List view of right side and some information can also be seen at the status bar of window.
3. Get Device Information by selecting the System Command under the categories of Commands as follow.



4. Under the categories of Commands, select "System Command" and then under Command from right drop down list, select "Get NV Information" and then click  button and then click  button on the right side of window.

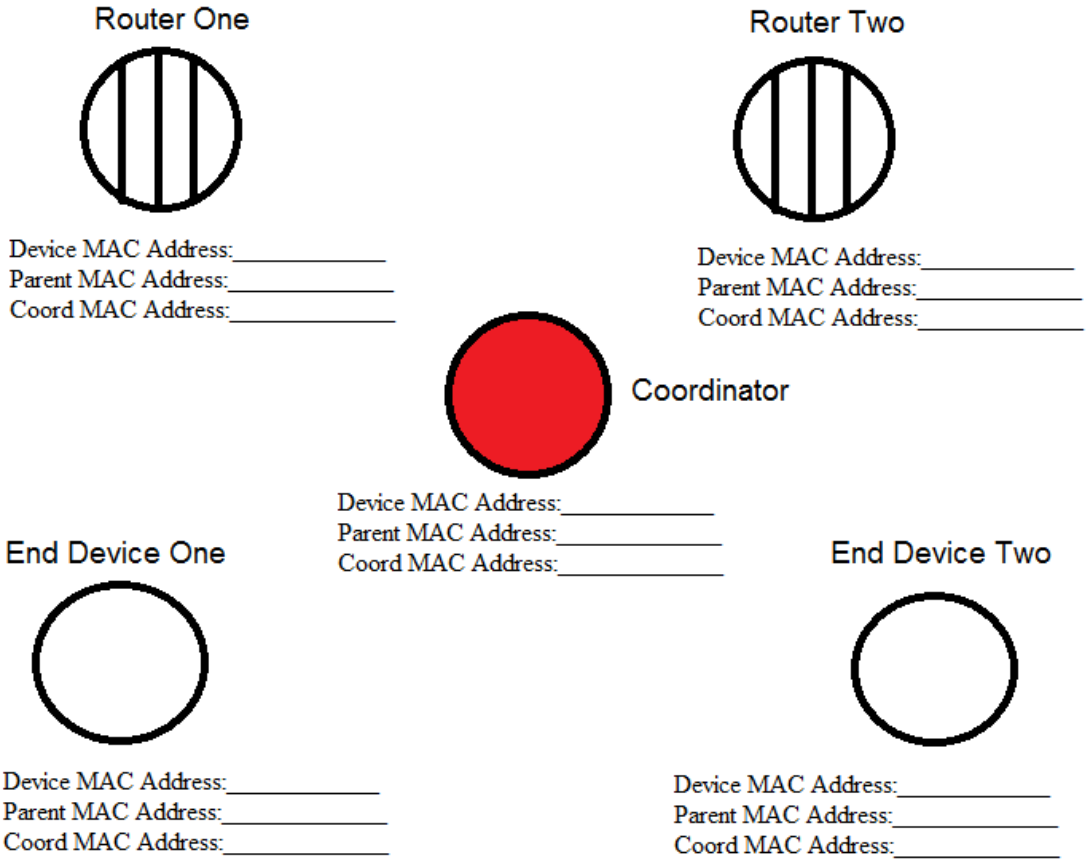


5. Record down the detail information in the following table to identify your device.

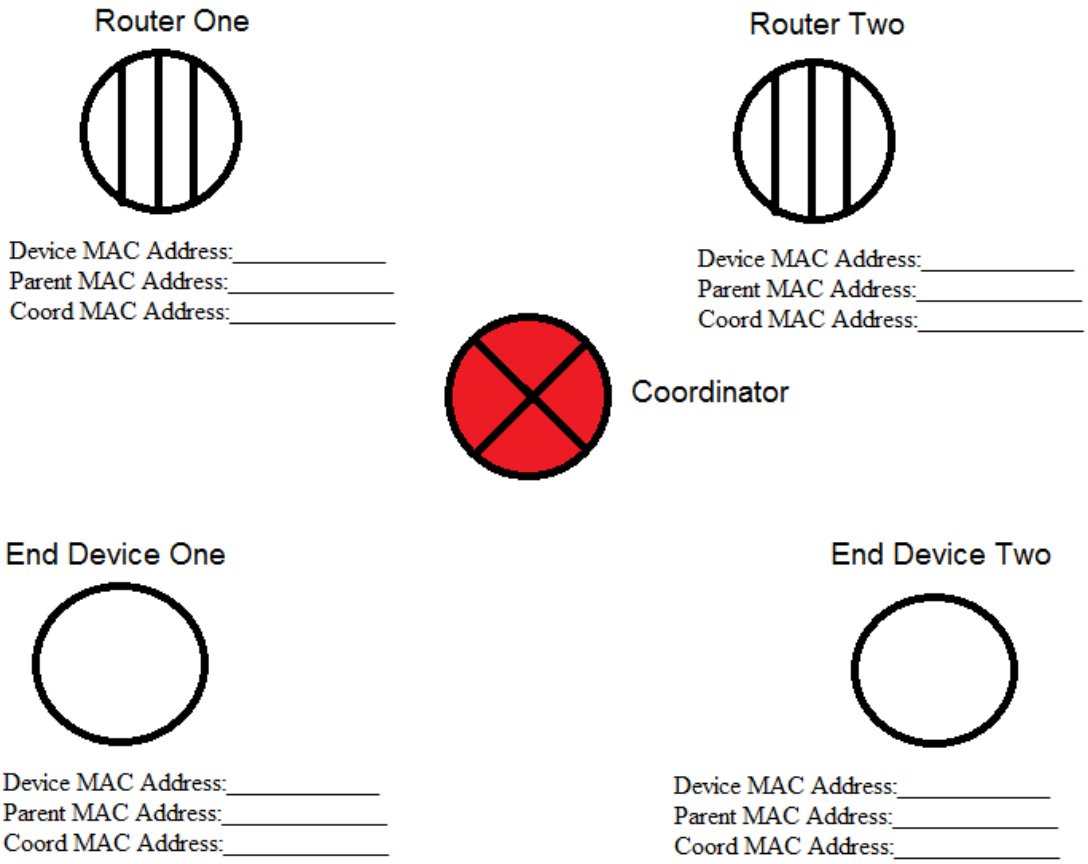
Device ID	
Device IEEE MAC Address	

Device Type	
Channel No.	
PAN ID	
Parent Short Address	
Parent IEEE MAC Address	
Coord Short Address	
Coord IEEE MAC Address	

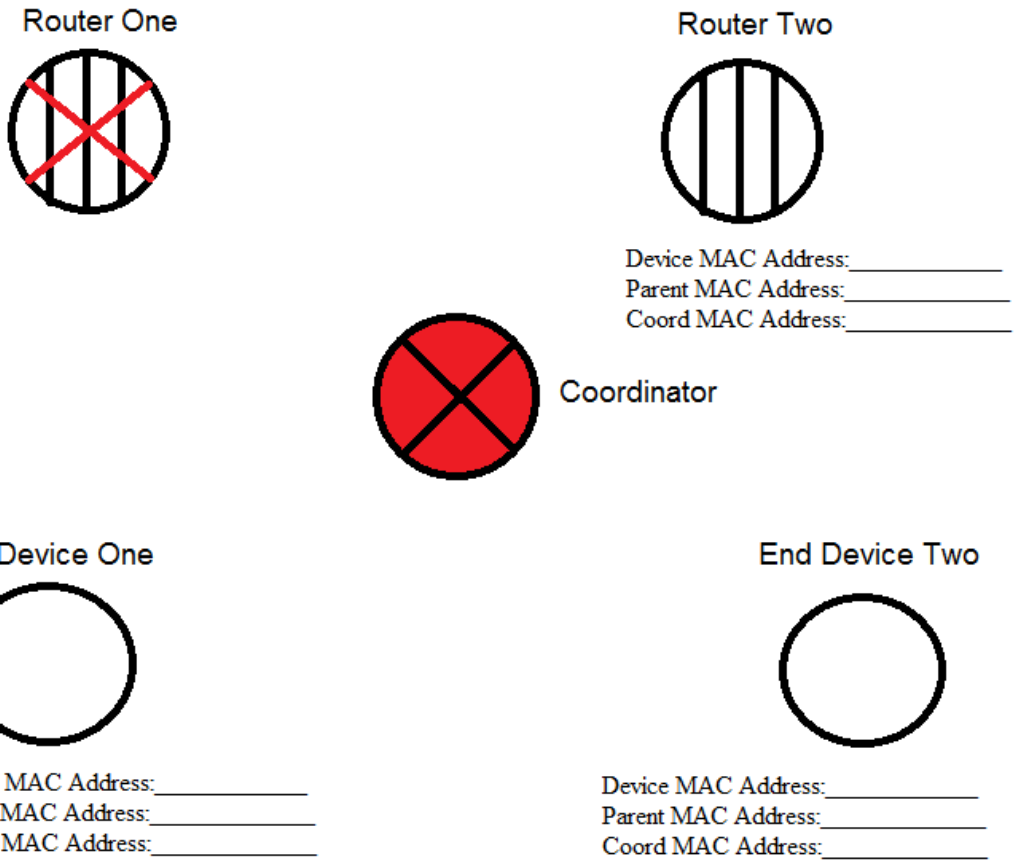
6. Check with your group members for detail of their device information and complete the diagram with their connection.



7. Close the program at Coordinator laptop and unplug the USB cable to turn off the device.
8. Check with your group members for detail of their device information and complete the diagram with their connection.



9. Close the program at Router One and unplug the USB cable to turn off the device.
10. Check with your group members for detail of their device information and complete the diagram with their connection.



11. Close the program at Router Two and unplug the USB cable to turn off the device. Check the status of the two end devices by seeing the LED indicator.
12. Which LED of the end device is blinking? Why?

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ZigBee Applications

There are 3 types of application in the ZigBee Training Kit.

1) Sensor Application
2) Light and Switch Application
3) Serial Application

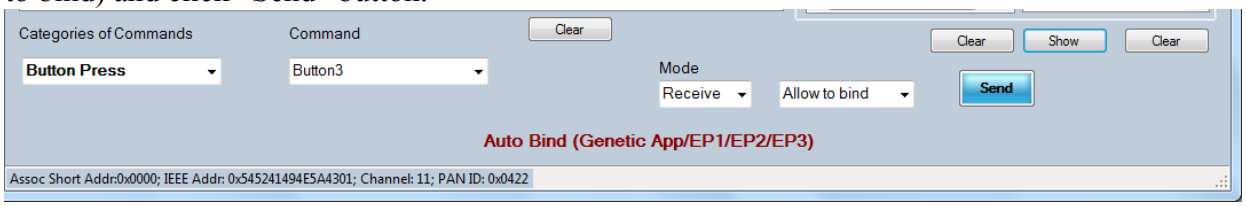
Sensor Application

This experiment needs a team work from all the group members. Firstly, the very important step is that identifies and decides who the sender is and who the receiver is. Here, "Sender" becomes sending sensor data and "Receiver" becomes receiving data.

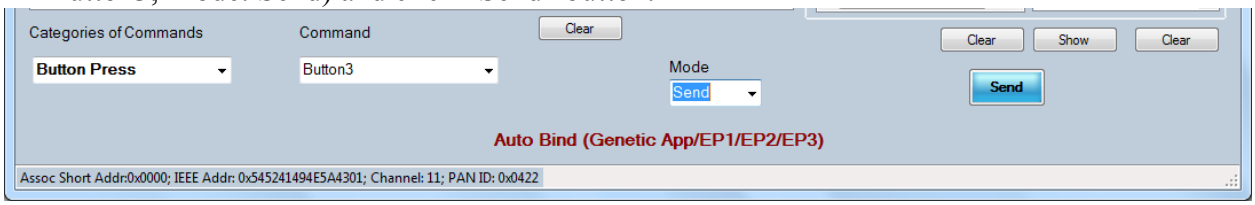
1. Connect back all the devices to laptop through USB cable and launch the ZigBee program. Select the correct serial comm port to be selected and make sure the successful connection by clicking "Connect" 

button.
2. Auto binding process is to be used to bind devices to transfer data among each other. The device sends broadcasts the message on the network with: Address, Profile ID,

Cluster Lists and compatible device responds and sender application stores binding record in binding table. If you want to be a receiver to collect senor data, select according to the following figure (Command: Button Press ➔ Button3, Mode: Receive ➔ Allow to bind) and click "Send" button.



3. From the "sender" side, select according to following figure (Command: Button Press ➔ Button3, Mode: Send) and click "Send" button.



4. The group members must assign two devices: "Sender" and "Receiver" and can choose any two prototype boards: two ZigBee End Device Boards or two ZigBee Router Boards or a ZigBee Router Board and a ZigBee End Device Board.
5. How do you check the successful binding?

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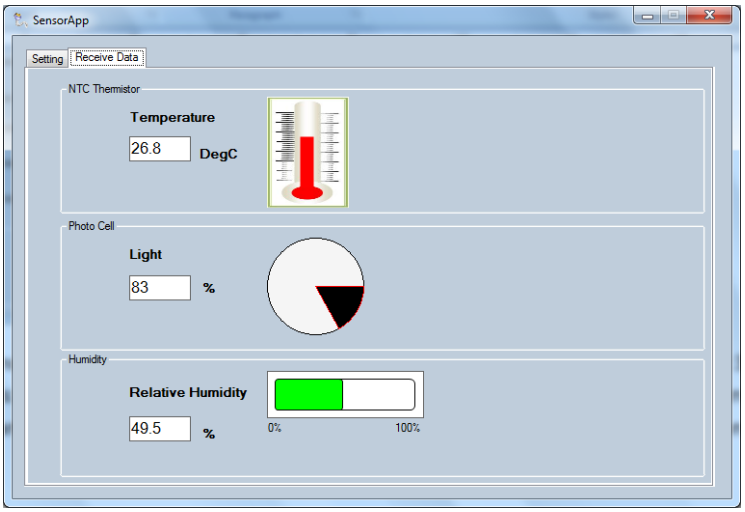
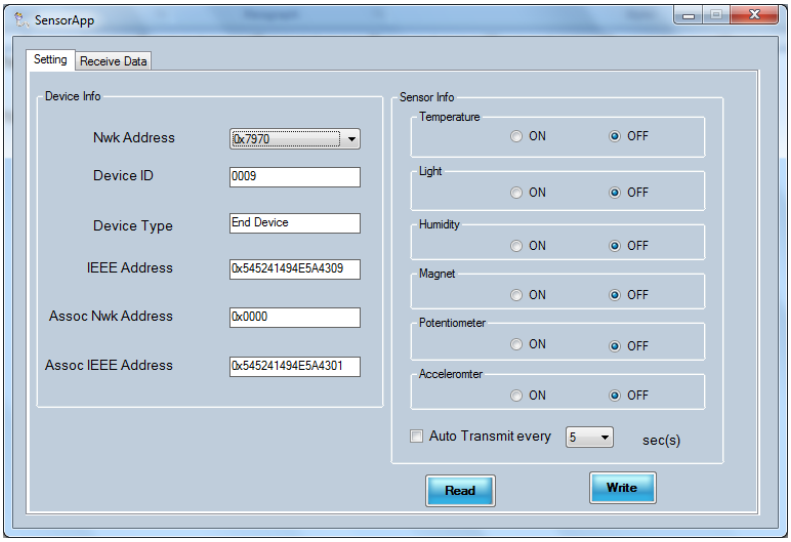
6. At the receiver side, click on the Receiver Data tap to display the data of Temperature, Light and Humidity.



7. At the sender side, click on the Setting tap and select on the Device info at Nwk Address from the drop down list to display "Device ID, Device type, IEEE Address, Assoc Network Address, etc..". Then, select Temperature "ON", Light "ON", Humidity "ON" and check the Auto Transmit every "XX" sec. at Sensor info window. Click on the write button to activate the sensors and enable the sending data to the receiver.



8. How do you know data are sending from the sender?

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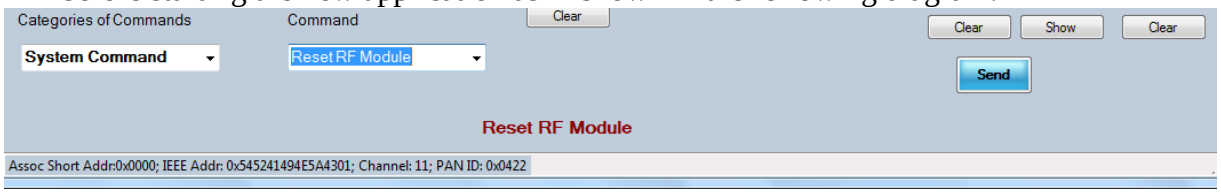
Light and Switch Application

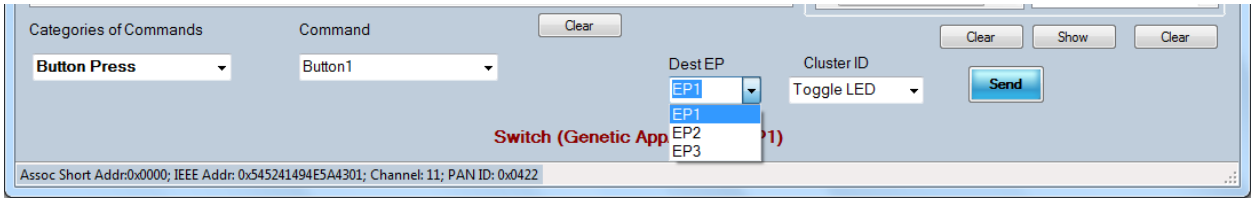
1. Select "Reset RF Module" Command and click "Send" button to reset all the devices before starting the new application as in shown in the following diagram.



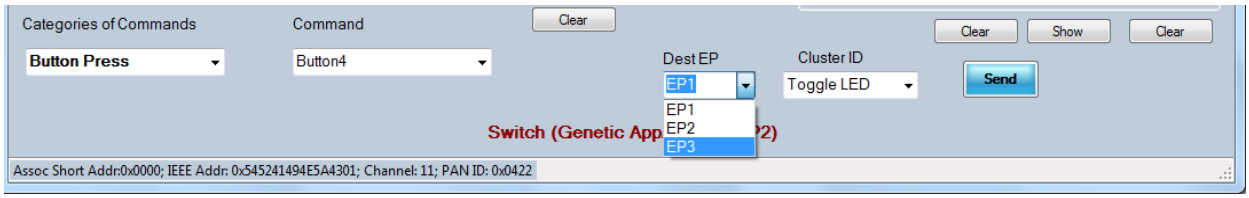
2. Select the correct serial comm port to be selected and make sure the successful connection by clicking "Connect"  button.

3. The experiment again involves a collaboration work among team members. Firstly, sender and receiver are to be decided. Take note that, we already defined "Sender" as Switch and "Receiver" as Light in this application at the prototype boards.
4. If you want to be a receiver to collect senor data, select according to the following figure (Command: Button Press ➔ Button3, Mode: Receive ➔ Allow to bind) and click "Send" button as in Sensor Application.
5. From the "sender" side, select according to following figure (Command: Button Press ➔ Button3, Mode: Send) and click "Send" button to complete the binding process.
6. By using the Button press command and different End point application to turn on and turn off LED at the receiving device as follow.

Button1" means "Switch1 (Endpoint1)" and "Destination EP1" means "LED1". Cluster ID is command for LED status.



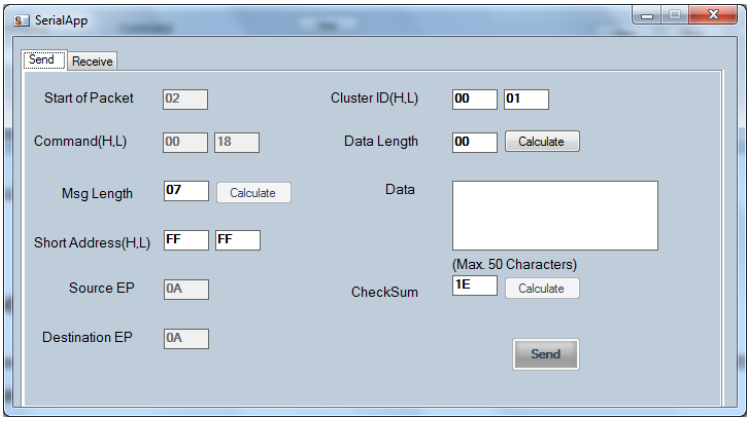
This button4 application is the same as previous one. Only the difference is button4 (Endpoint2) can control all destination Endpoints.



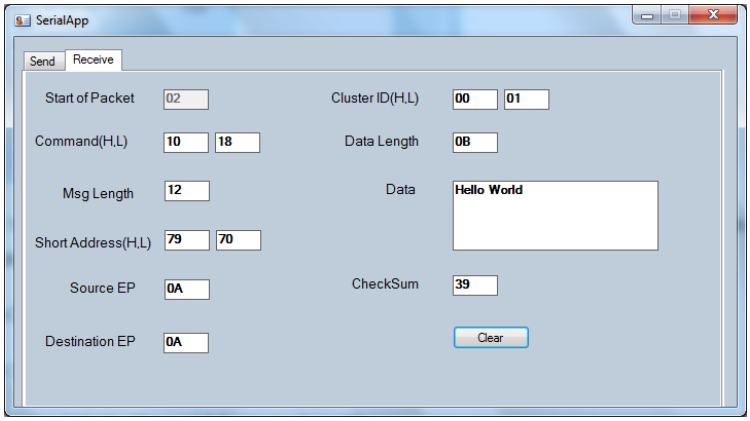
For the button5 application, source EP3 can control all LEDs.

Serial Application

1. Assume we had already done connection and select “Serial Application” from the categories of Commands.
2. There are 2 tabs inside the Serial application: “Send” and “Receive”. For sending data at the “Sender” side.
    - type Data first
    - click calculate button of Data Length
    - click calculate button of Message Length
    - click calculate button of Check Sum
    - click send button



3. For receiving data at the “Receiver” side, the user can see data packet as in the following figure.



4. The above procedure is used the broadcast mode, the user can try by using unicast mode with changing short address. This application can send message vice visa.