Unit 2
Prototyping the Embedded Devices for IoT and M2M Data communication

SENSOR TECHNOLOGY

- Sensor technology is a technology used for designing sensors and associated electronic readers, circuits and devices.
- A sensor can sense a change in physical parameters, such as temperature, pressure , light , metal , smoke and proximity to location , vibrations or smell, organic vapours or gases.
- A microphone senses the voice and changes in the sound, and is used to record voice or music.
- A sensor converts physical energy like heat, sound, strain, pressure, vibrations and motion into electrical energy.
- An electronic circuit connects to the input at a sensor. The circuit receives the output of the sensor. The output is according to the variation in physical condition.
- A smart sensor includes the electronic circuit within itself, and includes computing and communication capabilities.

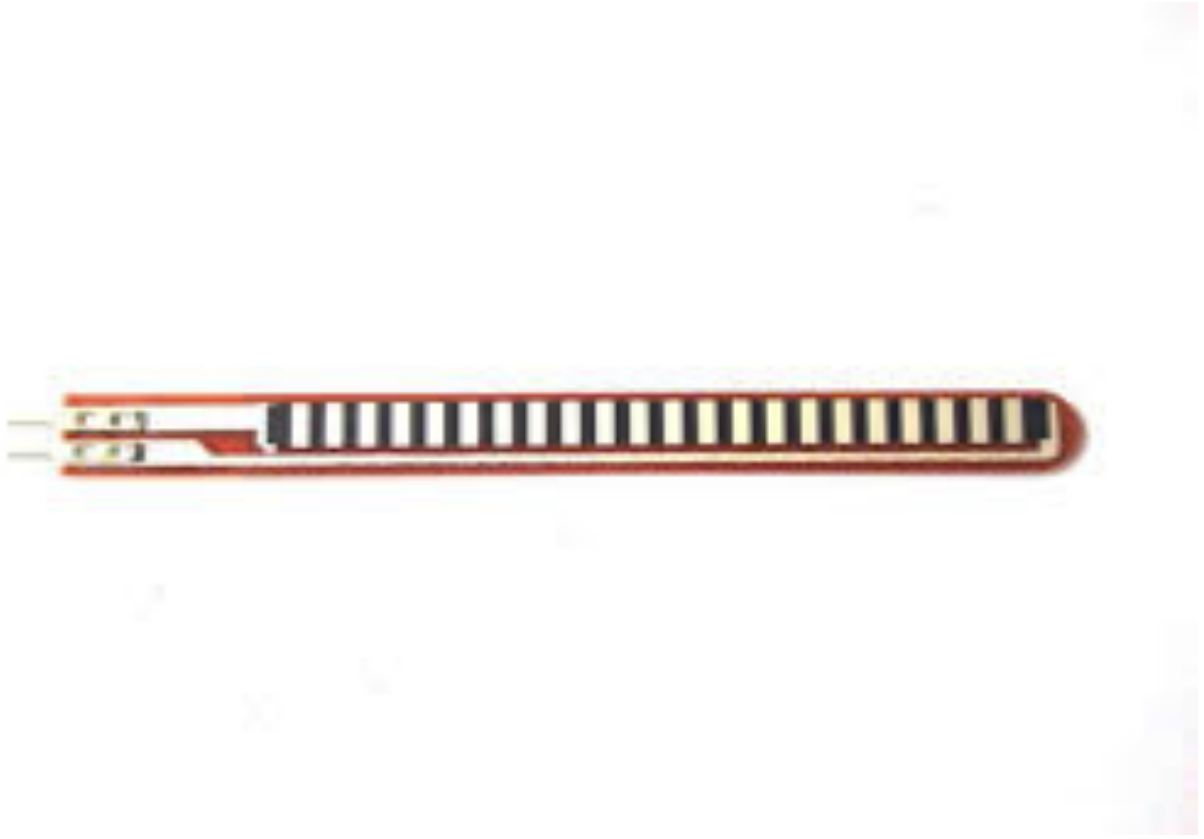
SENSOR TECHNOLOGY

- ## Sensing the real world
- Electronic components can function as sensors.
- Sensor is an electronic device in a circuit that senses a physical environment or condition.
- The sensor sends signals to an electronic circuit, which interconnects to a serial port interface at a micro-controller or controller or computing device.
- A sensor senses a specific physical condition when it exhibits a measurable change in a characteristics circuit parameter on the change in the specific physical condition or environment.
- A smartphone have resistive and capacitive sensors, photodiode current-based sensors, and acceleration , gyroscope, temperature and pressure sensors. The sensors enable the functioning of applications and games.

SENSOR TECHNOLOGY

- **Analog sensors**
- Analog sensors use a sensor and an associated electronic analog circuit.
- Analog sensors generate analog outputs as per the physical environmental parameters, such as temperature, strain, pressure , force, flex, vapours, magnetic field or proximity.
- Resistance of a pressure or strain or magnetic field or humidity. Resistance of a pressure sensor increases on pressure which creates a strain on the sensor.
- Example A flex sensor of 2.2inch or 4.5inch length shows that its resistance across the sensor strip increases on flexing due to a changed path and deflection of sensing resistor.

Flex sensor 2.2 inch



Reading temperature from Resistance sensor

When temperature, such as of oil or coolant plate in an M2M or IoT device in an automobile needs to be sensed then a simple electronic circuit uses the sensing component at the sensed object. The associate computing device calculates the temperature value at the measuring instance. Figure 7.1 shows a circuit consisting of a resistance bridge. The bridge has one sensing resistor at the sensing object and three fixed (standard) resistors. The figure shows a microcontroller using an electronic circuit with a port connected to sub-circuits, serial port interface, ADC, signal conditioning amplifier and resistance bridge.

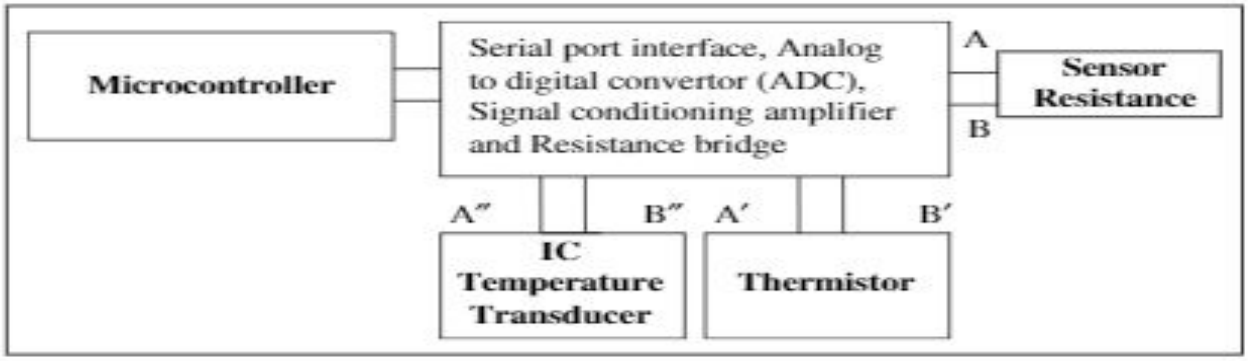


Figure 7.1 Microcontroller serial port connected to sub-circuits—serial port interface, ADC, signal conditioning amplifier, resistance bridge and sensor resistance outputs A ad B. Alternatively circuit connects to a thermistor output at A′ and B′ or IC based temperature-transducer output at A″ and B″

Reading from Capacitive Sensor

C of a sensor object is a part of a capacitive bridge. The associate computing device calculates the proximity distance in case 1 and touched position in case 2 as well as the successive variations. Microcontroller is a computing device which reads the input at its ports, saves the input at memory, and then uses the data for communication over the Internet.

Figure 7.2 shows a circuit using a capacitance bridge. The bridge consists of the sensing capacitor (object) and three fixed (standard) capacitors. The figure shows a microcontroller-based electronic circuit with port connected to four sub-circuits, serial port interface, ADC, signal conditioning amplifier, diode and capacitance bridge.

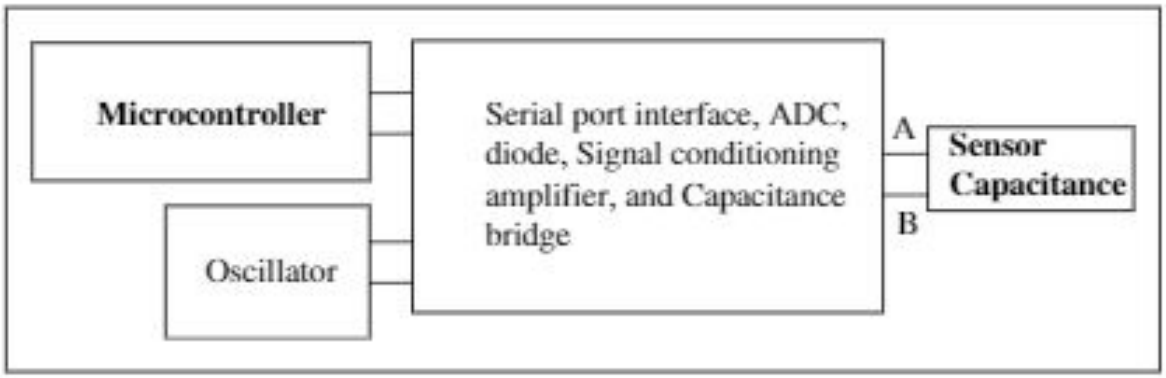


Figure 7.2 Microcontroller electronic circuit; port connected to sub-circuits; serial port interface, ADC, diode, signal conditioning amplifier and capacitance bridge, and sensor capacitance at A and B

Analog to Digital Converter(ADC)

- Analog sensor circuit connects to a signal conditioner amplifier, then to an analog to digital converter.
- A microcontroller may consist of an in-circuit ADC or multiple input ADC. It processes the digital output from the in-circuit ADC.
- Alternatively a port accepts the digital input consisting of 1s and 0s through an external ADC.

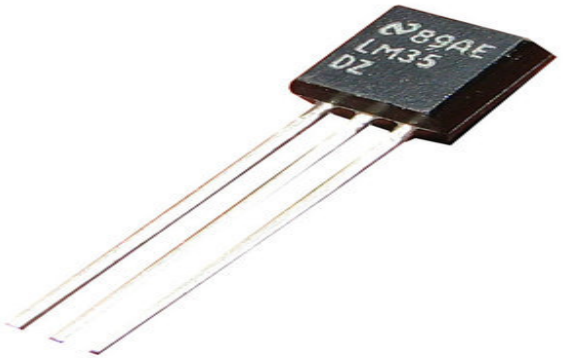
Digital sensor

- A specific electronic components or circuit gives digital output 1 or 0(on-off state) or output of 1s and 0s as a binary number.
- A digital sensor uses the sensor and has an associated electronic circuit which gives digital output.
- The output 1 or 0 is read through a port in a microcontroller.
- This circuit can be used for sensing a sudden change in specific physical state or condition or can be used for sensing a sudden change in specific set of physical state or conditions.

Examples of sensors

1. Temperature

- A component called thermistor, shows larger change in resistance within narrow environment temperature range (120c to 90c).
- An NTC thermistor shows negative temperature coefficient which means a drop in the resistance value with rise in temperature.
- A temperature sensor is called PTC , when it exhibits a positive temperature coefficient.



Examples of sensor

2. Humidity

- Humidity is measured in percentage. It is the relative percentage ratio(RH%) of content of water vapours in air compared to one in a situation of maximum possible water vapour content for the air temperature at the instance of measurement.
- Humidity sensors vary widely in size and functionality; some humidity sensors can be found in handheld devices (such as smartphones), while others are integrated into larger embedded systems (such as air quality monitoring systems). Humidity sensors are commonly used in the meteorology, medical, automobile, HVAC and manufacturing industries.

Examples of sensors

3. Distance

- Infrared(IR) sensor is useful for a 0.15m to 0.8m range of object.
- IR sensor works on the principle that when a narrow beam IT LED sends radiation at an inclined angle, the nearby phototransistor FPT receivers the reflected radiation after travelling two times the object distance.

Examples of sensors

4. **Light :**

- Use of photoconductor p-n junction photodiode or phototransistor for measuring the intensity of light.

5. **Acceleration:** A Micro-Electro-Mechanical Sensor (MEMS) detects linear accelerations ax, ay and az along three axes x, y and z, respectively. An MEMS moves when a mass moves along a direction. A mechanical movement has three components. The variations cause the variation in three capacitance values, Cx, Cy and Cz. The value of each C depends on the space between two plane surfaces, which varies on acceleration along an axis.

2.2 Embedded Computing Basics

Embedded Devices

- Each device generate data, the data is generated using embedded devices, sensors and systems at the physical layer.
- A system needs electronic circuits for computation and communication. The circuits use sensors and actuator devices, which embed the computing hardware and software.
- Prototyping and designing require the embedded device platforms for data generation. This also requires connectivity to the internet through computations, adaptation and networking.

Embedded computing

- Embedding means embedding function software into a computing hardware to enable a system function for the specific dedicated application.
- A device embeds software into the computing and communication hardware, and the device functions for the applications.

1. Embedded software
2. Integrated development environment
3. Embedded Hardware Units

Embedded software

- Software consists of instruction, commands and data.
- A computing and communicating device needs software.
- Software does the bootloading and enables the applications and services. The software includes an OS.
- A device embeds software which also includes the device APIs and middleware which enable the device to perform computing and communication functions.

1. Bootloader
2. Operating System
3. Real-time Operating System

Embedded software

1. Bootloader

- Bootloader is a program which runs at the start of a computing device, such as an MCU.A bootloader initiates loading of system software(OS) when the system power is switched on, and power-on-self test completes. Bootloader may also facilitate the use of system hardware and networking capabilities.

2. Operating System

- An operating system(OS) facilitates the use of system hardware and networking capabilities. When a load of the OS into RAM completes then the MCU starts the normal operational runtime environment. When the device is executing multiple tasks or threads, then also an OS is required.

3. Real-time Operating System

- Real-time Operating System(RTOS) is an OS that enables real-time execution of processes on computing and communication hardware.

Integrated development environment

- Integrated Development Environment(IDE) is a set of software components and modules which provide the software and hardware environment for developing and prototyping.
- An IDE enables the codes development on a computer, and later on enables download of the codes on the hardware platform.
- IDE enables software that communicates with the internet web server or cloud service.
- IDE consists of the device APIs , libraries , compilers , RTOS , simulator , editor , assembler,debugger,emulators,logic analyser , application codes burner for flash, PROM and EEPROM and other software components for integrated development of a system.
- IDE may be open source for example, Arduino has open source IDE from the Arduino website.

Integrated development environment

- The IDE or prototype tool enables a prototype design.
- IDE is used for developing embedded hardware and software platforms , simulating, and debugging.
- IDE is tool for software development of embedded devices, which makes application development easy.

Embedded Hardware Units

- The hardware includes the following:

- Single VLSI (very-large integrated) chip.
- A core in an application specific instruction set processor(ASIP), called MCU.
- A core in system-On-chip(Soc) or an Soc chip with an SD card for embedded software and operating system(OS) software.

Microcontroller Unit

- An MCU is a single-chip VLSI unit which though having limited computational capabilities , possesses enhanced input-output capability and has a number of on-chip functional units, such as internal RAM, flash ,IO ports ,GPIOs , serial interfaces ,timers ,serial ports and timers.
- An MCU is an IC chip, available from a number of sources, such as ATMEL, Nexperia, Microchip, Texas instruments or intel.
- MCU can be of 8-bit,16-bit or 32-bit family.
- MCU clock frequency can be 8MHz, 16 MHz,100MHz,200MHz or higher. The clock frequency depends on the version and family.
- MCU includes RAM which can be 4KB,16KB,32 KB or higher. RAM read and write of byte takes an instruction cycle each. RAM is used for temporary variables, stacks and run-time need of the memory.

Microcontroller Unit

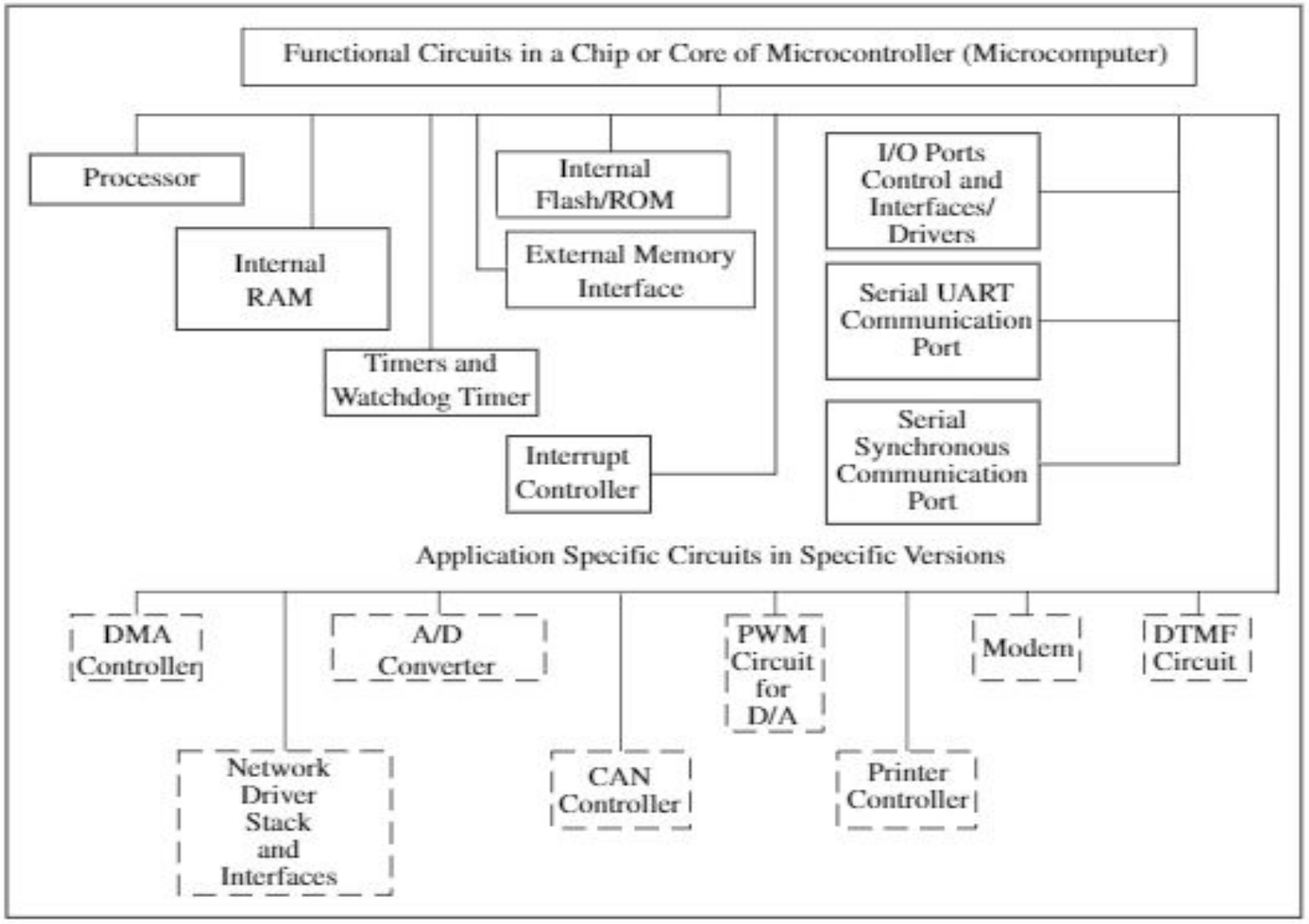


Figure 8.1 Microcontroller, on-chip functional units and application specific units

Microcontroller Unit

- MCU includes EEPROM and flash memory, which may be 512B, 1 KB, 2 KB, 4 KB, 16KB or higher.
- flash stores the programs, data, tables, and required information during building and testing stages, and then stores a final version of the application program in the embedded device.

Selection of embedded platform

- Selection among the number of different available platforms depends on a number of factors like price , open source availability, ease of application development and needed capabilities , performance required from IOT device and suitability for developing and using for prototyping and designing.

Hardware

The choice, beside the price, of embedded hardware depends on the following:

- Processor speed required which depends upon the applications and services. For example, image and video processing need the high-speed processors
- RAM need which may be 4 kB or higher depending upon the OS and applications. For example, requirement is 256 kB for using the Linux distribution. New generation mobile phones have over one GB RAM.
- Connection needs to ZigBee, ZigBee IP, Bluetooth LE, Wi-Fi or Wired Ethernet for networking using a supporting circuit (shield)
- USB host
- Sensor, actuator and controllers interfacing circuits, such as ADC, UART, I2C, SPI, CAN single or multiples
- Power requirements, V- and V+, 0 V and 3.3 V or 0 V and 5 V or other.

Software

Selection among a number of different available software depends on hardware platform, open source availability of software components, cost of availability or development of other required components for applications and services.

The choice of embedded software, beside the price, depends on the following: IDE with device APIs, libraries, OS or RTOS, emulator, simulator and other environment components, middleware with communication and Internet protocols, and Cloud and sensor-cloud platform for applications development, data storage and services.

Embedded platform for prototyping

Embedded platforms for prototyping

- Designing a product needs a prototype development first.
- A standard source board enables prototyping, an easy task for number of IoT and M2M devices.
- This is because of the open source availabilities of IDE, middleware and software components from number of sources and forums for the board.

Arduino

- Arduino boards, modules and shields are popular AVR MCU-based products.
- Each board has clear markings on the connection pins, sockets and in-circuit connections.
- Thus, Arduino boards are easy to work and simplify the prototyping of embedded platforms for IoTs.
- The IDE are open source.
- Arduino boards are thus easy to program. For example, Arduino Uno board is a robust as well as widely used board to get started with electronics and coding.
- Uno is most used and documented board of the whole Arduino family at present.

Wired and Wireless communication Technologies for M2M

Wireless Communication Technology :

- Near –Field communication
- RFID
- Bluetooth and Bluetooth low energy
- Zigbee IP/Zigbee SE 2.0
- Wi-fi
- GPRS/GSM cellular networks –mobile internet
- Wireless USB

Near-field Communication:

- NFC is a short distance(20 cm) wireless communication technology.
- It enables data exchange between cards in proximity and other devices.
- Device data transfer rates are 106 kbps,212 kbps,424 kbps and 848 kbps.
- Examples of application of NFC:
- Proximity card reader/RFID/IOT/M2M mobile device
- Mobile payment wallet
- Electronic keys for car, office entry keys, house
- Biometric passport reader

RFID:

- RFID use the internet. RFID usage in remote storage and reterival of data at the RFID tags.
- An RFID device functions as a tag or label, which may be placed on an object. The object can then be tracked for the movement. the object may be parcel, person, bird, or an animal.
- IOT application of RFID are in business process, such as parcel tracking and inventory control, sales log-ins and supply-chain management.

Bluetooth and Bluetooth low energy:

- Bluetooth devices follow IEEE 802.15.1 standard protocol.
- BT network uses features of self-discovery and self-configuration.
- Two modes –dual or single mode devices are used for IOT/M2M devices local area network.
- Operation in secured as well as unsecured modes.

Zigbee IP/Zigbee SE 2.0:

- Zigbee devices follow the IEEE 802.15.4 standard protocol.
- Zigbee end-point devices from a WPAN of embedded sensors, actuators, appliances, controllers or medical data system which connect to the internet for IOT applications, services and business processes.
- Zigbee neighbourhood area network is a version for a smart grid.
- Used for low-power ,short-range WPAN
- Range is 10-200m,data transfer rate is 250 kbps, low power operation.

Wi-Fi:

- Wi-fi is an interface technology that uses IEEE 802.11 protocol and enables the wireless local area networks.
- Wi-fi devices connect enterprises, universities and offices through home AP/public hotspots.
- Interface uses 2.4 GHz or 5GHz.
- Offers mobility and roaming.
- Coveragae range is 30m to 125m
- Provides security, integrity and reliability.

- Communication can be over a bus when several systems connect through a common set of interconnections.
- Wired communication can be done using ethernet IEEE 802.2 bus specification.

Wired Communication technology :

- UART/USART serial communication
- Serial peripheral interface
- I2C bus
- Wired bus
- Ethernet

UART/USART serial communication:

- A universal asynchronous transmitter (UART) enables serial communication of 8 bit serially.
- Serial means present one after another at successive time intervals.

Serial peripheral interface :

- It is a widely used serial synchronous communication methods.
- Source of serial synchronous output or input is called master when it also control the synchronizing clock information to the receiver.
- A receiver of serial synchronous input or output is called a slave, when along with a serial data is also receives the synchronous clock from the master.

I2C bus :

- The I2C was originally developed at Philips semiconductor.
- I2c has two lines that carries the signals – one line is for the clock, and one is for bidirectional data.
- I2C bus protocol has specific fields. Each field has a specific number of bits, sequences and time intervals between them.

Ethernet :

- Ethernet standard is IEEE 802.2 protocol for local area network of computers, workstation and device LANs.
- Features:
- Use passive broadcast medium
- Formatting of frame
- Uses a 48-bit MAC address
- Address resolution protocol(ARP)
- Uses wired bus topology