Sensitive Buildings

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Plan for Today

- Simple Sensor Network: discussion
- Merica Jensen
- I/O API review and Remote AT commands
- Sleep Mode
- End Devices
- Direct Actuation
- Readings & Assignments

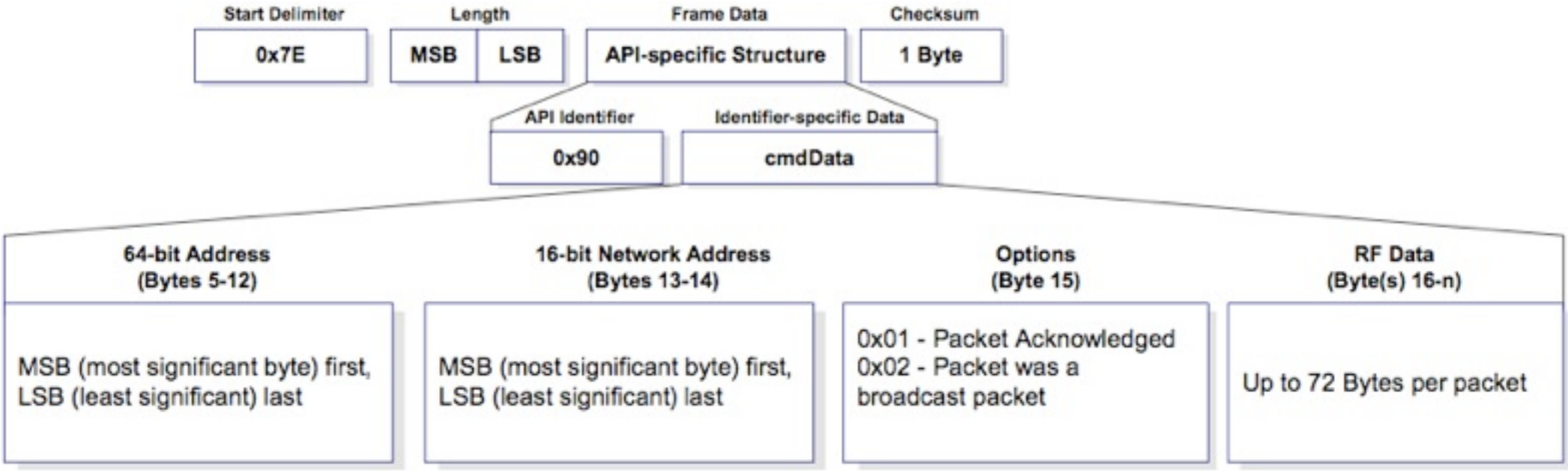
Merica Jensen

Simple Sensor Network

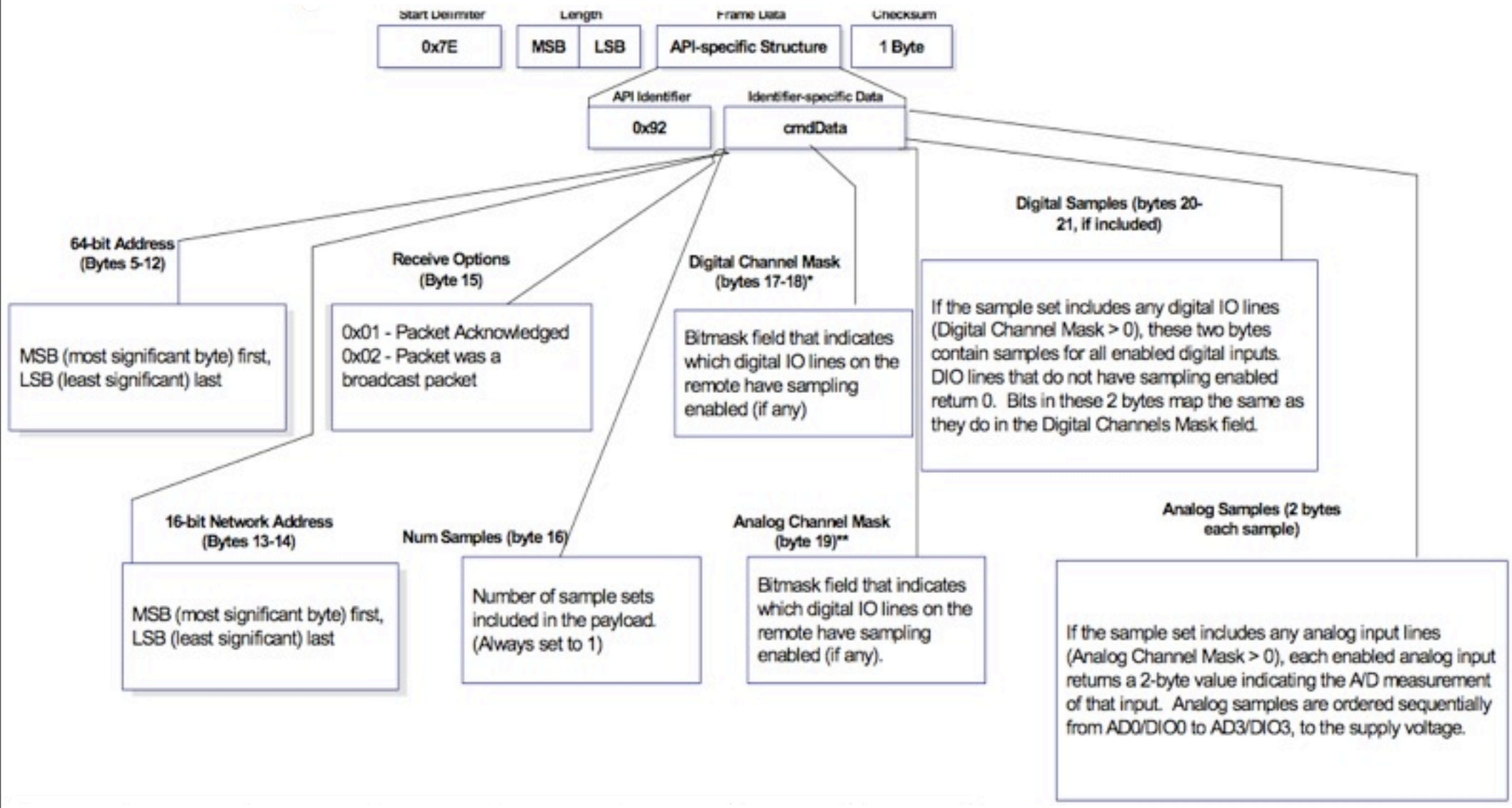
API for I/O and Remote AT

RX Packet

- Maximum of 72 bytes of data per packet
- RF Data section is basis for I/O packets



I/O RX Packet


Start Delimiter
0x7E
Length
MSB
LSB
Frame Data
API-specific Structure
Checksum
1 Byte
API Identifier
0x92
Identifier-specific Data
cmdData
64-bit Address
(Bytes 5-12)
MSB (most significant byte) first, LSB (least significant) last
Receive Options
(Byte 15)
0x01 - Packet Acknowledged
0x02 - Packet was a broadcast packet
Digital Channel Mask
(bytes 17-18)*
Bitmask field that indicates which digital IO lines on the remote have sampling enabled (if any)
Digital Samples (bytes 20-21, if included)
If the sample set includes any digital IO lines (Digital Channel Mask > 0), these two bytes contain samples for all enabled digital inputs. DIO lines that do not have sampling enabled return 0. Bits in these 2 bytes map the same as they do in the Digital Channels Mask field.
16-bit Network Address
(Bytes 13-14)
MSB (most significant byte) first, LSB (least significant) last
Num Samples (byte 16)
Number of sample sets included in the payload. (Always set to 1)
Analog Channel Mask
(byte 19)**
Bitmask field that indicates which digital IO lines on the remote have sampling enabled (if any).
Analog Samples (2 bytes each sample)
If the sample set includes any analog input lines (Analog Channel Mask > 0), each enabled analog input returns a 2-byte value indicating the A/D measurement of that input. Analog samples are ordered sequentially from AD0/DIO0 to AD3/DIO3, to the supply voltage.

I/O Digital Channel Mask and Digital Data

Digital Channel Mask (bytes 17-18)*

Bitmask field that indicates which digital IO lines on the remote have sampling enabled (if any)

*

N/A	N/A	N/A	CD/DIO 12	PWM/DI O11	RSSI/DI O10	N/A	N/A
CTS/DI O7	RTS/DI O6	ASSOC/ DIO5	DIO4	AD3/DI O3	AD2/DI O2	AD1/DI O1	AD0/DI O0

Digital Samples (bytes 20-21, if included)

If the sample set includes any digital IO lines (Digital Channel Mask > 0), these two bytes contain samples for all enabled digital inputs. DIO lines that do not have sampling enabled return 0. Bits in these 2 bytes map the same as they do in the Digital Channels Mask field.

I/O Analog Channel Mask and Analog Samples

Analog Channel Mask (byte 19)**

Bitmask field that indicates which digital IO lines on the remote have sampling enabled (if any).

**

Supply Voltage	N/A	N/A	N/A	AD3	AD2	AD1	AD0

Analog Samples (2 bytes each sample)

If the sample set includes any analog input lines (Analog Channel Mask > 0), each enabled analog input returns a 2-byte value indicating the A/D measurement of that input. Analog samples are ordered sequentially from AD0/DIO0 to AD3/DIO3, to the supply voltage.

I/O Structure Reviewed

- Num Samples (1 byte)
- Digital Channel Mask (2 bytes)
- Analog Channel Mask (1 byte)
- Two bytes of digital data IF ANY DIGITAL CHANNELS ENABLED followed by...
- ...two bytes for EACH analog channel enabled...

  - Q: How many bytes ATD02 ATD12 ATD23?

I/O Bytes Example

0x7E (start byte)
0x00
0x17 (length)
0x92 (API id)
0x00 (64-bit address)
0x13
0x20
0x00
0x43
0x23
0x12
0xEF
0x03 (16-bit address)
0xA4
0x01 (num samples)
0x00 (digital channel masks)
0x00
0x01 (analog channel mask)
0x02 (first analog sample)
0xF8
0x30 (the checksum)

I/O Code: Basic

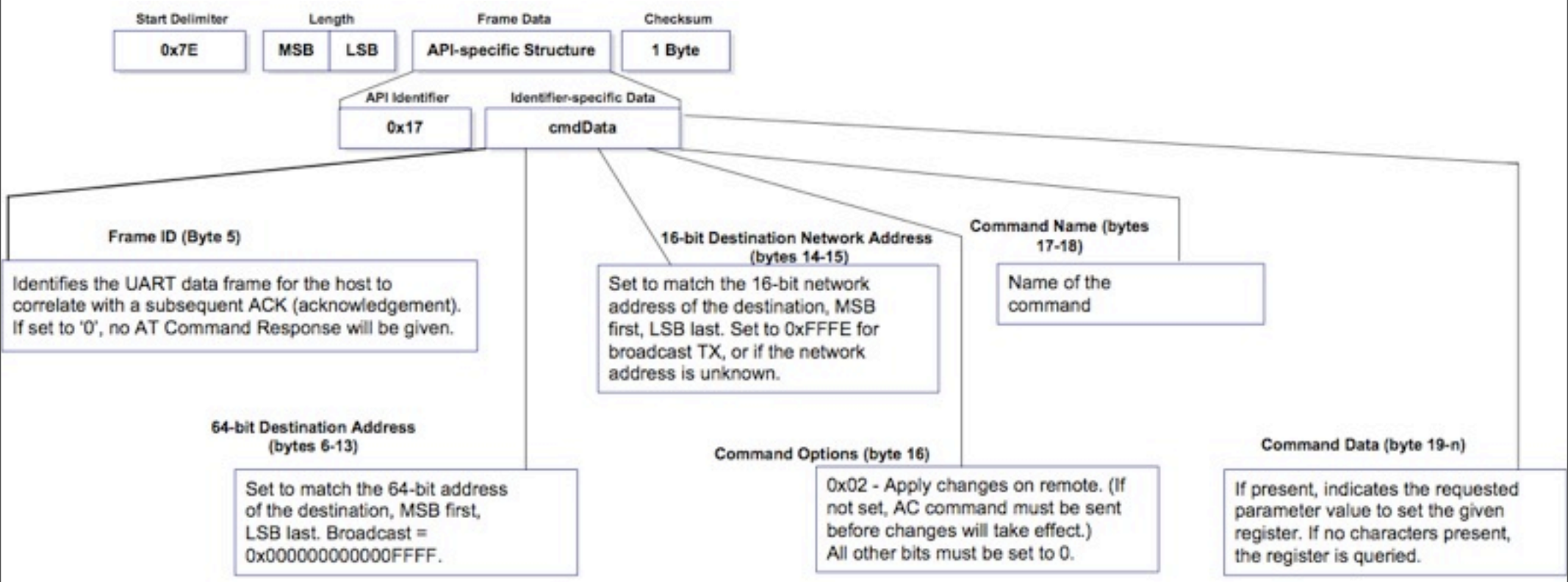
- Fixed parameters make for easier programming

- Assume we are just reading a single ADC channel:

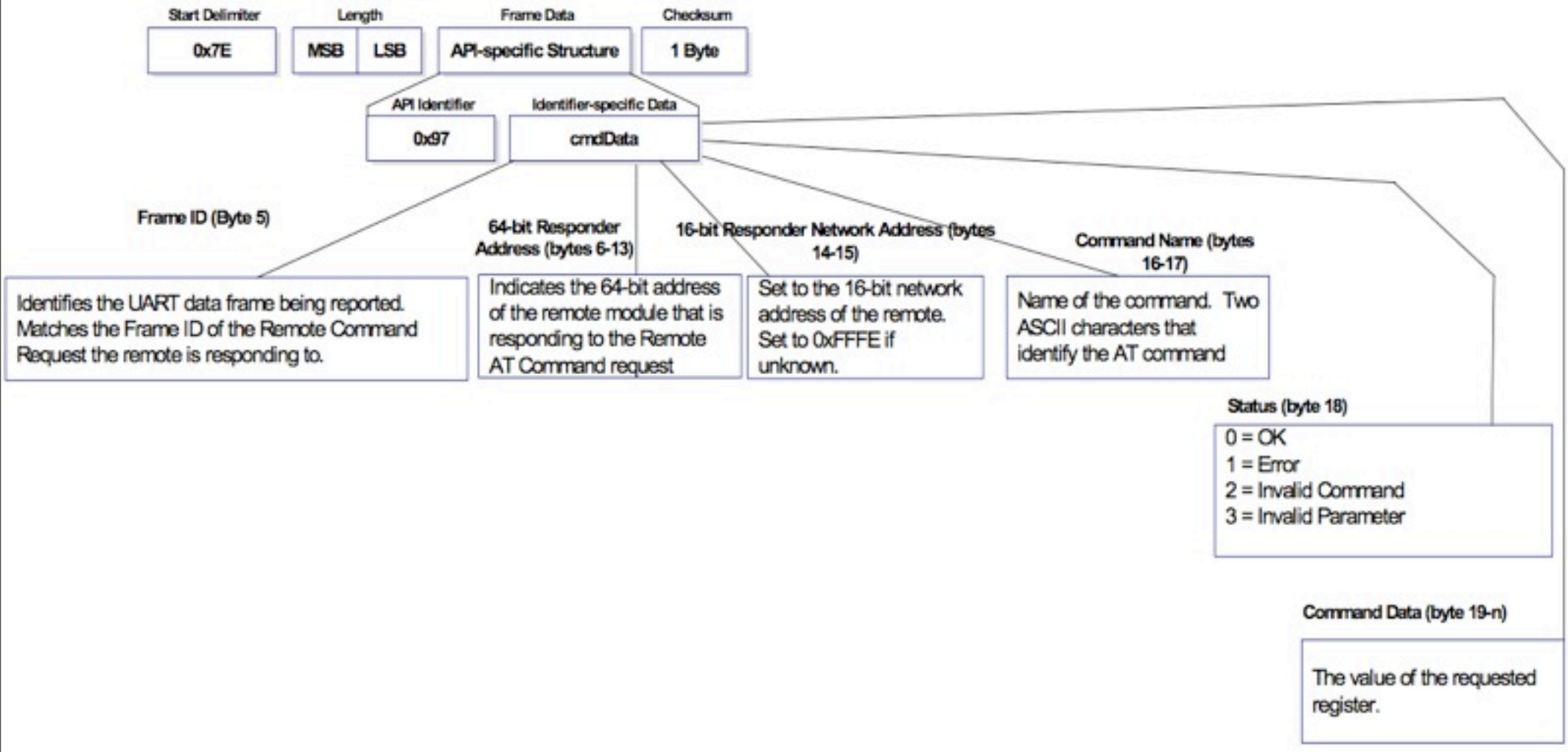
```
  Arduino Version:
// make sure everything we need is in the buffer
  if (Serial.available() >= 21) {
    // look for the start byte
    if (Serial.read() == 0x7E) {
      // read the variables that we're not using out of the buffer
      for (int i = 0; i<18; i++) {
        byte discard = Serial.read();
      }
     int analogHigh = Serial.read();
     int analogLow = Serial.read();
     analogValue =  analogLow + (analogHigh * 256);
    }
  }
```

Remote AT Command Request

- Send commands across the network



Remote AT Command Response



Remote AT Command Code

```
void setRemoteState(int value) { // pass either a 0x4 or and 0x5 to turn the pin on or off
  Serial.print(0x7E, BYTE);
  Serial.print(0x0, BYTE); // high part of length (always zero)
  Serial.print(0x10, BYTE); // low part of length (the number of bytes that follow, not including checksum)
  Serial.print(0x17, BYTE); // 0x17 is a remote AT command
  Serial.print(0x0, BYTE); // frame id set to zero for no reply
  // ID of recipient, or use 0xFFFF for broadcast
  Serial.print(00, BYTE);
  Serial.print(00, BYTE);
  Serial.print(00, BYTE);
  Serial.print(00, BYTE);
  Serial.print(00, BYTE);
  Serial.print(00, BYTE);
  Serial.print(0xFF, BYTE); // 0xFF for broadcast
  Serial.print(0xFF, BYTE); // 0xFF for broadcast
  // 16 bit of recipient or 0xFFFE if unknown
  Serial.print(0xFF, BYTE);
  Serial.print(0xFE, BYTE);
  Serial.print(0x02, BYTE); // 0x02 to apply changes immediately on remote
  // command name in ASCII characters
  Serial.print('D', BYTE);
  Serial.print('1', BYTE);
  // command data in as many bytes as needed
  Serial.print(value, BYTE);
  // checksum
  long sum = 0x17 + 0xFF + 0xFF + 0xFF + 0xFE + 0x02 + 'D' + '1' + value;
  Serial.print( 0xFF - ( sum & 0xFF) , BYTE );
  delay(10);
}
```

End Devices

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 and PAN
- Automatically attempts to join a valid PAN
- End devices can only communicate directly with their parent
- 16-bit address assigned by coordinator

Sleep Mode

Sleeping the XBee ZigBee: Basics

- Why Sleep?
- ATSM
  - 1: pin hibernate, <10 µA, 13.2 ms wakeup, uses pin 9
  - 2 and 3: <nothing>
  - 4: cyclic sleep, also <50 µA, 2 ms wakeup, module must be idle
  - 5: cyclic sleep with pin wakeup
- ATSP: Sleep Period (* 10 ms) [0x20-0xAFO]
- ATSN: Number of Sleep Periods (* 1 ms)
  used in external device control
- ATST: Sleep Timer (* 1 ms)
- ATSO: Options 0x2 = regular, 0x4 = extended

Sleep Commands

Table 10-015.Sleep Commands

AT Command	Name and Description	Node Type[1]	Parameter Range	Default
SM	**Sleep Mode** Sets the sleep mode on the RF module	E	0-Sleep disabled 1-Pin sleep enabled 4-Cyclic sleep enabled 5 - Cyclic sleep, pin wake	0
SN	**Number of Sleep Periods.** Sets the number of sleep periods to not assert the On/Sleep pin on wakeup if no RF data is waiting for the end device. This command allows a host application to sleep for an extended time if no RF data is present	CRE	1 - 0xFFFF	1
SP	**Sleep Period.** This value determines how long the end device will sleep at a time, up to 28 seconds. (The sleep time can effectively be extended past 28 seconds using the SN command.) On the parent, this value determines how long the parent will buffer a message for the sleeping end device. It should be set at least equal to the longest SP time of any child end device.	CRE	0x20 - 0xAF0 x 10ms (Quarter second resolution)	0x20
ST	**Time Before Sleep** Sets the time before sleep timer on an end device.The timer is reset each time serial or RF data is received. Once the timer expires, an end device may enter low power operation. Applicable for cyclic sleep end devices only.	E	1 - 0xFFFE (x 1ms)	0x1388 (5 seconds)
SO Command	**Sleep Options**. Configure options for sleep. Unused option bits should be set to 0. Sleep options include: 0x02 - Always wake for ST time 0x04 - Sleep entire SN * SP time Sleep options should not be used for most applications. See Sleep Mode chapter for more information.	E	0 - 0xFF	0
WH	**Wake Host**. Set/Read the wake host timer value. If the wake host timer is set to a non-zero value, this timer specifies a time (in millisecond units) that the device should allow after waking from sleep before sending data out the UART or transmitting an IO sample. If serial characters are received, the WH timer is stopped immediately.	E	0 - 0xFFFF (x 1ms)	

Sleeping the XBee Zigbee: Example

- ATSM5, SP64
  - Will wake up on pin 9 low, and also every 1000 ms
- Use in conjunction with I/O readings
  - Wakeup will always trigger an I/O sample
  - More samples if ATIR allows it during the awake period

- Everything in the PAN should have SP set the same or greater so that incoming frames for the end devices are buffered properly

Direct Actuation

Direct Actuation

- Direct output, i.e. without a microcontroller, should be used sparingly
  - no logic
  - limited pins
  - no feedback
  - API packets have to be perfect
- Only if you need to save money on a large number of devices or need your device to be as small as possible. Otherwise get a µ-controller!

Readings and Assignments

- Readings
    - Building Wireless Sensor Networks, Chapter 6
- Assignments
        - Final Project Proposals
            - six of your own
            - meet with your group to distill to six per group