# MIT Media Lab: XBee Workshop

Instructor: Rob Faludi

# Plan for Today

- XBees
- Serial Terminals
- Addressing
- Basic Config
- Chat Project
- I/O Mode
- Arduino & XBee
- Workshop, Q&A

# Student Introductions

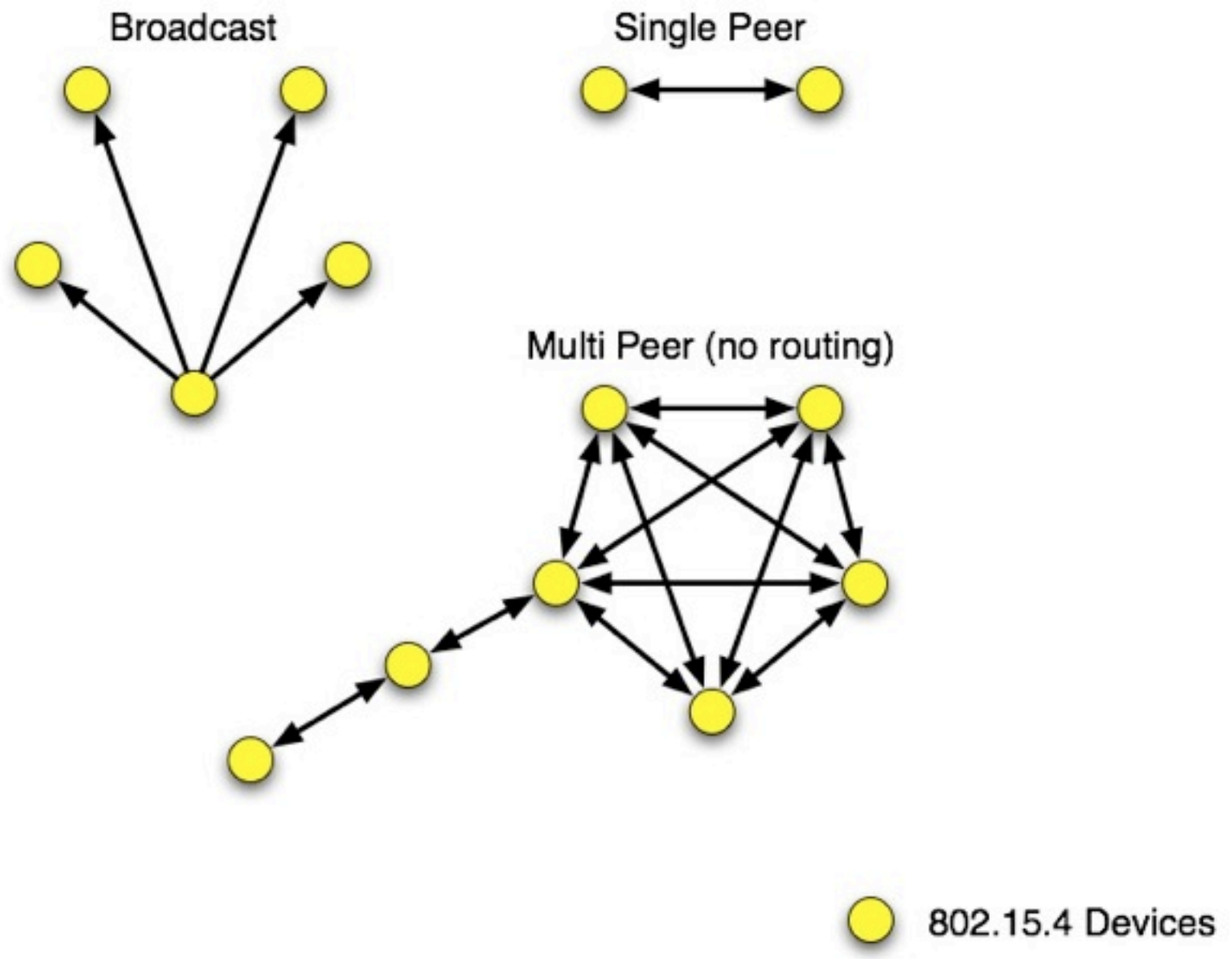
- Name, where you are from, what you do
- What you want out of this workshop
- Aspirational pet animal

# 802.15.4

- low power
- low bandwidth
- addressing
- affordable
- small
- standardized
- popular for DIY, easy to learn

# 802.15.4 Topologies

- single peer
- multi-peer
- broadcast



# ZigBee & 802.15.4

- ZigBee is built on top of the IEEE 802.15.4 protocol
- XBee radios can be purchased with or without ZigBee
- XBee 802.15.4 vs. ZNet 2.5 vs. ZB Pro vs. DigiMesh
- All ways are useful

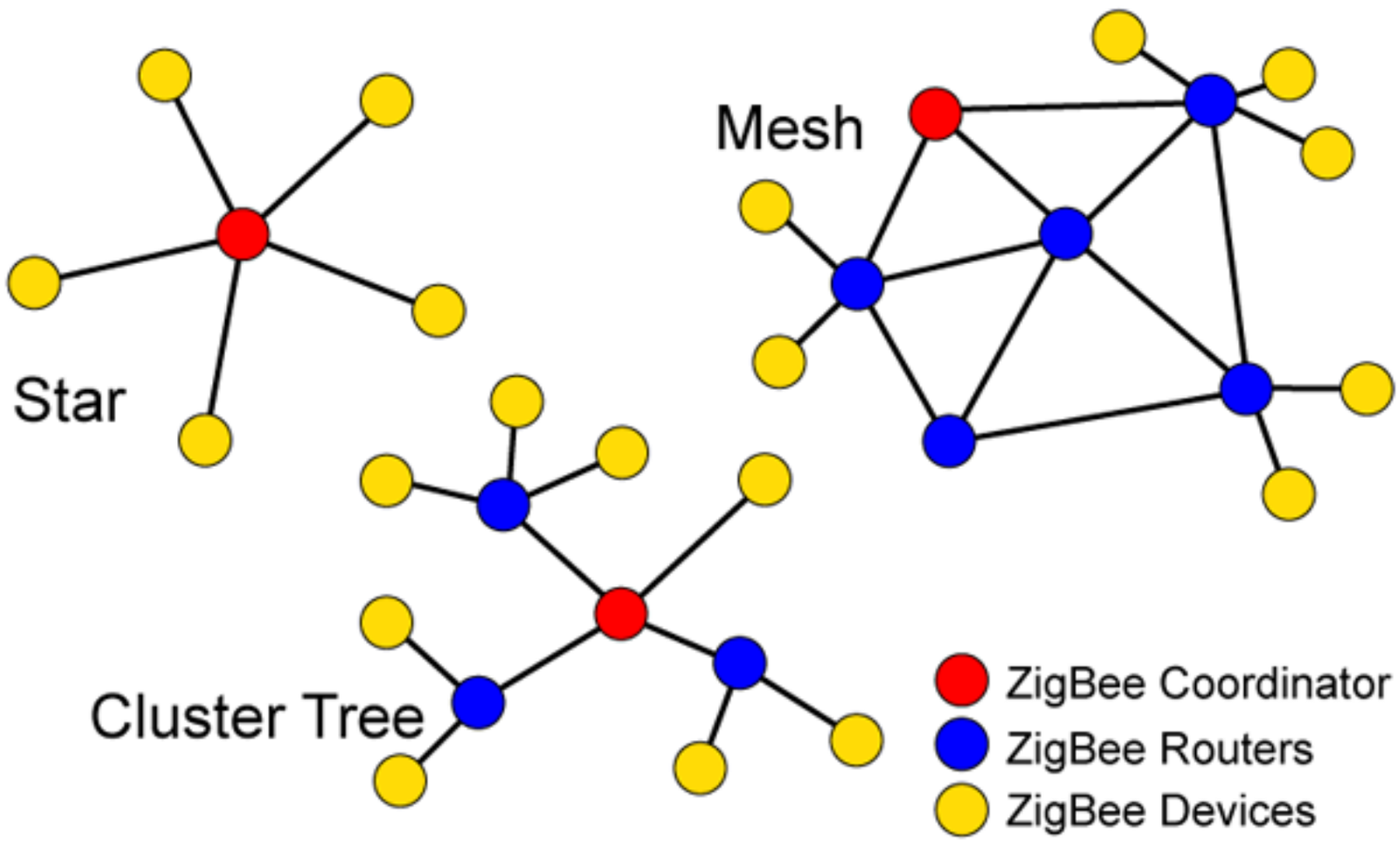
# ZigBee

- routing
- self-healing mesh
- ad-hoc network creation

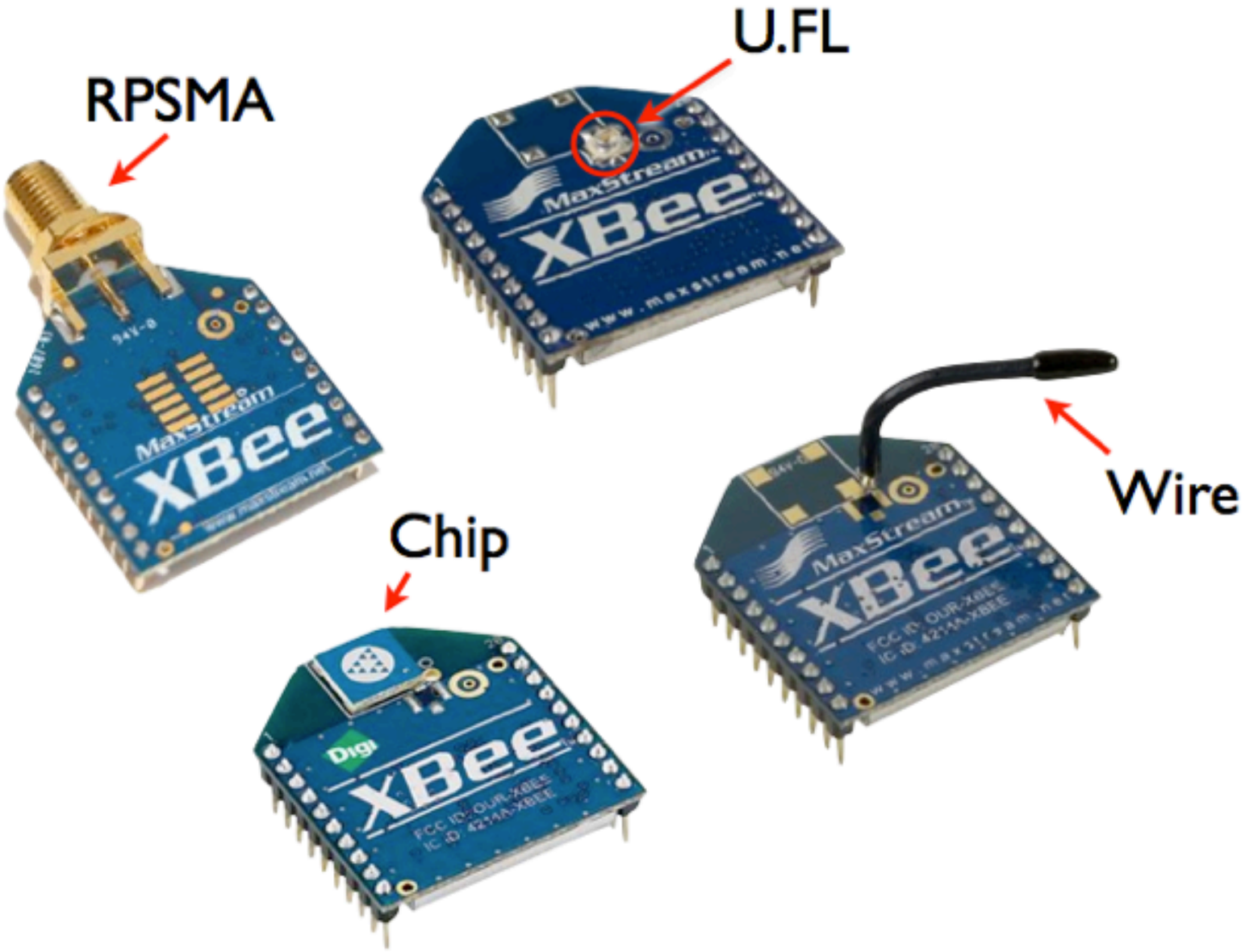
ZigBee™ Alliance

# ZigBee Topologies

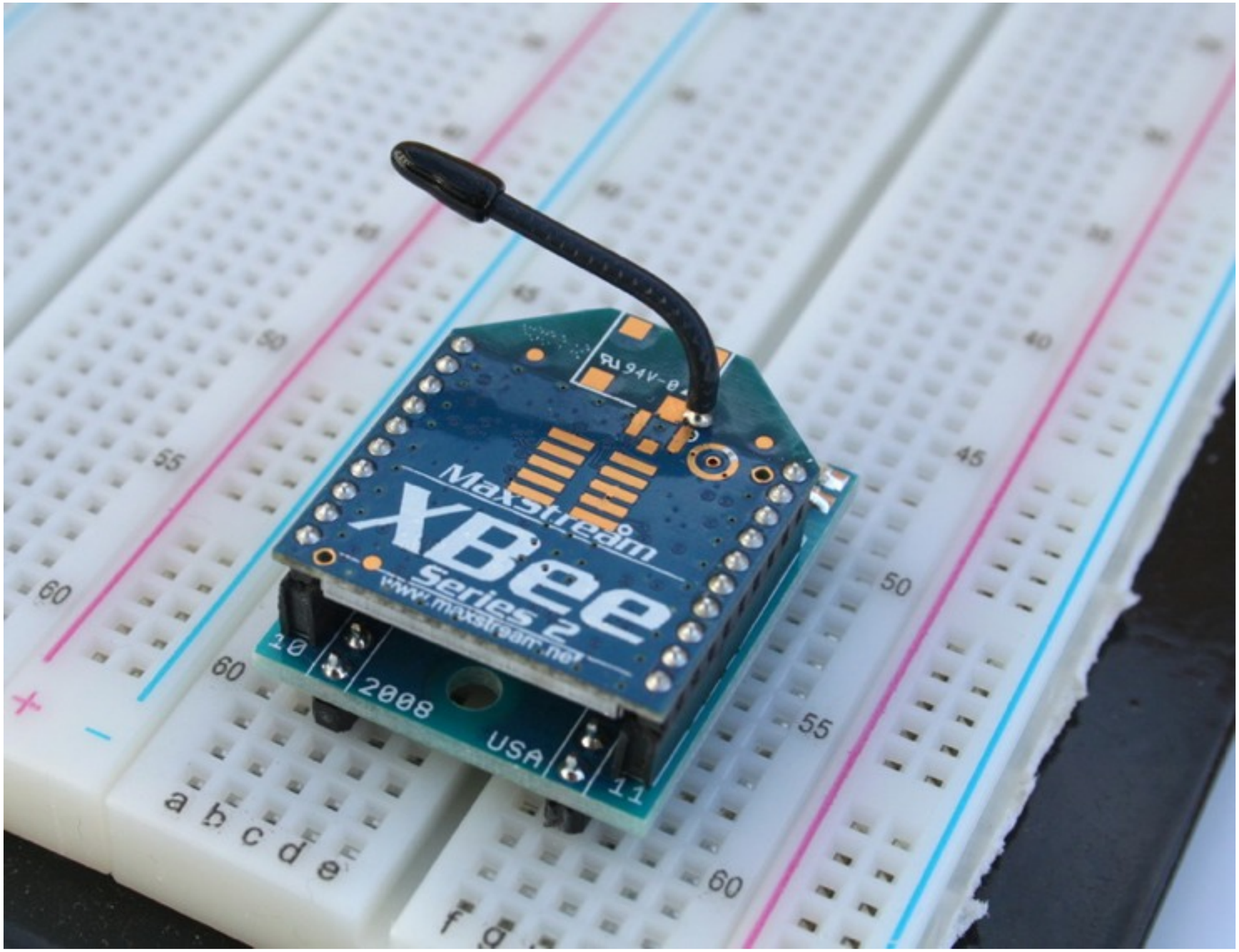
- peer
- star
- mesh
- routing



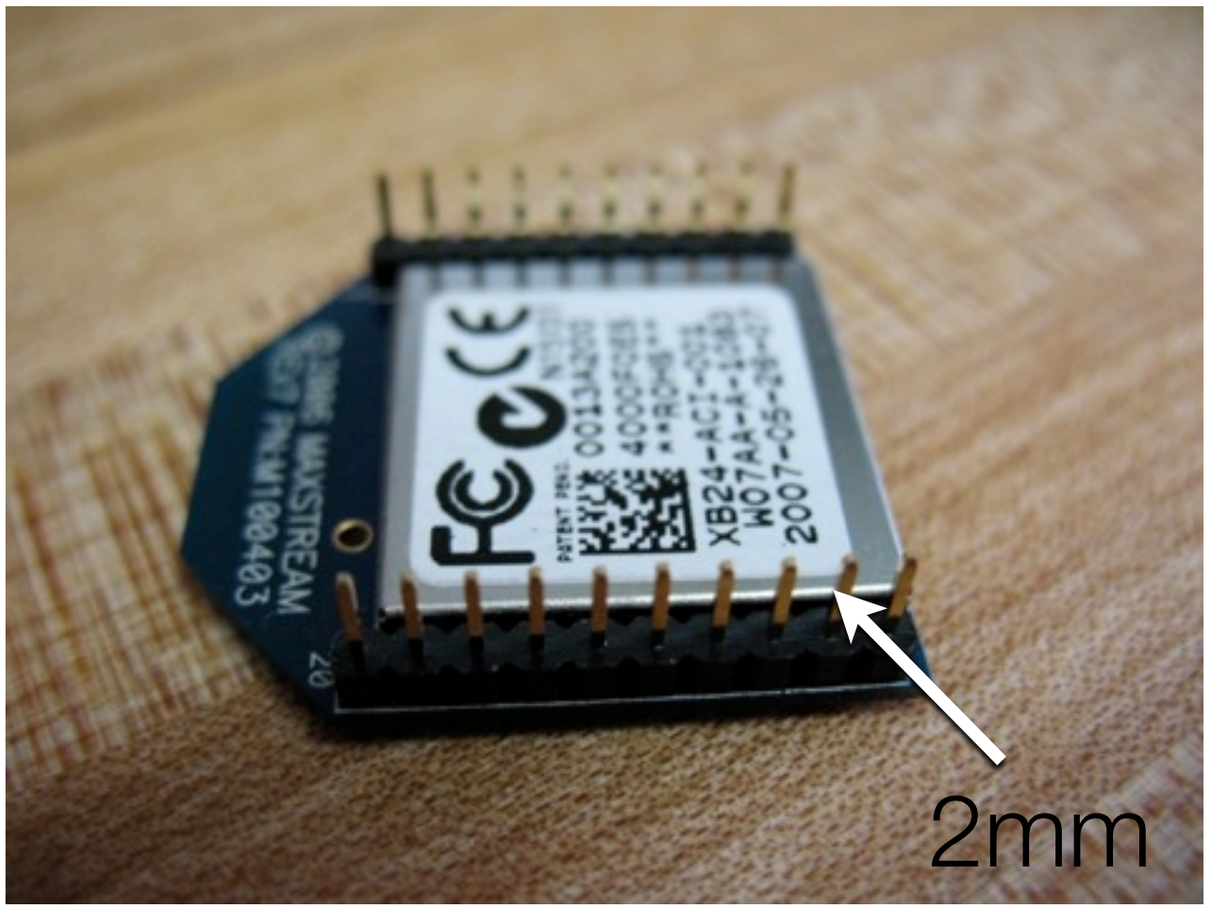
# Antennas

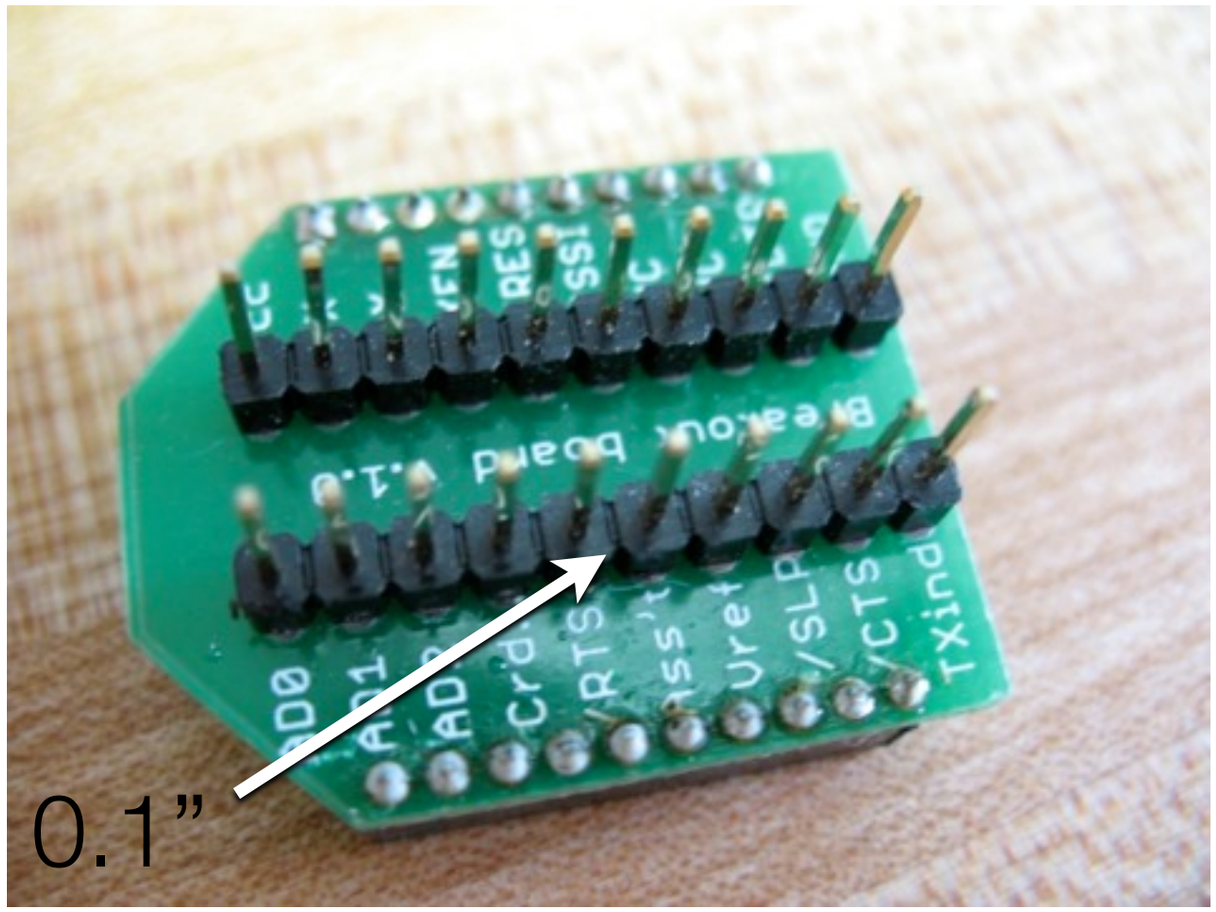


# Breakout for Breadboards

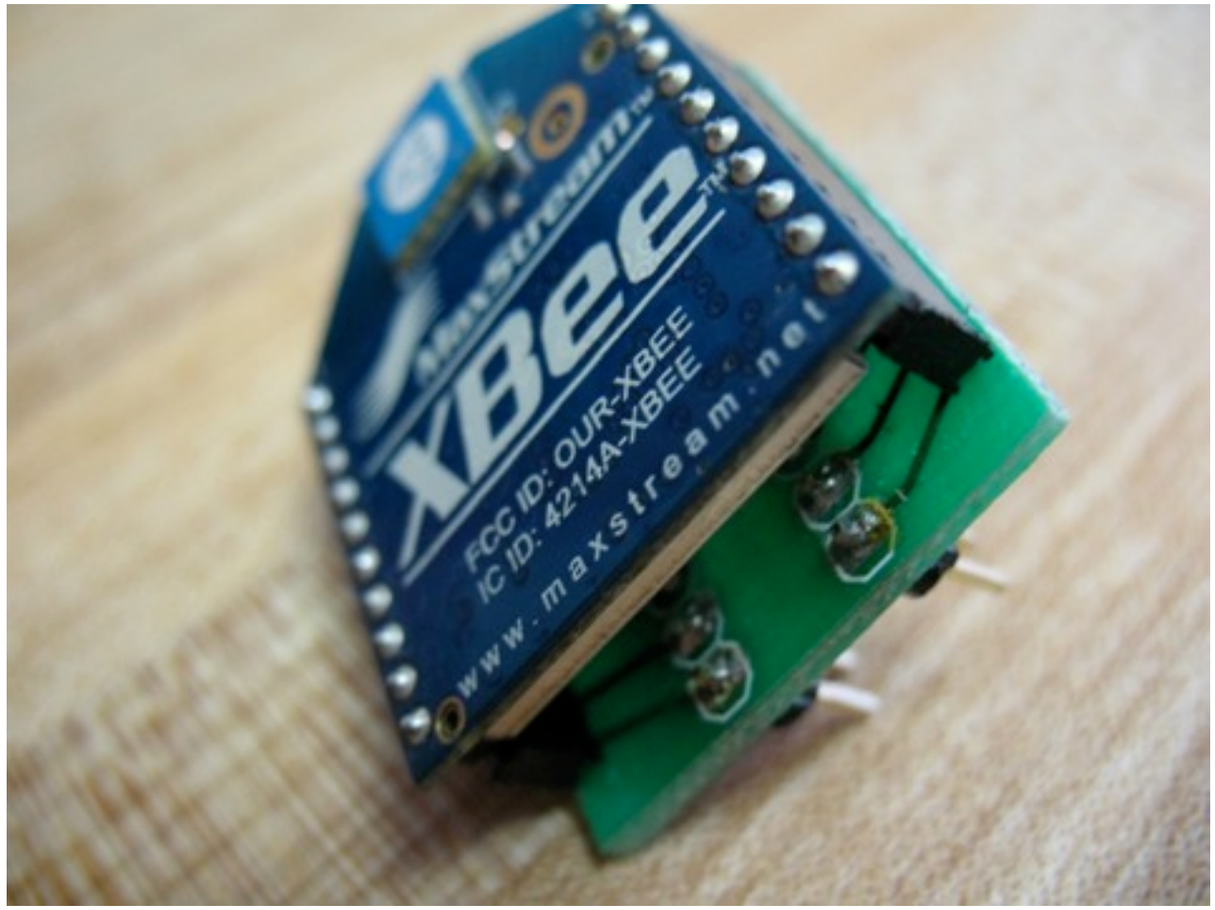


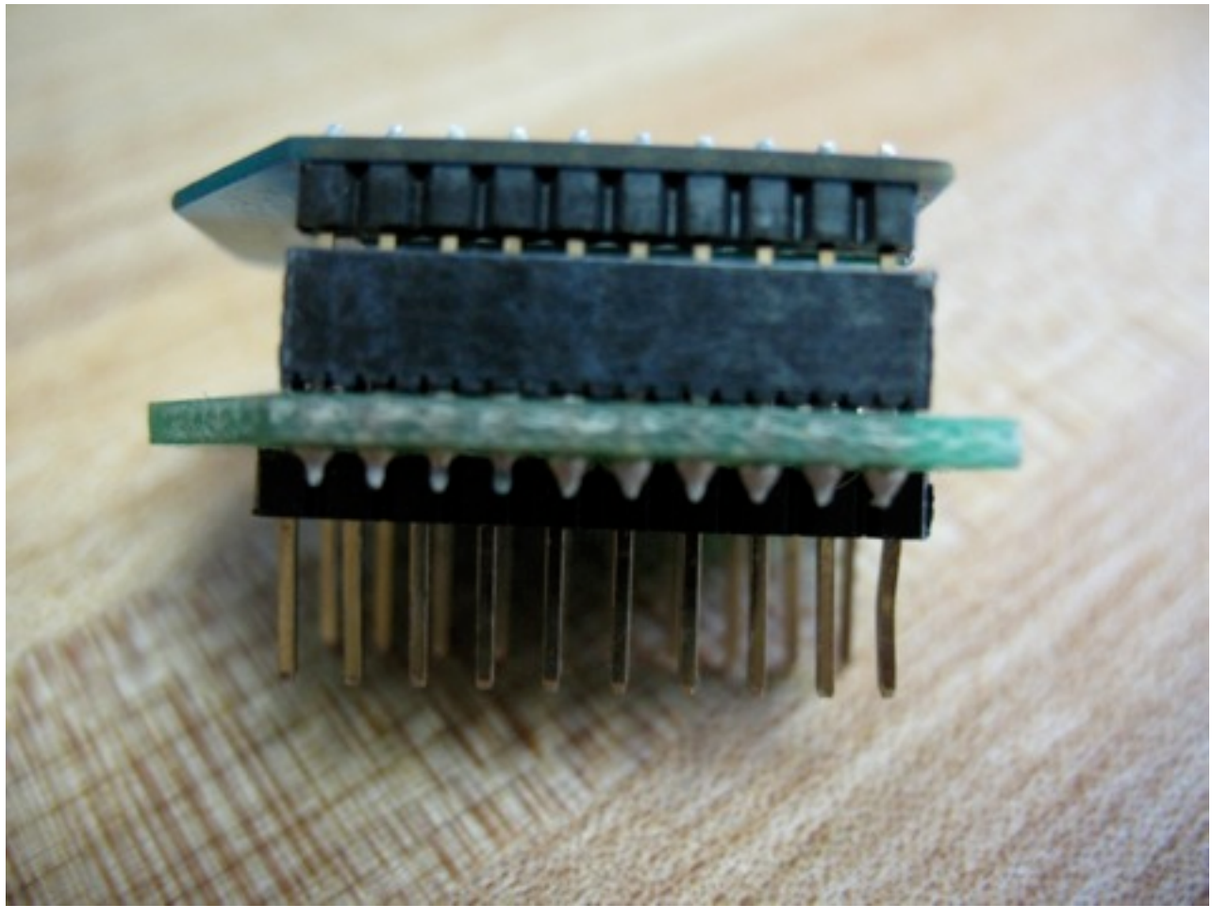
# Breakout Boards for breadboarding



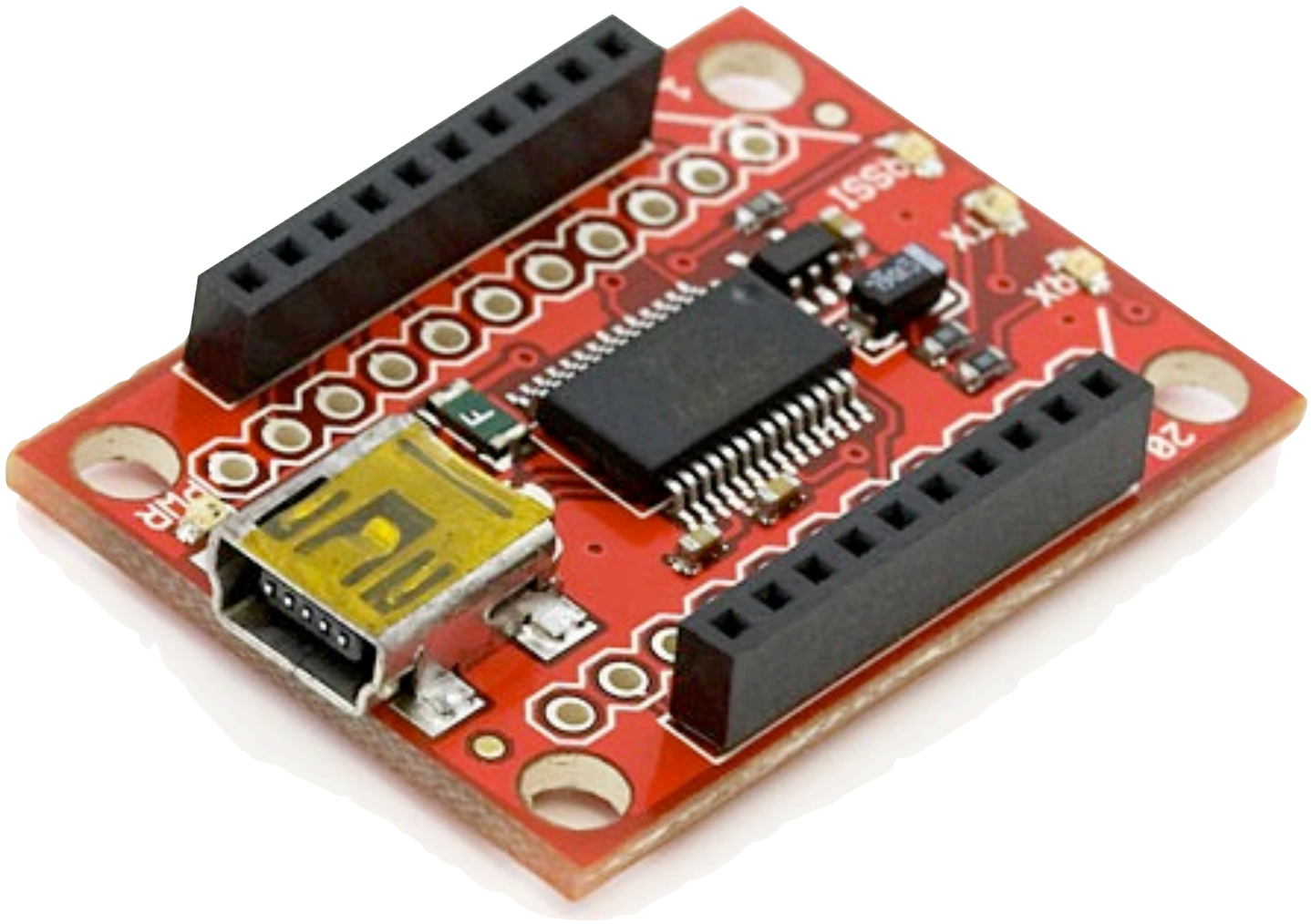



# Soldering Breakout Boards: finished

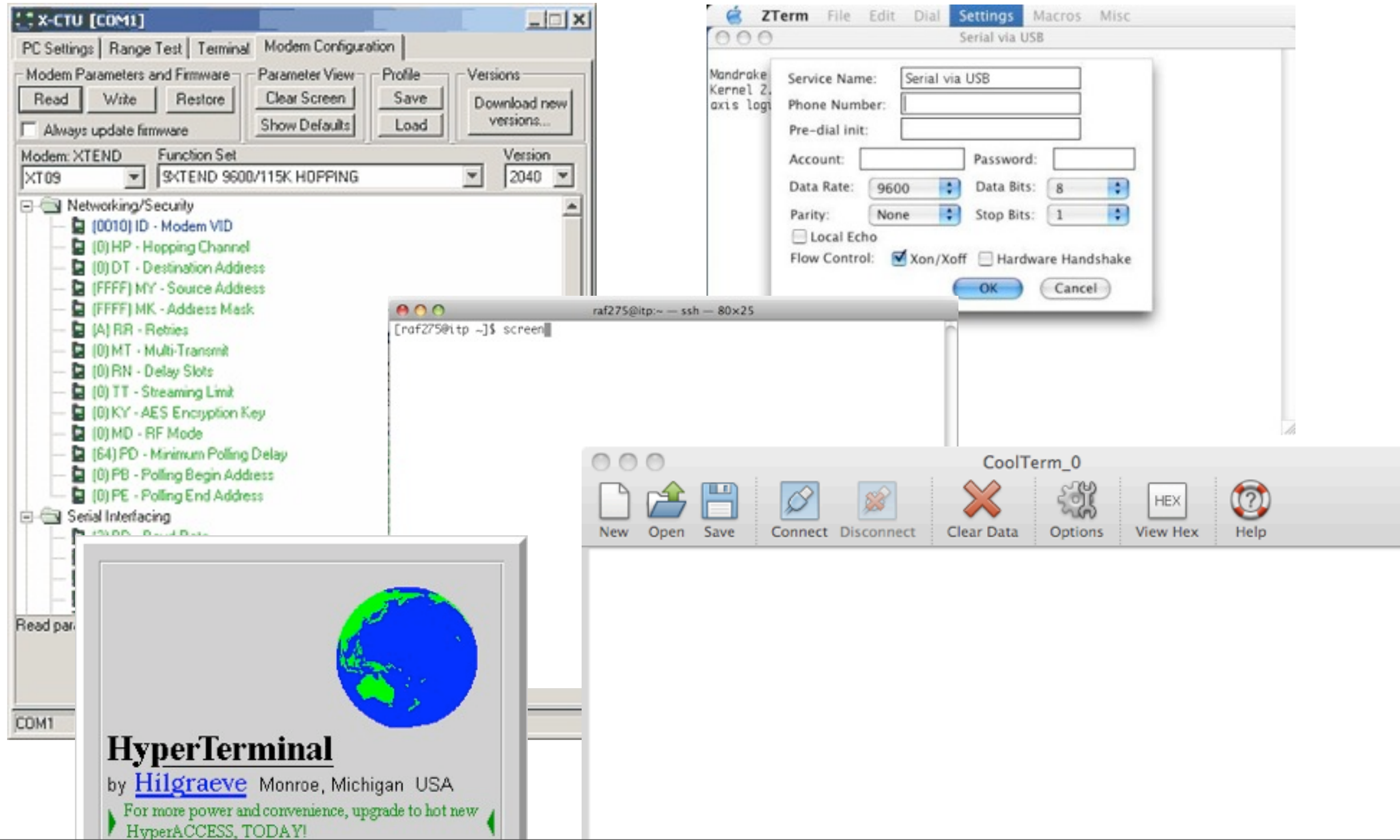


# XBee Explorer from Sparkfun



# Serial Terminal Programs



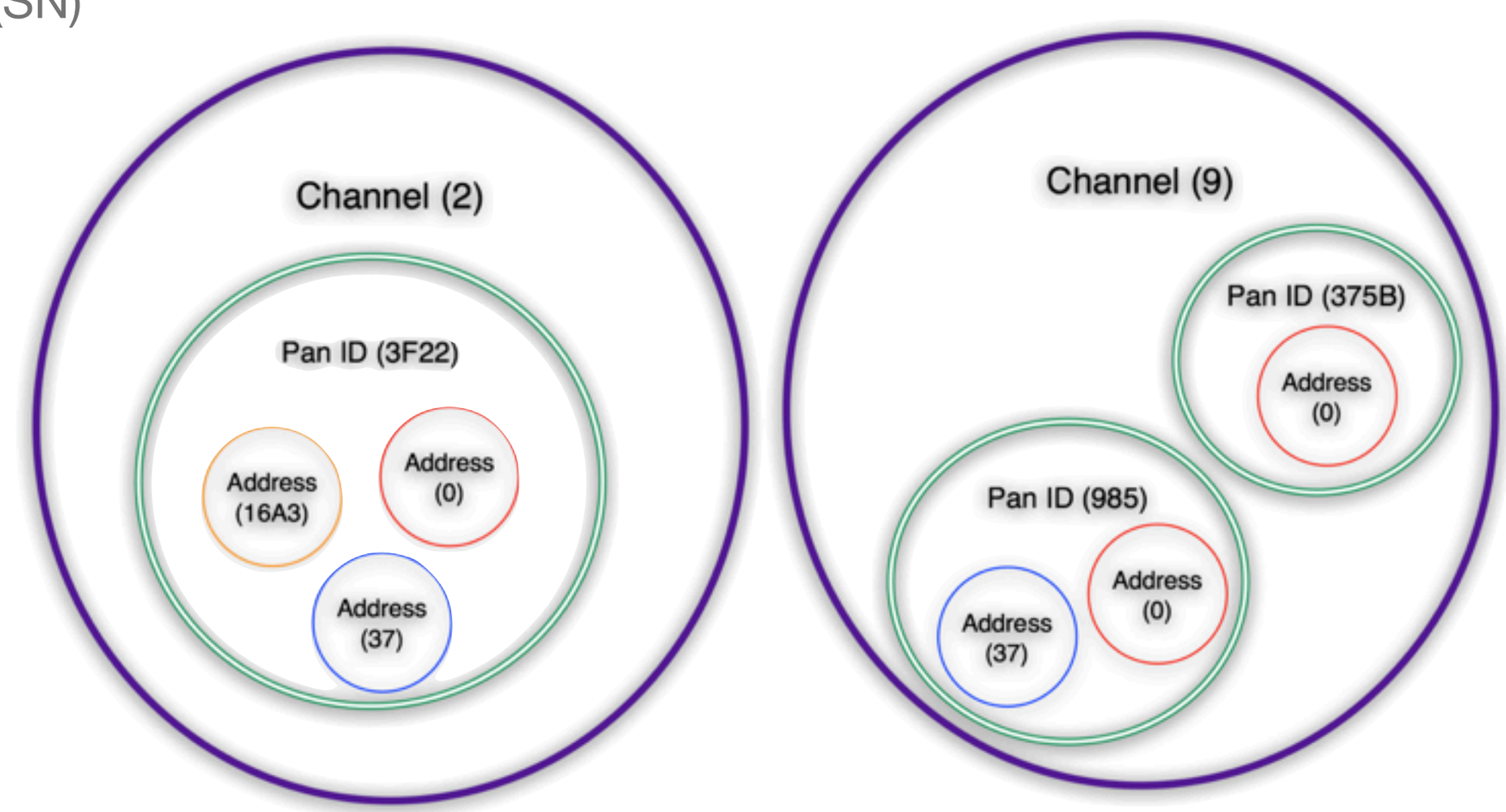
# Serial Terminal Programs

- X-CTU: http://www.digi.com/support/productdetl.jsp?pid=3352&osvid=57&tp=4&s=316
- CoolTerm: http://freeware.the-meiers.org/
- HyperTerm: Windows Start Menu, Accessories, Communication http://www.hilgraeve.com/hyperterminal/
- screen: Terminal program on the Mac (or Linux)
- plenty of others!
- settings: 9600 baud, 8 bits, no parity, one stop bit, no flow control

# 802.15.4 Addressing

# Addressing Basics

- channels
- PAN ID
- 64 bit addresses (SN)
- 16 bit addresses



# ZigBee Addressing

# ZigBee Coordinator

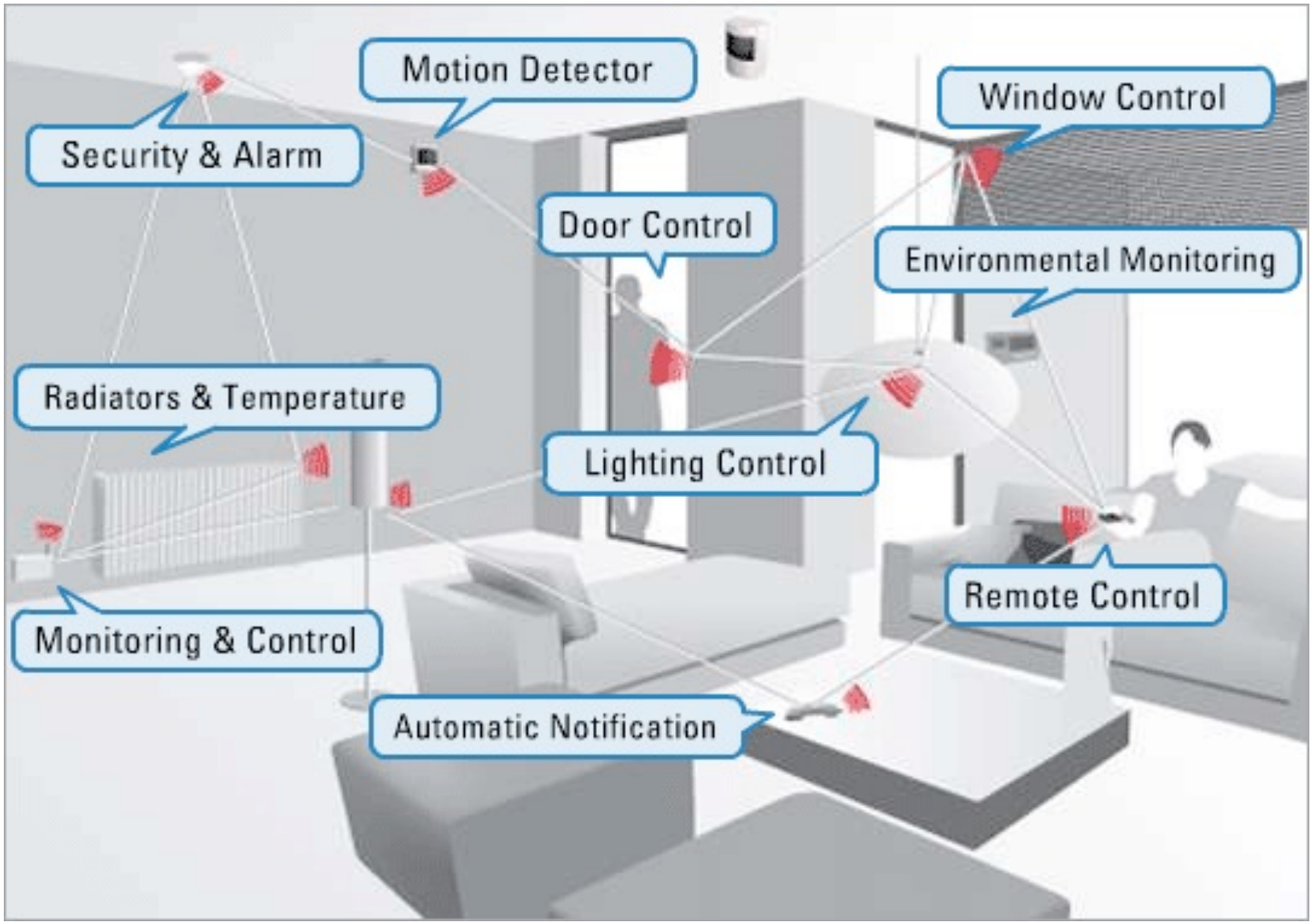
- Every ZigBee network must have a coordinator
- There can only be one coordinator
- Coordinator selects channel and PAN ID
- End devices and routers can then join the PAN
- Typically mains-powered
- Coordinator’s 16-bit address is always 0

# ZigBee Router

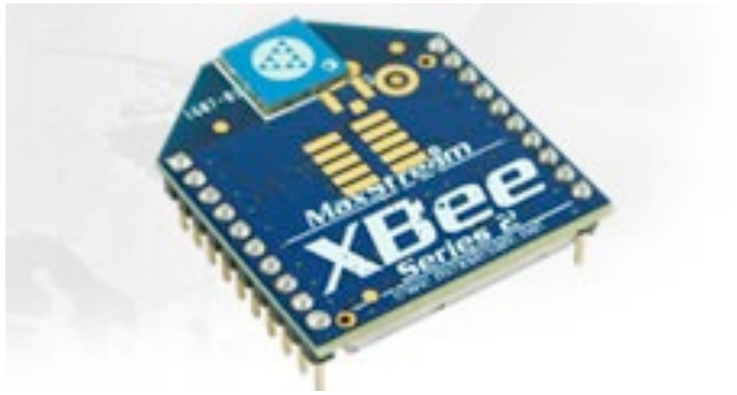
- Non-coordinator routers are optional to ZigBee networks
- Typically mains-powered
- Many can be on each PAN
- Issues a beacon request on startup to locate channel and PAN
- Routers can communicate with any device on the network
- Stores packets for sleeping end devices
- 16-bit address assigned by coordinator

# ZigBee End Device

- *Optional* to ZigBee networks
- Typically battery-powered
- Many can be on each PAN
- Issues a beacon request on startup to locate channel, PAN and parent
- End devices can only communicate directly with their parent
- 16-bit address assigned by coordinator


Motion Detector
Security & Alarm
Window Control
Door Control
Environmental Monitoring
Radiators & Temperature
Lighting Control
Remote Control
Monitoring & Control
Automatic Notification

# XBee ZB




- Coordinator Firmware
  - for AT commands or API
- Router and End Device Firmware
  - for AT commands or API
- ...so 6 different firmware combinations (you'll always use 2 at the same time)
- and two power levels, regular and Pro
- and 4 antennas! whip, chip, U.FL and RPSMA.

# Firmware Updates

X-CTU

About

PC Settings | Range Test | Terminal | Modem Configuration

Com Port Setup

Select Com Port

MaxStream PKG-U Serial Port...(COM6)

Baud 9600

Flow Control NONE

Data Bits 8

Parity NONE

Stop Bits 1

Test / Query

Host Setup | User Com Ports | Network Interface

API

Enable API

Use escape characters (ATAP = 2)

AT command Setup

| | ASCII | Hex |
|---|---|---|
| Command Character (CC) | + | 2B |
| Guard Time Before (BT) | | 1000 |
| Guard Time After (AT) | | 1000 |

Modem Flash Update

No baud change

X-CTU [COM6]

Remote Configuration

PC Settings | Range Test | Terminal | Modem Configuration

Modem Parameters and Firmware

Read | Write | Restore

Always update firmware

Parameter View

Clear Screen | Show Defaults

Profile

Save | Load

Versions

Download new versions...

Modem: XBEE: XB24-ZB

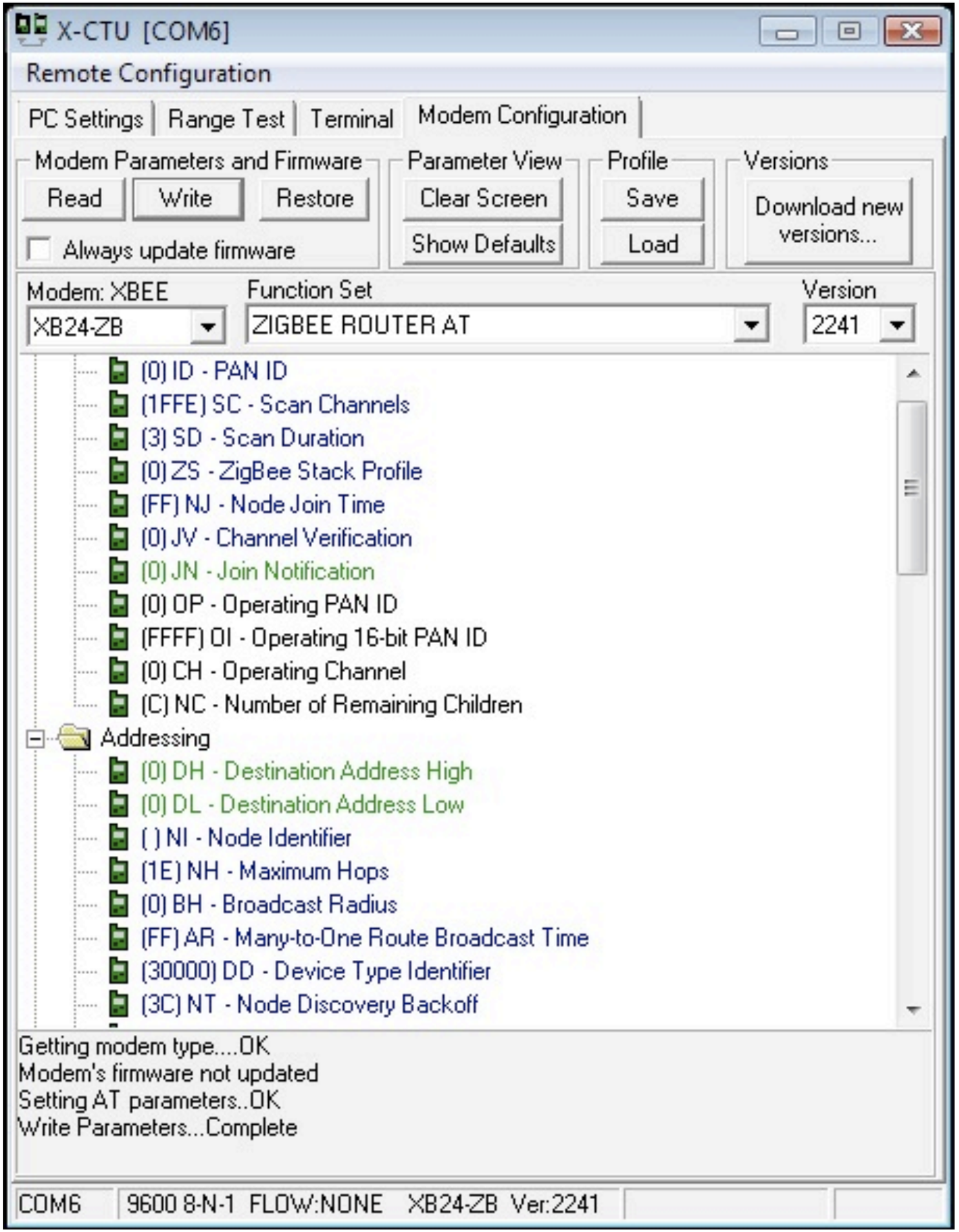
Function Set: ZIGBEE COORDINATOR AT

Version: 2041

- Networking
  - (0) ID - PAN ID
  - (1FFE) SC - Scan Channels
  - (3) SD - Scan Duration
  - (0) ZS - ZigBee Stack Profile
  - (FF) NJ - Node Join Time
  - OP - Operating PAN ID
  - OI - Operating 16-bit PAN ID
  - CH - Operating Channel
  - NC - Number of Remaining Children
- Addressing
  - (0) DH - Destination Address High
  - (FFFF) DL - Destination Address Low
  - ( ) NI - Node Identifier
  - (1E) NH - Maximum Hops
  - (0) BH - Broadcast Radius
  - (FF) AR - Many-to-One Route Broadcast Time
  - (30000) DD - Device Type Identifier
  - (3C) NT - Node Discovery Backoff
  - (0) NO - Node Discovery Options

Getting modem type....OK
Modem's firmware not updated
Setting AT parameters..OK
Write Parameters...Complete

COM6 | 9600 8-N-1 FLOW:NONE | XB24-ZB Ver:2241


X-CTU [COM6]
Remote Configuration
PC Settings
Range Test
Terminal
Modem Configuration
Modem Parameters and Firmware
Read
Write
Restore
Always update firmware
Parameter View
Clear Screen
Show Defaults
Profile
Save
Load
Versions
Download new versions...
Modem: XBEE
XB24-ZB
Function Set
ZIGBEE ROUTER AT
Version
2241
(0) ID - PAN ID
(1FFE) SC - Scan Channels
(3) SD - Scan Duration
(0) ZS - ZigBee Stack Profile
(FF) NJ - Node Join Time
(0) JV - Channel Verification
(0) JN - Join Notification
(0) OP - Operating PAN ID
(FFFF) OI - Operating 16-bit PAN ID
(0) CH - Operating Channel
(C) NC - Number of Remaining Children
Addressing
(0) DH - Destination Address High
(0) DL - Destination Address Low
( ) NI - Node Identifier
(1E) NH - Maximum Hops
(0) BH - Broadcast Radius
(FF) AR - Many-to-One Route Broadcast Time
(30000) DD - Device Type Identifier
(3C) NT - Node Discovery Backoff
Getting modem type....OK
Modem's firmware not updated
Setting AT parameters..OK
Write Parameters...Complete
COM6
9600 8-N-1 FLOW:NONE XB24-ZB Ver:2241

# Basic Configuration

# Download and Install Software & Drivers

- Download & install the FTDI USB drivers:
  http://www.ftdichip.com/Drivers/VCP.htm

- Download the CoolTerm:
  http://freeware.the-meiers.org/

**Other Serial Terminal Options:**
settings: 9600 baud, 8 bits, no parity, one stop bit, no flow control

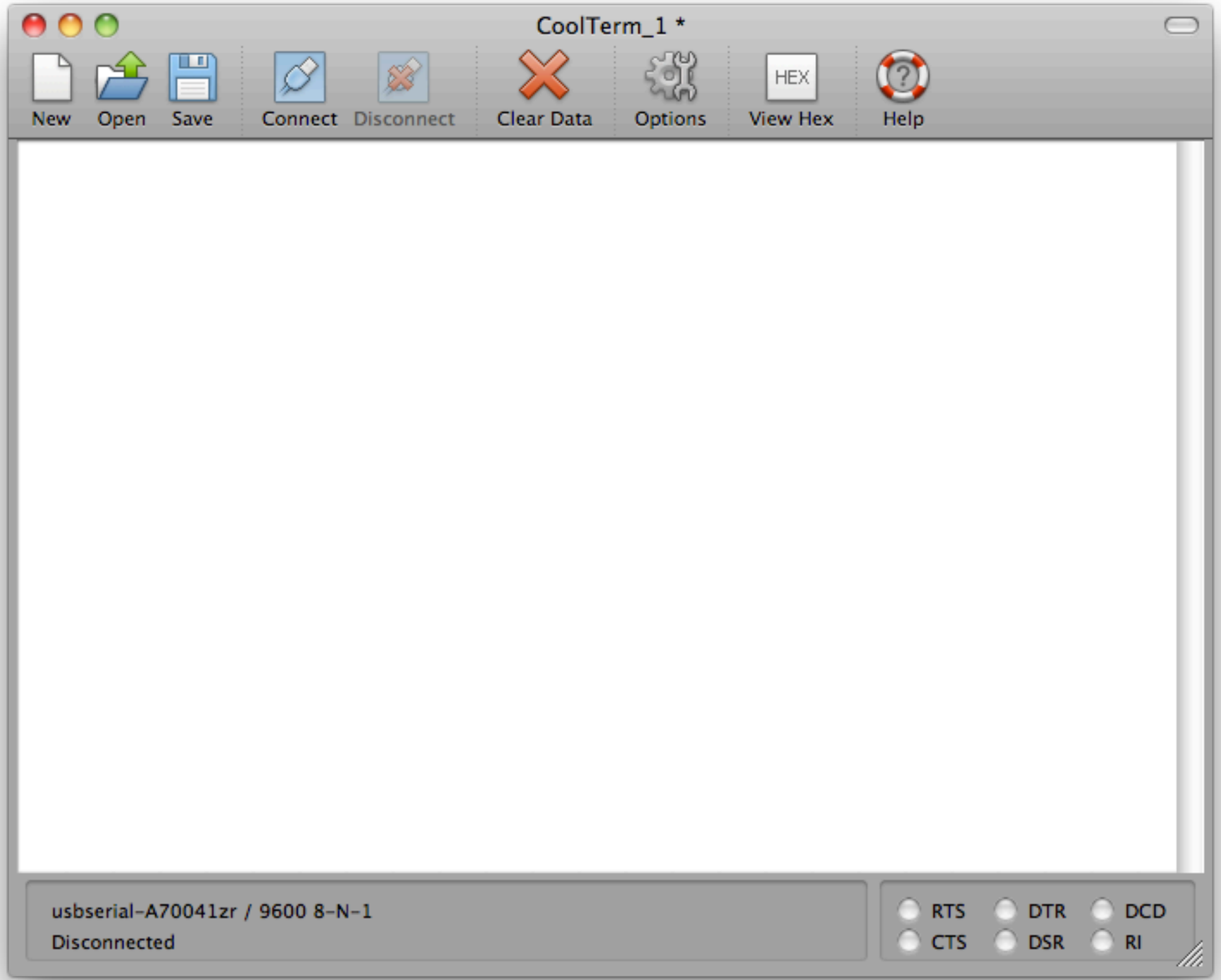
- X-CTU: http://www.digi.com/support/productdetl.jsp?pid=3352&osvid=57&tp=4&s=316

- Z-Term: http://homepage.mac.com/dalverson/zterm/

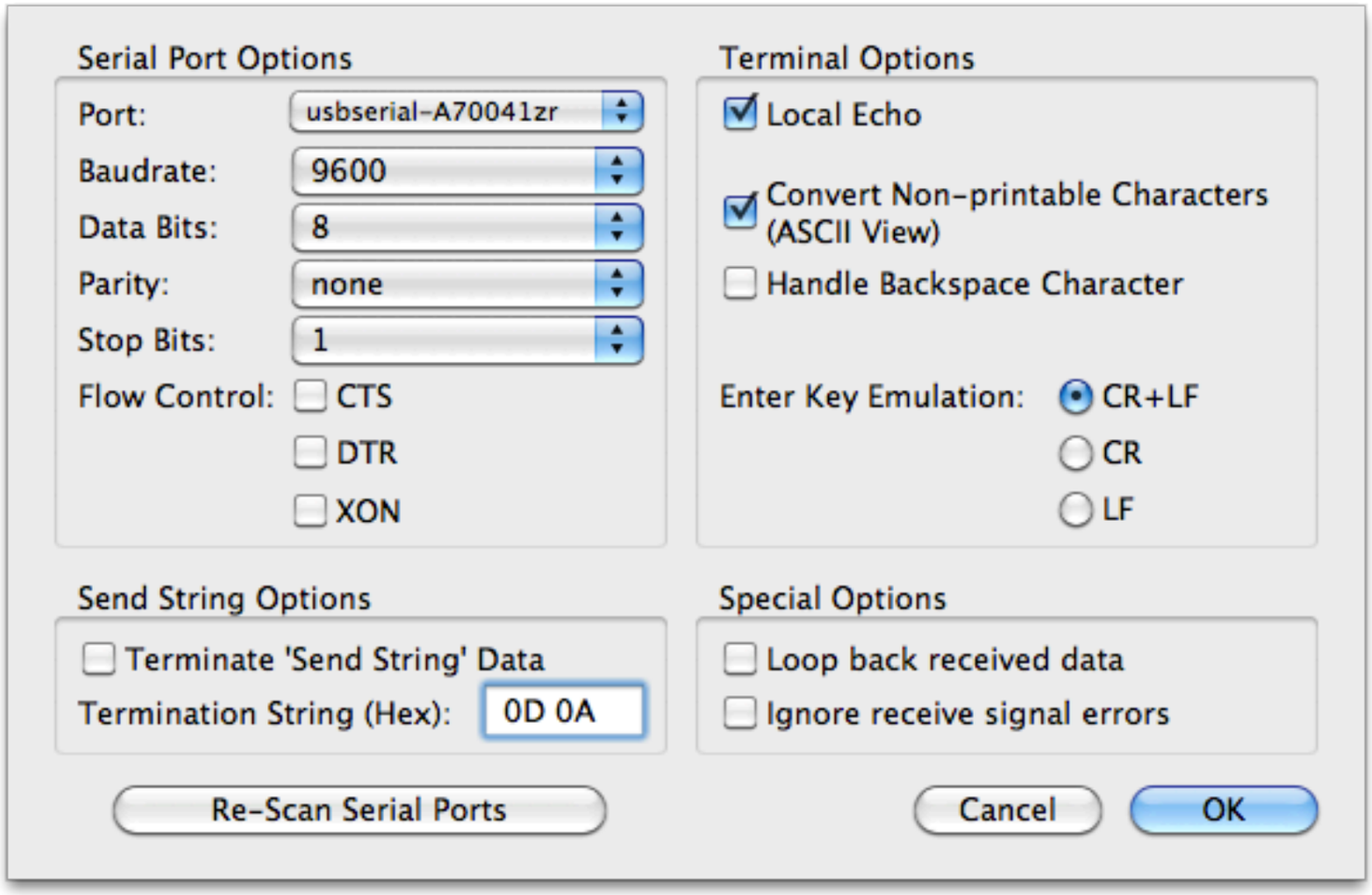
- HyperTerm: Windows Start Menu, Accessories, Communication

- Screen: Terminal program on the Mac (or Linux)

# Open CoolTerm

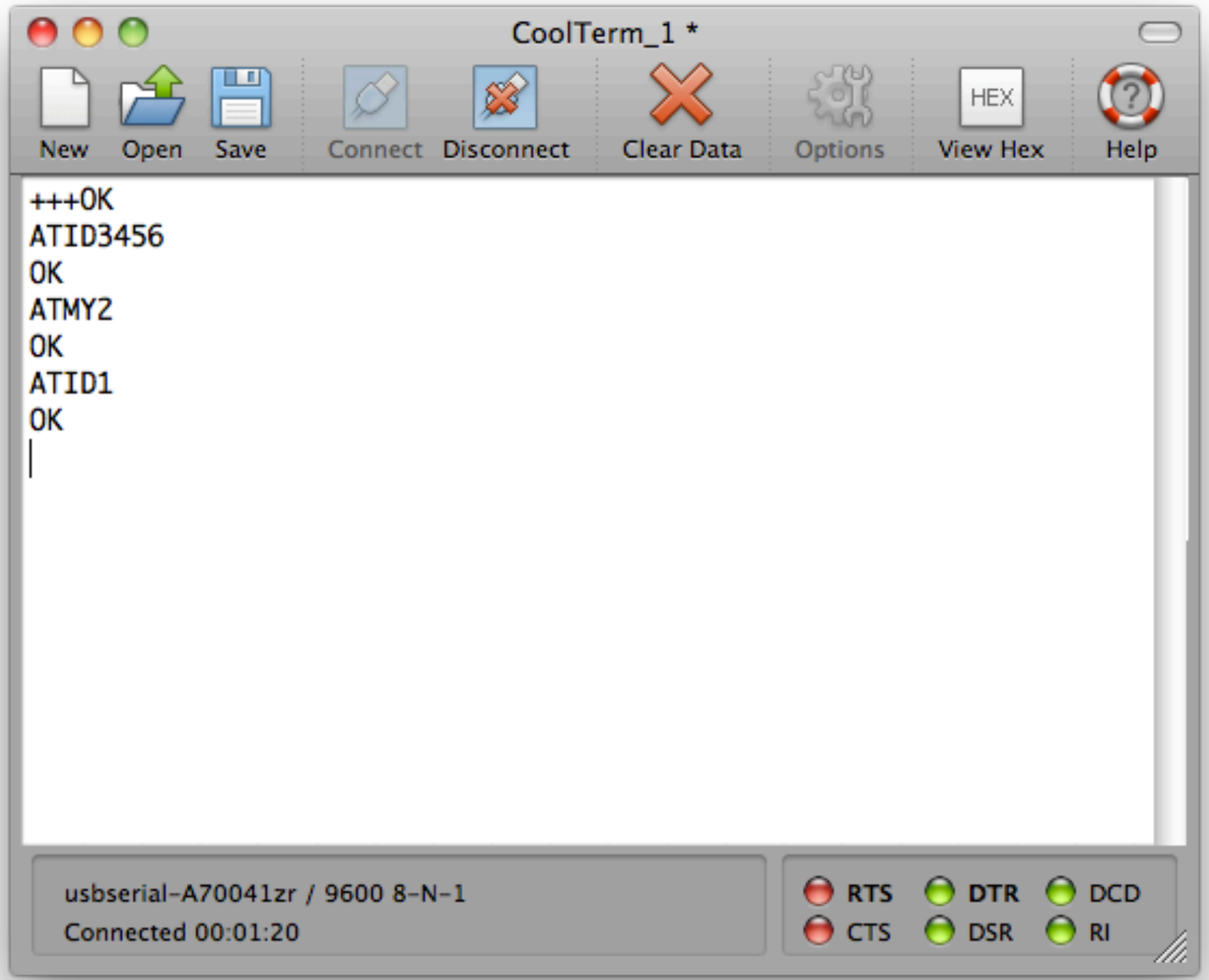


# Set Connection Options



# Configure your radio with AT commands

- Configure your radio



# Baud, Bits and Parity

- Baud rate: 9600
- Data bits: 8
- Stop bits: 1
- Parity: None
- Flow control: none for now...

# Data Mode vs. Command Mode

- Idle Mode, transmit and receive data
- Command Mode, talk to the XBee itself
  - +++ "*Yo, XBee*"
  - AT "*Attention!*" (Hayes command set)
    - always press enter after AT commands
    - *never* press enter after +++

# AT Commands

# Some AT Commands

- AT  ->  OK
- ATMY  ->  my address (*not settable for ZigBee!!*)
- ATDH, ATDL  ->  destination address hi/lo
- ATID  -> personal area network ID
- ATCN  -> end command mode
- ATWR  -> write configuration to flash memory
- ATRE  -> reset to factory defaults

# Addressing In-Depth

- SL, SH: fixed serial number address
- MY: configured local 16 bit address
- DH, DL: destination address low and high
- ID: Personal Area Network ID
- Broadcast FFFF
- Broadcast PAN FFFF

# Assignment

- Pick a PAN ID now and document it.

# Basic 802.15.4 Chat

# Create a Basic 802.15.4 Pair

- Two radios
- Use the 16-bit addresses for destinations
- HANDOUT
- Remember, the radios work reliably, troubleshooting is mostly about figuring out what they’re doing.

# Create a Basic ZigBee Pair

- One coordinator and one router
- Use the 64-bit addresses for destinations
- ATNR will reset your network layer, useful if you join the wrong ID
- Remember, the radios work reliably, troubleshooting is mostly about figuring out what they’re doing.

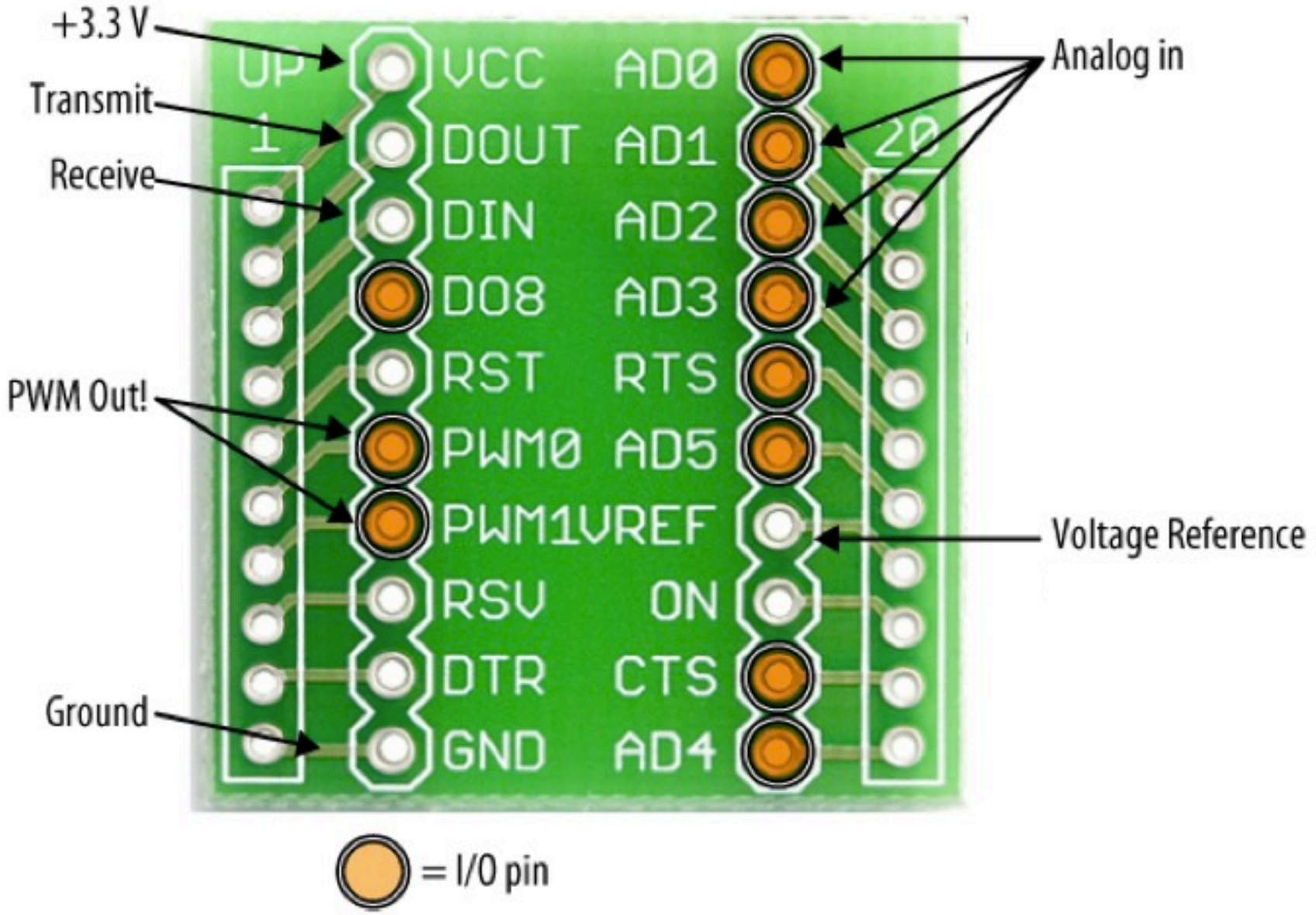
# I/O Intro

- For simple input and/or output
- Eight digital input/outputs
- One additional digital output
- Seven analog inputs
- Two analog outputs
- But not all at once! Pins are shared.

# I/O Why

- Why:
  - Save space, save power, save weight and save money
  - Reduce complications for simple projects
- Why not:
  - Limited inputs/outputs
  - No access to logic
  - Might make complicated projects even more complicated

# Input/Output Wiring



# I/O AT Commands

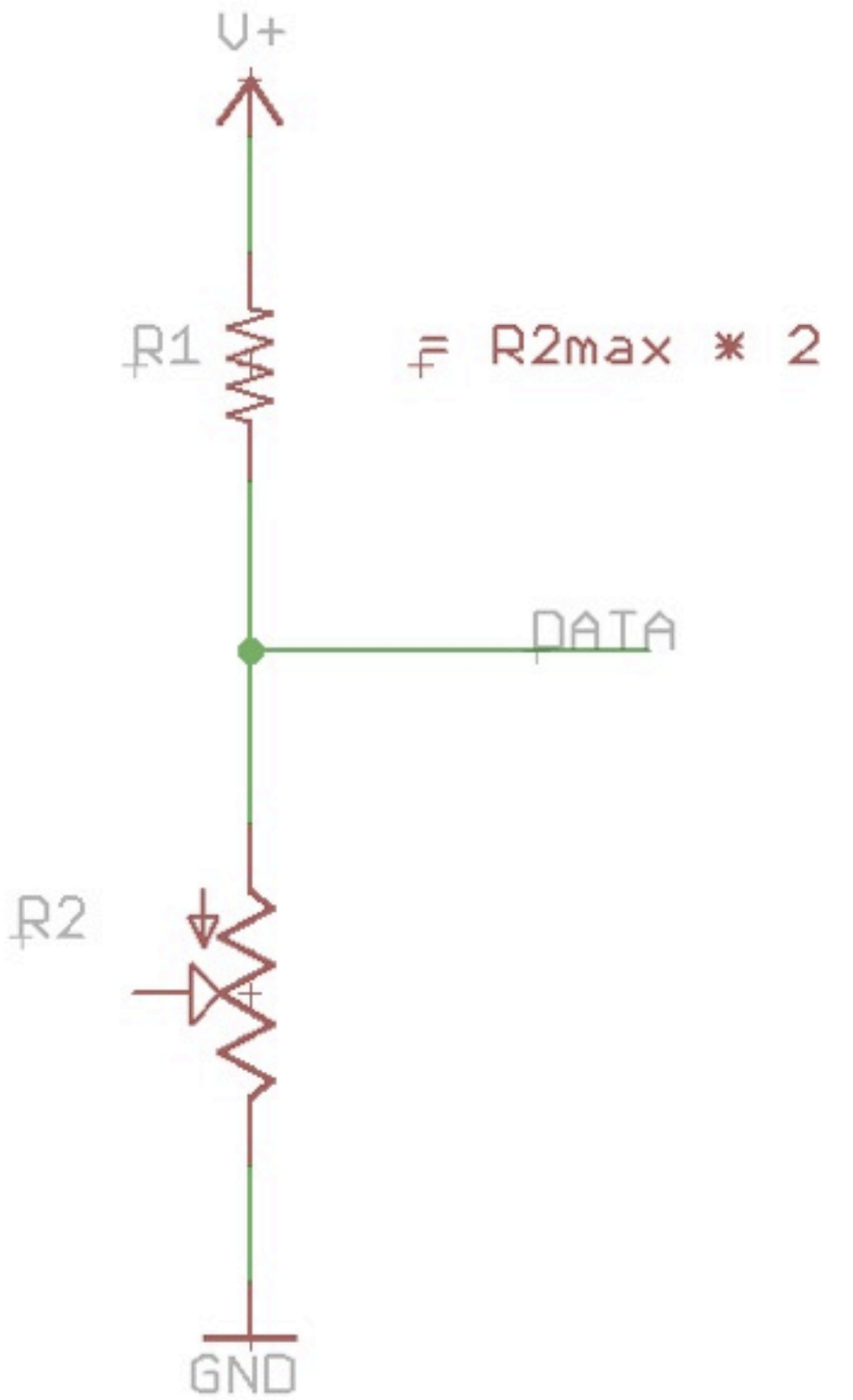
- ATD0...D8 -> configure pins for I/O
- ATIR -> sample rate
- ATIT -> samples before transmit
- ATP0...P1 -> PWM configuration
- ATIA -> I/O input address

# I/O AT Commands: ZigBee

- ATD0...D7 -> configure pins for I/O (D8 and D9 not supported yet)
- ATP0...P2 -> configure pins 10 - 11 for I/O (P3 not supported yet)
- ATIR -> sample rate
- samples before transmit is always 1
- destination address receives sample info
- ALL PINS READ BETWEEN 0 AND 1.2 VOLTS ONLY

XBee ZigBees inputs are 1.2V range

# Voltage Divider to map 3.3V range to 1.2V range



# Setting I/O Pins

- ATDx 0  Disabled
- ATDx 1  Built-in Function (sometimes)
- ATDx 2  Analog Input (sometimes)
- ATDx 3  Digital Input
- ATDx 4  Digital Output, low to start with
- ATDx 5  Digital Output, high to start with
    - ...so ATD32 would do what?

# Input/Output Settings

- ATIR
  sets the data sample rate (uses hexadecimal notation)

- ATIT
  how many samples transmitted at a time

- ATD0
  mode for digital pin zero (3=digital input, 5=digital output)

- ATIA
  remote address that’s allowed to control local pins

- ATWR
  writes the settings to firmware (like saving to a disk)

# XBee and Arduino

# Why Arduino

- local logic
- pinouts
- fast prototyping
- connect to a huge variety of components, SPI, $IC^2$, PWM, etc.

# Arduino Serial Library

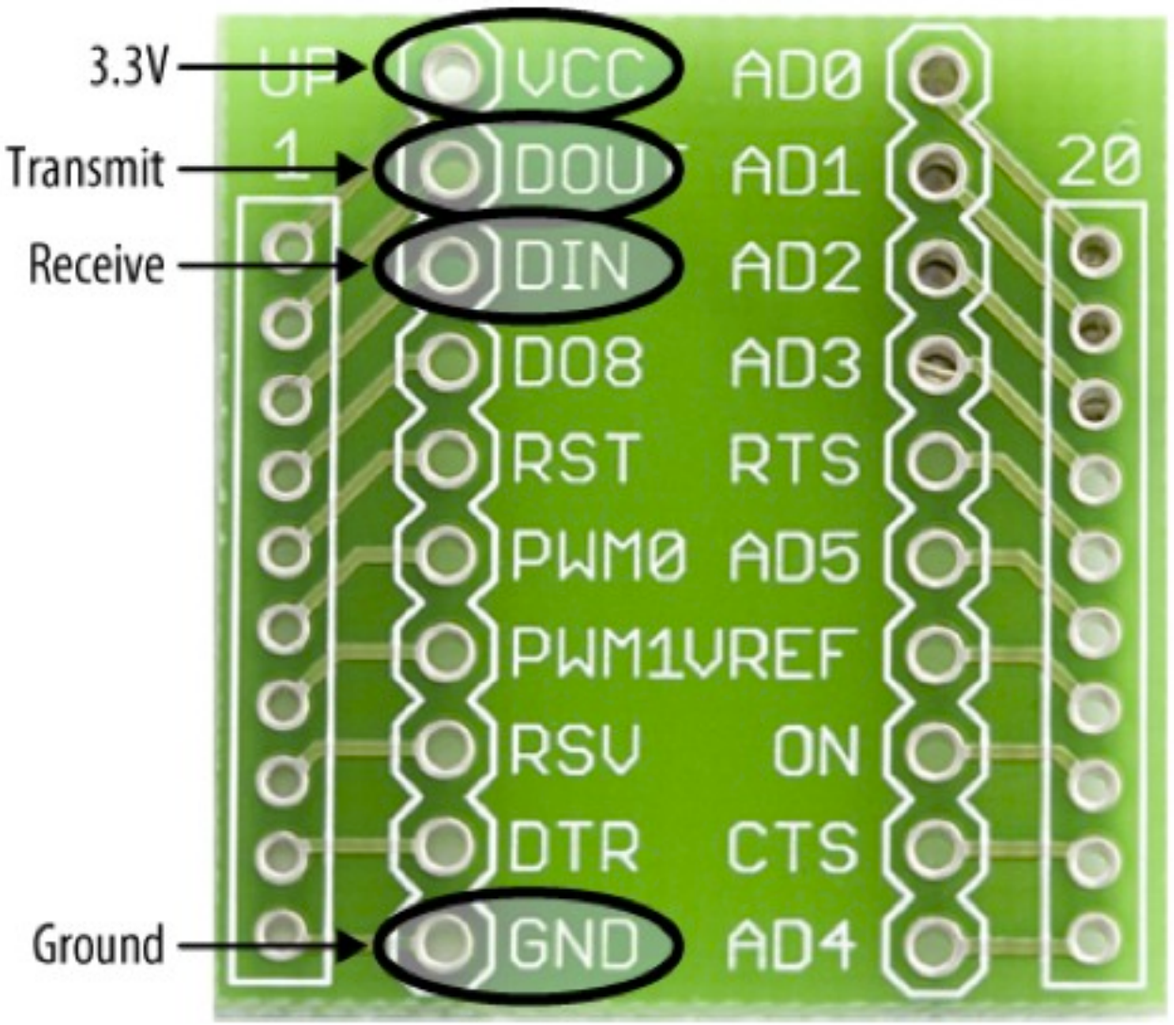
- Serial.begin(speed)
- Serial.available()
- Serial.read()
- Serial.flush()
- Serial.print(data)
- Serial.write(byte)

# NEW Software Serial

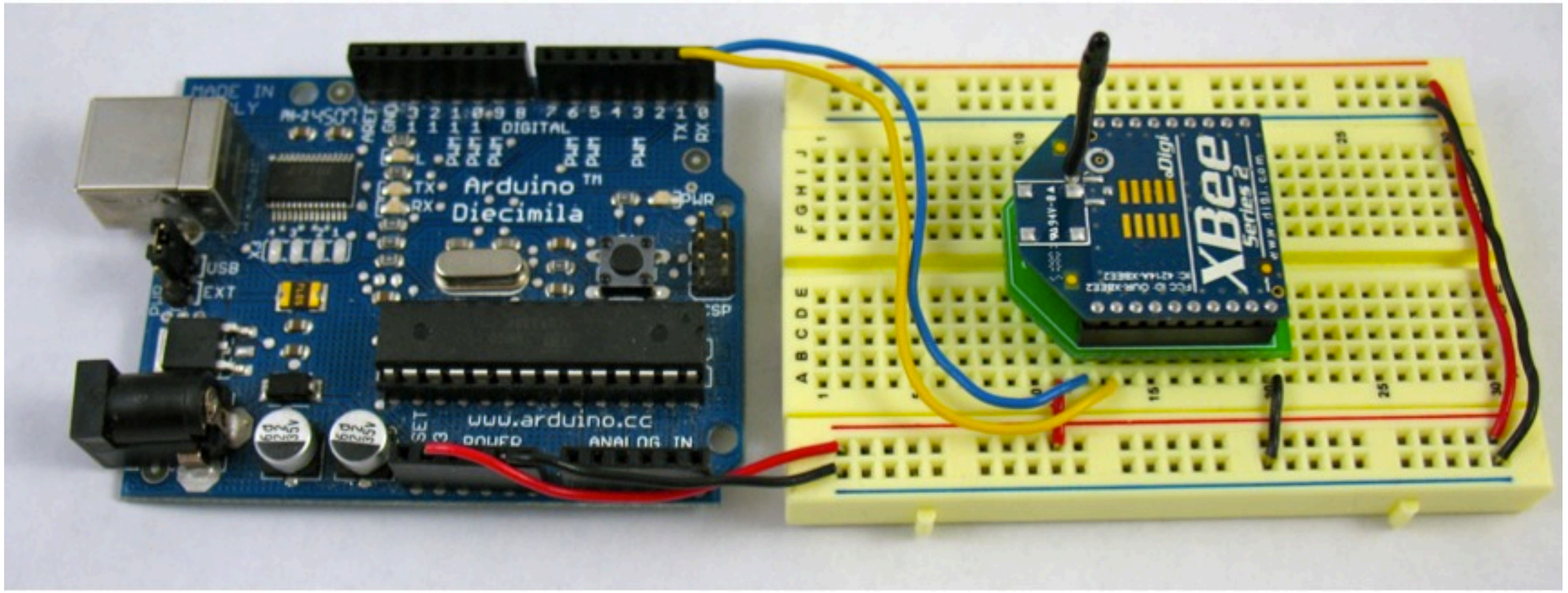
- 115K baud max, all pins are okay to use
- SWserial.read() does not block
- serial.available() function in software serial
  - buffering!
  - good choice for input, great for debug output w/ USB-serial converter
- http://arduiniana.org/libraries/NewSoftSerial/

# Breadboard Hookups

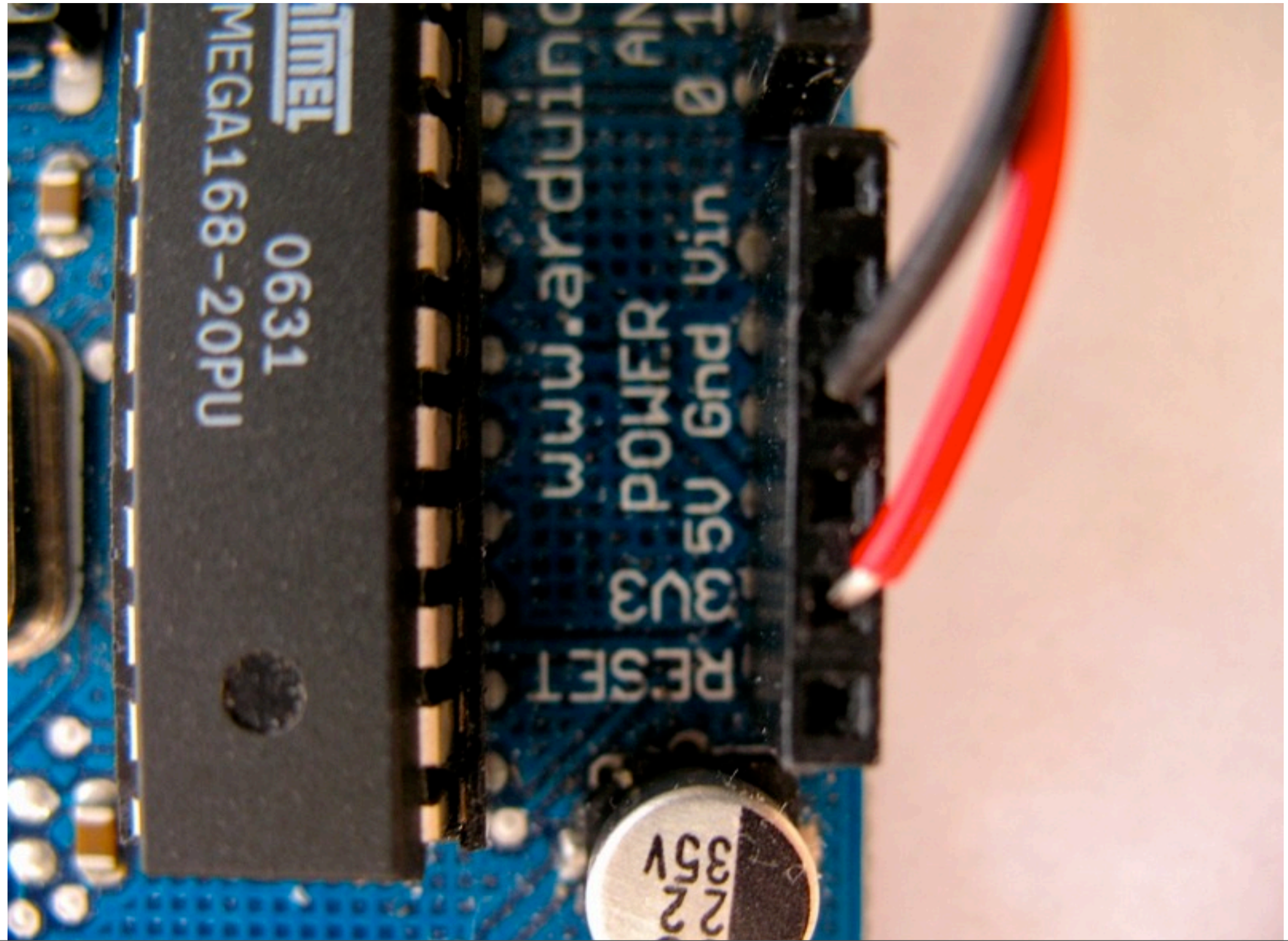
# Wiring


3.3V
Transmit
Receive
Ground
UP
1
VCC
DOUT
DIN
DO8
RST
PWM0
PWM1
RSV
DTR
GND
AD0
AD1
AD2
AD3
RTS
AD5
VREF
ON
CTS
AD4
20

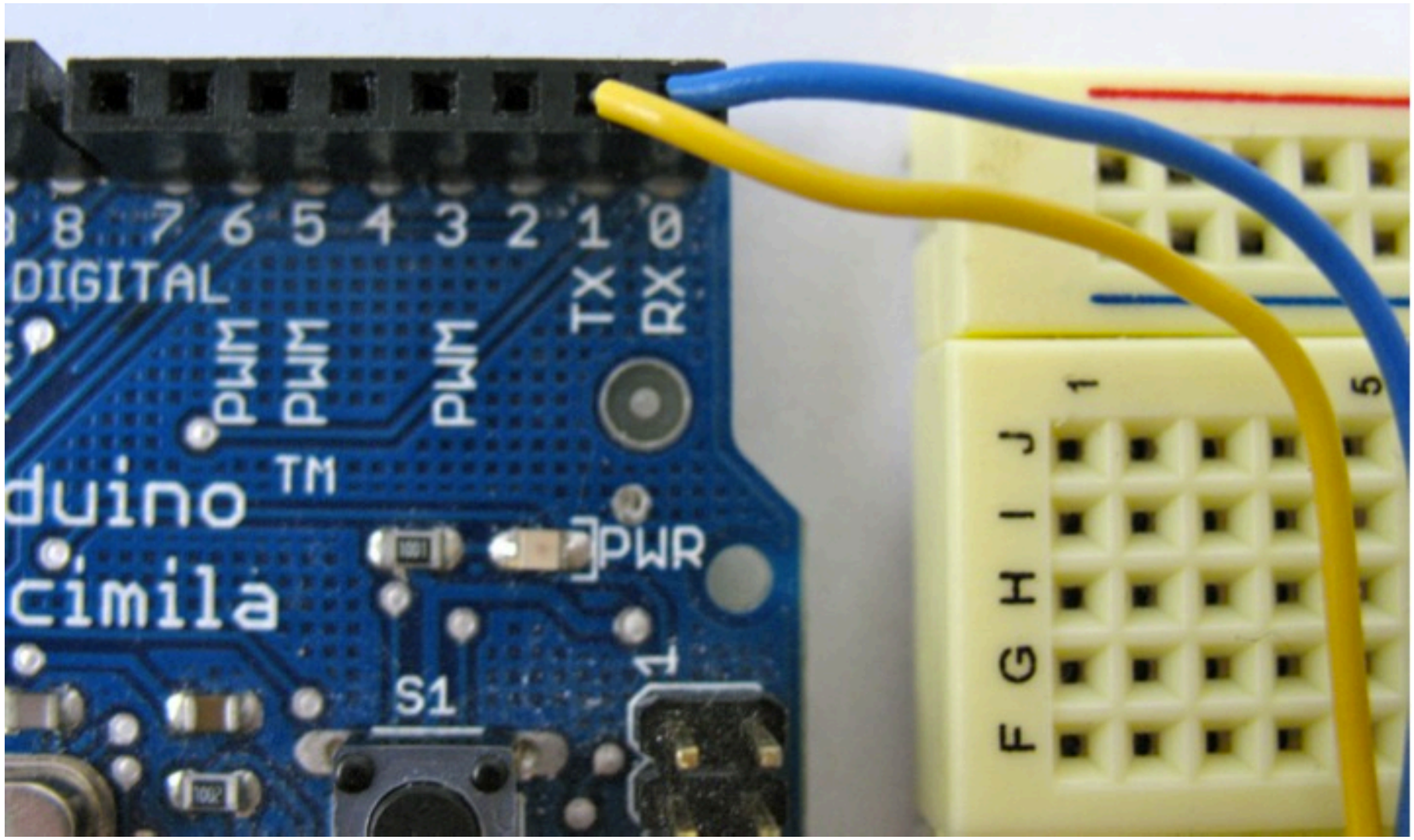
# XBee Arduino Breadboard Layout



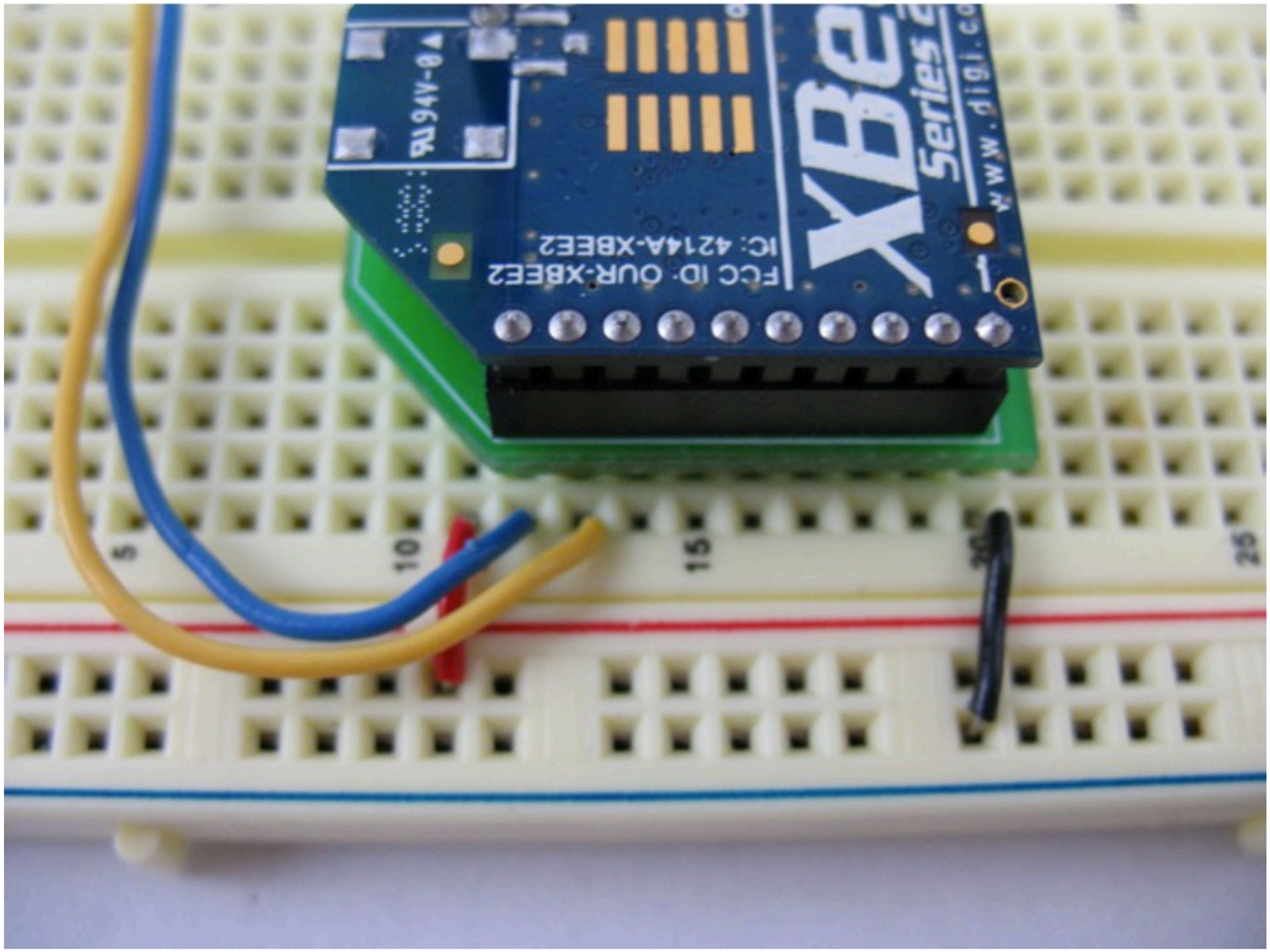
# Power, Ground



# TX, RX


8 7 6 5 4 3 2 1 0
DIGITAL
TX
RX
PWM
PWM
PWM
duino
TM
cimila
PWR
S1
F G H I J
1
5

# XBee Connections (pin 1, 2, 3 and 10)



# Remember!

- Use only +3.3 Volts. More than +7 Volts will kill your radio
- If you use a voltage regulator, always use decoupling capacitors. The radios often don't work without them.
- XBee TX goes to Arduino RX and vice versa.
- Unplug the TX & RX before uploading Arduino code (or use switches)
- You can't send infinitely fast. Try putting a 10 ms delay into your loop.