Inter Device and Serial Communication

ZIGBEE (Xbee)

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Introduction to ZigBee

- Technological standard for wireless network protocol designed for low data rate control networks.

- Based on IEEE 802.15.4 specification

- Created by Zigbee Alliance

- Provides a standard methodology for functions such as:

✓ Network formation

✓ Messaging

✓ Device discovery

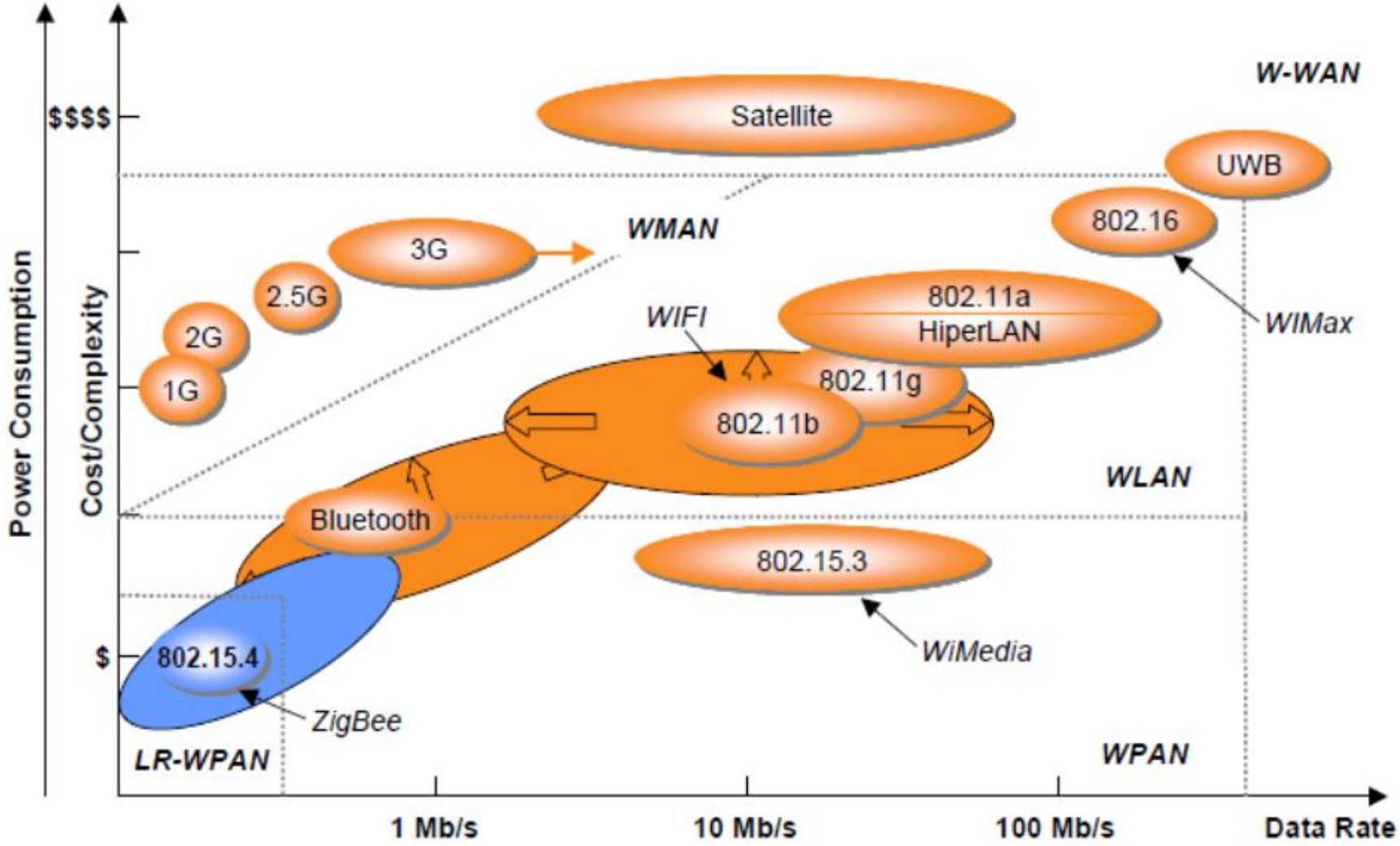
Zigbee characteristics

- Frequency Bands supported by Zigbee: **2.4GHz and 868/915 MHz**

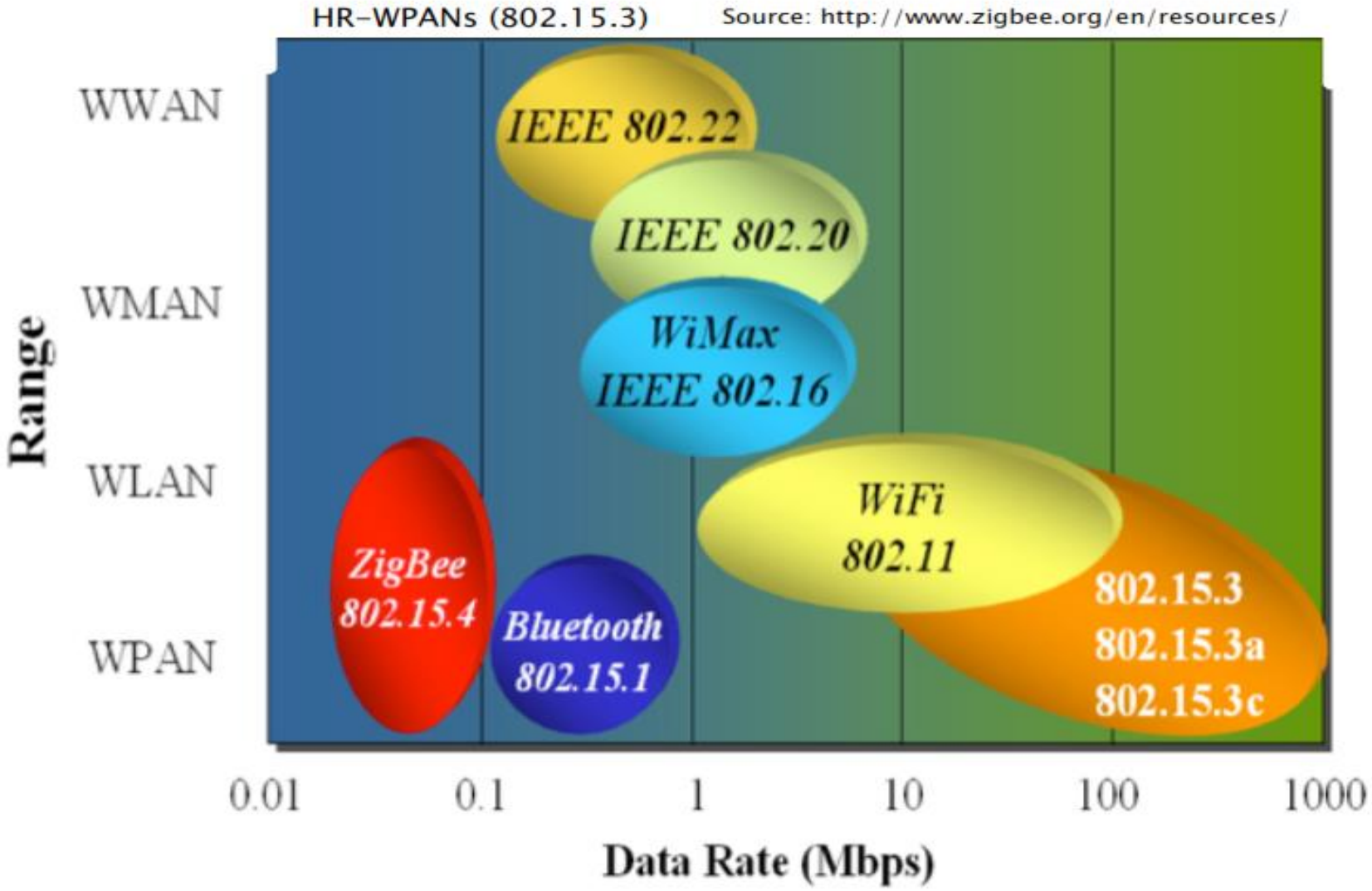
Frequency Band	Availability	# of channels allocated	Maximum Data Rate
2.45 GHz band	Global / Unlicensed Band	16	250 kbps
915 MHz band	American Band	10	40 kbps
868 MHz band	European Band	1	20 kbps

- Allocation of guaranteed time slots (GTSs).
- Carrier sense multiple access with collision avoidance (CSMA-CA) channel access Yields high throughput and low latency for low duty cycle devices like sensors and controls.
- Low power consumption with battery life ranging from months to years.
- Reduced complexity
- Lower implementation cost
- Short range communication
- Large mesh networks

Standard Technology Map



IEEE 802 Wireless Space



Applications

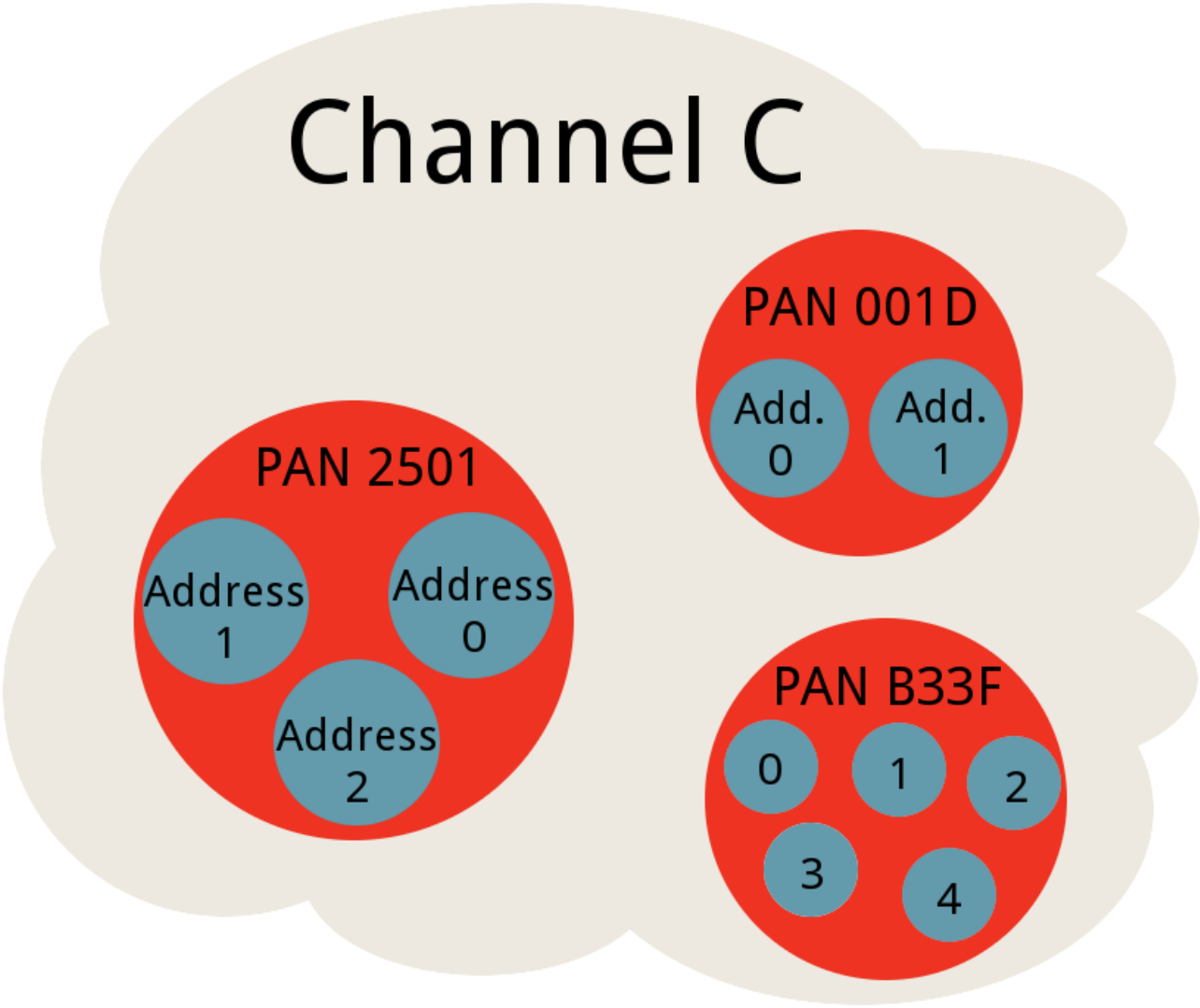
- In-home patient information monitoring remotely and securely
- Monitoring structural health of buildings using Sensor network
- Security systems using ZigBee for wireless camera system
- Irrigation and water management using sensors across landscaping fields
- Wireless light control Industrial automation and control
- Livestock tracking using ZigBee as active tags with extended life
- Hotel guest room access using portable ZigBee device as key for each door and eliminating the wiring
- Utility meter-reading systems
  - Passing the information to one or more node and connecting to the Internet using ZigBee gateway
  - Self-forming mesh network to connect to the corporate office

802.15.4 : Network Addressing

- **ZigBee in turn provides a Network Layer Address**
- ✓ -16-bit address
- ✓ It maps 64-bit address of the radio to NWK address

- **Channels must be the same within a network for nodes to communicate with one another**
- ✓ Wireless links under 802.15.4 can operate in 27 different channels
- ✓ PHY layer should be able to tune its transceiver into a certain channel upon receiving the request from MAC sub-layer
- ✓ Channel selection can be performed automatically

Addressing


Channel C
PAN 001D
Add. 0
Add. 1
PAN 2501
Address 1
Address 0
Address 2
PAN B33F
0
1
2
3
4

Addressing

- Channels
- PAN
- 64-bit address
- High - same for all XBees
- Low – each XBee has its own address
- 16-bit address (configurable on Series 1)

Scan Channels Values

Scan Channel Value	Channels Allocated
0x0001	11 (0x0B)
0x0002	12 (0x0C)
0x0004	13 (0x0D)
0x0008	14 (0x0E)
0x0010	15 (0x0F)
0x0020	16 (0x10)
0x0040	17 (0x11)
0x0080	18 (0x12)
0x0100	19 (0x13)
0x0200	20 (0x14)
0x0400	21 (0x15)
0x0800	22 (0x16)
0x1000	23 (0x17)
0x2000	24 (0x18)
0x4000	25 (0x19)
0x8000	26 (0x1A)

Network Creation and Routing

Network Creation

- **The Application layer sets the Coordinator for Self-forming network**
- **The network is coordinated by the Coordinator**

✓ Scans the channels (all other networks) : Active or passive

✓ Select an available channel and a PAN ID with no PAN/Channel ID conflict

Routing

- **Performed by the coordinator and router on behalf of the end-device**
- **Routing is based on NEXT-HOP routing**
- **Based on finding the best link**

✓ Link with the lowest cost

✓ Energy efficient, least probability of error, etc.

- **Path cost is sum of all link costs**

802.15.4 Devices Types

- Only implementing the MAC and PHY
- IEEE 802.15.4 Devices
- **Full-function devices (FFD)**

❖ Accepts all roles (Node, Router, Base Station)

- **Reduced-function device (RFD)**

❖ Limited capacity and can only talk to FFD device

❖ Used for simple applications (turning on and off a device)

❖ Less memory and lower power consumption

ZigBee Device Types

Coordinator

- An FFD with network device functionality that provides coordination and other services to the network.

PAN Coordinator

- A coordinator that is the principal controller of the PAN. A network has exactly one PAN coordinator.

Network Device

- An RFD or FFD implementation containing an IEEE 802.15.4 medium access control and physical interface to the wireless medium.

Coordinators

- Each network has 1 coordinator
- Coordinator selects channel and PAN ID
- Other devices then join the PAN
- 16-bit address is always 0
- Assigns 16-bit address for the router and end devices

Routers

- Optional
- Can have as many as you want
- Issues a request on startup to find a coordinator/network it can join
- Can talk to any device
- If an end device is sleeping it stores its data
- Coordinator can act as a “super router”

End Devices

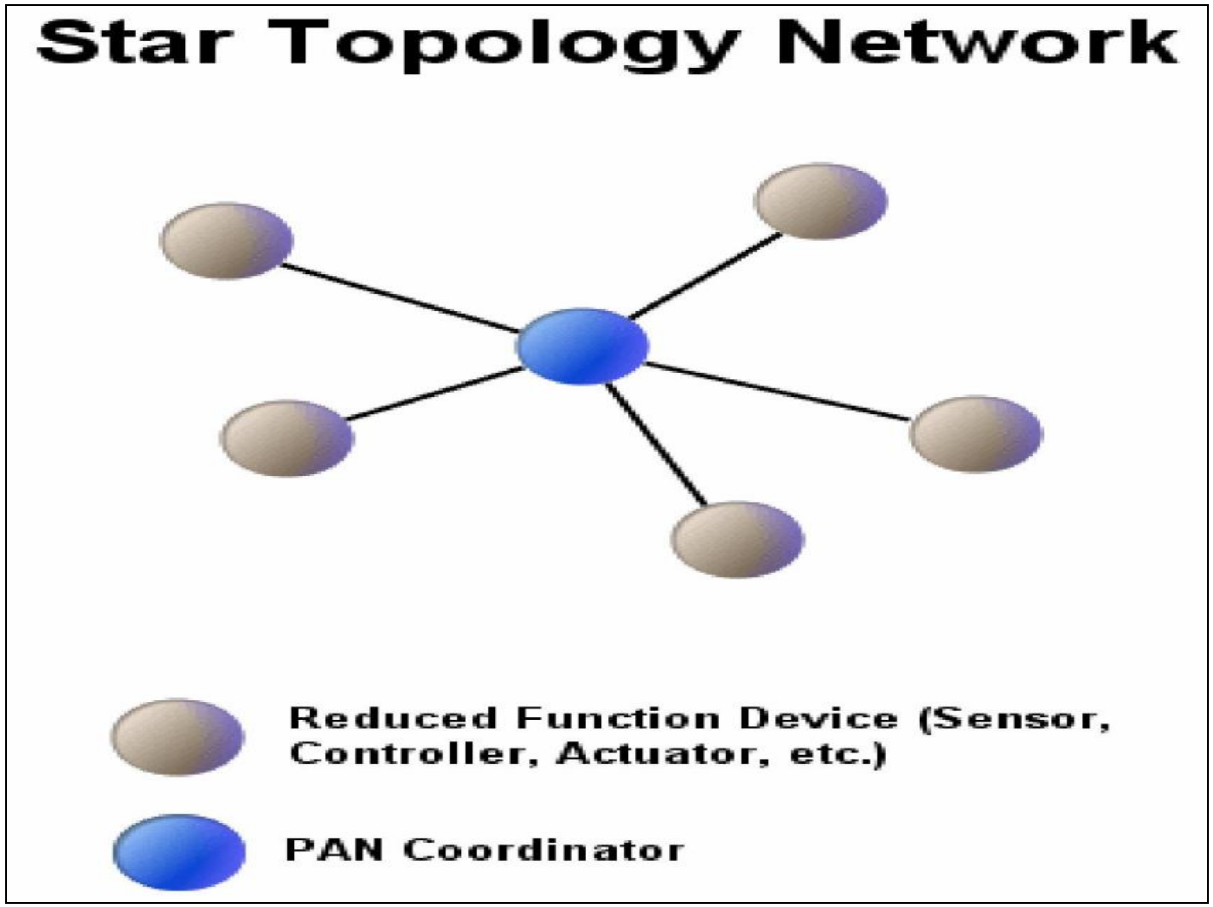
- Optional
- Usually battery powered
- Can have as many as you want
- Issues a request on startup to find a network it can join and a parent device (router or coordinator)
- Can only communicate with its parent

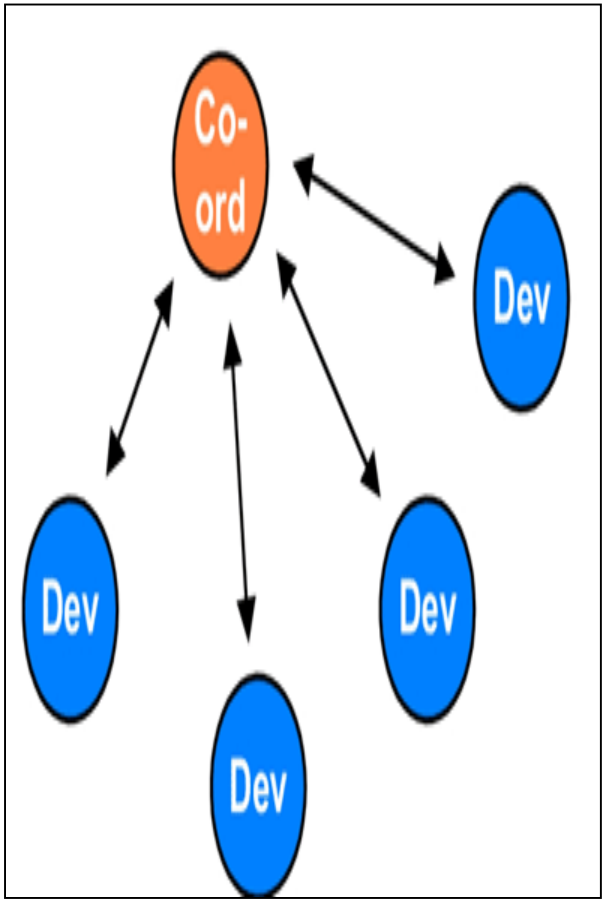
Network Topologies

Network Topology Types

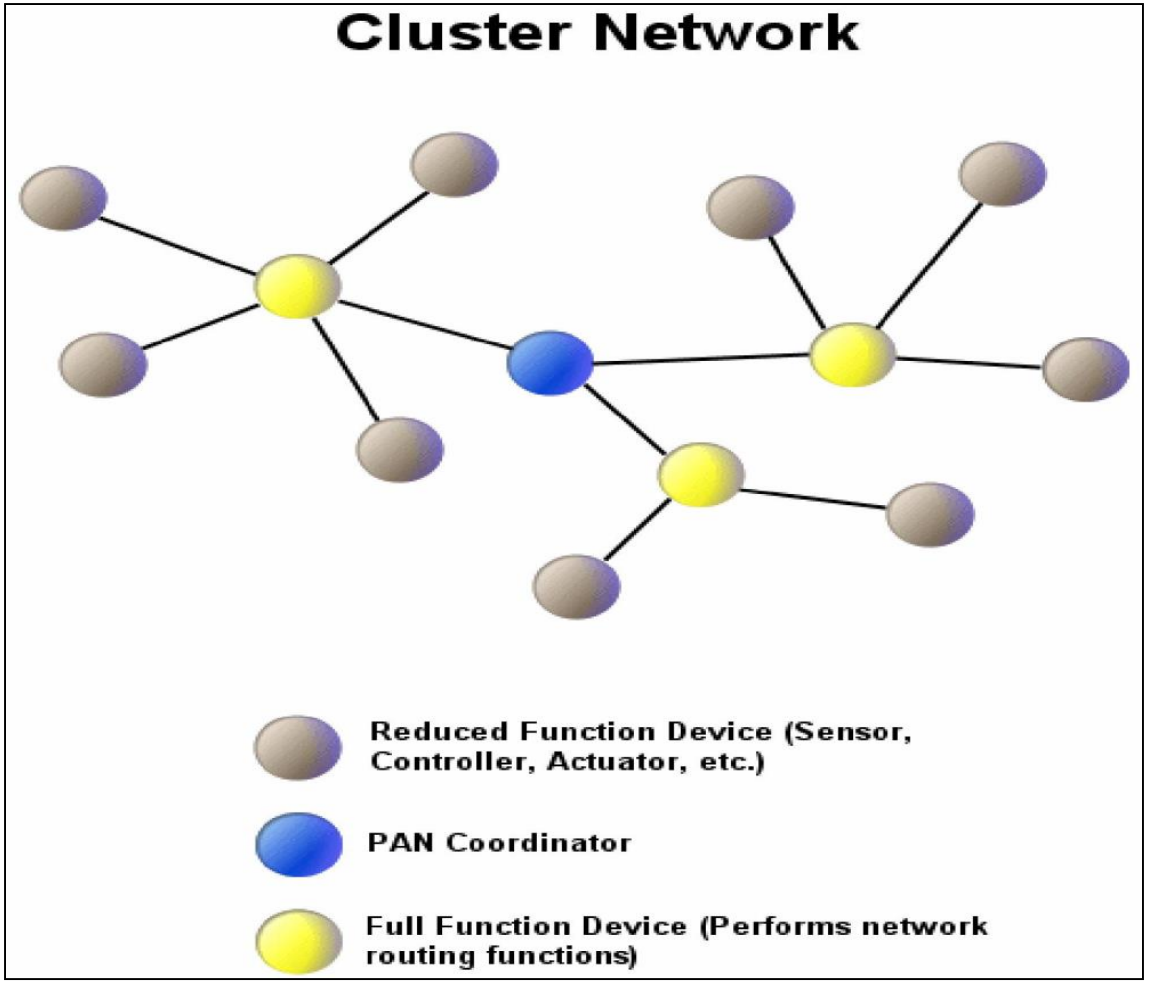
- Star
- Cluster Tree
- Mesh

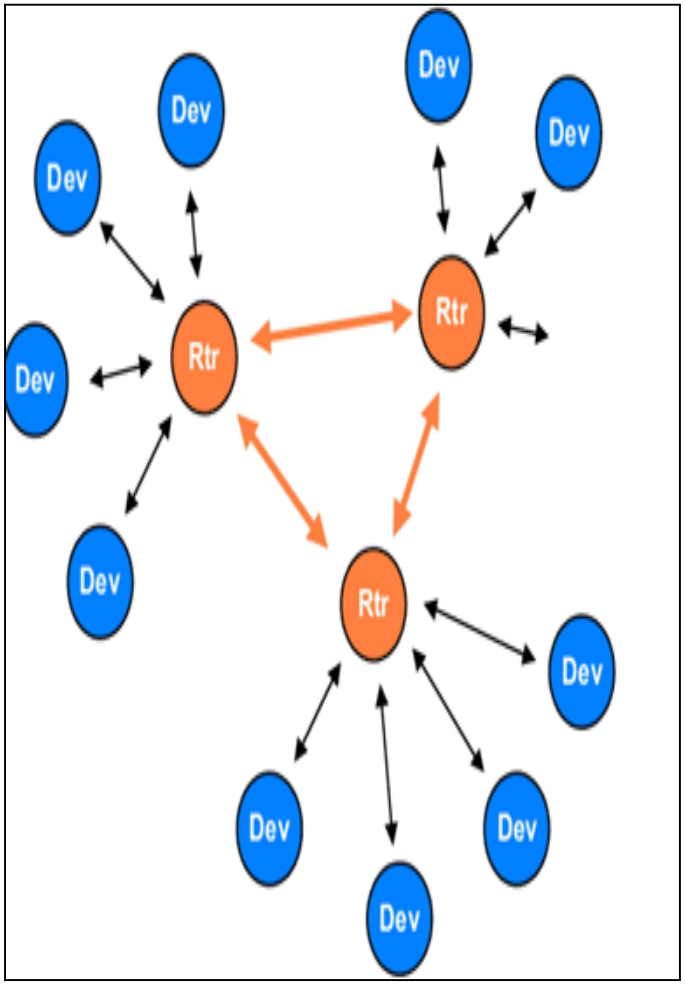
Network Topologies



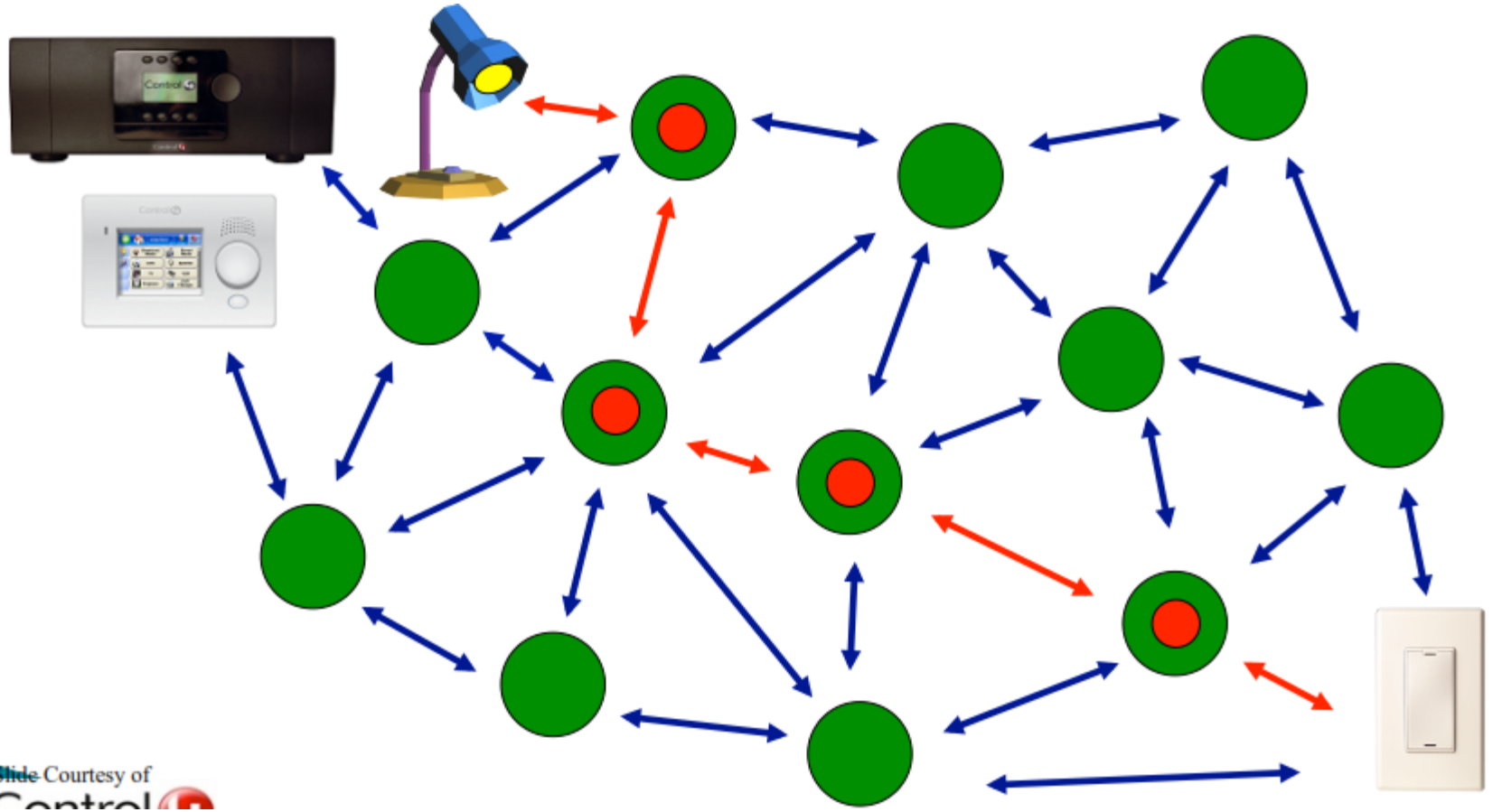


Network Topologies



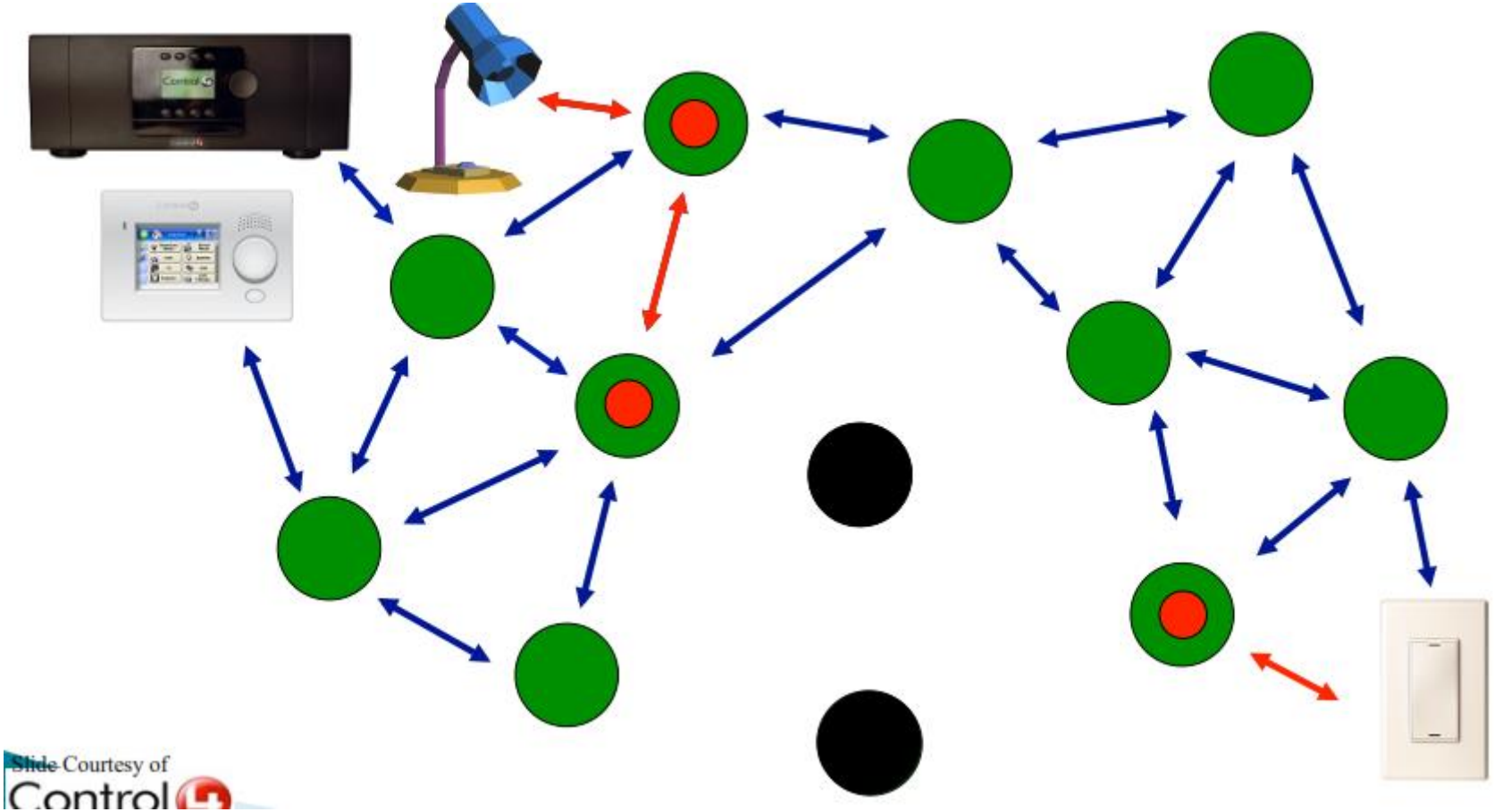


ZigBee Mesh Networking- Available Routes and Route Selection



Slide Courtesy of

ZigBee Mesh Networking- Power Loss



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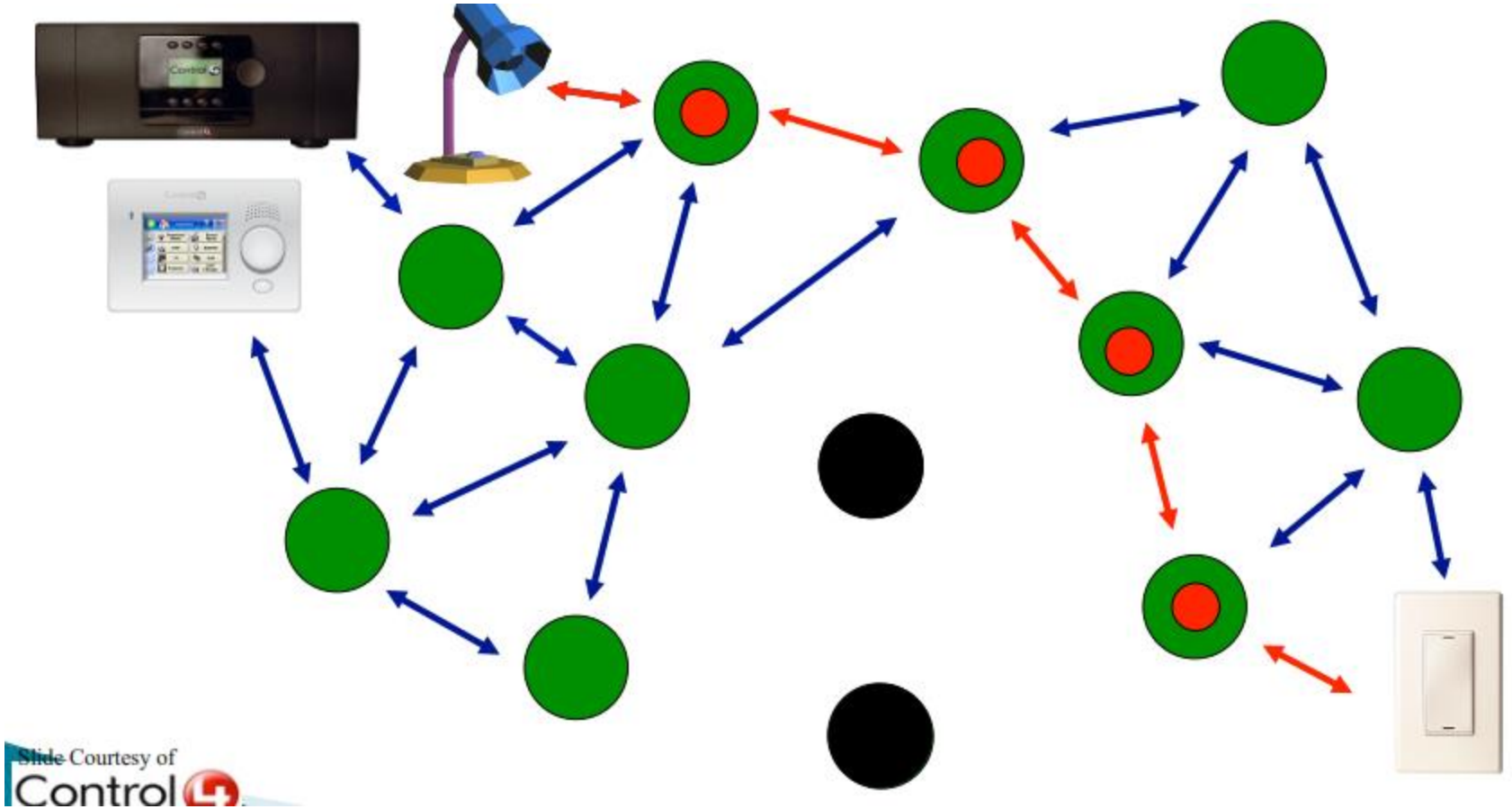
ZigBee Mesh Networking- Self Healing Reroute Selection



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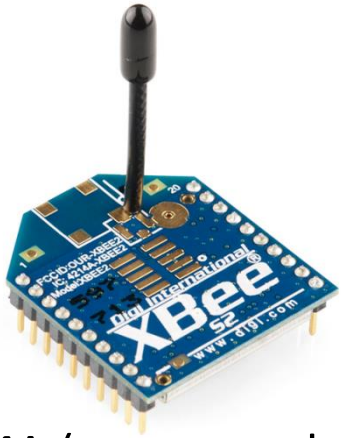
Antennas

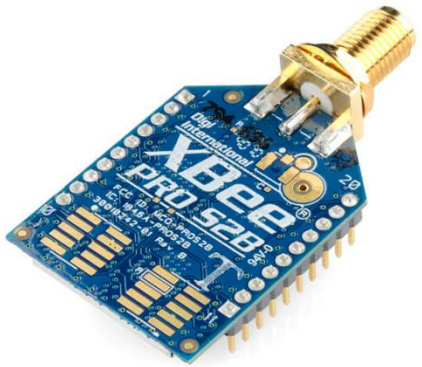
- Chip

- u.FL

- Whip

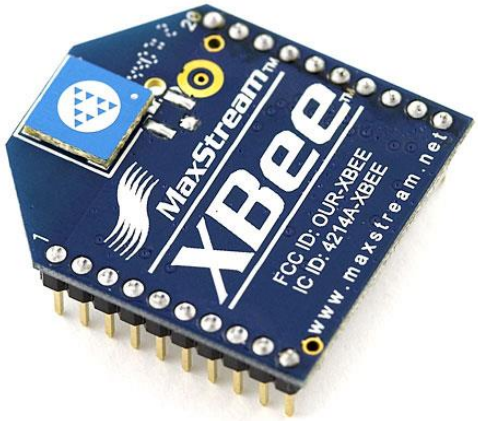


- RPSMA (reverse-polarity SubMiniature version A)



Regular vs. Pro

- 1-2mW
- Smaller
- Shorter range (100m)
- Cheaper



- 50-60mW
- Longer
- Longer range (300m)
- More expensive

How to use Xbee!

- To connect an XBee to Arduino or computer XBee Explorer or XBee Shield is used. With the help of these tools we can configure our Xbees and will be able to establish connections between remote RF modules.
- The explorer board has a USB-to-Serial converter. Which translates data betw ee

Xbee Shield

Xbee Explorer

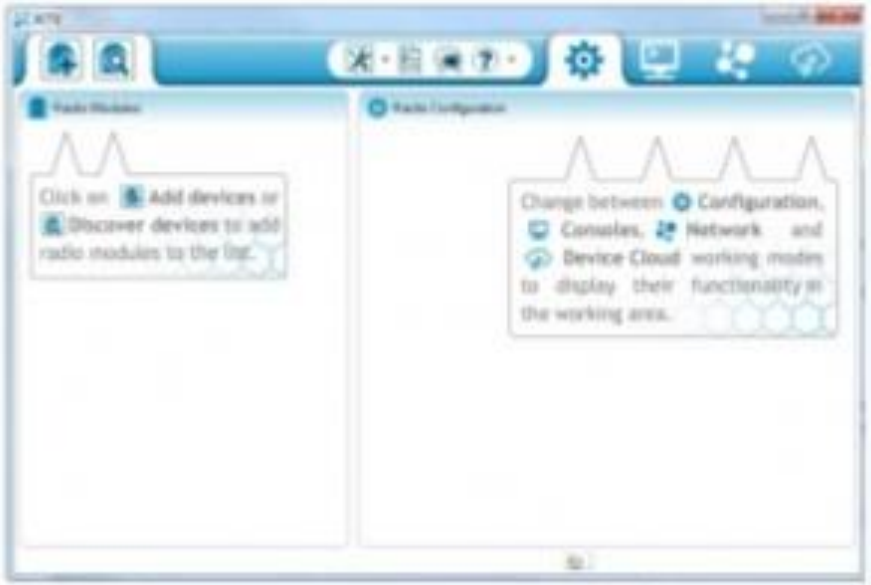
- Connect the Xbee module onto the Explorer and connect with

Firmware

- Must upload with X-CTU (on Windows)
- AT firmware vs API firmware
- Coordinator, Router, End Device
- Other
- Each Firmware has different settings

X-CTU Software

- Opening X-CTU this window will appear:



- The application will start a search for different connected devices:

- To add your XBee modules, click the "Add device" icon in the upper-left part of the window this screen will appear

- Select communication port and for Serial Explorer board, pick the "Communications Port" option. This window also allows to modify specific serial characteristics like baud rate, data bits, and stop bits.

- Click the add modules, and then click on the module that appeared at left after a few seconds as X-CTU reads the configuration settings of XBee. The entire configuration of XBee will be shown.

- To test the communication between XBee's second XBee needs to be connected to the computer and for that click the 'add device' button on left. If second XBee is also connected to the same computer, a second entry will be added to the "Radio Modules" list. Selecting any one of those entries will display its configuration settings.

- Click the "Switch to Consoles" icon in the upper-right part of the window. This will switch from the configuration tab to the console mode. We can use the console to send data to other remote XBeez.
- If two XBees are connected to computer, each radio's console can be selected by clicking the device on the left. Open a serial connection of each device by clicking the connect icon it will turn the console's border to green.
- Once all Gateway and devices are configured in the same network, switch to Working Network mode. Press the 'Scan the radio module network' button and all connected devices will be shown, in its corresponding topology (P2P, tree or mesh).
- Now write anything in console log and notice that data is transmitted or not. Red and blue letters denotes the successful transmission link is created.

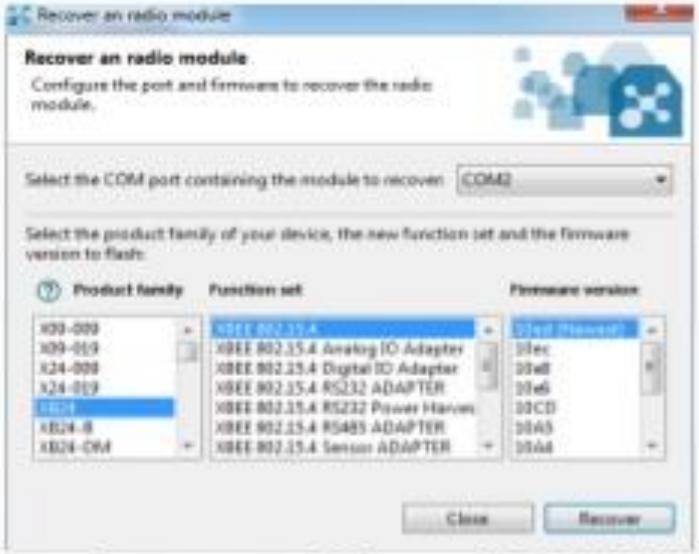
- Range test tool allows to perform a range test between a local radio module and any of the remote modules working in the same network.

- Click the 'Discover radio nodes in the same network' button and connected devices will appear.

- Add the device and start the range test.

- If XBee is not working properly click the Tools icon, and select XBee Recovery:

- Select COM port and product family. This can be found on the bottom sticker of your XBee. For series 1 module, the family should be XB24. Beyond that you'll need to select a "Function Set" and "Firmware Version".



- Radio Configuration: Connect one XBee to X-CTU. Click back over to the Configuration tab. CH, ID, DH, DL, and MY. Beside each of those blocks is a text box – that's where new settings are typed.
- Network ID (ID): Begin by coming up with a unique network ID number i.e 3345 convert it to hexadecimal. Or if you don't want to put that much effort into it, use a random value like J7U1.
- Type your 16-bit network ID into the white text box next to PAN ID.
- MY Address (MY): Create addresses for each XBee in network. These values should be unique to each XBee in a network. The MY address can be any value between 0x0000 and 0xFFFF. Type this address into the text box next to "MY 16-bit Source Address".

- For two XBees, assign the first an MY address of 0, and the other an address of 1. (XBee's can share the same MY address, they'll both receive the same data if it's broadcast ed to that address.)
- Destination Address (DH & DL): The destination address defines with which XBee, source XBee is talking to. There are actually two values used to set the destination: destination high (DH) and destination low (DL).
- Leave DH set to 0, and set DL to the MY address of the receiving XBee.
- Set DH to the Serial Number High (SH) and DL to the Serial Number Low (SL) of destination XBee.
- Either method works, but the former – setting DH to 0 and DL to the destination's MY address – is usually easier.
- Example for setting up the ID, DH, DL, and MY values for a pair of XBees:

Setting	Acronym	XBee 1	XBee 2
Channel	CH	C	C
PAN ID	ID	A1B7	A1B7
Destination Address High	DH	0	0
Destination Address Low	DL	1	0
16-bit Source Address	MY	0	1

Youtube Tutorial

https://www.youtube.com/watch?v=uBkQUph9EKM