Network Objects

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Plan for Today

- XBee Firmware
- XBee I/O Workshop
- API Mode
- Readings & Assignments

XBee Firmware

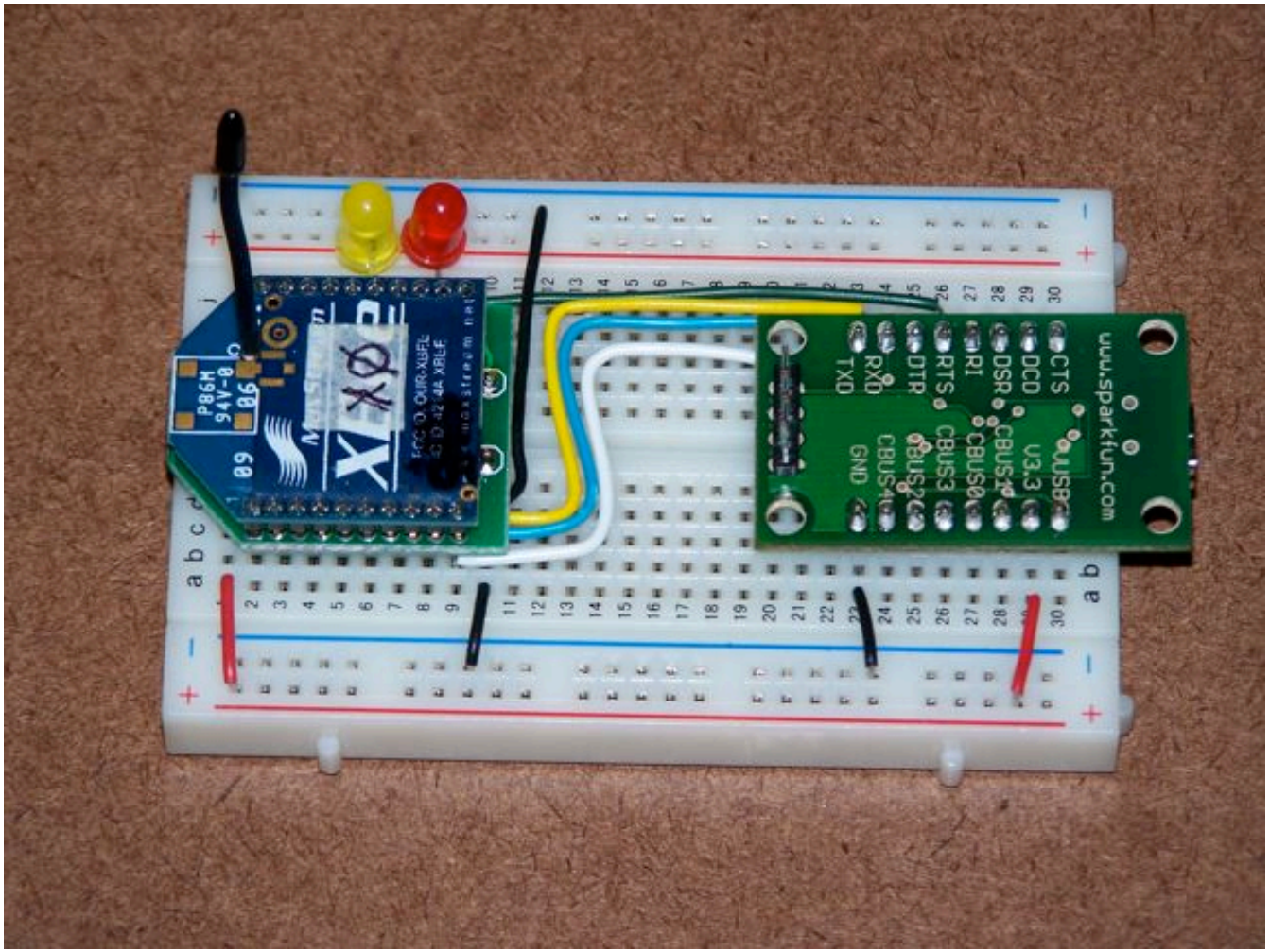
X-CTU

- Features:
  - terminal
  - firmware
  - configuration
  - tests
- Demo: updating firmware

Firmware Upload

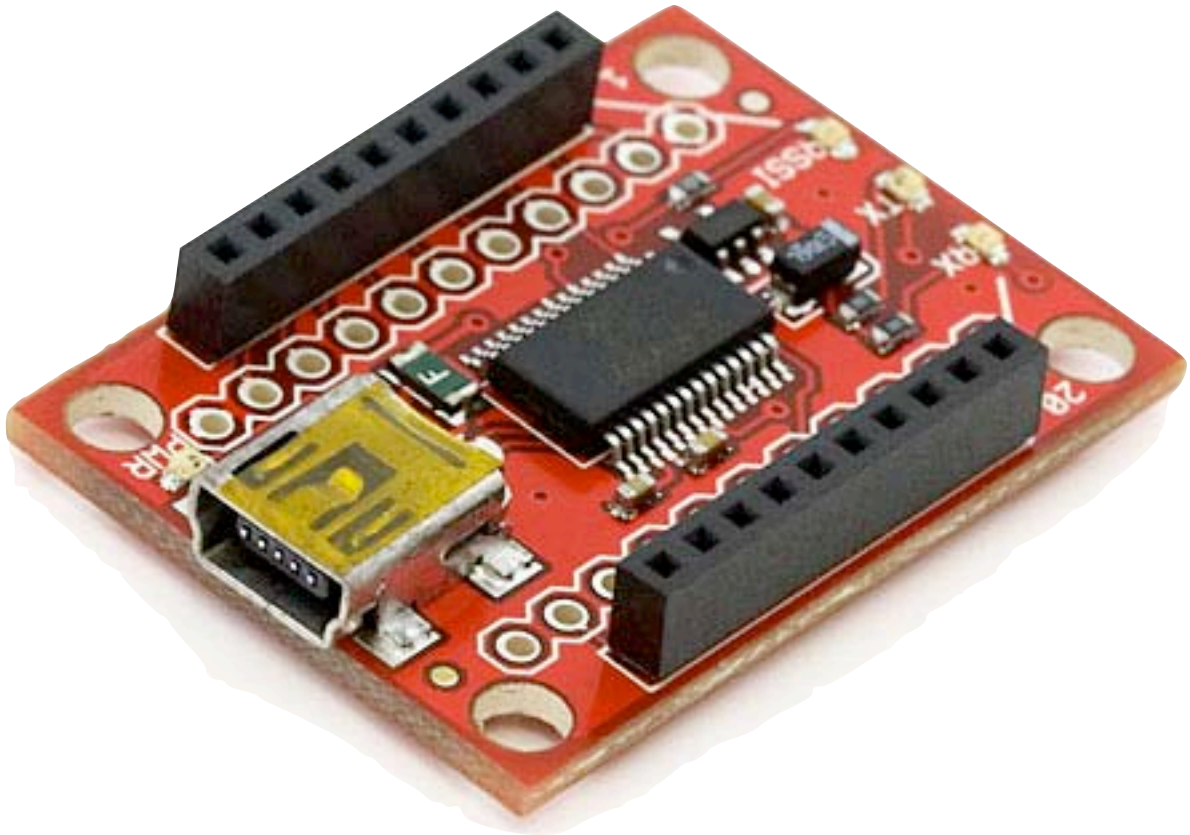
- X-CTU Program
- Special circuit, dongle or development board
- Firmware, command interface, test area, terminal all Windows-only

Firmware Upload Board



SparkFun part#PCB-FT232RL, wired to RX, TX, RTS, DTR, 3.3V, Gnd

XBee Explorer



XBee I/O mode

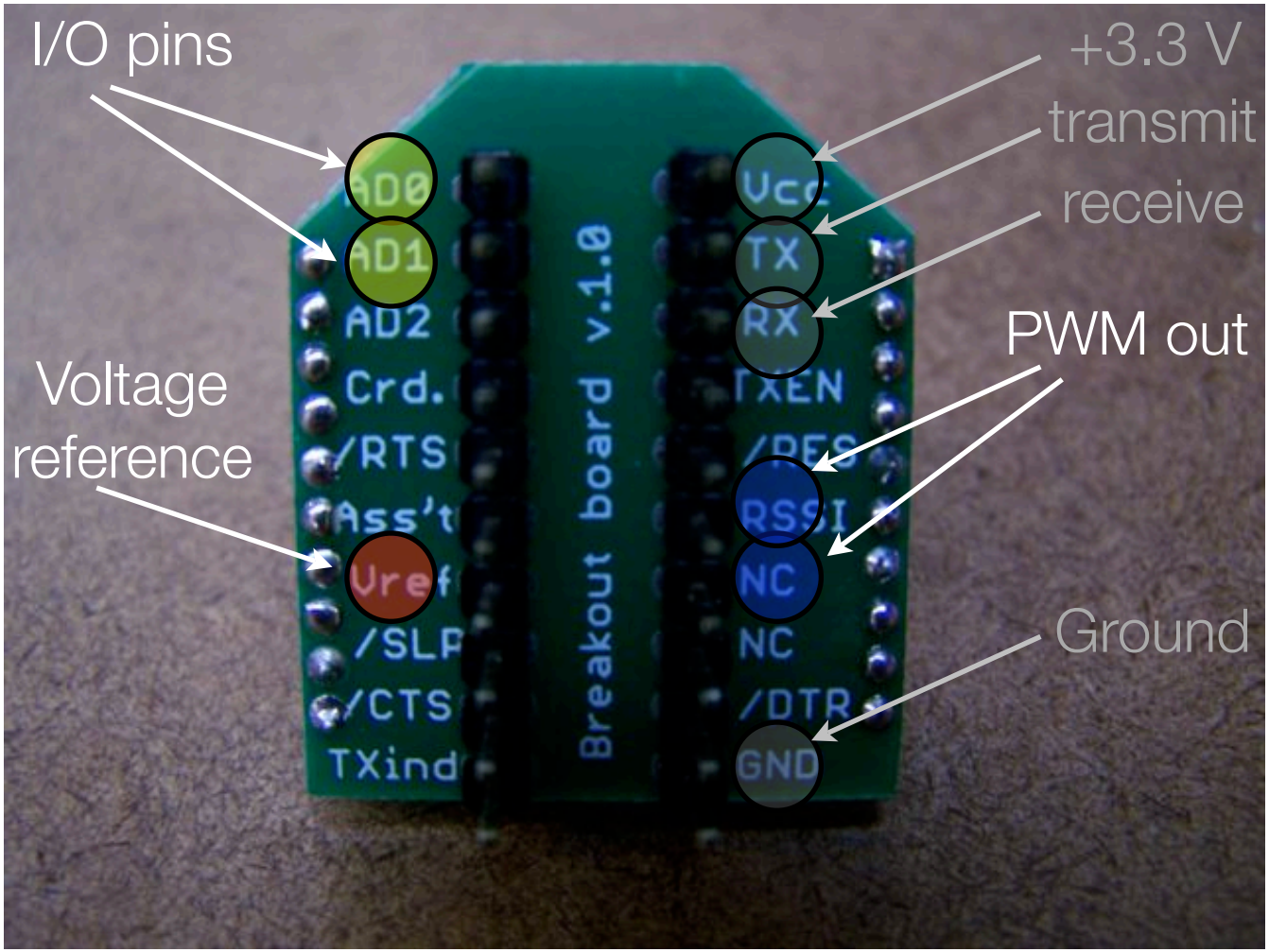
I/O Why

- Why:
  - Save space, save power, save weight and save money
  - Reduce complications
- Why not:
  - Limited inputs/outputs
  - No access to logic
  - Each radio must be manually configured

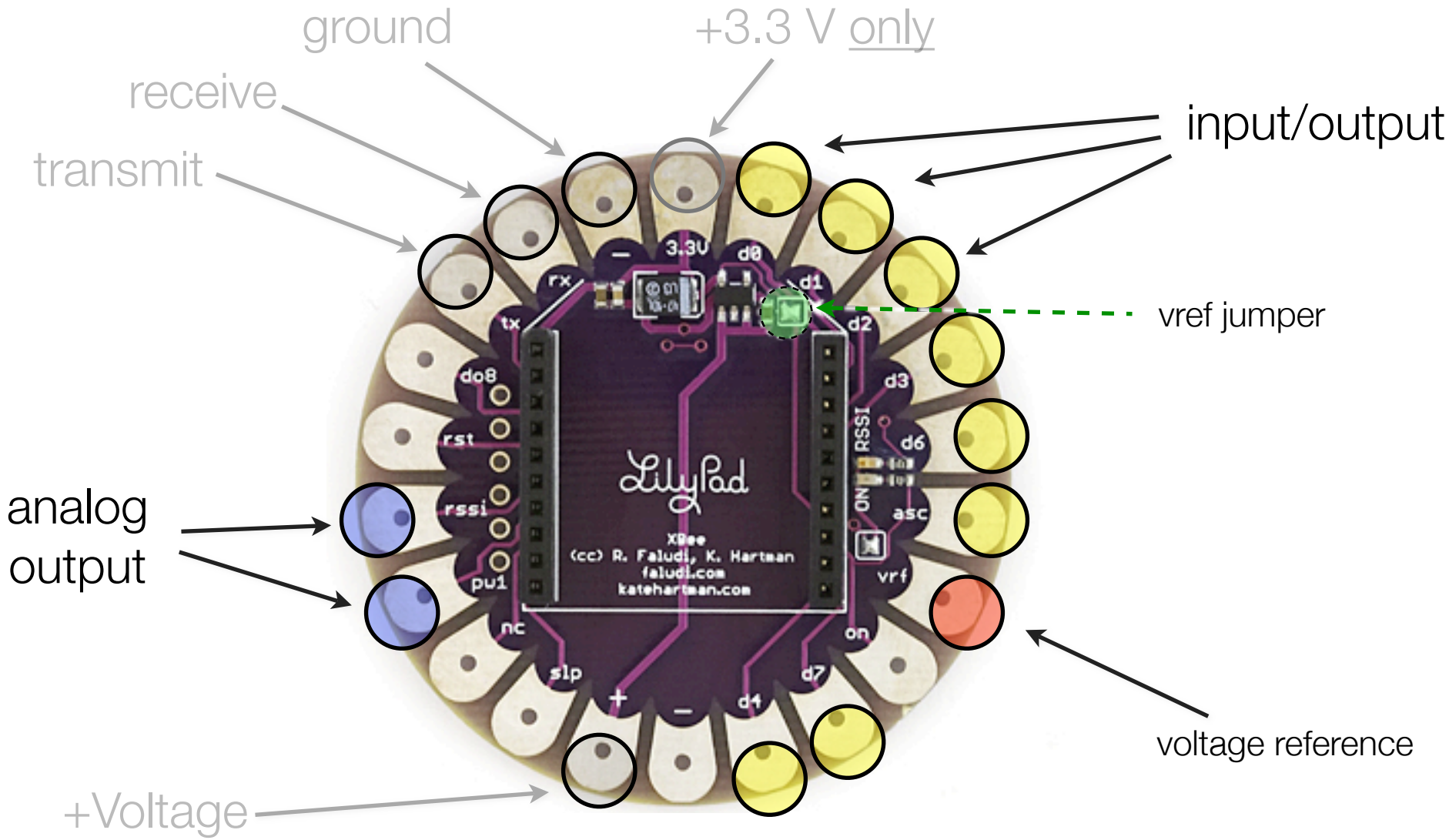
I/O Intro

- 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.

Input/Output Wiring



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
- ATIU -> I/O output enable (UART)
- ATIA -> I/O input address

Example Configuration

- ATID3456 (PAN ID)
  ATMY1 my address 1
  ATDL2 destination address 2
  ATD02 pin 0 in analog in mode
  ATD13 pin 1 in digital in mode
  ATIR14 sample rate 20 milliseconds (hex 14)
  ATIT5 samples before transmit 5
  ATWR write settings to firmware

- ATID3456 (PAN ID)
  ATMY2 my address 2
  ATDL1 destination address 1
  ATP02 PWM 0 in PWM mode
  ATD15 pin 1 in digital out high mode
  ATIU1 I/O output enabled
  ATIA1 I/O input from address 1
  ATWR write settings to firmware

I/O Workshop

- Set up input and output radios with sensors
- Transmit values without any external microcontroller

Common XBee Mistakes

- http://www.faludi.com/projects/common-xbee-mistakes/

Protocols

- Sending
- Flow control
- Call / response
- Broadcast
- Start / stop
- Checksums
- Collisions

XBee API Mode

API Mode

- Application Programming Interface
  - “An application programming interface (API) is a source code interface that an operating system or library provides to support requests for services to be made of it by computer programs.”

    http://www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=43487

- XBees in API mode are ready to talk to computers and microcontrollers
  - structured
  - predictable
  - reliable

API Structure

- Used in serial communications with the XBee radio
- Frames of data
  - envelope structure contains data with metadata inside a constrained format
- Radio must be in API Mode
  - AT command ATAP 1 on Series 1 radios
  - API firmware on Series 2 radios

Why API

- Rather than:

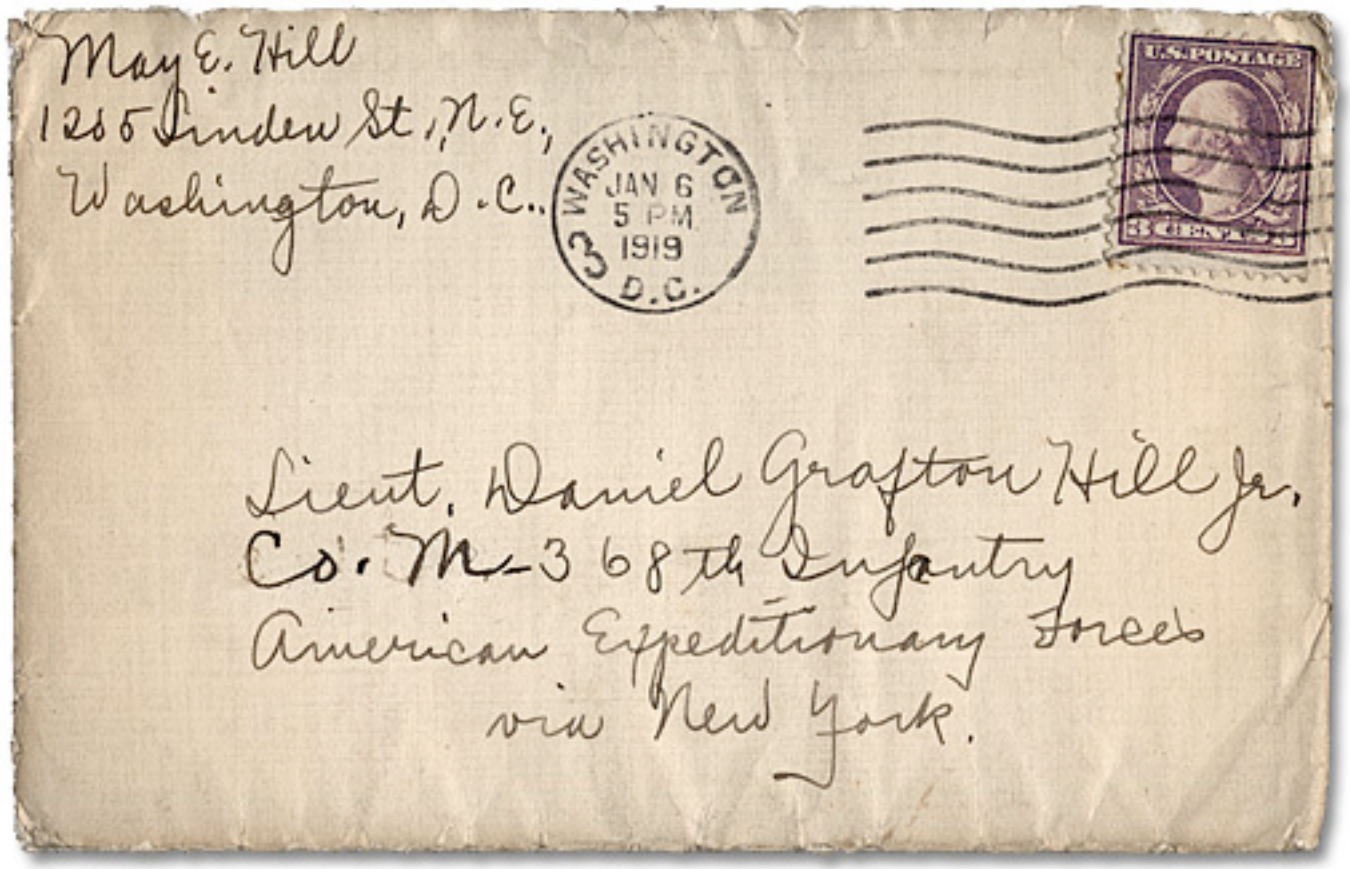
```
delay(1100);
// put the XBee in command mode
Serial.print("+++");
delay(1100);
if (checkFor("OK", 1000)) {
   Serial.println("ATID7777,CN");
    if (checkFor("OK", 1000)) {
       // if an OK was received then continue
       debugPrintln("SetupOK");
       success = true;
   }
}
```

- With a library you just write:

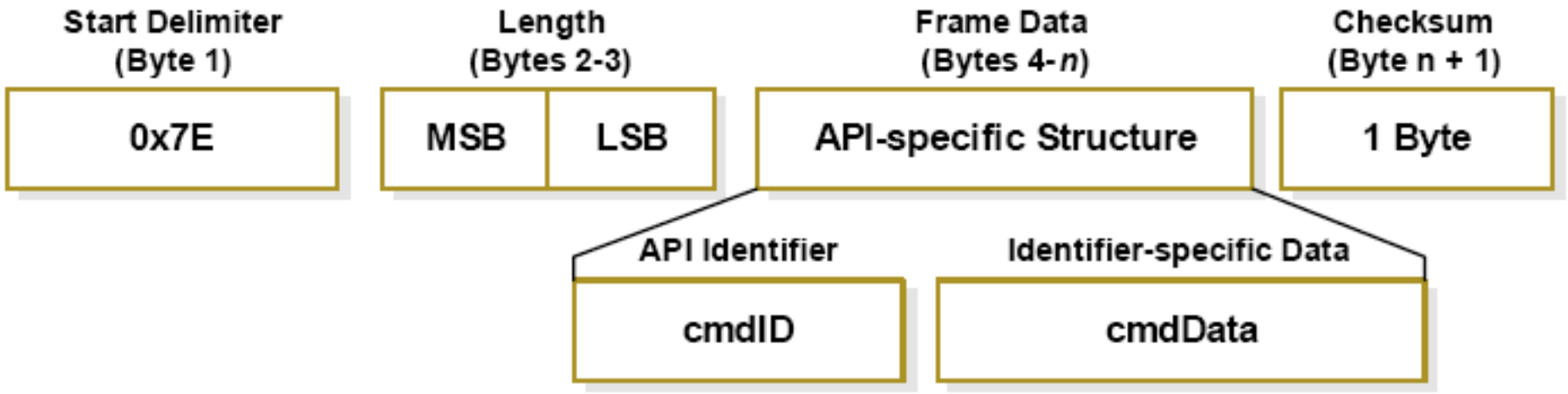
```
sendCommand(ID,0x7777);
```

Envelope Has:

- From address, to address, outside, inside, size, contents, error check



API Basic Frame Envelope



Start Byte

- 0x7E --> also known as the tilde in ASCII: ~

- First thing to do is look for it:

```
  // ARDUINO VERSION:
if (Serial.available() > 0) { // if a byte is waiting in the buffer
    inByte = Serial.read(); // read a byte from the buffer
    if (inByte == 0x7E) {
       // we're at the start of an API frame!
       // add more code here
     }
  }


  // PROCESSING VERSION:
if (port.available() > 0 {
  int inByte = port.read();
    if (inByte == 0x7E) {
       // we're at the start of an API frame!
       // add more code here
}
```

Length Bytes

- MSB: the Most Significant Byte
    - the big part of the number
- LSB: the Least Significant Byte
    - the small part of the number
- bit shift MSB to the right and add it to LSB

```
 // PROCESSING VERSION:
int lengthMSB = port.read(); // high byte for length of packet
int lengthLSB = port.read(); // low byte for length of packet

int lengthTotal = (lengthMSB << 8) + lengthLSB; // bit shift and add for total
```

API Identifier

- Specifies the remaining structure of the frame
  - modem status: 0x8A
  - AT command (immediate): 0x08
  - AT command (queued): 0x09
  - AT command response: 0x88
  - TX request (64 bit): 0x00
  - TX request (16 bit): 0x01
  - TX status response: 0x89
  - RX packet (64 bit): 0x80
  - RX packet (16 bit): 0x81
  - RX packet I/O data (64 bit): 0x82
  - RX packet I/O data (16 bit): 0x83

```
 // PROCESSING VERSION:
int API_ID = port.read(); // API Identifier indicates type of packet received
```

Identifier-specific Data

- Structures are different for each API identifier and might include:
  - addressing information (333B)
  - status information (received OK)
  - source information (broadcast packet)
  - unstructured data (“Hello World, this is Rob!”)
  - structured data (typically for I/O packets)

Checksum

- Simple check to detect errors
- To calculate: Not including frame delimiters and length, add all bytes keeping only the lowest 8 bits of the result and subtract from 0xFF.
- To verify: Add all bytes (include checksum, but not the delimiter and length). If the checksum is correct, the sum will equal 0xFF.

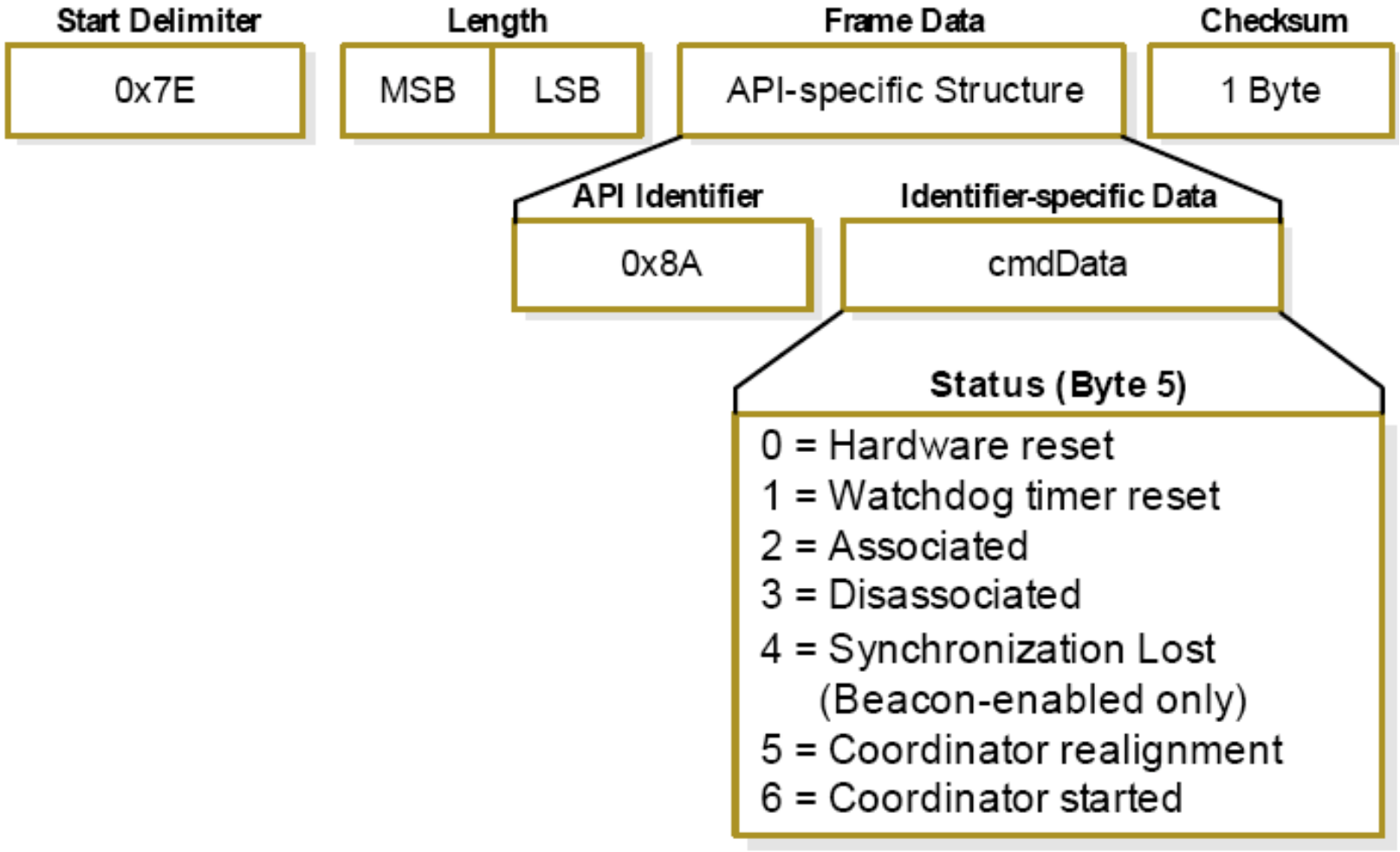
```
 // PROCESSING VERSION:
int localChecksum = (API_ID + addrMSB + addrLSB + RSSI + options + dataSum);

int checksum = port.read();
localChecksum = byte(0xFF -localChecksum);

if ( (byte) checksum - localChecksum == 0) {
  returnVal = dataADC[0];
}
else {
  print("\n\nchecksum error!  " + "\n\n");
}
```

Many Kinds of Envelopes

Modem Status



AT Command

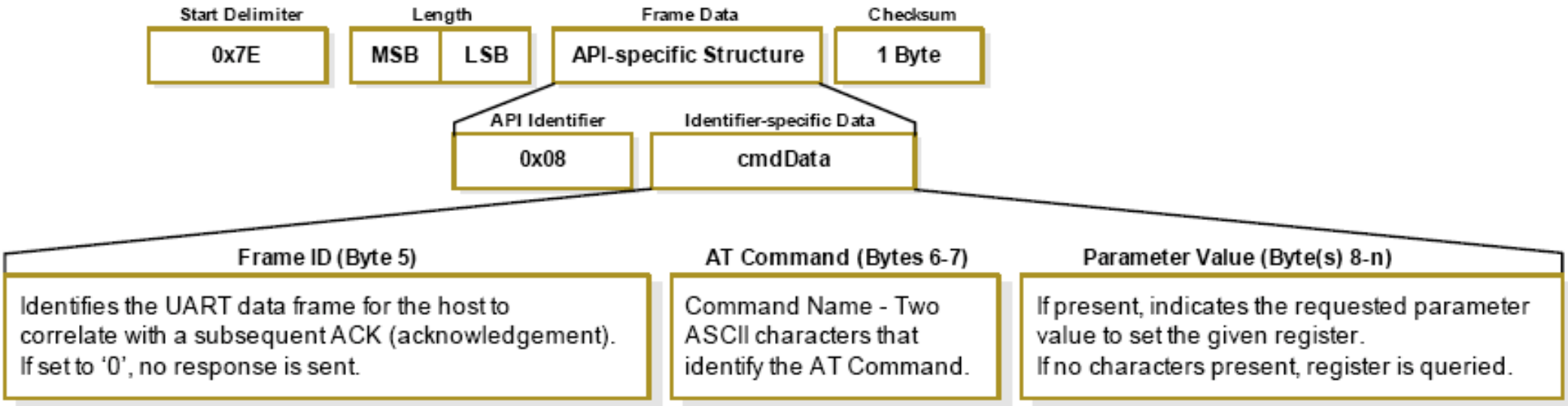
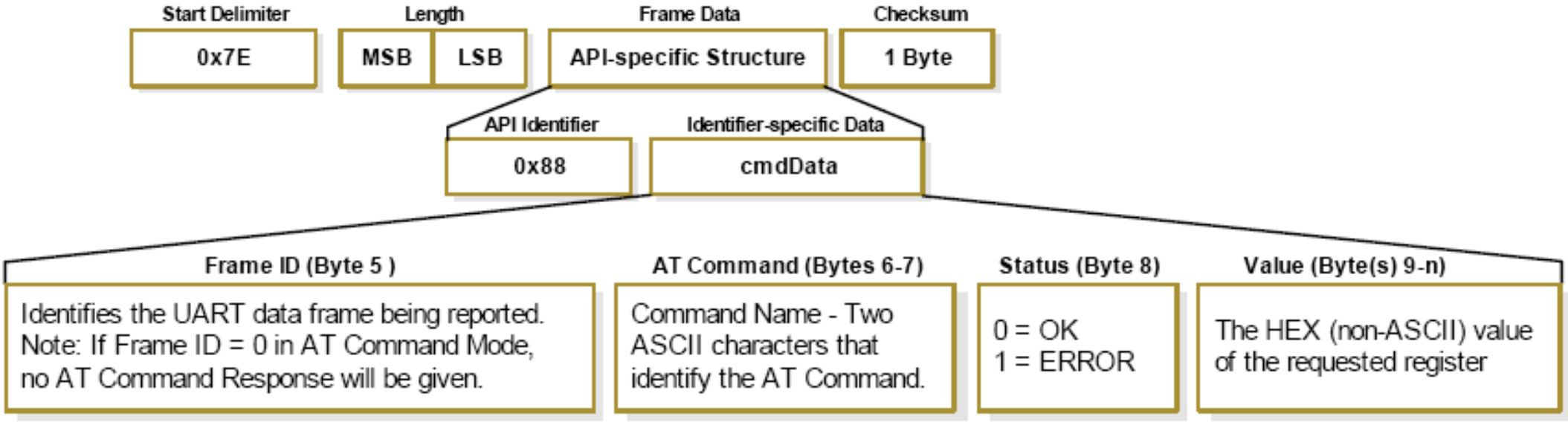


Figure 3-06. Example: API frames when reading the DL parameter value of the module.

Byte 1	Bytes 2-3	Byte 4	Byte 5	Bytes 6-7	Byte 8
0x7E	0x00 | 0x04	0x08	0x52 (R)	0x44 (D) | 0x4C (L)	0x15
Start Delimiter	Length*	API Identifier	Frame ID**	AT Command	Checksum

AT Response

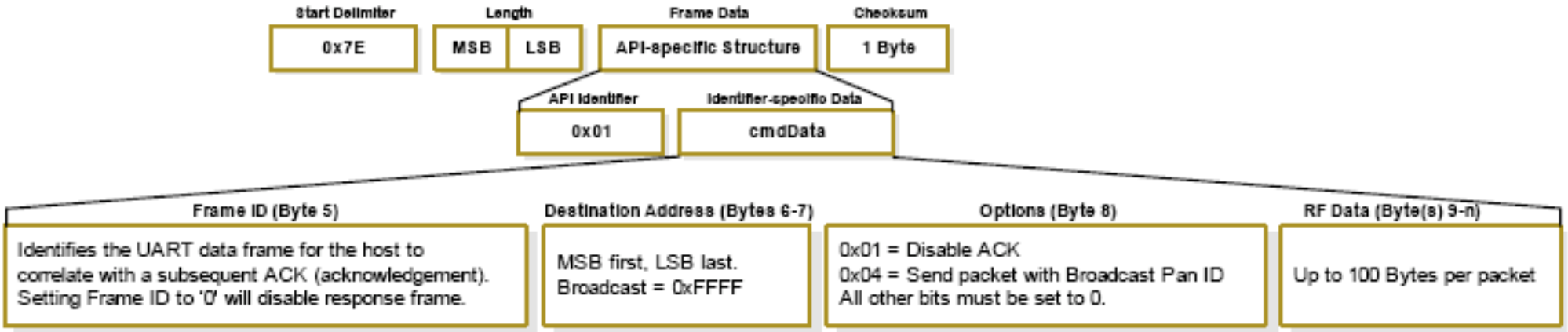
- Frame ID for the response is the same as the matching AT Command request



TX (Transmit) Request

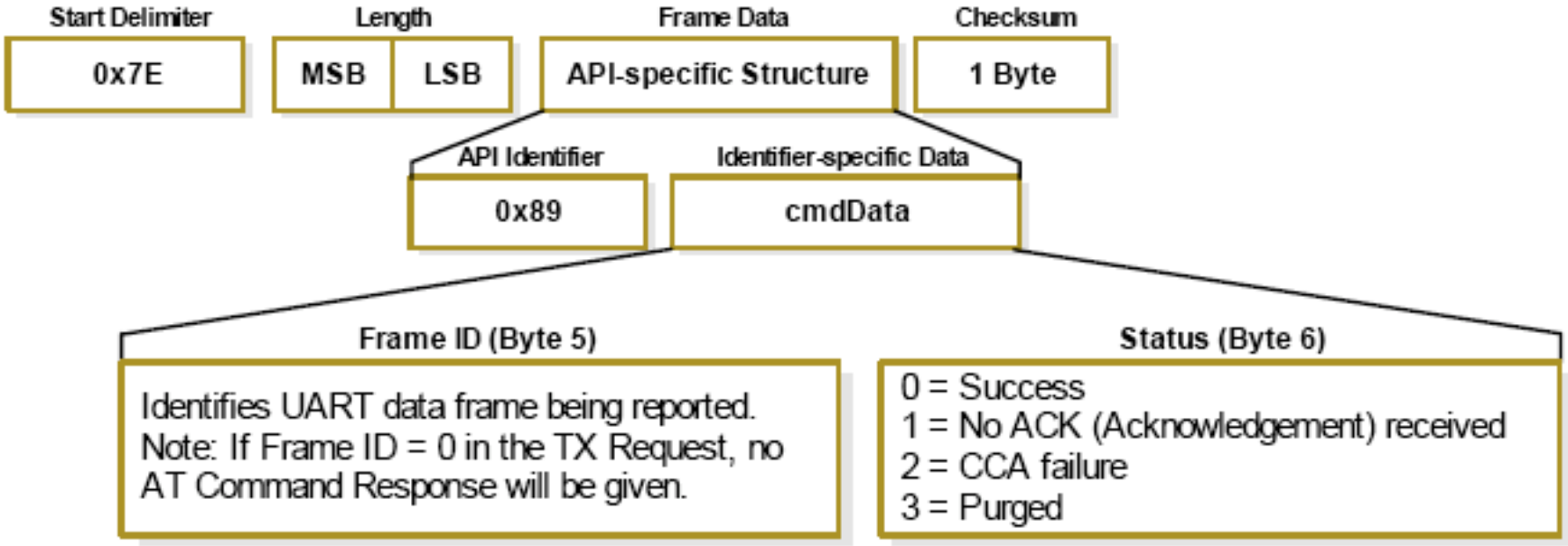
- Remember that this is a request

- Also need to check for results by Frame ID



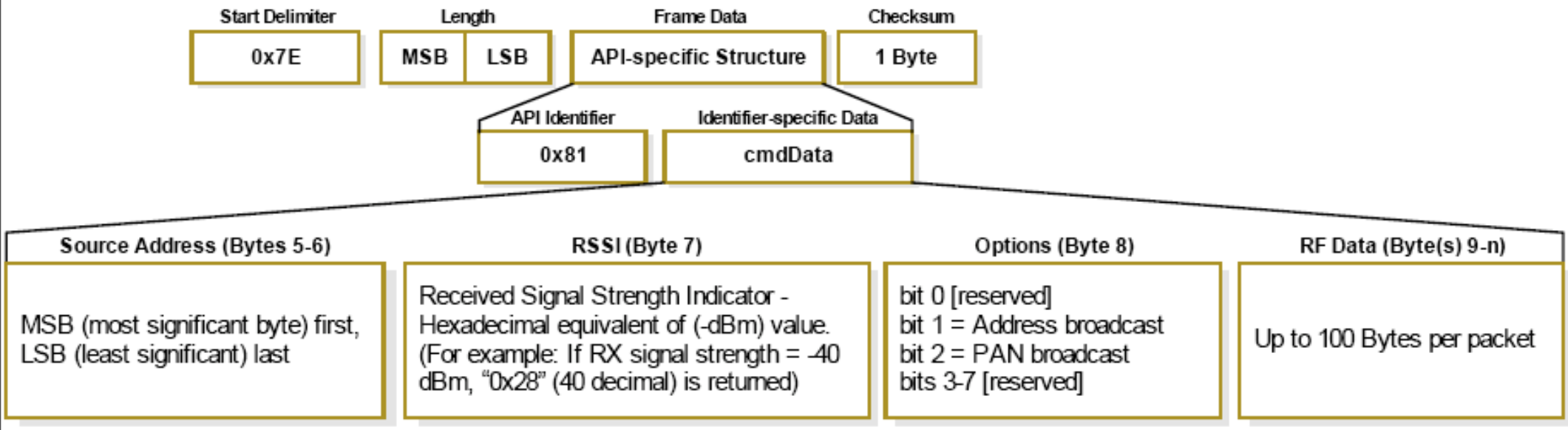
TX Status (Results)

- See if your message was transmitted or not
- Use your Frame ID to see which message is being described



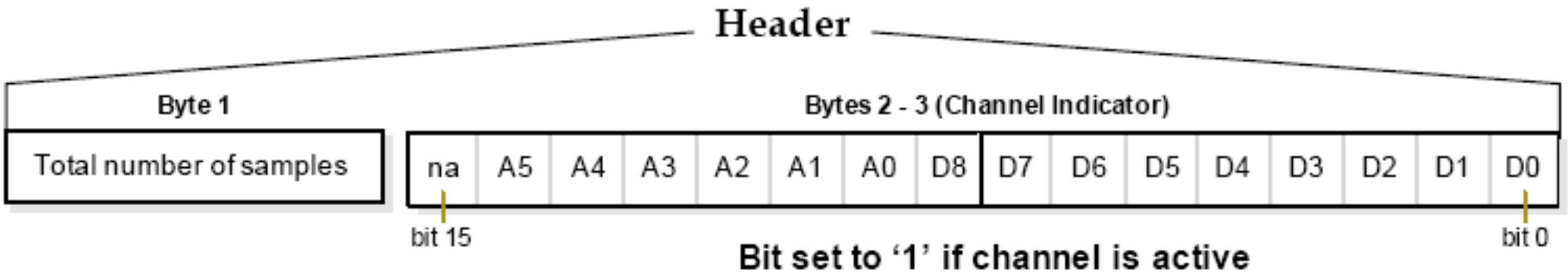
RX Packet (16 bit addressing)

- Maximum of 100 bytes of data per packet
- RF Data section is basis for I/O packets



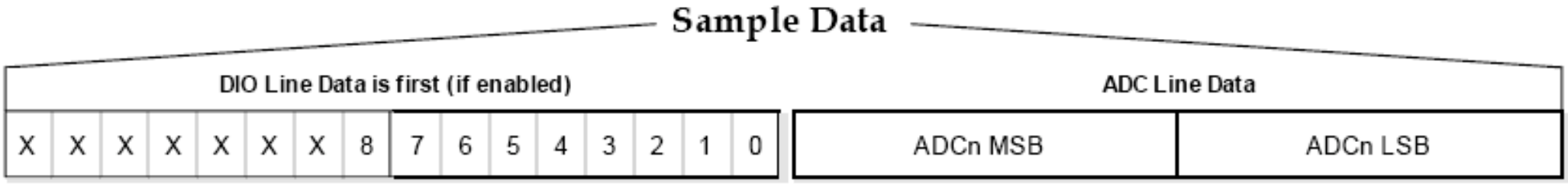
I/O Data Header

- Inside the RF Data section of the RX Packet
  - Total number of samples set with ATIS
  - Channels set with ATD0...9



I/O Data Sample

- Follows the header
- Two bytes of digital data IF ANY DIGITAL CHANNELS ENABLED followed by...
- ...two bytes for EACH analog channel enabled...
- ...then repeats for each sample



- How many bytes if ATIS5 ATD02 ATD12 ATD23?

I/O Code: Basic

- Fixed parameters make for easier programming

- Assume we are just reading a single sample of one ADC channel at a time:

```
 // PROCESSING VERSION:
int totalSamples = port.read(); // this is the number of samples we're receiving
int channelIndicatorHigh = port.read(); // this tells us which analog channels
                  // are in use (and one digital channel)
int channelIndicatorLow = port.read();  // this tells us which digital channels
                  // are in use.

int  dataADCMSB = port.read(); // read in the most significant ADC byte
int dataADCLSB = port.read(); // read in the least significant ADC byte
int dataADC = (dataADCMSB << 8) + dataADCLSB;  // bit shift the MSB into
                  // position and add it to the LSB

      print(dataADC);  // print the information
}
```

Readings and Assignments

- Assignment
    - Final Project