TI-RSLK MAX

Texas Instruments Robotics System Learning Kit

Texas Instruments

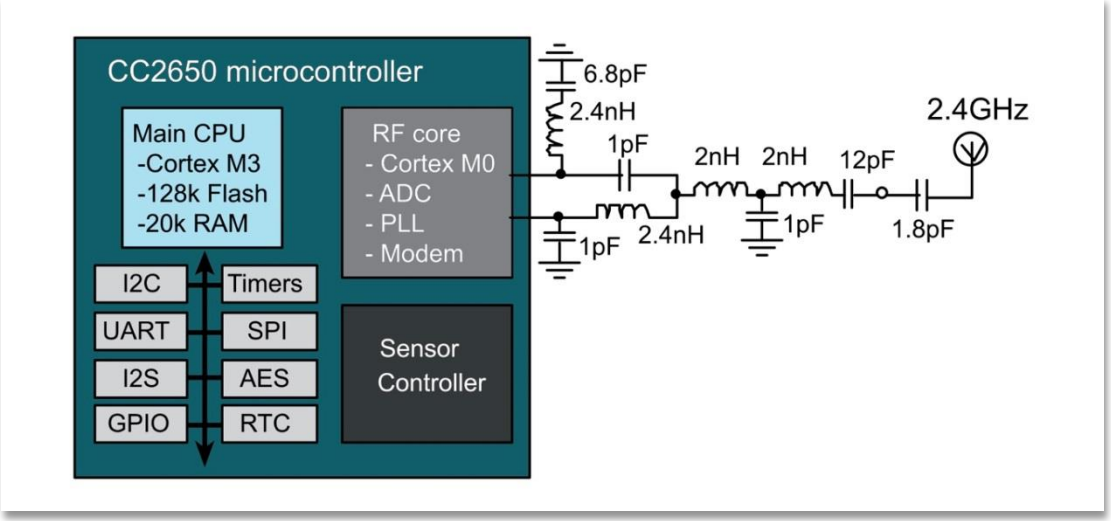
Module 19

Lecture: Bluetooth low energy - Wireless

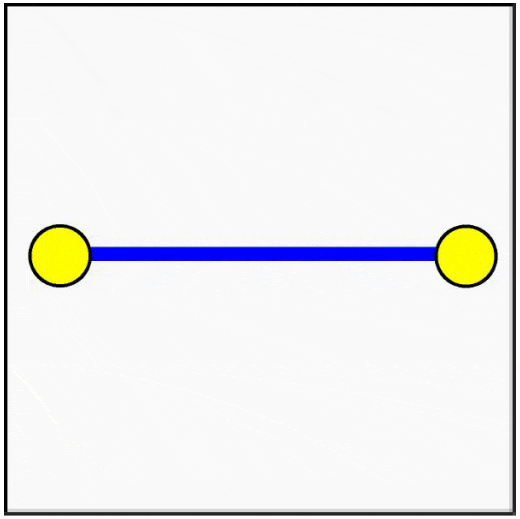
Bluetooth Low Energy

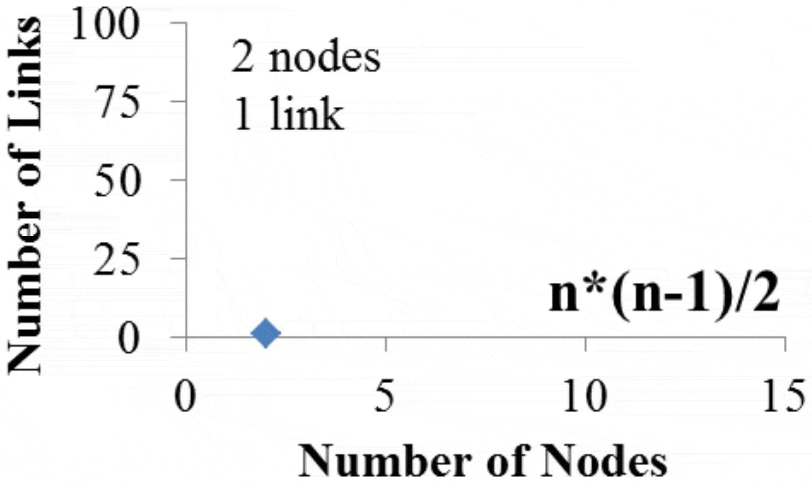
You will learn in this module

- Introduction to Communication
  - Internet
  - Internet of Things
  - Challenges
- Wireless
  - Encode
  - Transmit
  - Decode
- Radio
  - Frequencies
  - Channels

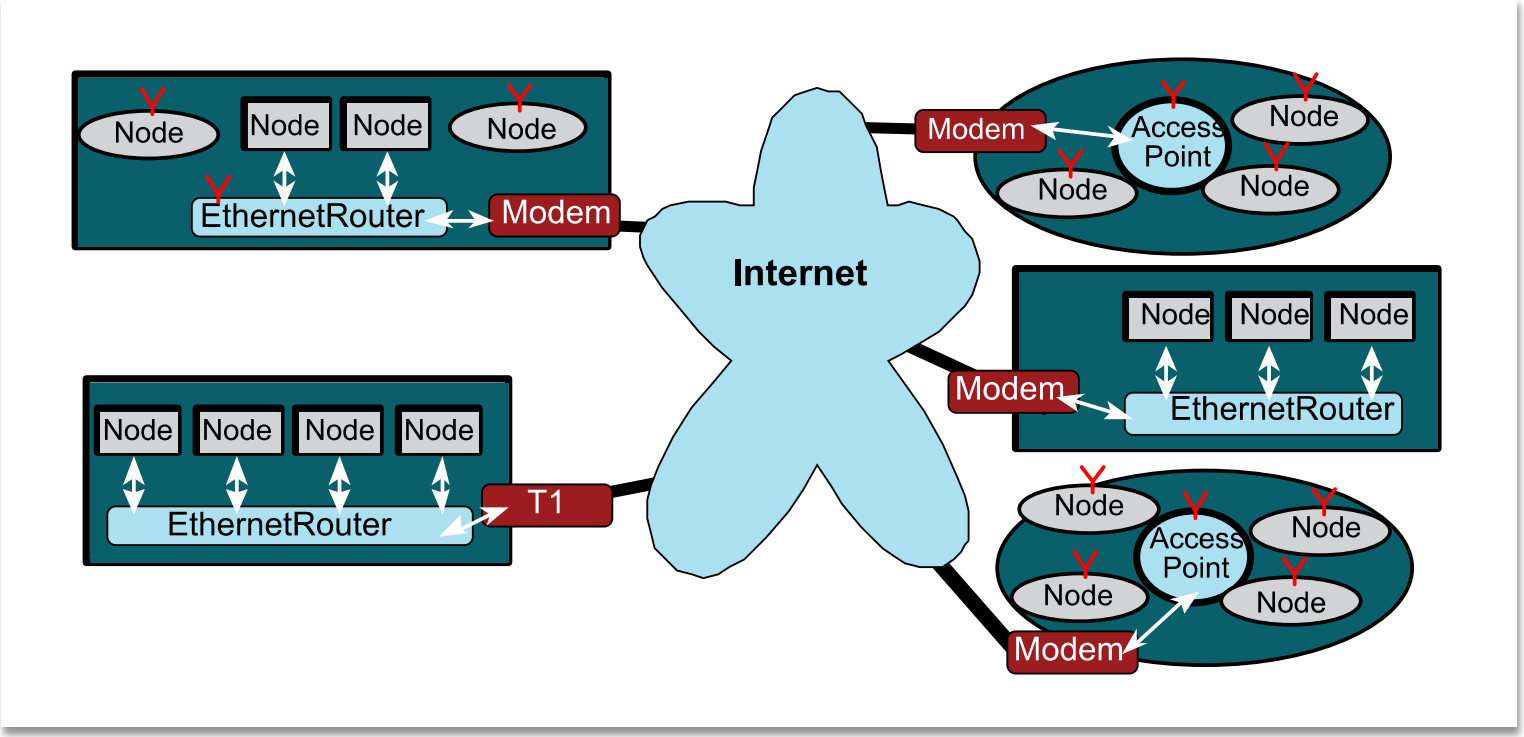


Motivation

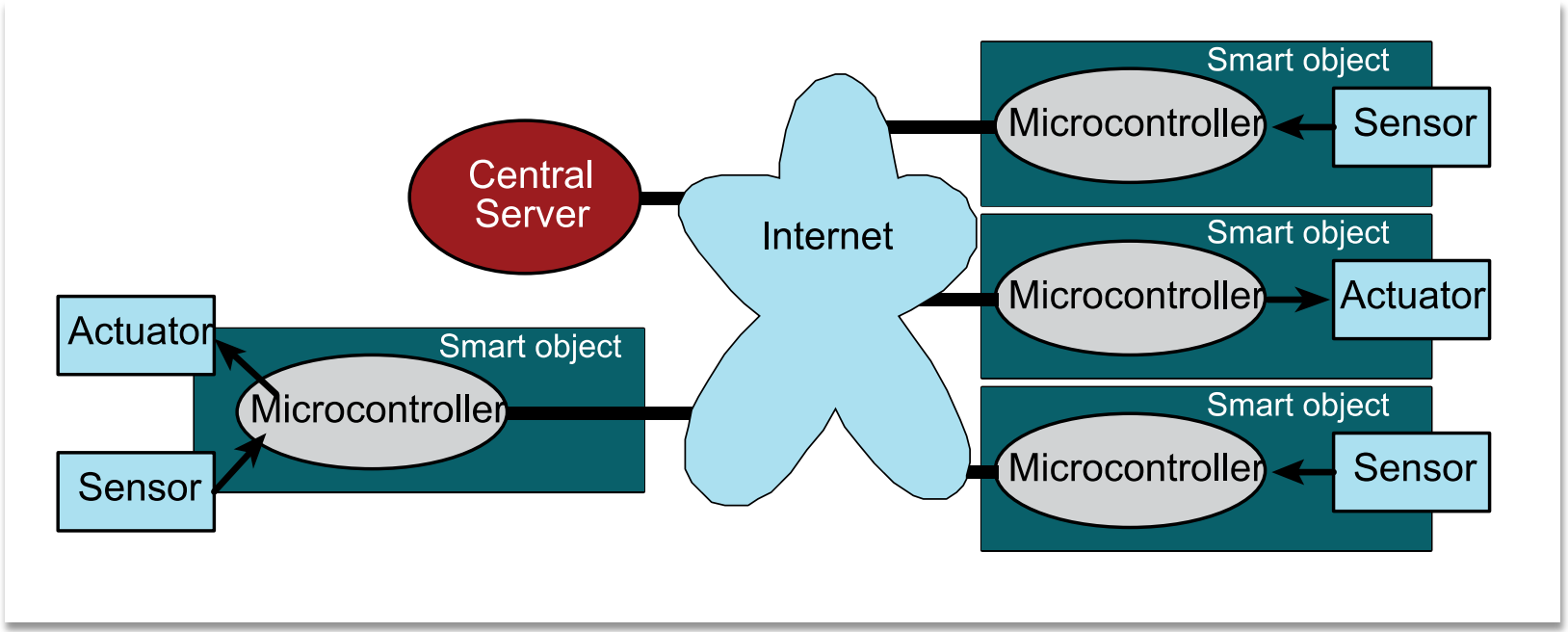



Number of Links
100
75
50
25
0
2 nodes
1 link
n*(n-1)/2
0
5
10
15
Number of Nodes

What is the Internet?



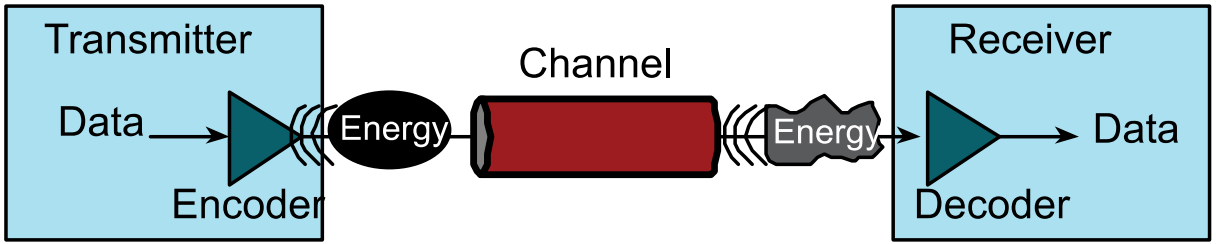
What is the Internet of Things?

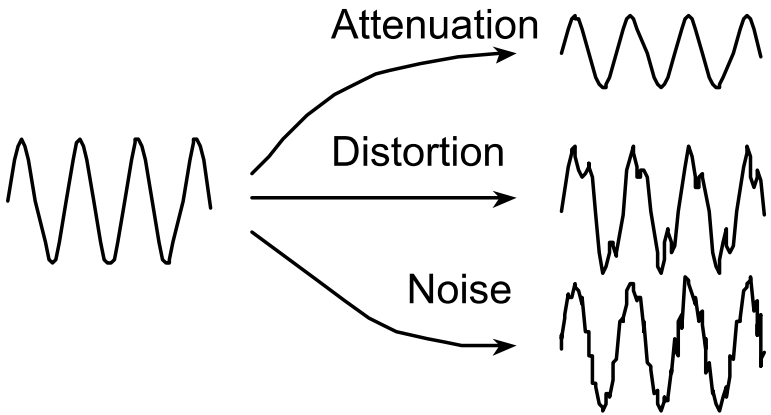


Challenges

- Standardization
  - Bluetooth Low Energy, Simple Network Processor
- Interoperability
  - Technologies, vendors, companies
- Evolution
  - Incremental/continuous vs revolutionary
- Stability
- Abstraction
- Scalability, 50 million to 50 billion
- Security
  - Confidentiality, integrity, availability

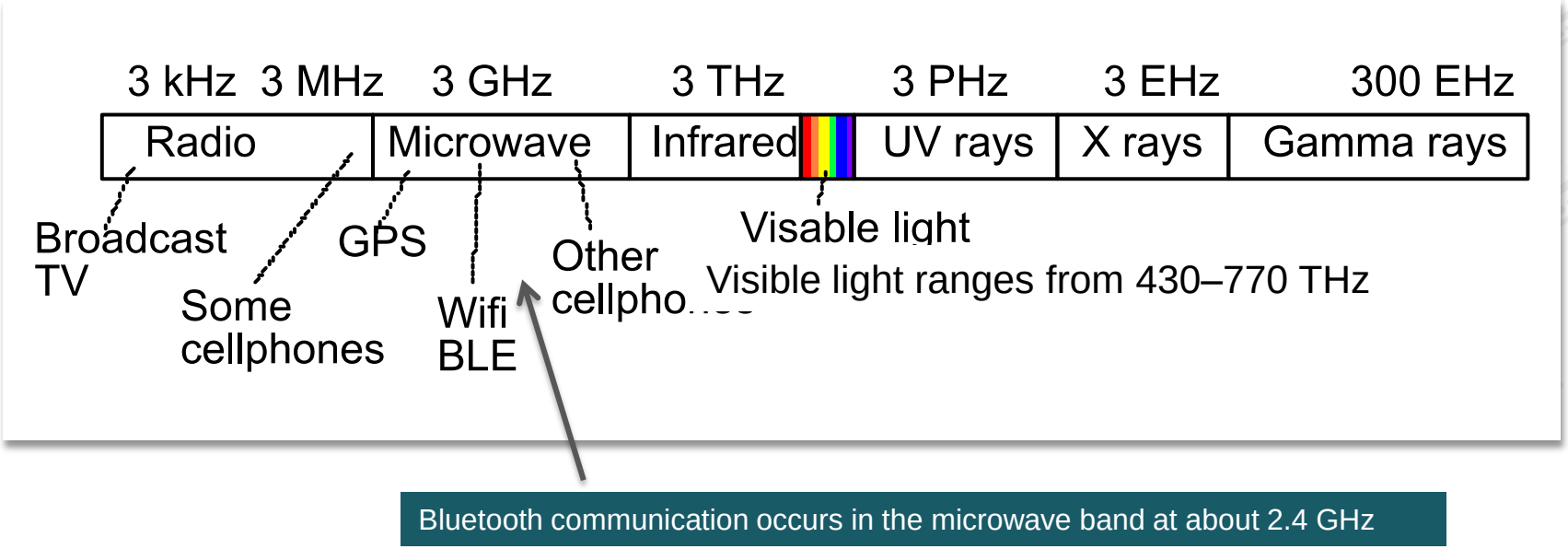
Wireless Communication





Medium
- Unguided
- Guided

Radio


3 kHz
3 MHz
3 GHz
3 THz
3 PHz
3 EHz
300 EHz
Radio
Microwave
Infrared
UV rays
X rays
Gamma rays
Broadcast TV
Some cellphones
GPS
Wifi BLE
Other cellpho...
Visable light
Visible light ranges from 430–770 THz
Bluetooth communication occurs in the microwave band at about 2.4 GHz

Wifi

Standard	Description
Wifi	Up to 600 Mbits/sec Fixed wide frequency channels Requires lots of power Support for 2.4 and 5 GHz channels Extensive security features

Bluetooth/BLE

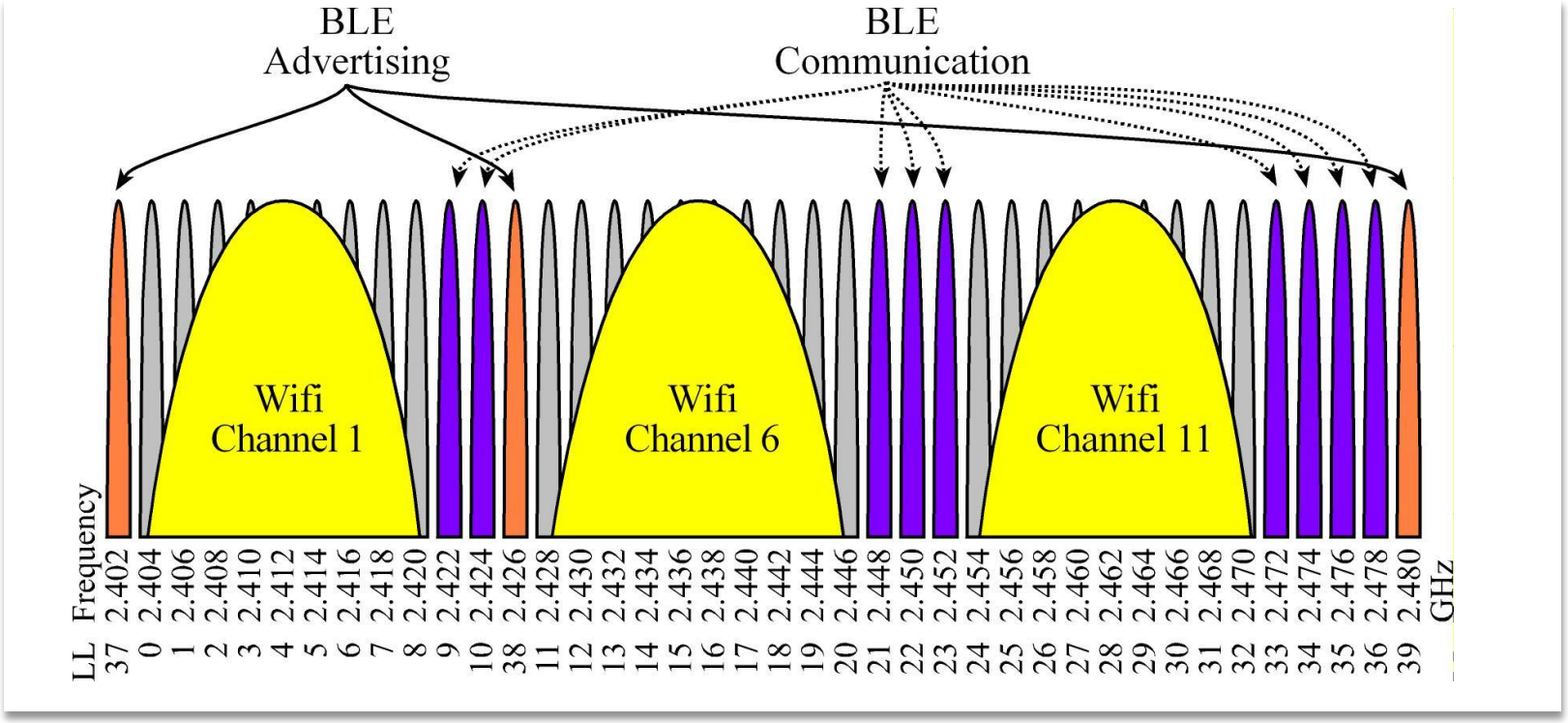
Standard	Description
Wifi	Up to 600 Mbits/sec Fixed wide frequency channels Requires lots of power Support for 2.4 and 5 GHz channels Extensive security features
Bluetooth/BLE	Very low power BT up to 2 Mbps Massive deployed base Frequency hopping Good performance in congested/noisy environment Ease of use No roaming

ZigBee

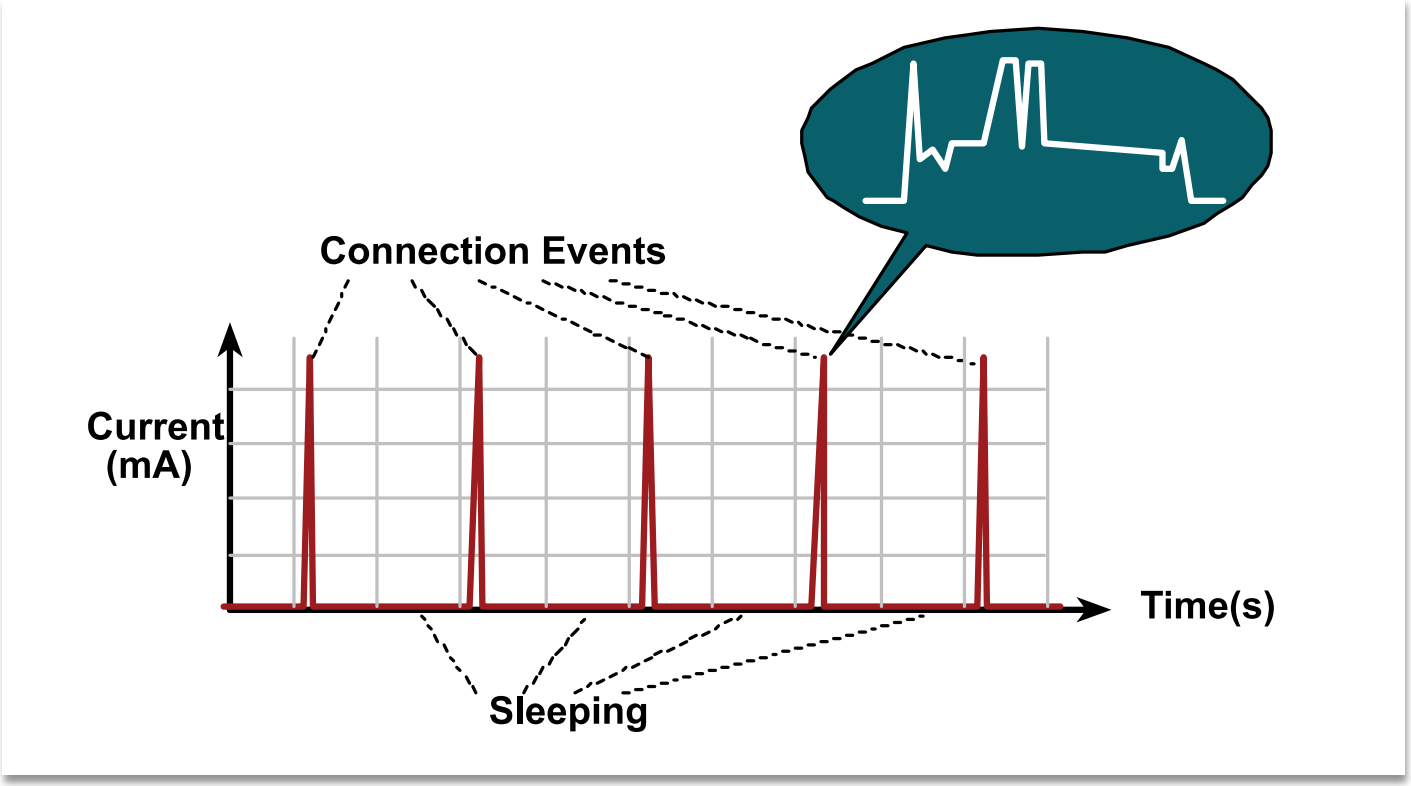
Standard	Description
Wifi	Up to 600 Mbits/sec Fixed wide frequency channels Requires lots of power Support for 2.4 and 5 GHz channels Extensive security features
Bluetooth/BLE	Very low power BT up to 2 Mbps Massive deployed base Frequency hopping Good performance in congested/noisy environment Ease of use No roaming
ZigBee	Very low power Fixed channels Complex mesh network 250 kbps bandwidth

Radio has 40 narrow bands

Each band is ±1 MHz.



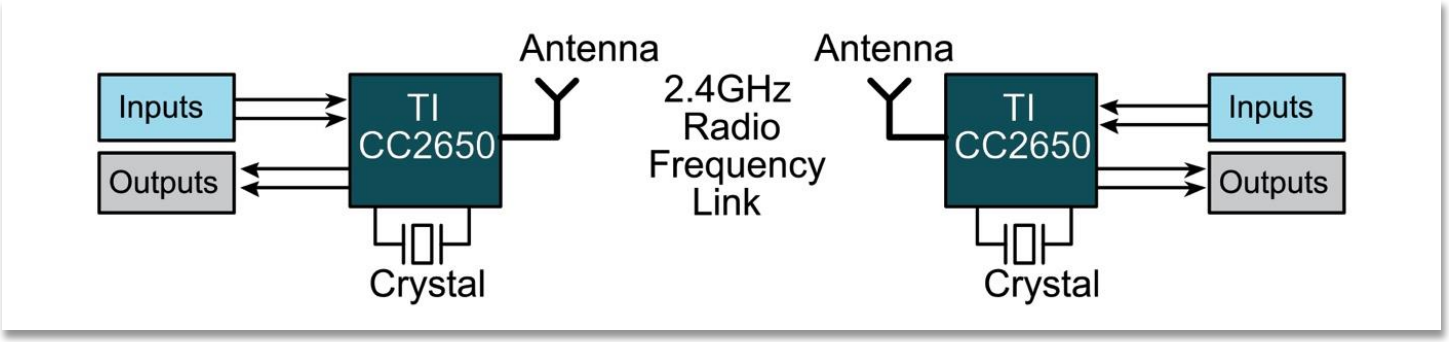
Low power



Summary

Wireless Communication

- Internet of Things
- Standardization
- Radio
- Low power



Module 19

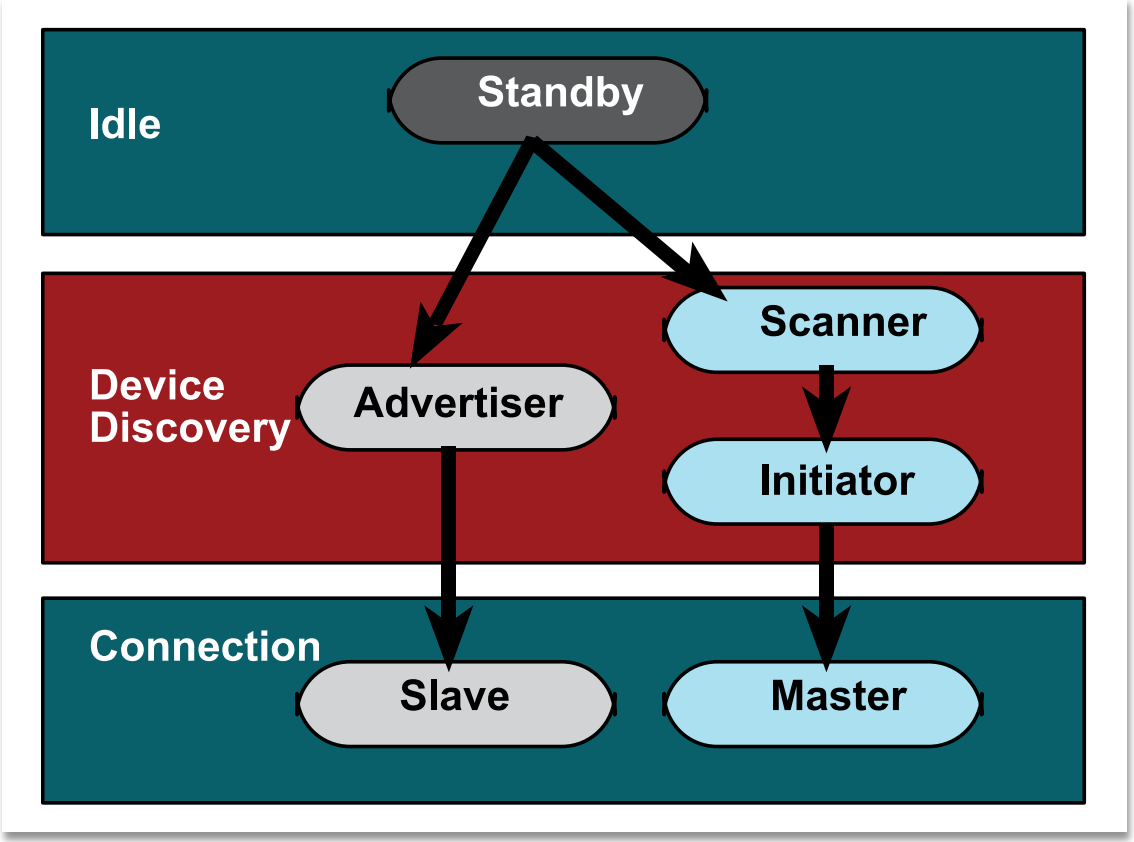
Lecture: Bluetooth low energy - Theory

Bluetooth Low Energy

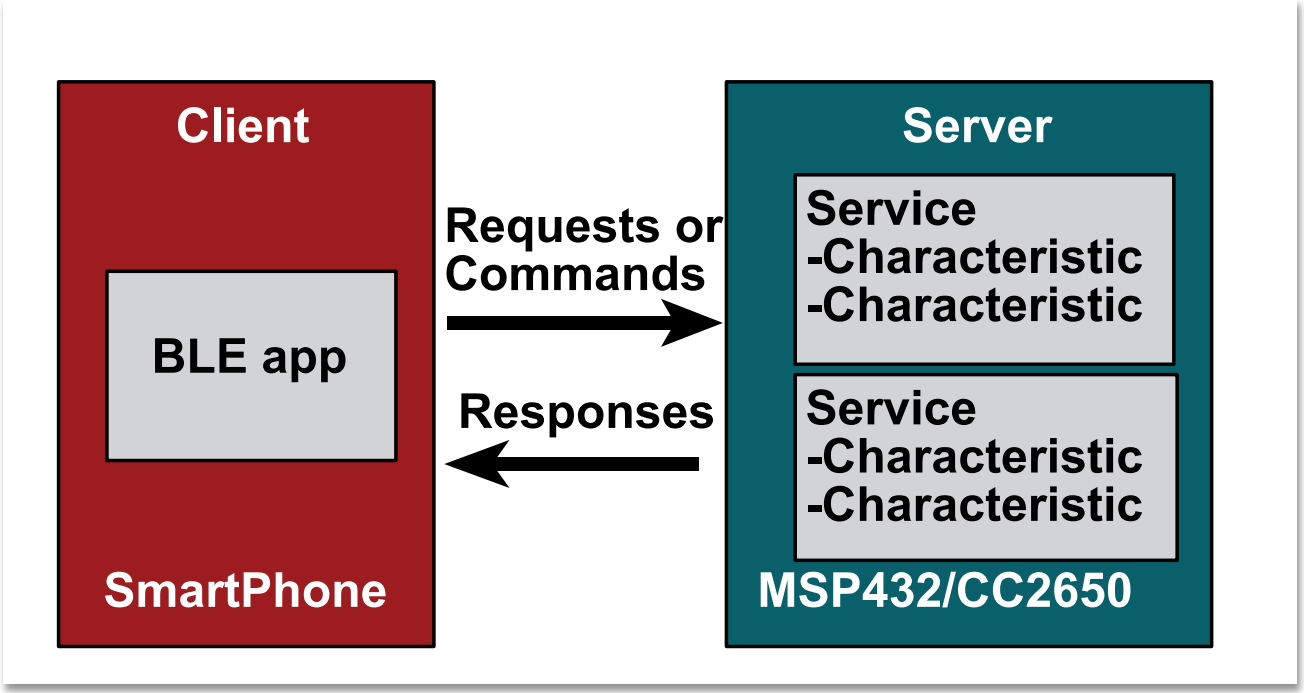
You will learn in this module

- Client-server paradigm
  - Request-response
- BLE
  - Profile
  - Service
  - Characteristic
- CC2650
  - Microcontroller
  - RF radio
  - Sensor interface
- CC2650 – MSP432 BLE Server
  - SNP – SAP

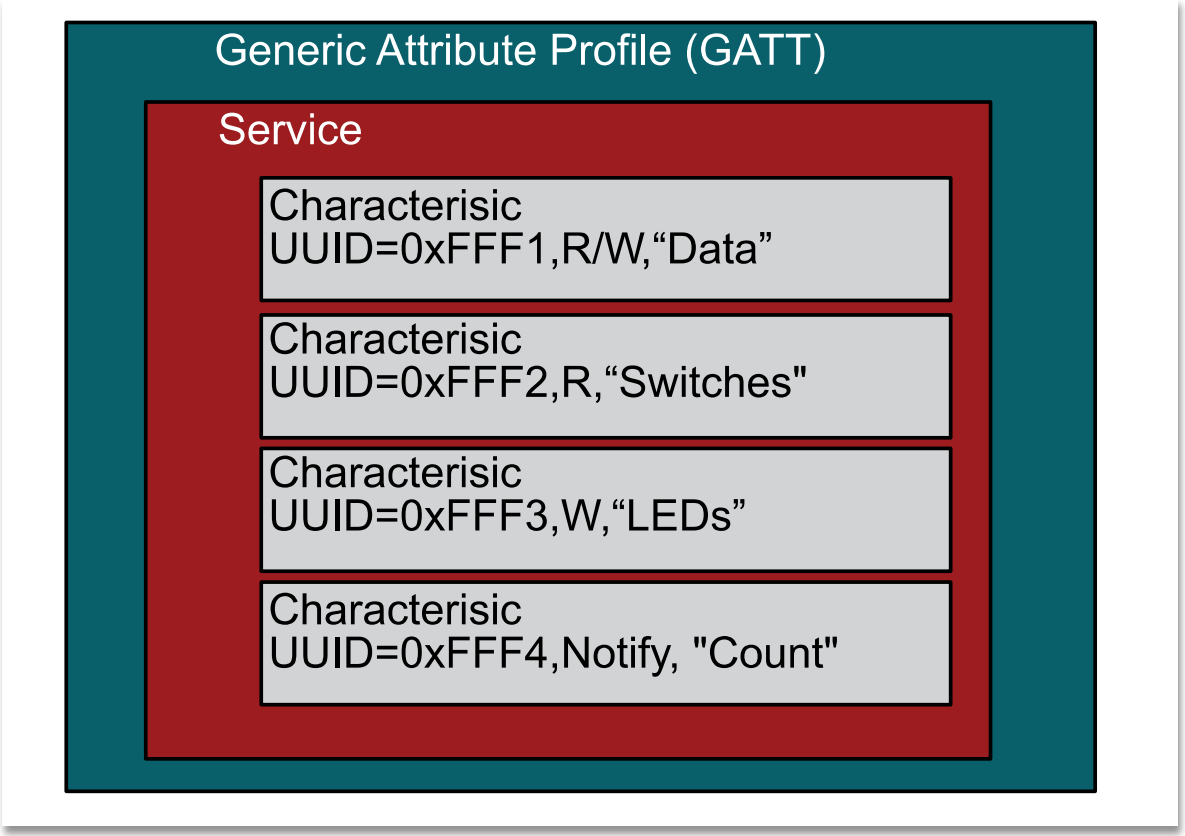
BLE Advertising



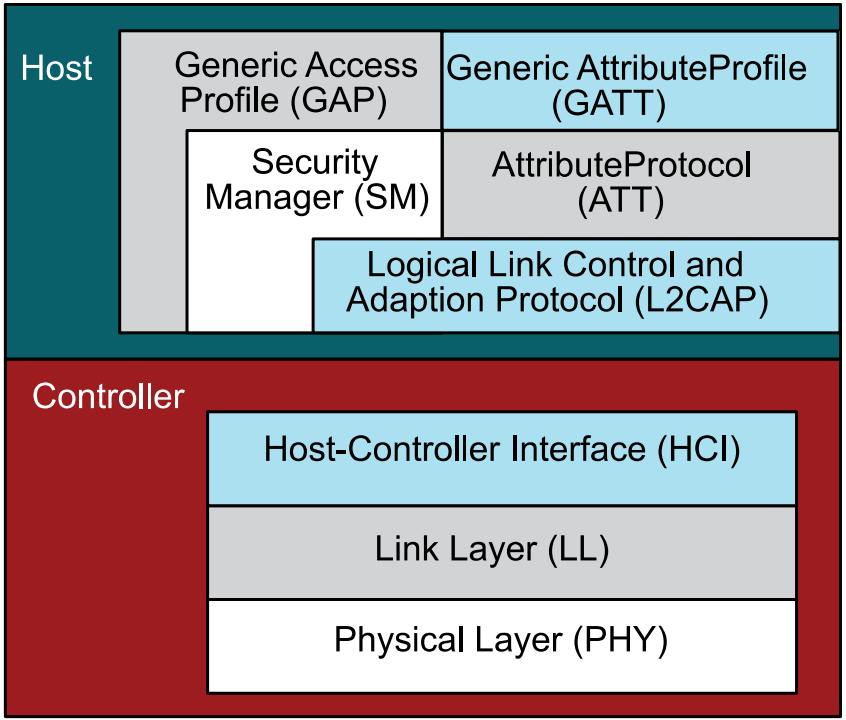
Client-server

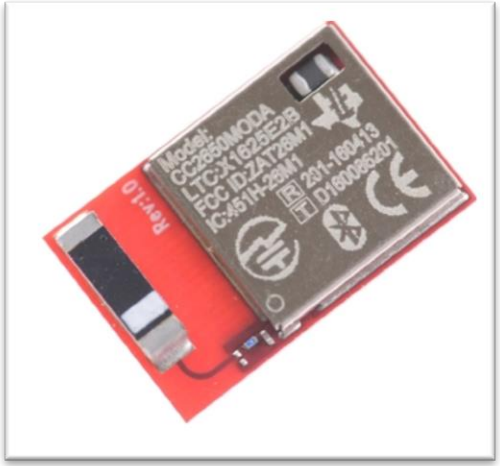


Profile


Generic Attribute Profile (GATT)
Service
Characterisic
UUID=0xFFF1,R/W,“Data”
Characterisic
UUID=0xFFF2,R,“Switches"
Characterisic
UUID=0xFFF3,W,“LEDs”
Characterisic
UUID=0xFFF4,Notify, "Count"

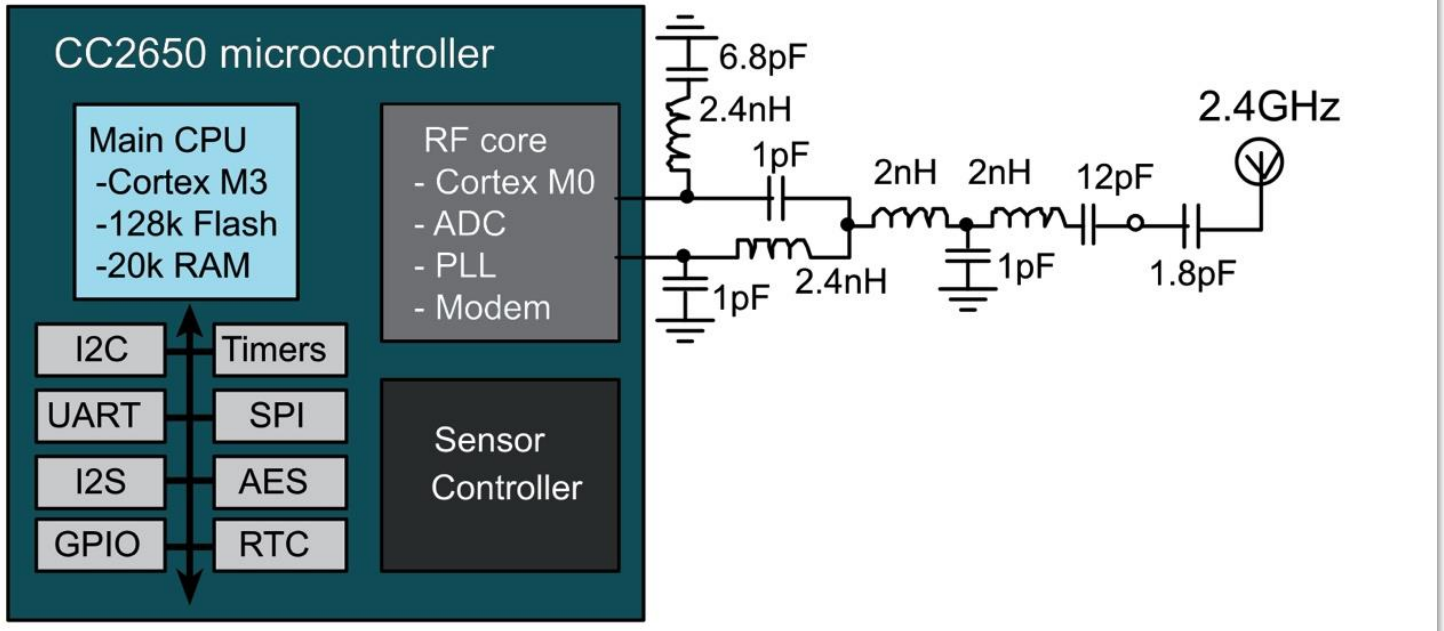
BLE layers



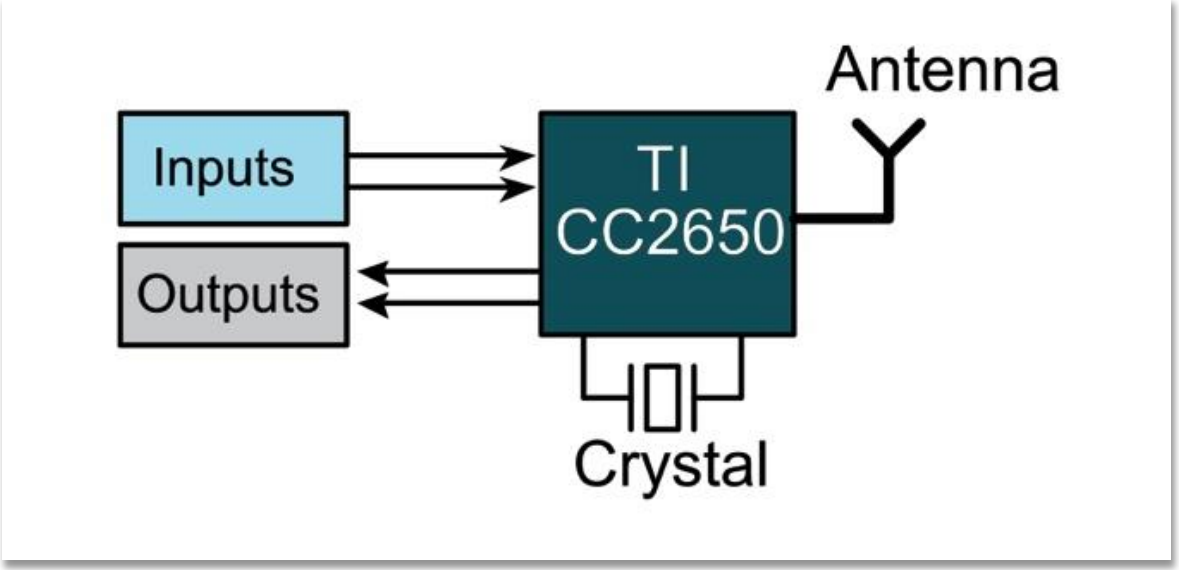


TI SimpleLink™ Bluetooth log energy
CC2650 Module BoosterPack™

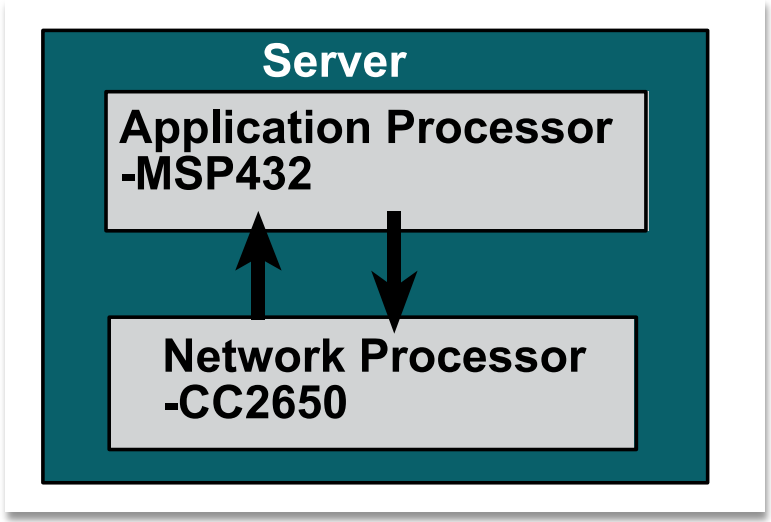
CC2650

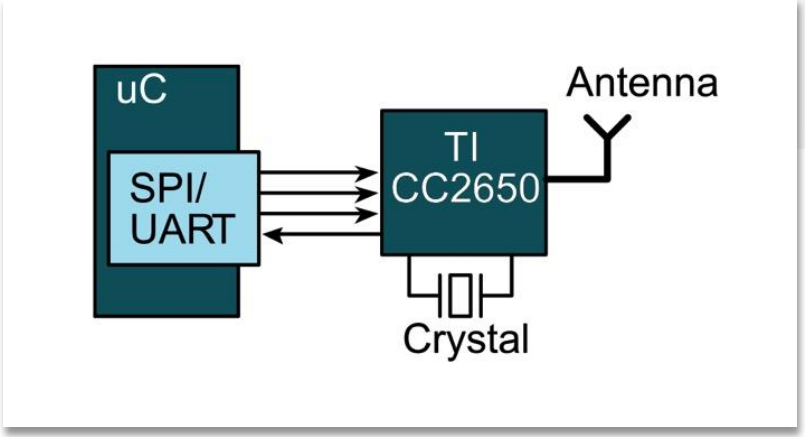

CC2650 microcontroller
Main CPU
-Cortex M3
-128k Flash
-20k RAM
RF core
- Cortex M0
- ADC
- PLL
- Modem
I2C
Timers
UART
SPI
I2S
AES
GPIO
RTC
Sensor
Controller
6.8pF
2.4nH
1pF
1pF
2.4nH
2nH
2nH
12pF
1pF
1.8pF
2.4GHz

CC2650 Single-chip solution

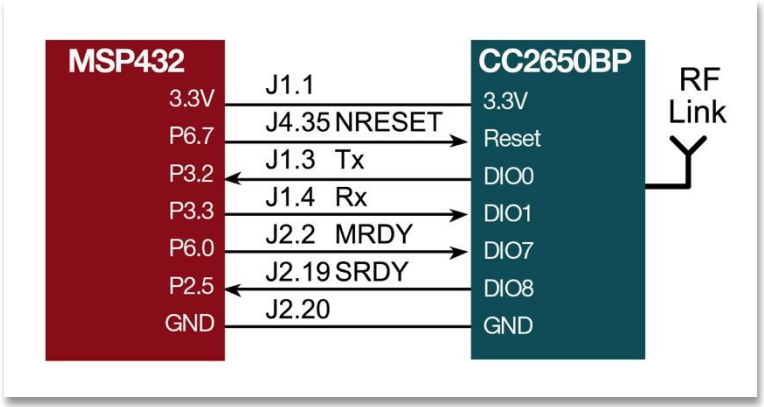


CC2650 – MSP432 BLE Server





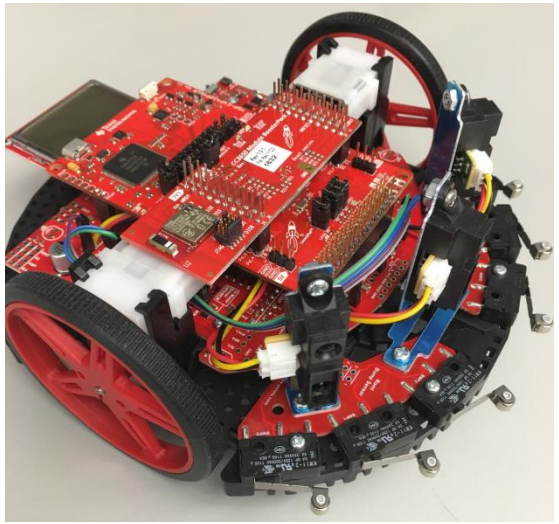
CC2650 – MSP432 BLE Server



Summary

Bluetooth Low Energy

- Client – server
- Profile, service, characteristic
- Advertising
- CC2650
- CC2650-MSP432 system



Module 19

Lecture: Bluetooth low energy - Simple Network Processor

Bluetooth low energy

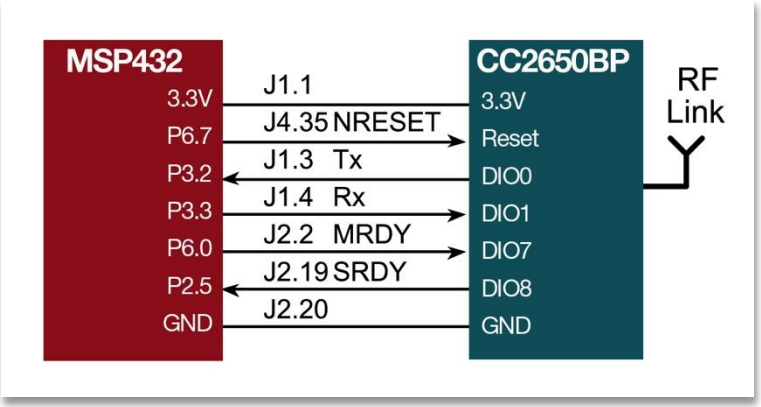
You will learn in this module

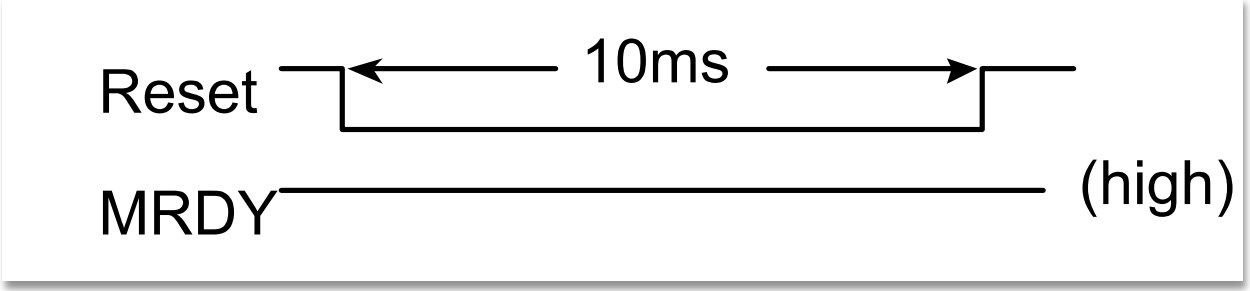
- BLE server
  - CC2650-MSP432 Interface
  - Serial, interrupt driven

- Simple Network Processor
  - Handshake
  - Message protocol

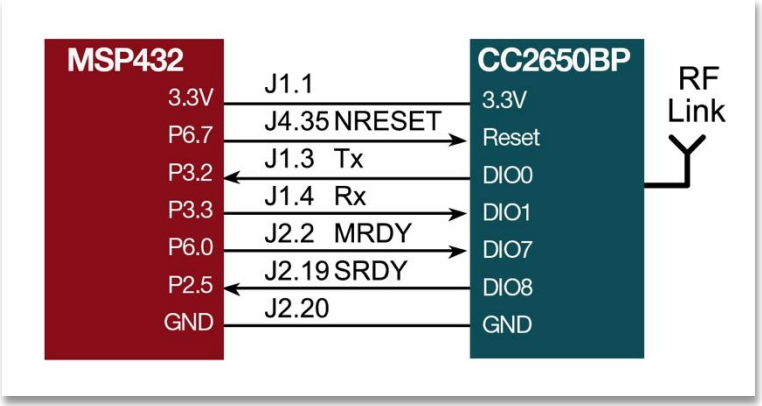
Reset

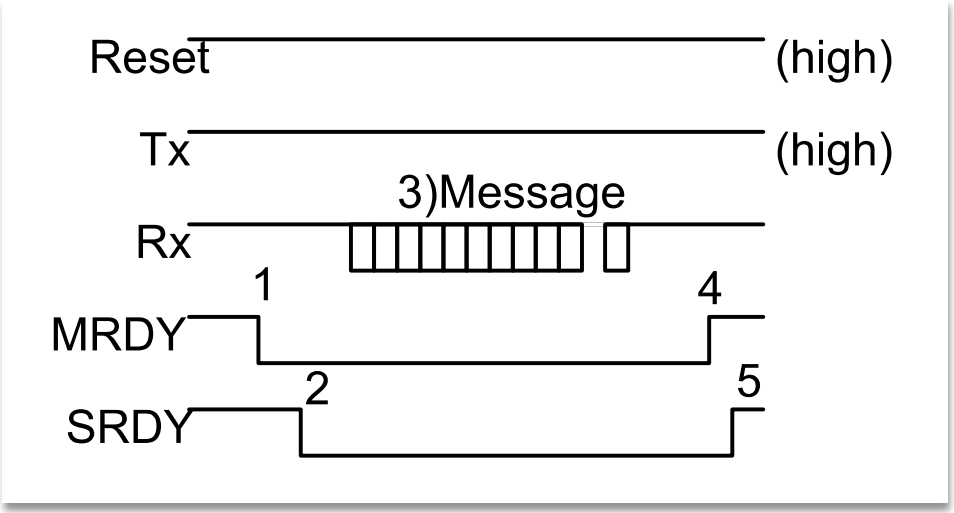
- MSP432 is master
  - MSP432 can reset CC2650
- CC2650 is slave
- Command/response protocol



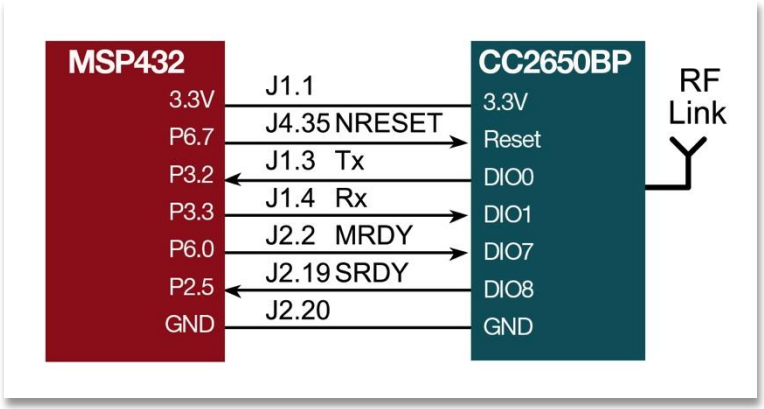


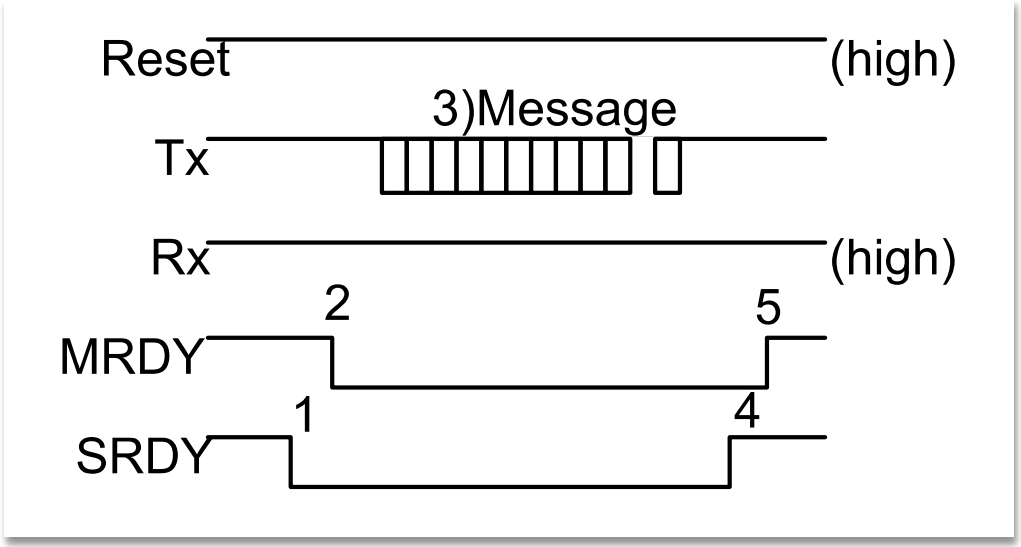
MSP432 to CC2650 message



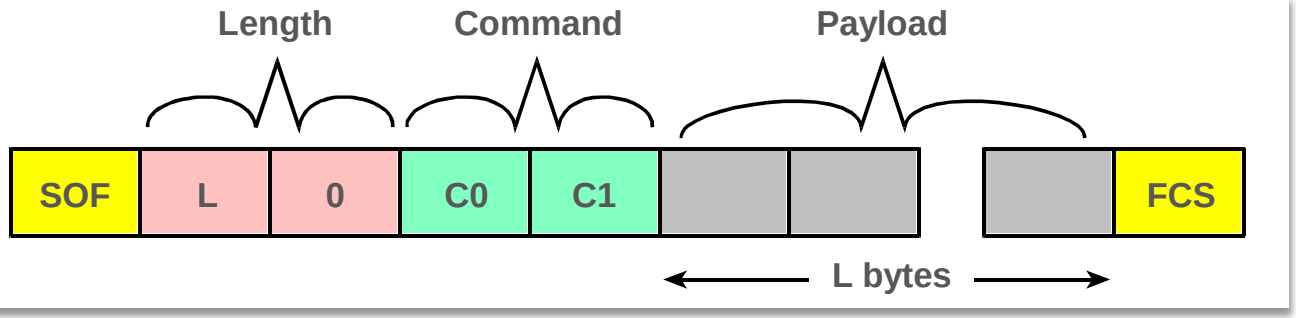


CC2650 to MSP432 message



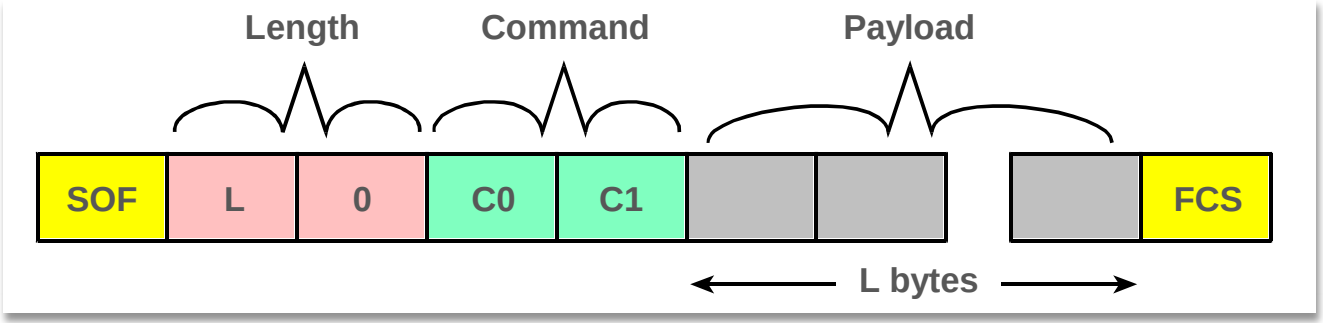


Advertising



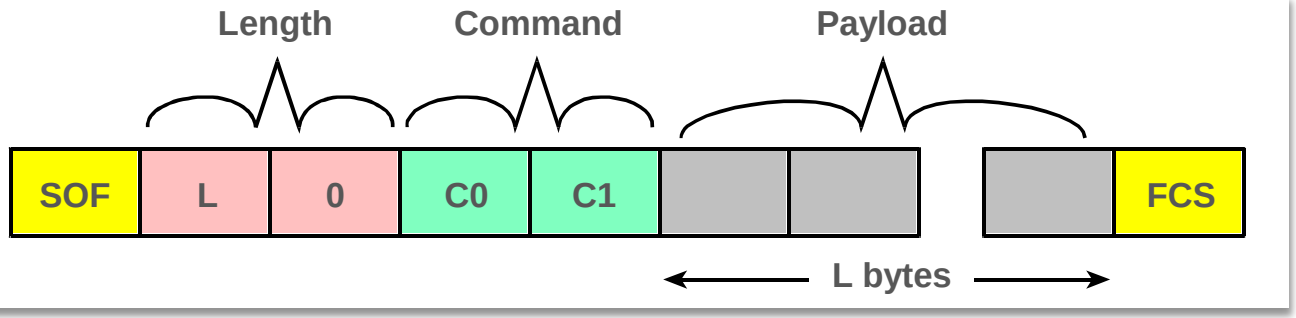

```
const uint8_t NPI_GATTSetDeviceNameMsg[] = {
  SOF,18,0x00,     // length = 18
  0x35,0x8C,       // Set GATT Parameter
  0x01,            // Generic Access Service
  0x00,0x00,       // Device Name
  'S','h','a','p','e',' ','t','h','e',
  ' ','W','o','r','l','d',
  0x77};           // FCS
```

Advertising



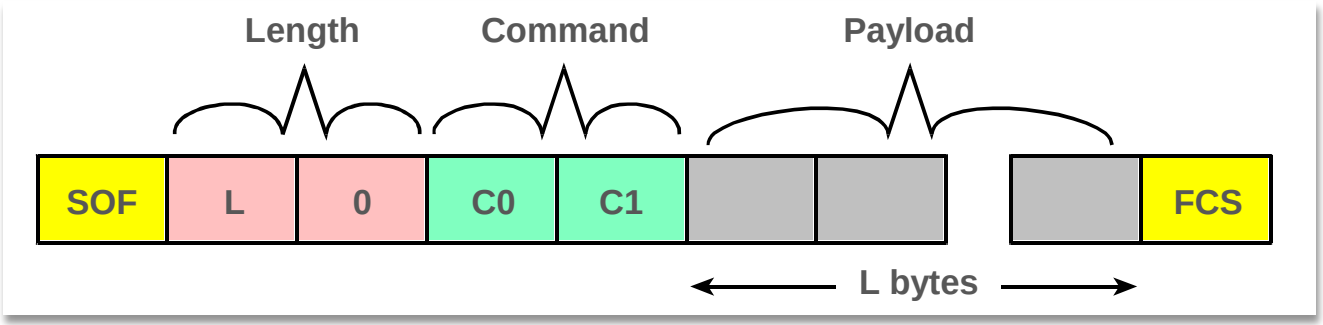

```
GATT Set DeviceName
   LP->SNP FE,12,00,35,8C,01,00,00,53,68,61,70,65,20,74,68,65,20,57,6F,72,6C,64,DE
   SNP->LP FE,01,00,75,8C,00,F8
SetAdvertisement1
   LP->SNP FE,0B,00,55,43,01,02,01,06,06,FF,0D,00,03,00,00,EE
   SNP->LP FE,01,00,55,43,00,17
SetAdvertisement2
   LP->SNP FE,1B,00,55,43,00,10,09,53,68,61,70,65,20,74,68,65,20,57,6F,...,00,0C
   SNP->LP FE,01,00,55,43,00,17
StartAdvertisement
   LP->SNP FE,0E,00,55,42,00,00,00,64,00,00,00,00,01,00,00,00,C5,02,BB
   SNP->LP FE,03,00,55,05,08,00,00,5B
```

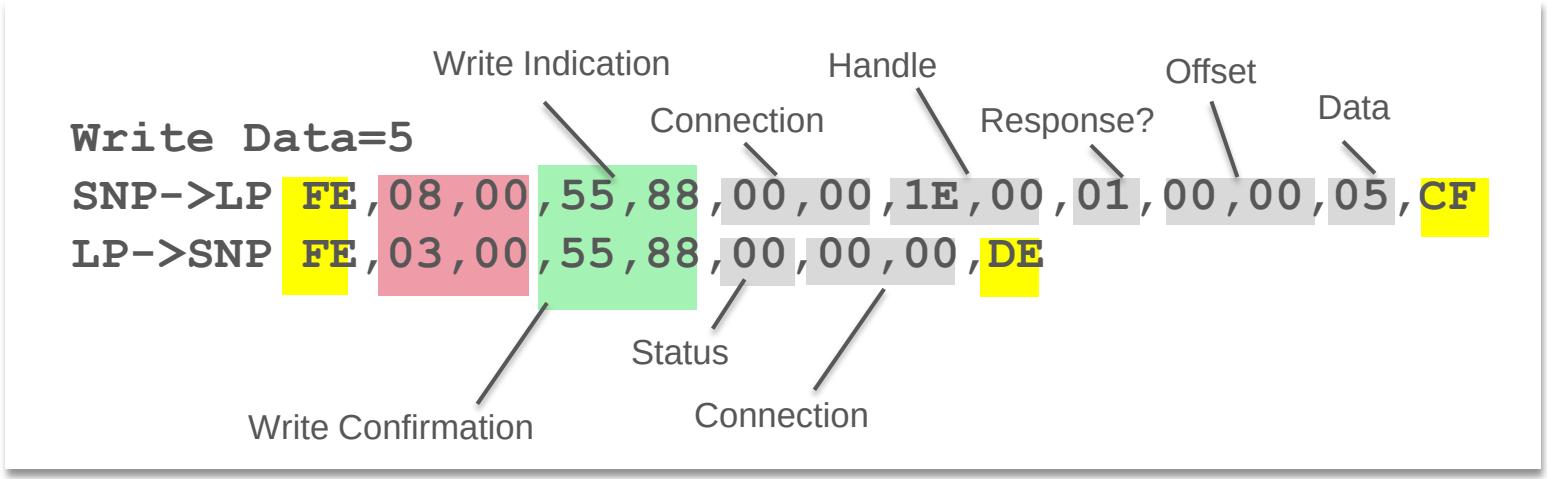
Add service



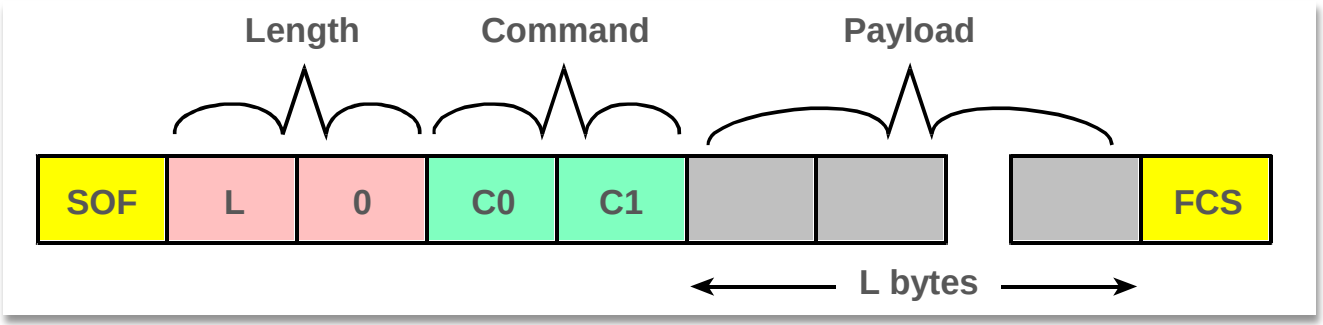

```
Add service
  LP->SNP FE,03,00,35,81,01,F0,FF,B9
  SNP->LP FE,01,00,75,81,00,F5
Add CharValue1
  LP->SNP FE,08,00,35,82,03,0A,00,00,00,02,F1,FF,BA
  SNP->LP FE,03,00,75,82,00,1E,00,EA
Add CharDescriptor1
  LP->SNP FE,0B,00,35,83,80,01,05,00,05,00,44,61,74,61,00,0C
  SNP->LP FE,04,00,75,83,00,80,1F,00,6D
Register service
  LP->SNP FE,00,00,35,84,B1
  SNP->LP FE,05,00,75,84,00,1C,00,29,00,C1
```

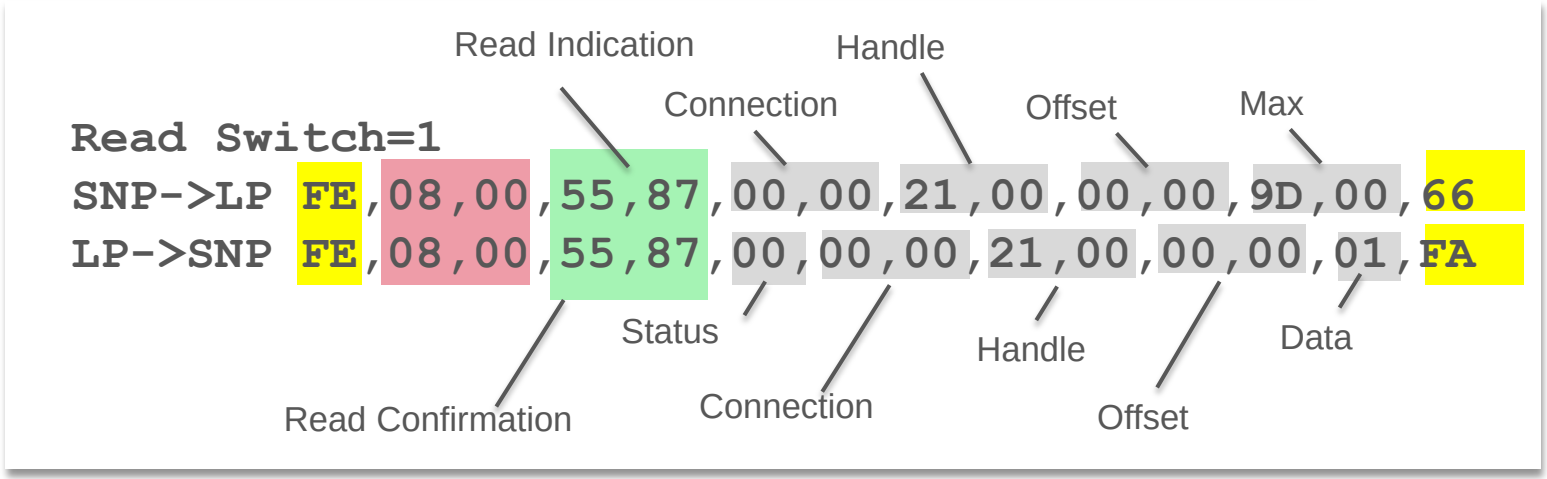
Write indication





Read indication

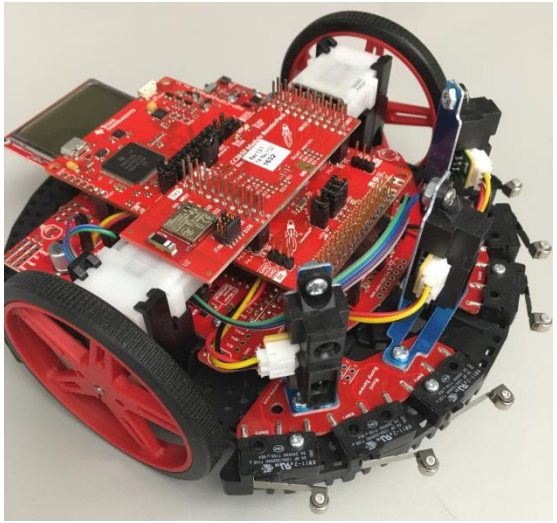




Summary

Bluetooth Low Energy

- Network Processor
- Application Processor



ti.com/rslk

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265