CSE461
Introduction to Robotics
Communication in Robotics

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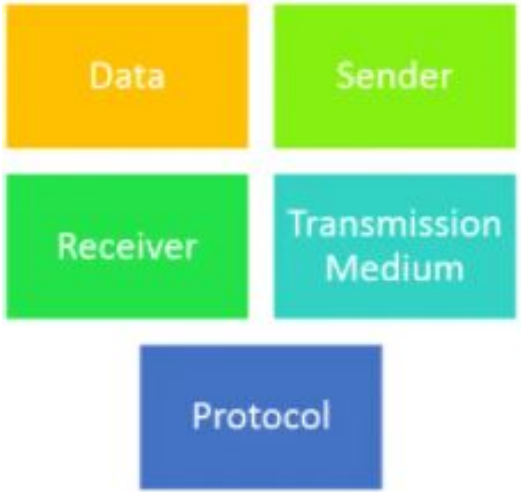

Communicating between electronic devices is like communicating between human!!!

Both side need to speak the same Language.

In electronics these languages are called protocols

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https://onlineclassnotes.com/what-are-five-components-of-data-communications-system/

Protocol: A protocol is a set of rules agreed by both sender and receiver on

- How the data are packed
- When the data begins and ends
- How many bits constitute a character

Baud Rate: represents the rate of data transfer. Amount of bits transmitted per seconds is called Baud Rate or bps

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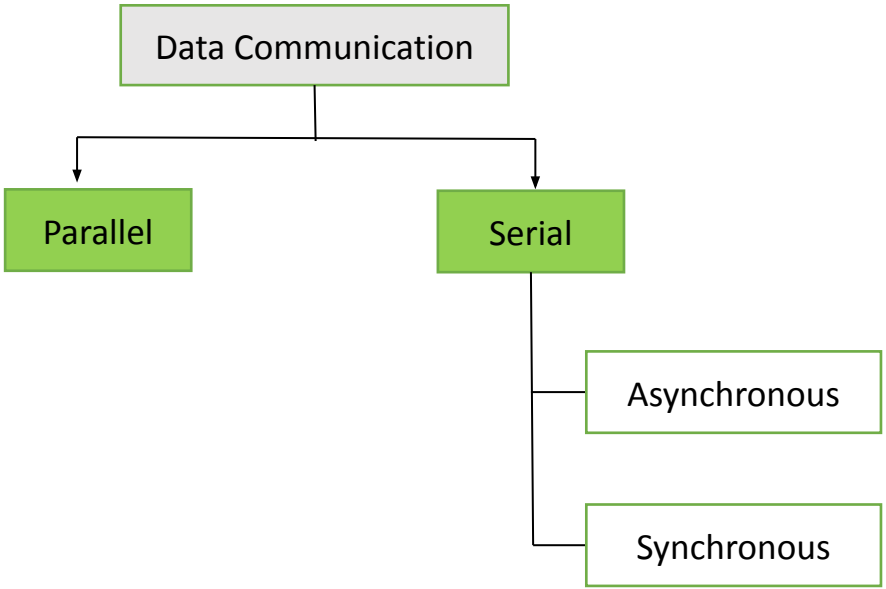
Data Communication Types



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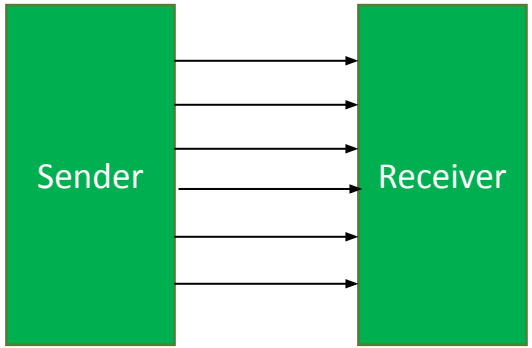
Parallel communication: All bit of data are transmitted simultaneously.

- To transmit ‘n’ bits, ‘n’ wires or lines are requires
- Used for shorter distance
- Costly but faster that serial communication.

Example: printer ,hard disk



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Serial Communication: data are transmitted serially
By using one communication wire.

- Only one line required
- Long distance data transfer
- Less costly

Example: Telephone

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Asynchronous: Transfer single byte in one time, no need clock signal

Example: UART

Synchronous: Transfer a block of data at a time, it requires clock signal

Example : SPI,I2C

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We will talk about SPI, I2C and UART Protocols. These protocols are suitable where large amount of high speed data transfer is not required.

For example:

- communication between microcontrollers
- communication between microcontrollers and sensors

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UART (Universal Asynchronous Receiver Transmitter)

UART: most commonly used serial communication. It is used in GPS receiver, Bluetooth modules, GSM and GPRS modems.

- Two UART device communicate directly via Tx and Rx pin using two wires.
- Transmitting UART converts parallel data from controlling devices (cpu) into serial data and then transmit that serial data to receiving UART.
- Receiving UART after receiving the serial data converts into parallel data and send to receiving devices.
- Transmits data asynchronously so no clock required.

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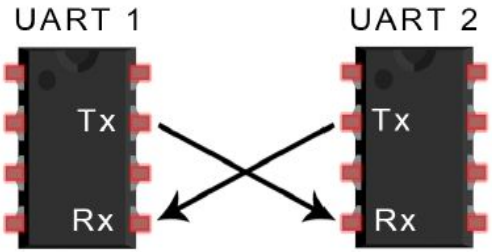

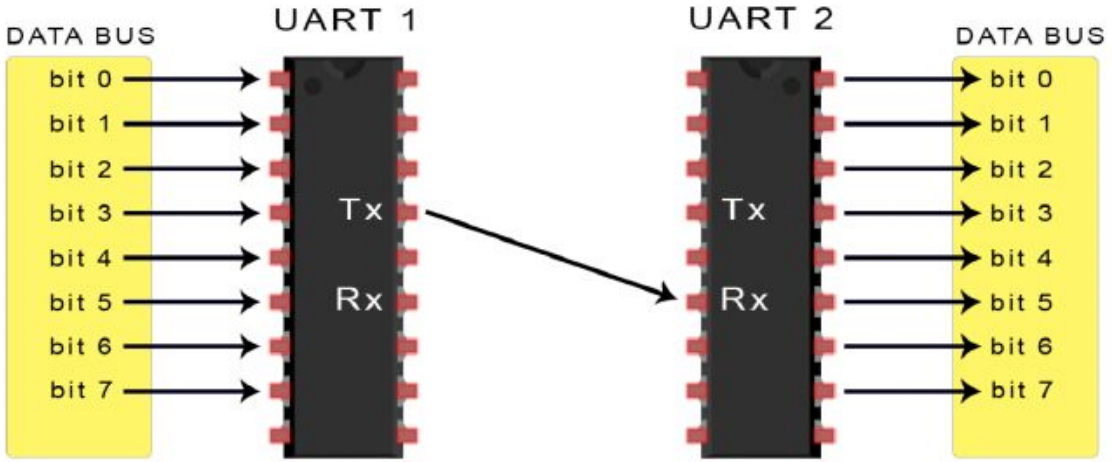

UART data transmission

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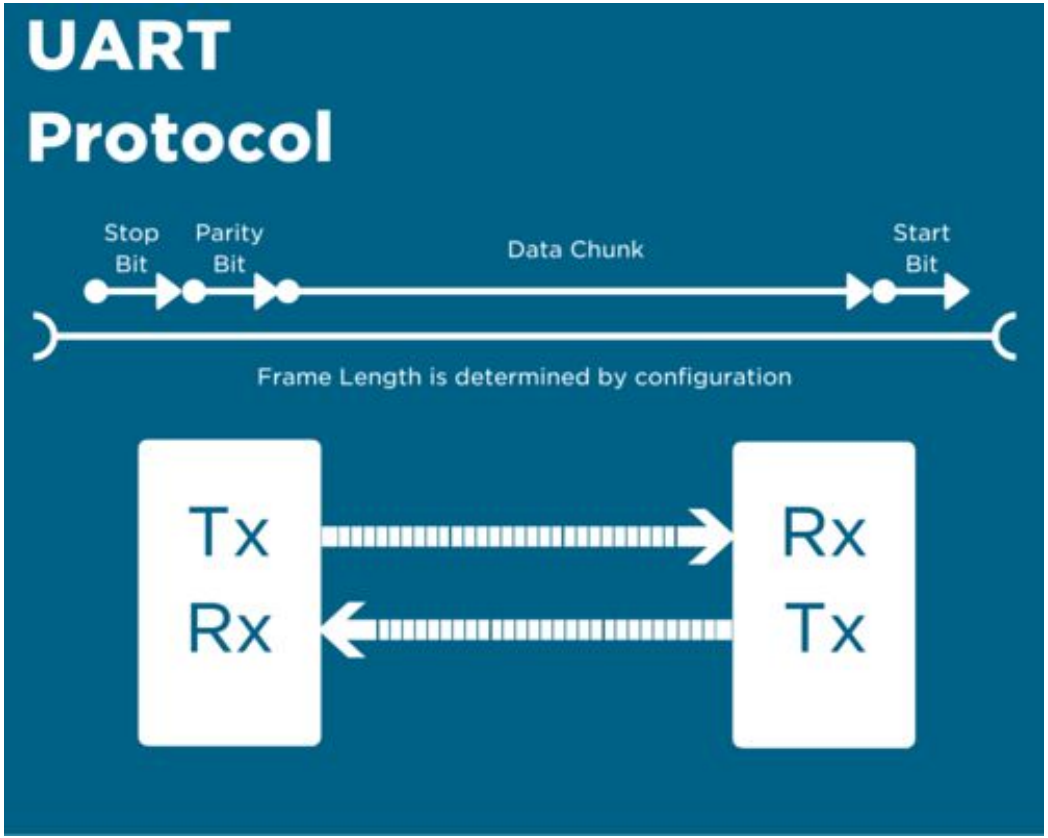
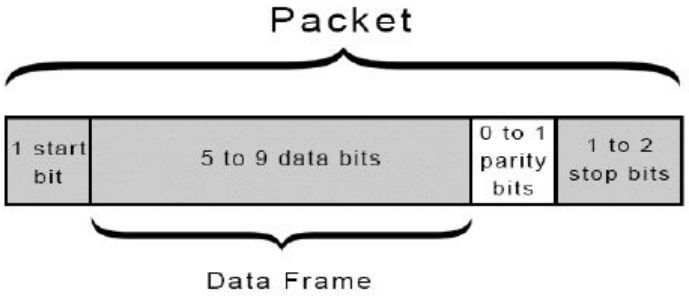


https://technobyte.org/arduino-communication-protocols-wired-wireless-for-iot/

Data are transmitted via **packet**. Each packet consists 1 start bit, 5-9 data bits, an optional parity bit and 1 or 2 stop bit.



pros

- Only two wires needed
- Parity bit for error checking
- No clock signal is required
- Well documented and widely used

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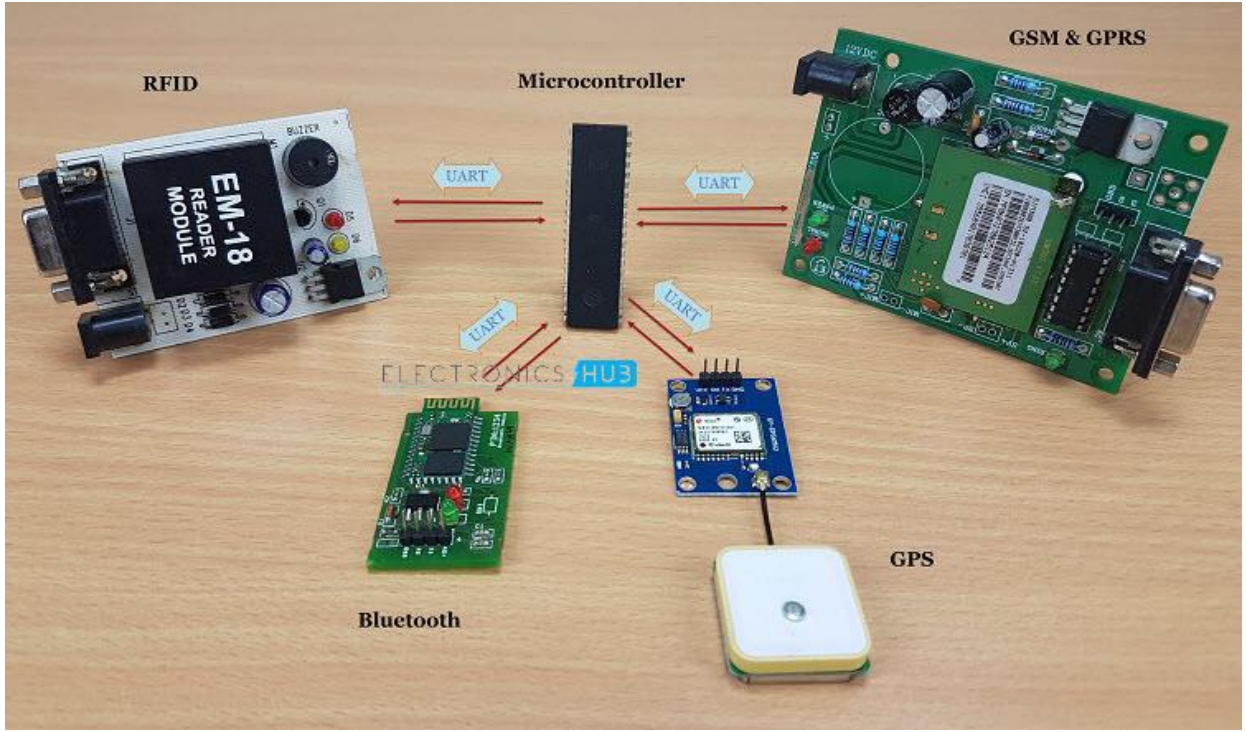
Cons

- Size of data frame is limited to maximum 9 bits
- Doesn’t support multiple slave or master system
- Baud rate of each UART must be with in 10% of each other



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SPI (Serial Peripheral Interface) Communication Protocol

Very commonly used protocol. SD card module, RFID card reader module and 2.4 wireless transmitter/receiver use SPI to communicate with microcontroller.

SPI devices work in master-slave manner. Controlling devices are master (microcontroller) that gives instruction to slave (sensor, display or Memory chip) devices

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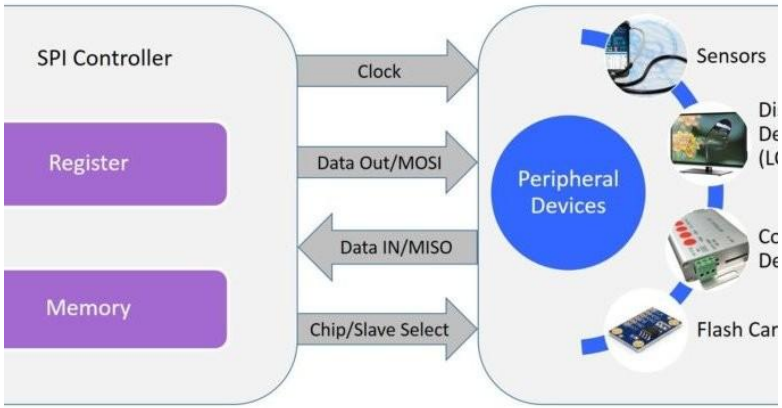

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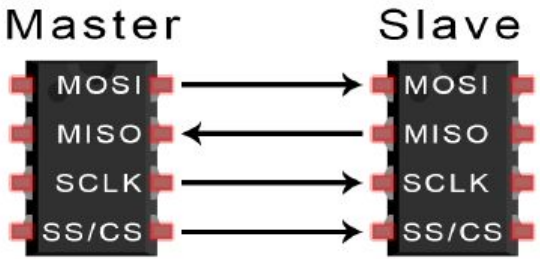
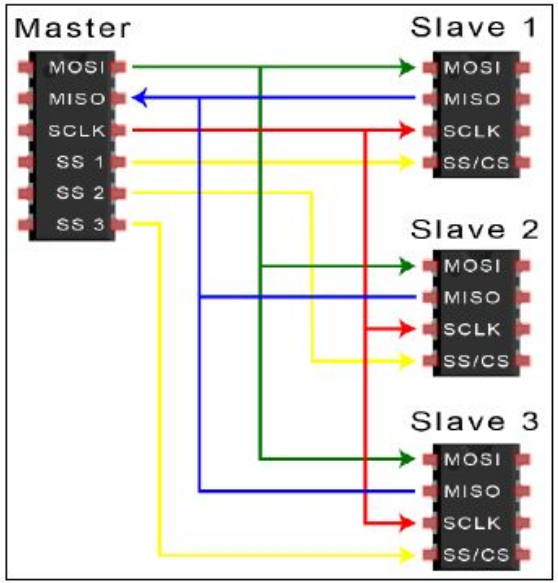
https://blogs.synopsys.com/vip-central/2017/08/16/flavors-of-spi-emerging-protocol-in-automotive/

A master can control one or many slaves based on configuration



SPI Master connected to single slave



SPI Master connected to multiple slaves

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MOSI (Master Output/Slave Input) – Line for the master to send data to the slave.

MISO (Master Input/Slave Output) – Line for the slave to send data to the master

SCLK (Clock) – Line for the clock signal.

SS/CS (Slave Select/Chip Select) – Line for the master to select which slave to send data to.

CLOCK:

- ✔ clock signal is used for synchronization. In each clock cycle one bit of data is transferred therefore data transmission speed depends on the frequency of the clock signal.
- ✔ SPI communication is always initiated by master as it configures and generates the clock signals

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Pros

- Higher data transmission that I2C
- No start and stop bits, so data can be transferred without interruption

cons

- Uses four wires
- No acknowledgement of data
- Only allow a single master

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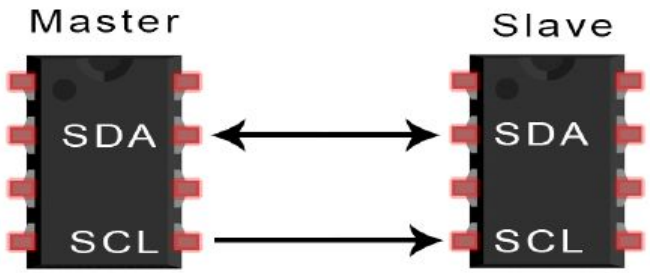
I2C or IIC protocol

Combination of SPI and UART. It is a serial bus interface. I2C stands for Inter-Integrated Circuit

It allows to connect multiple slaves to a single master or multiple masters to single slave.
It uses two wires for data transmission.

1. Serial data line (SDA): Line for sending and receiving data
2. Serial clock line (SCL): line for clock signal



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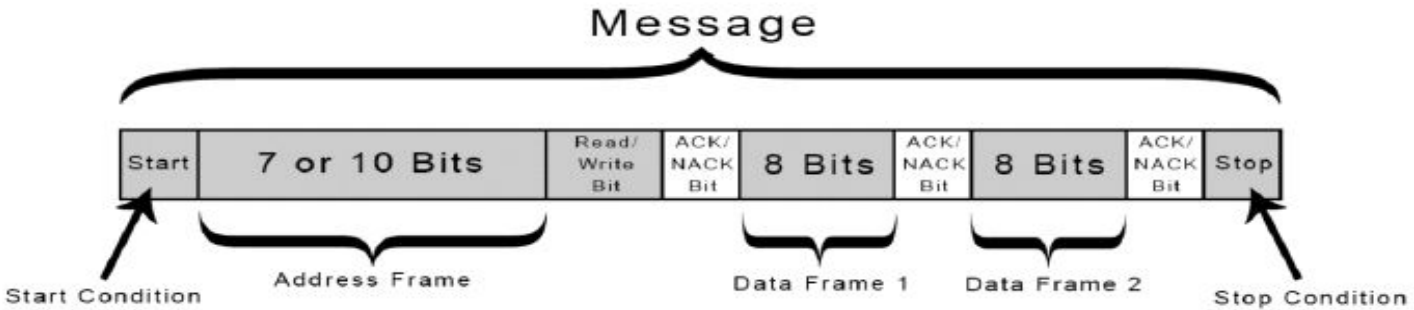
With I2C, data is transferred in *messages*. Messages are broken up into *frames* of data. Each message has an address frame that contains the binary address of the slave, and one or more data frames that contain the data being transmitted. The message also includes start and stop conditions, read/write bits, and ACK/NACK bits between each data frame:



Read/write: single bit specifies whether masters is sending (low voltage) or requesting data(high voltage)
ACK/NACK: specifies acknowledgement or non-acknowledgement of the receipt of data

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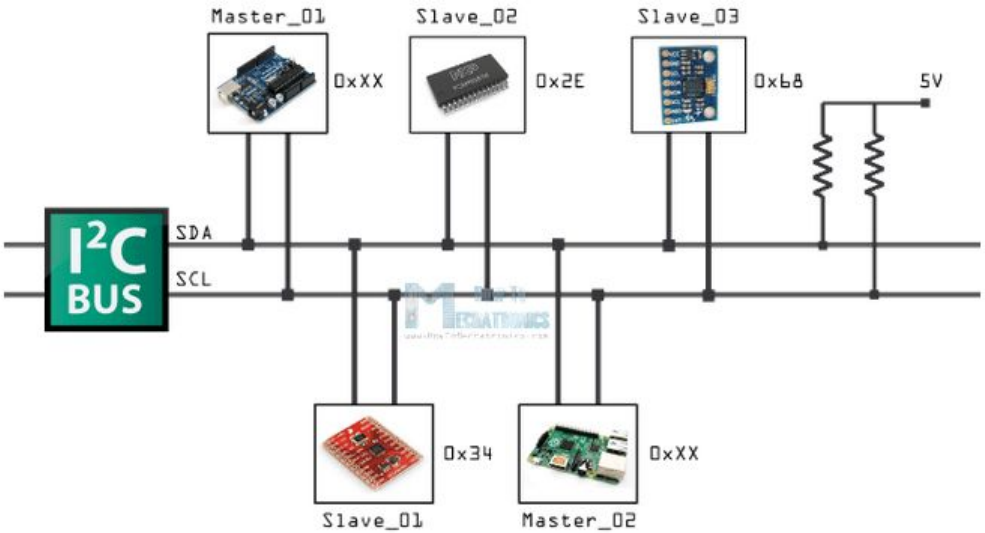

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https://howtomechatronics.com/tutorials/arduino/how-i2c-communication-works-and-how-to-use-it-with-arduino/

USB

- USB stands for **Universal Serial Bus**, a new standard for connecting external devices like mice, keyboards, scanners and printers.
- USB offers many benefits over traditional connection method, including thinner and cheaper cables, greater expandability (with the addition of a USB hub, a single USB controller can handle up to 125 devices) and greater speed.
- To use USB, your computer needs integrated USB ports or a USB expansion card and Windows 98; Mac users require a Mac with USB and MacOS 8.1 or greater.

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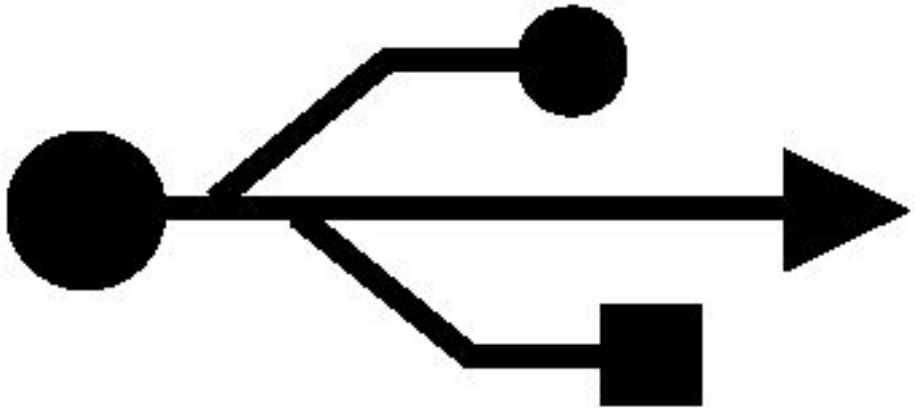

This icon is used to identify USB cables, connectors, hubs, and peripherals.

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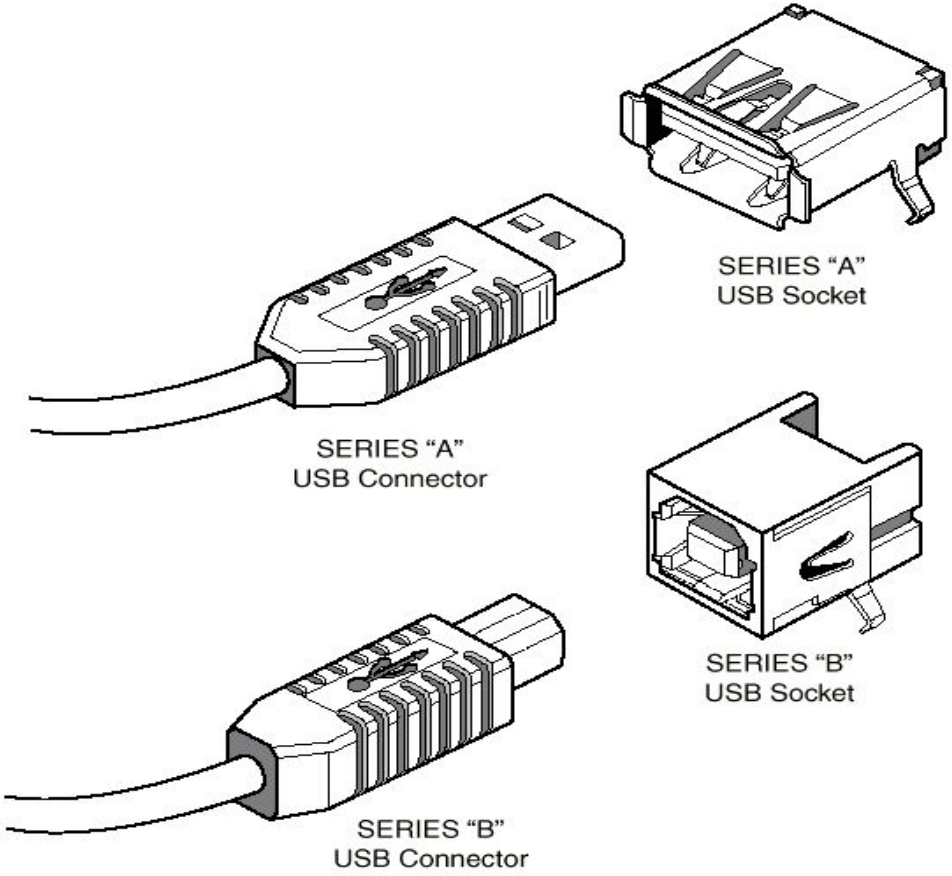
USB Series-A and Series-B Plugs and Receptacles



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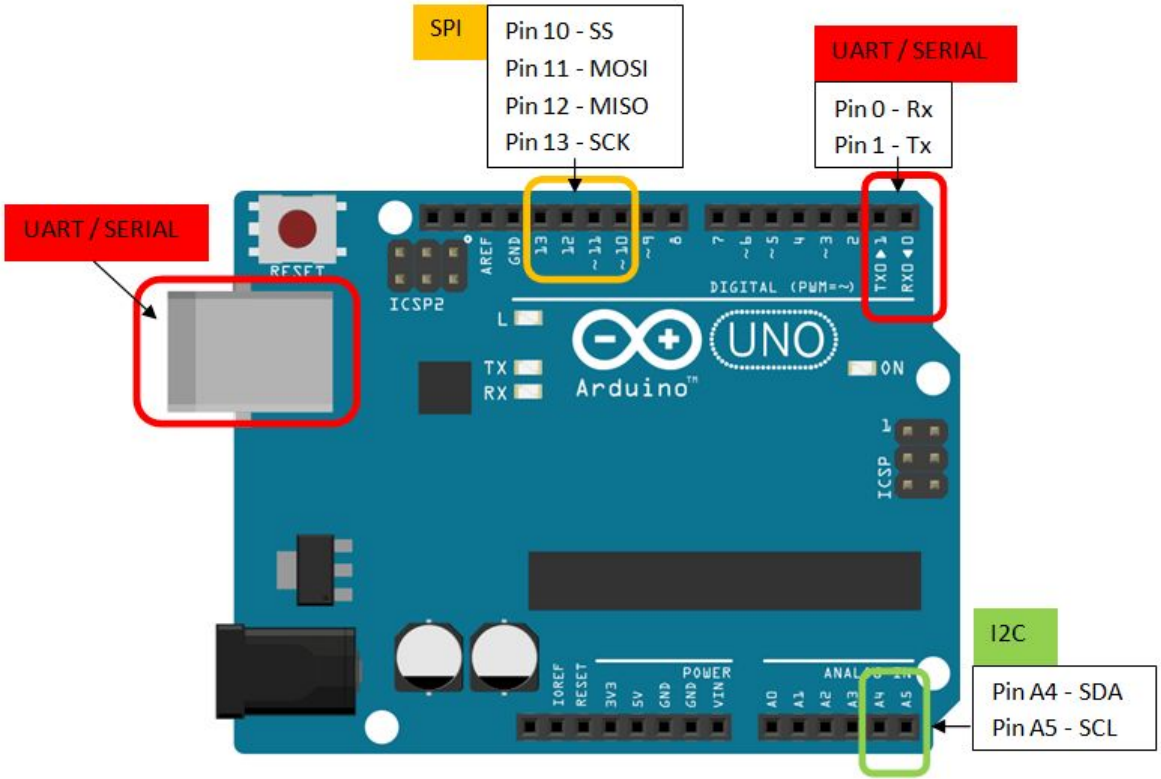

Serial and parallel communication Ports in Arduino Uno

https://solarduino.com/how-to-use-datalogger-shield-with-arduino/

Wireless Communication in Robot

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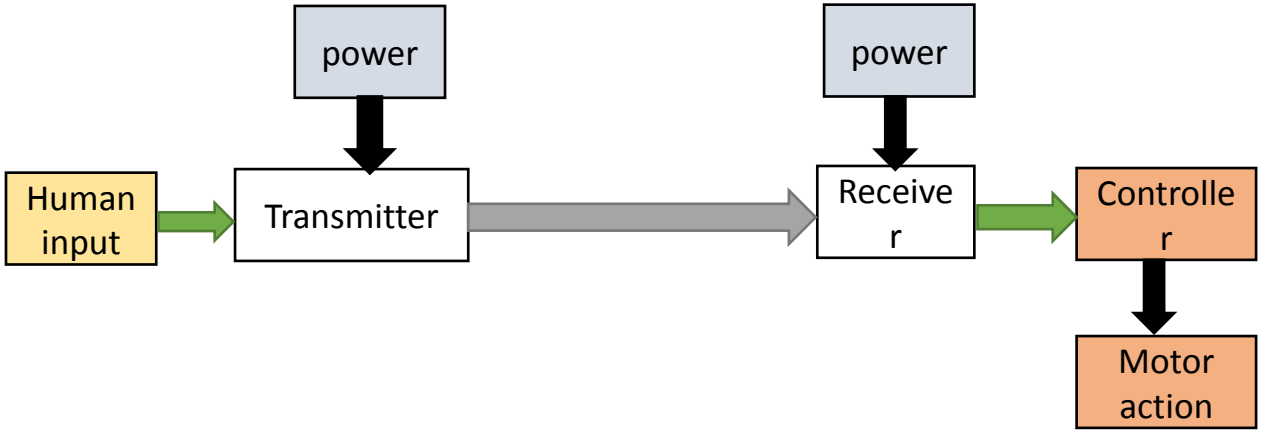
Wireless Communication of Robot

Wireless communication means transferring data/information from its controller to robot without the help of any physical connection. Radio frequency module, WIFI, Bluetooth, GPS, Cellular communication are the medium of wireless communication.



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remote control system

- In wireless remote control system a transmitter transmits the control signals and a receiver receives these particular frequency signals. It then sends them to the main controller part.
- This transmitter and receiver will decide the frequency of signals to use for their communication. like 27MHz, 75MHz,2.4GHz etc.
- This selection is very important because it is illegal to use any frequency that may cause interface with other communication systems like aircraft, telephone, etc.
- The main controllers consist of microprocessors, microcontrollers and other controlling devices that perform the tasks.

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CHALLENGES!!!

Wireless communication is one of the major concerns in robotics. But it comes with lots of challenges. It is usually less reliable and more interference prone. The design of a wireless communication includes several variables such as

- frequency and modulation selection
- signal propagation characteristics
- a huge set of wireless communication standards and protocols.
- Stability, robustness and performance

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https://www.intechopen.com/chapters/56073

Communication system for remote control of a service system, IFAC PapersOnLine 52-25 (2019) 186–191

WIFI

WIFI uses radio frequencies to send signals between devices.

- In this type of communication, a wireless network adapter in a computer converts digital data into radio signals and transmits
- the Wi-Fi unit on receiver (another network adapter) converts these signals into digital data.

frequencies of 2.4 GHz or 5 GHz are used in WIFI

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Lets see an example of robotic arm that is controlled wirelessly via WIFI!!!

This system is based on IoT, web, WIFI, ROS. A service robot is designed to be combined with a smart home management system.

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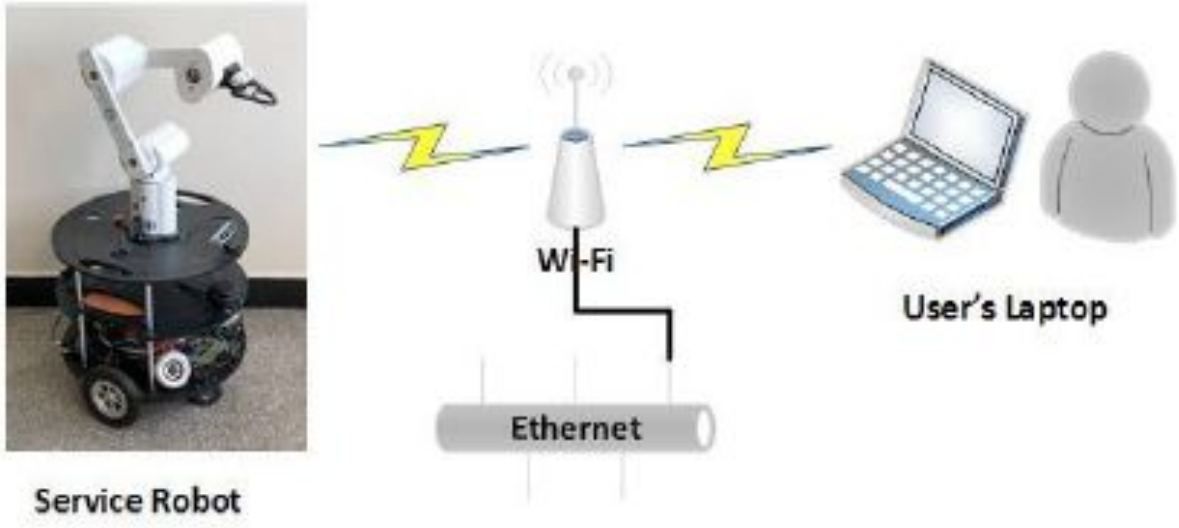
Communication of the Robot

Operator’s device is connected to the robot’s controller through WIFI router.
The wireless communication of this system is divided into three parts: ROS process, web server and web user interface.

ROBOT’S END:

The ROS processes, along with the web server are executed on the robot's own computer.



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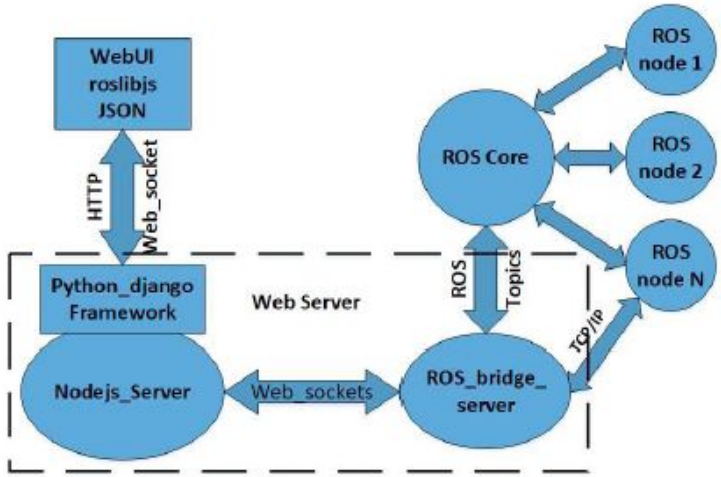
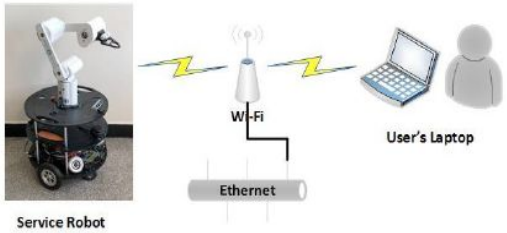
ROS(Robot operating System) is a framework for robot software development. It is a collection of tools, libraries, and conventions that aim to simplify the task of creating complex and robust robot.

One of the core components offered by ROS is Communication Infrastructure. ROS offers a message passing interface that provides inter-process communication

A *node* is a process that performs computation. Each Ros system is composed of one or more nodes. Nodes can communicate with each other.



Structure of the developed communication system



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1. Some of ROS nodes are for robot management, others are for communication with the web server
2. The web server with management features is used in the robot to access the robot over internet

USER END

A web based user interface is used to control the robot from user end. This can be run from any device that supports a web browser such as : smart phone, computer, table.

1. In the UI video and sensor data by the robot's hardware can be received
2. via the UI user can send data for moving the robot's arm.

This Communication between user computers and robot's web server is done by sending HTTP Requests and receiving HTTP Responses

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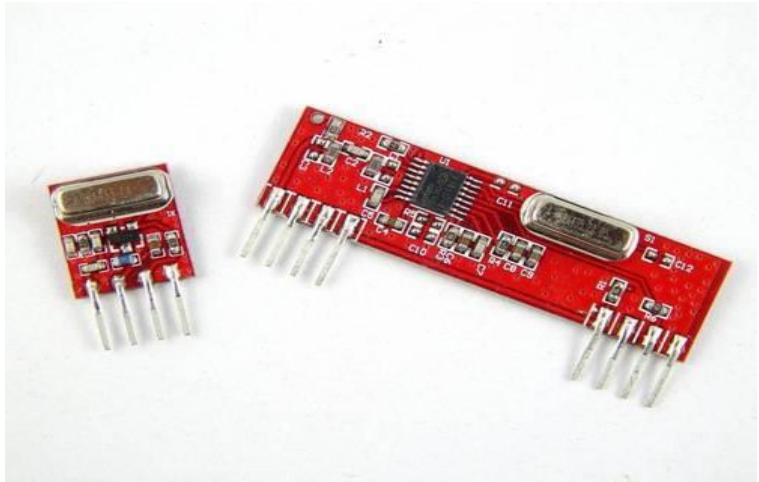
RF MODULE

small electronic device for transmitting and receiving radio signals



RF
433/435Mgh

The 433MHz wireless module is one of the cheap and easy to use device.

- Transmission Distance is 3 meters (without antenna) to 100 meters (maximum)
- Data Transmission speed is 10Kbp

For a simple wireless communication to transmit information within a short distance, RF pair could be the right choice.

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RF Module

The communication is done through optical communication or radio frequency. RF modules are usually fabricated using RF CMOS technology.

- ✔ Several ranges of frequencies are used in RF modules such as 433.92 MHZ, 915 MHZ and 2400MHZ
- ✔ RF communications are Zigbee, Bluetooth, or Wi-Fi. proprietary protocol can also be implemented

Uses: RF modules are most often used in medium and low volume products for consumer applications such

- as garage door openers
- wireless alarm or monitoring systems
- industrial remote controls wireless home automation systems.

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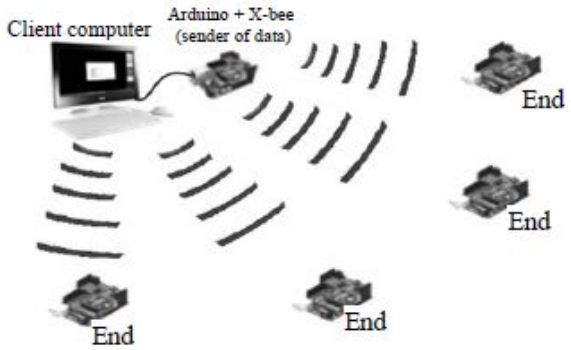
Example of a Wireless control robot using Zigbee

Now we will see an example of a ZigBee protocol **(IEEE 802.15.4 specification)** based wireless robot where **two Arduino** and **two X-Bee** modules were used . X-Bee module use ZigBee protocol for the communication.

- In one side an Arduino + X-Bee module is connected with computer which will act as the sender of data.
- On the other hand another set of Arduino + X-Bee module is placed on robot which will act as a receiver of data.



Wireless communication, Arduino+ X-Bee

The main objective of this work is to communicate
With small sized robot wirelessly

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"Design and Implementation of a System for Wireless Control of a Robot", Christian Hernández1, Raciel Poot1, Lizzie Narváez2, Erika Llanes2 and Victor Chi2, IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 5, September 2010ISSN (Online): 1694-0814www.IJCSI.org

Zigbee Protocol: zig Bee is a IEEE 802.15.4 specification that suites high level communication protocol for wireless personal area network. It is cheaper than other personal area network such as Bluetooth. Therefore, ZigBee is intended at Radio Frequency applications which requires low data rate, low power, long battery life.

Zigbee is usually used for home automation such as intelligent lighting, advanced temperature control, security etc.

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Bluetooth

It is a personal area network used for exchanging data between devices over short distance. It intends to replace cable connecting portable unit

For communication Bluetooth uses radio frequency. It uses frequency modulation to generate radio wave
In ISM band (2.402 GHz to 2.48 GHz).

Bluetooth has layered protocol architecture. Mandatory protocols for Bluetooth are
LMP (Link management protocol)
L2CAP(Logical Link Control and Adaptation Protocol) ,
SPD (Protocol to find other Bluetooth devices)

Symbol of Bluetooth

An example of a Bluetooth device

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Commercial robot e-puck

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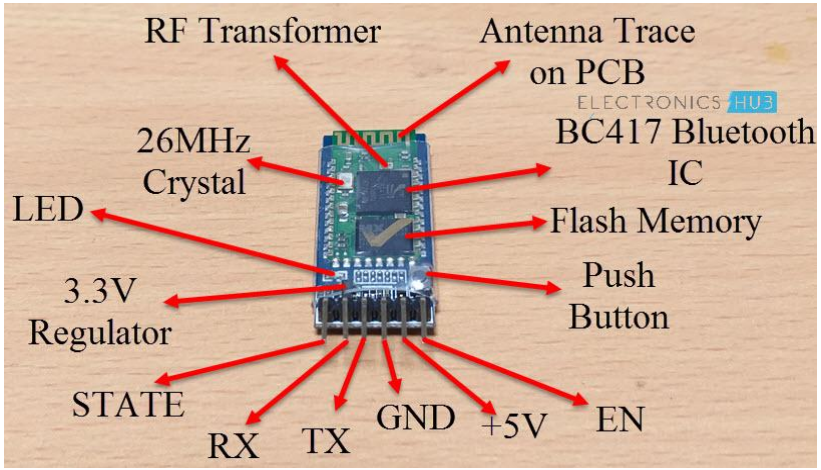
HC-05 Bluetooth Module is a simple Wireless Communication device based on the Bluetooth Protocol. This module is compliant with Bluetooth v2.0 standard and supports for both UART and USB interfaces.

Range: <100m

The **HC-05** module enables two-way (full-duplex) wireless functionality. This can be used to communicate between two microcontrollers or communicate with any device with Bluetooth functionality like a Phone or Laptop.



https://www.electronicshub.org/hc-05-bluetooth-module/

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The **HC-05** has two operating modes, one is the Data mode in which it can send and receive data from other Bluetooth devices and the other is the AT Command mode where the default device settings can be changed

Applications

1. Wireless communication between two microcontrollers
2. Communicate with Laptop, Desktops and mobile phones
3. Data Logging application
4. Consumer applications
5. Wireless Robots
6. Home Automation

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https://components101.com/wireless/hc-05-bluetooth-module

LoRa Wireless module

Low power wide area modulation technique

- It uses license free radio frequency bands (433MHz,863MHz,915MHz) depends on regions like Europe, North America, Australia etc
- It can transmit data in a long distance with very low power consumption
- Bit rate is low
- It is based on spread-spectrum modulation techniques derived fromchirp spread spectrum (CSS) technology
- LoRa modules and LoRa WAN devices are widely used in IoT (Internet of Things) applications as they can handle many nodes at a time
- LoRa WAN is a specialized technology to transmit data in mountainous areas

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https://www.semtech.com/lora/what-is-lora https://en.wikipedia.org/wiki/LoRa https://www.murata.com/en-us/products/connectivitymodule/lpwa/overview/lora

GPS: global positioning system is a navigation system based on satellites. This is a system of 31 satellites that emit signals. A GPS receiver on an object or robot can precisely calculate the position of that object in earth based on the signal sent by satellite. The receiver uses four satellites to compute latitude, longitude, altitude, and time.

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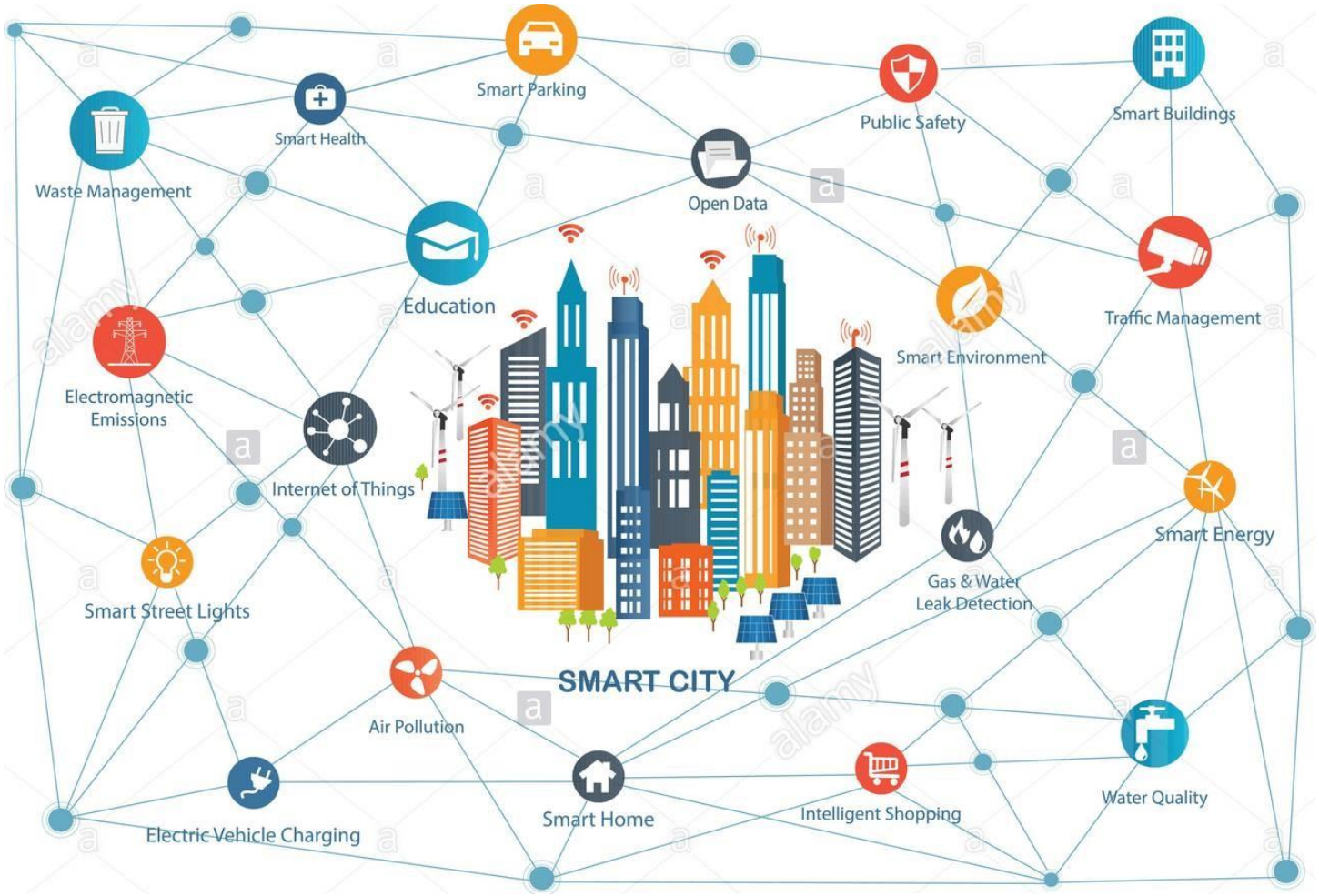
https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/gps/howitworks/



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