ESCUELA DE
CIENCIAS MATEMÁTICAS Y
TECNOLOGÍA INFORMÁTICA

Wireless Network

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LAB 7: Use Bluetooth module with Arduino

Objective

1. Describe the basic principles of radio communications.
2. Understand the usage of Bluetooth serial communication module and AT command to set the control parameters.
3. Learn how use the Bluetooth module for controlling Arduino via Bluetooth communication.

Discussion of fundamentals

Wireless communication systems and their interconnections by networks have become increasingly popular in recent years, particularly with the surge of interest in the Internet of Things (IoT). The most common wireless communication systems use Radio Frequency (RF) waves, which can penetrate objects and operate without direct line of sight between devices. Bluetooth is a short-range wireless data transfer that operates in the 2.4GHz frequency range with multiple data transfer rates possible with real-time two-way rates up to 24Mb/s. Nowadays, Bluetooth devices are seamlessly integrated into our daily lives, in the form of headsets, smart phones, mice, keyboards and portable speakers, and are widely used all over the world. Furthermore, hands-free voice communication devices are becoming increasingly more popular in cars for safety reasons or homes for convenience.

Despite the Bluetooth Special Interest Group releasing newer versions of Bluetooth such as version 5.0 (currently compatible with newer technologies such as Apple AirPods), there is still a huge number of devices in use that use older versions of Bluetooth, such as Bluetooth Smart / Bluetooth Low Energy in version 4.0 and 4.1. In fact, it is estimated that there are over 4 billion Bluetooth Low Energy (BLE) enabled devices in 2018 (using version 4.0 or 4.1).

Piconets and Scatternets

The basic unit of Bluetooth networking is a piconet. The terms piconet and scatternet are typically applied to Bluetooth wireless technology. A brief description of each of the two terminologies is given below:

- Piconet - It is a Bluetooth network that can have up to eight stations, one of which is called as master and the rest are called as slaves as shown in Figure 1.

- Scatternet - It is computer network comprising of two or more piconets. A scatternet has the advantage of supporting communication between more than eight devices.

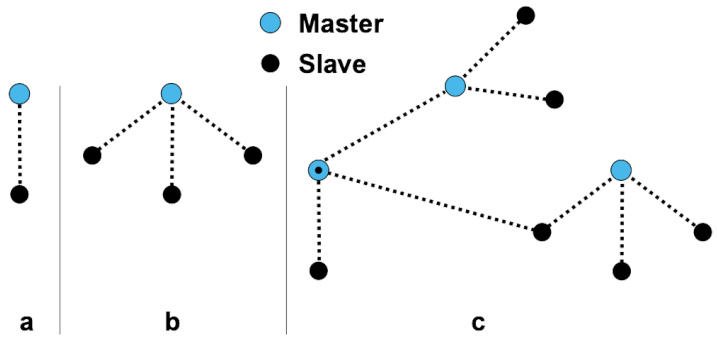

Figure 1: Piconets with a single slave operation (a), a multi-slave operation (b) and a scatternet operation (c).

HC-05 Bluetooth Module

HC-05 Bluetooth Module is a Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Its communication is via serial communication which makes an easy way to interface with controller or PC. HC-05 Bluetooth module provides switching mode between master and slave mode which means it able to use neither receiving nor transmitting data. The bluetooth module has six pins Vcc, GND, RX, TX, Key and State.

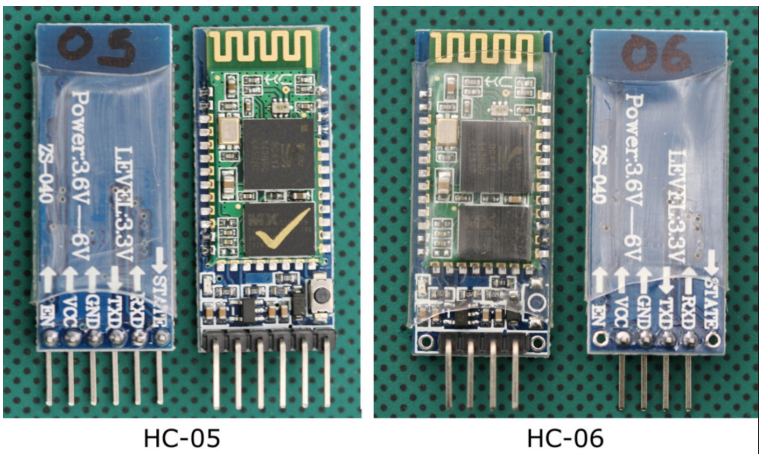

Figure 2: Bluetooth Module

To use the Bluetooth module, simply connect the VCC to the 5V output on the Arduino, GND to Ground, RX to TX pin of the Arduino, and TX to RX pin of the Arduino. If the module is being used for the first time, you will want to change the name, passcode etc. To do this the module should be set to command mode. To program the module, a set of commands known as AT commands are used. Here are some of them:

AT commands	Description
AT	Check connection status.
AT+NAME =ModuleName	Set a name for the device
AT+ADDR	Check MAC Address
AT+UART	Check Baudrate
AT+UART=9600	Sets Baudrate to 9600
AT+PSWD	Check Default Passcode
AT+PSWD=1234	Sets Passcode to 1234

Table 1: AT commands

Exercise 1. AT Command Mode of HC-05 or HC-06 Bluetooth Module

Sometimes it may require to change the default settings like password, name, baud rate, or master/slave role of the module. This exercise shows how to enter AT command mode of HC05/HC-06 bluetooth .

Building Circuit

Before making the connection make sure to unplug the power source from Arduino UNO. Make following circuit.

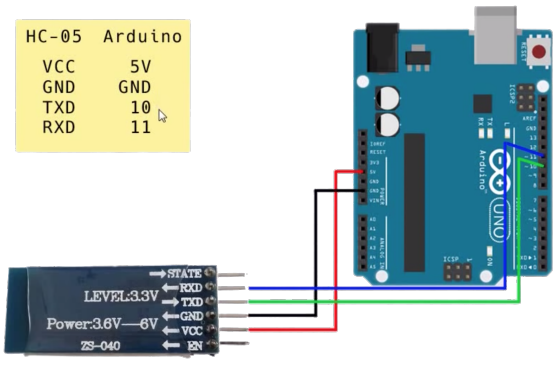

Figure 3: AT commands in Arduino

Configure with AT Mode

After the connection, If you Plug the power source, you will see the HC-05 power on with short rapid blink, which is standard pairing mode of module.

For At Mode, you need to plug the power source while holding down the reset button on the module. The long slow blinks shows that we are in AT Command mode.

Programming

After configured this in AT Mode, open up the Arduino IDE and write the following code into a new sketch:

Code

```
#include <SoftwareSerial.h> // 'set digital pins for  serial  communication'

SoftwareSerial wirelessNetworkYT(10, 11); // 'pin 10 as RX, pin 11 as TX'

void setup(){
  Serial.begin(9600); // ' serial  monitor communication at 9600 bps'
  Serial.println("Done"); // 'write "Done" on the monitor'
  wirelessNetworkYT.begin(38400); // 'communication at 38400 bps'
}

void loop(){
  if (wirelessNetworkYT.available())       // 'information available  from module'
    Serial.write(wirelessNetworkYT.read());  // 'read Bluetooth and send it to Arduino serial
        monitor'

  if ( Serial.available ())        // 'information available from the serial  monitor'
    wirelessNetworkYT.write(Serial.read());   // 'read  serial  monitor and send to Bluetooth'
}
```

Changing Codes

Open the serial monitor. Be sure that the baud rate are set to 9600 and Both NL & CR are selected. If you send AT from serial monitor, OK will appear on the screen. Now you can change the name or password of the module, check address, version.

Attention! When uploading to the microcontroller, the Bluetooth module must be removed. Otherwise the error message appears that the code can not be uploaded. After uploading the module can be used again.

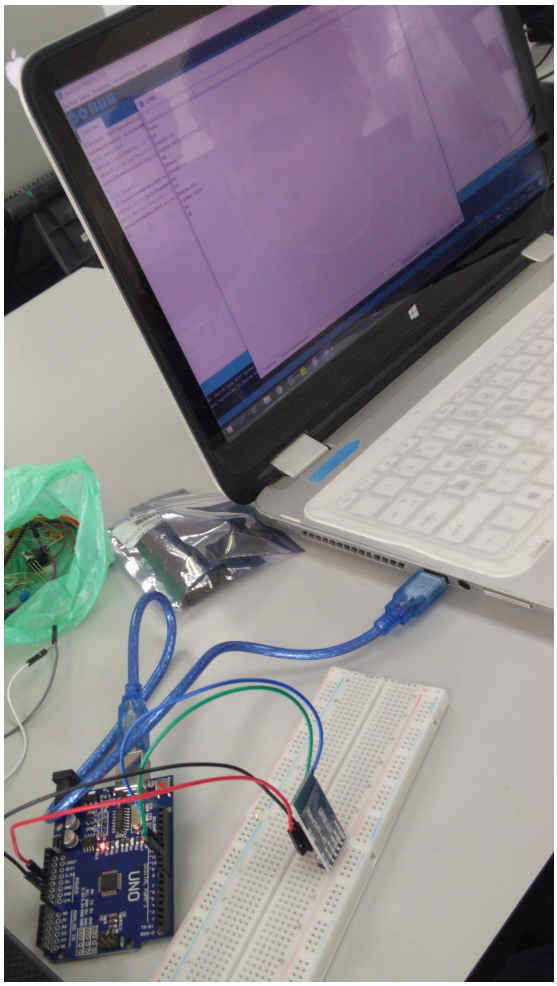

Figure 4: Configuration of the Bluetooth device.

Exercise 2. Control a LED via Bluetooth and Android

Write a program that allows you to turn on and off two LEDs through the Bluetooth module and an App on the mobile phone.

Building Circuit

Before making the connection make sure to unplug the power source from Arduino UNO. Make following circuit.

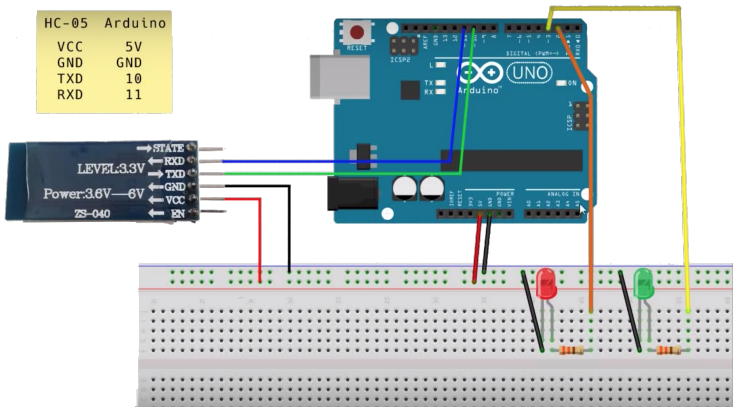

Figure 5: Control a LED via Bluetooth and Android

Programming

Open up the Arduino IDE and write the following code into a new sketch:

Code

```
#include <SoftwareSerial.h> // 'set digital pins for serial communication'

SoftwareSerial wirelessNetworkYT(10, 11); // 'pin 10 as RX, pin 11 as TX'

char DAT = 0; // 'variable to store received character'
int REDLED = 2; // 'Red LED to digital pin number 2'
int BLUELED = 3; // 'Green LED with digital pin number 3'

void setup(){
  wirelessNetworkYT.begin(38400); // 'Serial communication between Arduino and the module at
        38400 bps'
  pinMode(REDLED, OUTPUT); // 'pin 2 as output'
  pinMode(BLUELED, OUTPUT); // 'pin 3 as output'
}

void loop(){
  if (wirelessNetworkYT.available()){  // 'if there is information available from module'
    DAT = wirelessNetworkYT.read();  // 'stores in DATO the character received from module'
    if ( DAT == '1' ) // 'if the character received is number 1'
      digitalWrite (REDLED, HIGH); // turn on red LED
    if ( DAT == '2' ) // 'if the character received is number 2'
      digitalWrite (REDLED, LOW); // turn off red LED
    if ( DAT == '3' ) // 'if the character received is number 3'
      digitalWrite (BLUELED, HIGH); // turn on green LED
    if ( DAT == '4' ) // 'if the character received is number 4'
      digitalWrite (BLUELED, LOW); // turn off green LED
  }
}
```

Developing Front-end Using CircuitMagic

You can use the free Arduino Bluetooth app from CircuitMagic here in the Google Play Store to control our system. Pair the device with your mobile phone (when you are connecting your Bluetooth module for the first time with your smartphone it will ask for the passcode) and test the project.

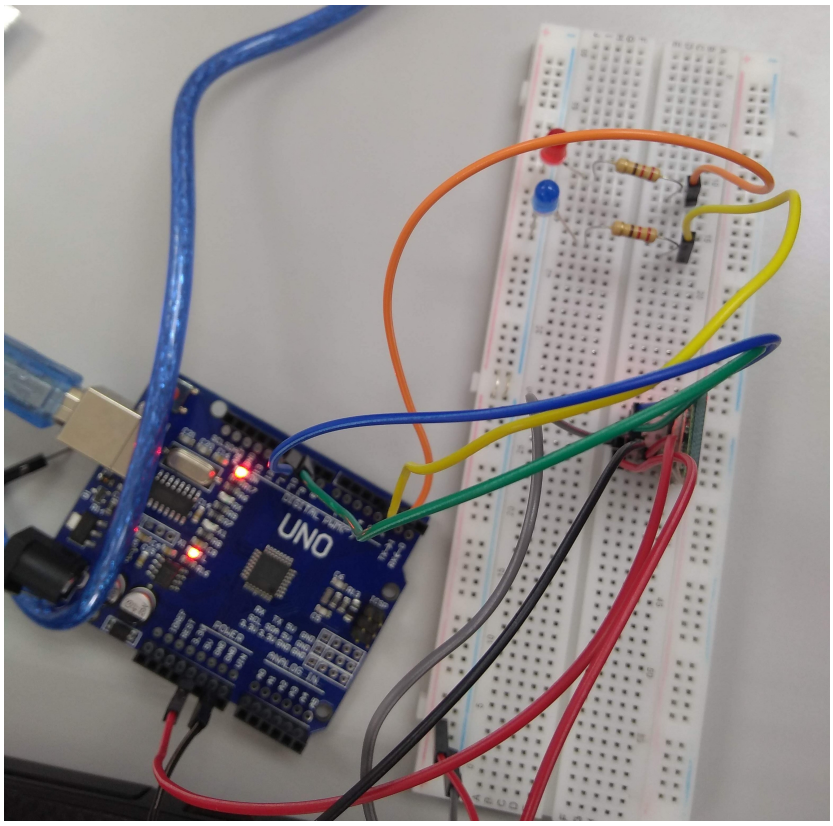

Figure 6: Implementation of control a LED via Bluetooth and Android

Exercise 3. Remote Controlled LED Using HC-05 Bluetooth, Arduino and Mobile Phone App

Write a program that allows to turn on and off two LEDs through the Bluetooth module and an App on the mobile phone. Upon receiving the number 1 it turns on or off the red LED, upon receiving the number 2 it turns on or off the green LED.

Code

```
#include <SoftwareSerial.h>

SoftwareSerial wirelessNetworkYT(10, 11);

char DAT = 0;
int REDLED = 2;
int BLUELED = 3;
int REDON=0;
int BLUEON=0;

void setup(){
  wirelessNetworkYT.begin(38400);
  pinMode(REDLED, OUTPUT);
  pinMode(BLUELED, OUTPUT);
}

void loop(){
  if (wirelessNetworkYT.available()){
    DAT = wirelessNetworkYT.read();
    if ( DAT == '1' && REDON==0 ){
      digitalWrite (REDLED, HIGH);
      REDON=1;
      delay(1000);
    } else {
      if ( DAT == '1' && REDON==1 ){
        digitalWrite (REDLED, LOW);
        REDON=0;
        delay(1000);
      }
    }
    if( DAT == '2' && BLUEON==0 ){
      digitalWrite (BLUELED, HIGH);
      BLUEON=1;
      delay(1000);
    } else {
      if ( DAT == '2' && BLUEON==1 ){
        digitalWrite (BLUELED, LOW);
        BLUEON=0;
        delay(1000);
      }
    }
  }
}
```

Exercise 4. Remote Controlled LED Brightness Using HC-05 Bluetooth, Arduino and Mobile Phone App

Write a program that allows to turn on and off two LEDs through the Bluetooth module and an App on the mobile phone. When receiving the number 1 it turns on or off the red LED, upon receiving the number 2 it increases the brightness of the green LED, upon receiving the number 3 it decreases the brightness of the green LED.

Code

```
#include <SoftwareSerial.h>

SoftwareSerial wirelessNetworkYT(10, 11);

char DAT = 0;
int REDLED = 2;
int BLUELED = 3;
int REDON=0;
int BLUEON=0;
int brightness=0;

void setup(){
  wirelessNetworkYT.begin(38400);
  pinMode(REDLED, OUTPUT);
  pinMode(BLUELED, OUTPUT);
}

void loop(){
  if (wirelessNetworkYT.available()){
    DAT = wirelessNetworkYT.read();
    if ( DAT == '1' && REDON==0 ){
      digitalWrite (REDLED, HIGH);
      REDON=1;delay(1000);
    } else {
      if ( DAT == '1' && REDON==1 ){
        digitalWrite (REDLED, LOW);
        REDON=0;delay(1000);
      }
    }
    if ( DAT == '2'&& brightness<255 ){
      brightness=brightness+10;
      analogWrite (BLUELED, brightness);
      delay(1000);
    } else {
      if ( DAT == '3'&& brightness>0 ){
        brightness=brightness-10;
        analogWrite (BLUELED, brightness);
        delay(1000);
      }
    }
  }
}
```

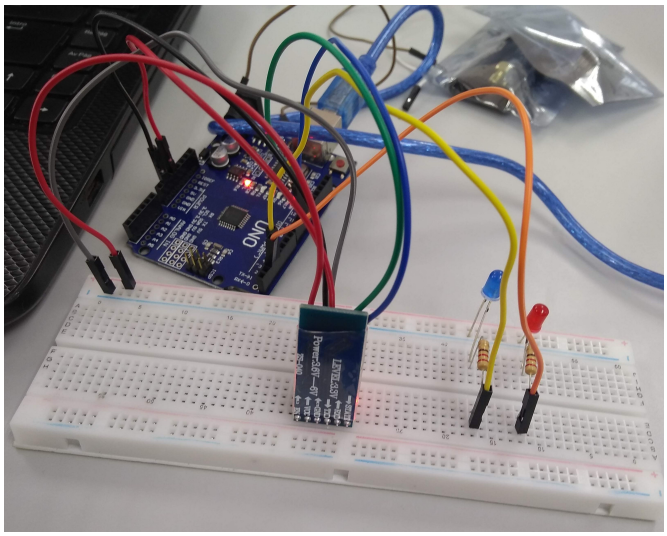

Figure 7: Implementation of controlling LEDs using Bluetooth, Arduino and Android

Exercise 5. Voice Controlled LEDs Using HC-05 Bluetooth, Arduino and Mobile Phone App

Write a program for controlling 5 LED (see Figure 5) using voice control. To accomplish this you may use the free Android app BT Voice Control for Arduino by SA Tech. LEDs will be On/Off on your voice command

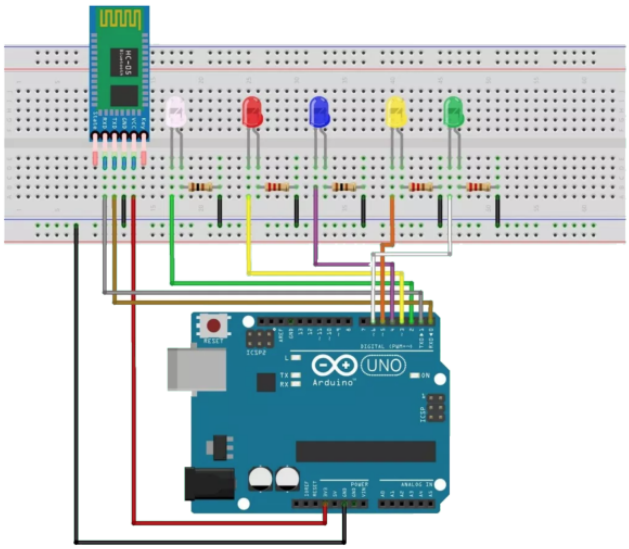

Figure 8: Voice Controlled LEDs

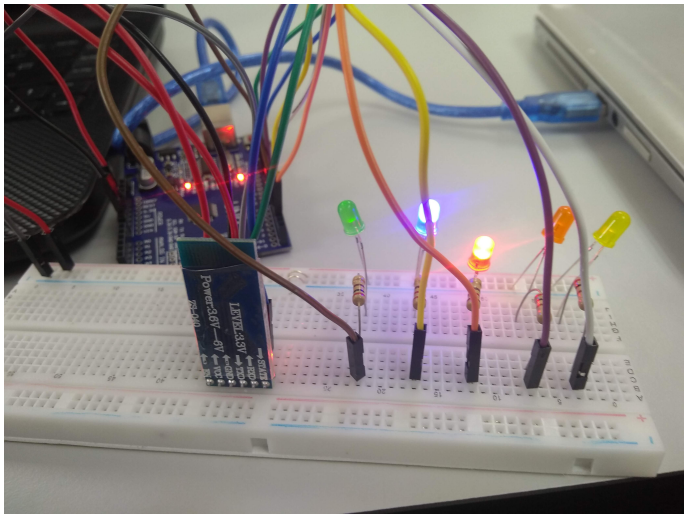

Figure 9: Implementation of Voice Controlled LEDs

Code

```
#include <SoftwareSerial.h>

SoftwareSerial wirelessNetworkYT(10, 11);

char DAT = 0;
int REDLED = 2;
int BLUELED = 3;
int REDON=0;
int BLUEON=0;
int brightness=0;
int YELLOWLED=6;
int ORANGELED=5;
int GREENLED=4;
int YELLOWON=0;
int ORANGEON=0;
int GREENON=0;

void setup(){
  wirelessNetworkYT.begin(38400);
  pinMode(REDLED, OUTPUT);
  pinMode(BLUELED, OUTPUT);
}

void loop(){
  if (wirelessNetworkYT.available()){
    DAT = wirelessNetworkYT.read();
    if ( DAT == '1' && REDON==0 ){
      digitalWrite (REDLED, HIGH);
      REDON=1;delay(1000);
    } else {
      if ( DAT == '1' && REDON==1 ){
        digitalWrite (REDLED, LOW);
        REDON=0;delay(1000);
      }
    } if ( DAT == '2' && BLUEON==0 ){
        digitalWrite (BLUELED, HIGH);
        BLUEON=1;delay(1000);
    } else {
      if ( DAT == '2' && BLUEON==1 ){
        digitalWrite (BLUELED, LOW);
        BLUEON=0;delay(1000);
      }
    }
    if ( DAT == '3' && ORANGEON==0 ){
      digitalWrite (ORANGELED, HIGH);
      ORANGEON=1;delay(1000);
    } else {
      if ( DAT == '3' && ORANGEON==1 ){
        digitalWrite (ORANGELED, LOW);
        ORANGEON=0;delay(1000);
      }
    }
    if ( DAT == '4' && YELLOWON==0 ){
      digitalWrite (YELLOWLED, HIGH);
      YELLOWON=1;delay(1000);
    } else {
      if ( DAT == '4' && YELLOWON==1 ){
        digitalWrite (YELLOWLED, LOW);
        YELLOWON=0;delay(1000);
      }
    }
    if ( DAT == '5' && GREENON==0 ){
      digitalWrite (GREENLED, HIGH);
      GREENON=1;delay(1000);
    } else {
      if ( DAT == '5' && GREENON==1 ){
        digitalWrite (GREENLED, LOW);
        GREENON=0;delay(1000);
      }
    }
    if ( DAT == '6' ){
      digitalWrite (GREENLED, HIGH);
      digitalWrite (YELLOWLED, HIGH);
      digitalWrite (REDLED, HIGH);
      digitalWrite (BLUELED, HIGH);
      digitalWrite (ORANGELED, HIGH);
      delay(1000);
    }
  }
}
```

Exercise 6. Frequently Asked Questions about Bluetooth Technology

1. What Is Bluetooth?.
   Bluetooth is a short-range wireless communication technology that allows devices such as mobile phones, computers, and peripherals to transmit data or voice wirelessly over a short distance

2. Why Is It Called Bluetooth?.
   The "Bluetooth" name is taken from a 10th-century Danish king named Harald Bluetooth, who was said to unite disparate, warring regional factions. Like its namesake, Bluetooth technology brings together a broad range of devices across many different industries through a unifying communication standard.

3. What Is the Difference Between Bluetooth and Wi-Fi?
   Bluetooth and Wi-Fi are both methods that provide wireless communication, but the difference between the two mainly stems from what they are designed to do and how they are used. The main difference is that Bluetooth is primarily used to connect devices without using cables, while Wi-Fi provides high-speed access to the internet.

4. What types of Bluetooth are there?
   There are many types of Bluetooth technologies out there, all of which help users stay connected without actually having to be connected. Types of Bluetooth devices include dongles, headsets, radios, and PC cards, among other products. Stereo headphones are becoming increasingly popular as a wireless Bluetooth option that can be used with iPods, music phones or other MP3 players. Also, laptop's and other small Internet-enabled devices are offering accessories that utilize Bluetooth technology for wireless functionality, such as in wireless keyboards and mice.

5. Is Bluetooth Safe?
   There is no proof that Bluetooth radiation can be dangerous to humans. Most Disease Control Centres mark Bluetooth as safe. The main reason is that though riding on high frequencies, the amplitude of Bluetooth waves dont have much strength to pass through objects, walls, and other similar obstacles. So one can generally say that using Bluetooth headphones or speakers is safe if used within limits. But long-term exposure could potentially cause health issues.

6. Name Few Applications Of Bluetooth?

   - **Cordless Desktop**: All (or most) of the peripheral devices (e.g., mouse, keyboard, printer, speakers, etc.) are connected to the PC cordlessly.
   - **Ultimate headset**: It can be used to allow one headset to be used with myriad devices, including telephones, portable computers, stereos, etc.

- **Automatic synchronization**: This usage model makes use of the hidden computing paradigm, which focuses on applications in which devices automatically carry out certain tasks on behalf of the user without user intervention or awareness.
- **Multimedia Transfer**:- Exchanging of multimedia data like songs, videos, pictures can be transferred among devices using Bluetooth.

7. How Many Devices Can Communicate Concurrently?
   Bluetooth devices automatically detect and connect to one another and up to eight of them can communicate at any one time. They don't interfere with one another because each pair of devices uses a different one of the 79 available channels. If two devices want to talk, they pick a channel randomly and, if that's already taken, randomly switch to one of the others (a technique known as spread-spectrum frequency hopping). To minimize the risks of interference from other electrical appliances (and also to improve security), pairs of devices constantly shift the frequency they're usingthousands of times a second.

8. What Is Pairing?
   Establishing a connection between two Bluetooth devices. For example, to pair a headset with a phone, the phone is configured to "Discoverable" mode and the headset is set up to pair by pressing one or more keys for some number of seconds. The headset finds the phone and establishes a connection using an assigned passkey, which is typically 0000

9. What is Piconet?
   When a group of two or more Bluetooth devices are sharing information together, they form a kind of ad-hoc, mini computer network called a piconet. Other devices can join or leave an existing piconet at any time. One device (known as the master) acts as the overall controller of the network, while the others (known as slaves) obey its instructions. Two or more separate piconets can also join up and share information forming what's called a scatternet.

10. What versions of Bluetooth standards are there?

    - **Bluetooth 1.x**: The basic Bluetooth rate with no additional/optional profiles or codecs. This version of Bluetooth is obsolete and was rarely implemented on mobile devices due to its limited speed of 1mbs and difficulty pairing.
    - **Bluetooth 2.x**: The most popular variant of Bluetooth, especially in the earlier days when phones were not as advanced. It supports enhanced data rates (EDR) up to 3 Mbps, and the V2.1 variant significantly simplified the pairing procedure making it a more practical for commercial use.
    - **Bluetooth 3.x**: Bluetooth 3.0 improves on the speed limitations of Bluetooth 2.1, with the optional High-Speed feature (HS), which

allows the Bluetooth module to transmit over an adjacent radio (802.11). However, Bluetooth 3.0 consumes a lot more power than Bluetooth 2.x.

- **Bluetooth 4.x**: Bluetooth 4.0 has the high-speed capability of Bluetooth 3.0 but also comes with a Low Energy feature to collect data from the sensors of low rate devices. This feature allows the Bluetooth module to reduce power consumption with connected devices like wearable smartwatches, heart monitors, mobile phones and smart headphones.
- **Bluetooth 5.x**: The most recent iteration of Bluetooth, better suited for the Internet of Things (IoT). It's speculated to have twice the bandwidth of Bluetooth 4.2 LE and 4x the range. It also has a new feature called Slot Availability Masking (SAM) which can detect and prevent interference on neighboring bands for a more efficient use of broadcasting channels. However, we have yet to test the Bluetooth 5.0's capabilities for ourselves.

11. Technology is used to avoid interference in Bluetooth
    Interference is being avoided by utilizing the frequency-hop(FH) spread spectrum technology. It is adaptable for low-power, low-cost radio implementations and also used in certain wireless LAN products.

12. Will other RF (Radio Frequency) devices interfere with Bluetooth Devices?
    Bluetooth and Wi-Fi have shared the same 2.4GHz frequency spectrum for a long time, which can cause the radio signals to interfere with each other. An often overlooked source of interference is the common microwave oven. Microwave ovens also use the same 2.4GHz spectrum as Bluetooth, but use a very high power signal that heats food. This high power signal can make it difficult for the Bluetooth signals to be received correctly and will result in audio static or slower Bluetooth data connections. A little known fact about Bluetooth is that the radio signals do not go through your body very well. This is because Bluetooth's radio frequency is blocked by water, and the human body is made up of mostly water.