Learning Manual for

Emerging Trends in Electronics (22636)

Semester– VI

(DE/EJ/ET/EN/EX/EQ/IE/IS/IC/TE)

W.E.F. 2022-2023

Maharashtra State Board of Technical Education, Mumbai

(Autonomous) (ISO-9001-2015) (ISO/IEC 27001:2013)

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Preface

The primary focus of any engineering work in the technical education system is to develop the much needed industry relevant competency and skills. With this in view, MSBTE embarked on innovative "I" scheme curricula for engineering diploma programs with outcome based education through continuous inputs from socio economic sectors. The industry experts during the consultation while preparing the Perspective Plan for diploma level technical education categorically mentioned that the curriculum, which is revised and implemented normally further revised after 4-5 years. The technological advancements being envisaged and faced by the industry in the present era are rapid and curriculum needs to be revised by taking care of such advancements and therefore should have a provision of accommodating continual changes. These views of industry experts were well taken and further discussed in the academic committee of MSBTE, wherein it was decided to have a dynamism in curriculum for imparting the latest technological advancements in the respective field of engineering. In order to provide an opportunity to students to learn the technological advancements, a course with a nomenclature of "Emerging Trends in Electronics Engineering" is introduced in the 6th semester of Electronics Engineering Group.

The technological advancements to be depicted in the course called emerging trends was a challenging task and therefore it was decided to prepare a learning material with the involvement of industrial and academic experts for its uniformity in the aspect of delivery, implementation and evaluation.

In the electronics sector, new applications are coming up and it is mandatory for all technologists to be well versed in these developments to survive and provide satisfactory and quality services to the society and industry. This course aims to prepare the diploma graduates to be conversant with such emerging trends. The main areas in which such developments encompass are Advanced Processors, Electronic System Manufacturing, Smart systems, Digital Factory and Communication. Each unit in the course given an insight to the learner about the latest development in the relevant fields.

This learning manual is designed to help all stakeholders, especially the students and teachers and to develop in the student the pre-determined outcomes. It is expected to explore further by both students and teachers, on the various topics mentioned in learning manual to keep updated themselves about the advancements in related technology.

MSBTE wishes to thank the Learning Manual development team, specifically Mr. Sudhir Panditrao, Industry Experts, Mr. K.P. Akole, Coordinator, Smt. Vidya Lunge, Co-coordinator of the programs, other Industry Experts and academic experts for their intensive efforts to formulate the learning material on "Emerging Trends in Electronics Engineering". Being emerging trend and with the provision of dynamism in the curricula, any suggestions towards enrichment of the topic and thereby course will be highly appreciated.

(Dr. Vinod M. Mohitkar)
Director
MSBTE, Mumbai

Content

Unit 1: Advance Processors

Expected Course Outcome: Suggest the relevant computing systems/processor for specific type of application

Teaching Hrs. 10 **Marks 16**

To attain above course outcome candidate must able to:

a. Describe the given advancement in the processor architecture.
b. Describe the given feature of the ARM7 processors
c. Describe the given features of Arduino board.
d. Describe the given functions in Arduino IDE.
e. Enlist features of GPU.

Unit focus on following major points:

1.1 Advances in processor architecture: Introduction, Processor Selection Criteria
1.2 ARM: Introduction, Features of ARM7 and ARM7TDMI, advantages, applications.
1.3 Arduino: Introduction, Compatible R2/R3 Uno board Features. ATmega 328: Introduction, pin description.
1.4 Arduino IDE: Features, Sketch: C, C++ functions setup (), loop (), pinMode (), digitalWrite (), digital Read () and delay ()
1.5 Arduino Interfacing: LED, Relay and DC motor.
1.6 Graphical Processing Unit (GPU): Introduction, Features, Basic architecture of GPU, Architectural difference between GPU and CPU, GPU applications.

1.1 Advances in processor architecture:

1.1.1 Introduction

Processors have undergone a tremendous evolution throughout their history. A key milestone in this evolution was the introduction of the microprocessor, term that refers to a processor that is implemented in a single chip. The first microprocessor was introduced by Intel under the name of Intel 4004 in 1971. It contained about 2,300 transistors, was clocked at 740 KHz and delivered 92,000 instructions per second while dissipating around 0.5 watts. Since then, practically every year we have witnessed the launch of a new microprocessor, delivering significant performance improvements over previous ones. Some studies have estimated this growth to be exponential, in the order of about 50% per year, which results in a cumulative growth of over three orders of magnitude in a time span of two decades. These improvements have been fueled by advances in the manufacturing process and innovations in processor architecture.

The complexity of an integrated circuit is bounded by physical limitations on the number of transistors that can be put onto one chip, the number of package terminations that can connect the processor to other parts of the system, the number of interconnections it is possible to make on the chip, and the heat that the chip can dissipate.

1.1.2 Processor Selection Criteria

With numerous kinds of processors, various design philosophies are available for digital systems. Following considerations need to be factored during processor selection for a Digital Systems.

1. Performance Considerations
2. Power considerations
3. Memory
4. Peripheral Set
5. Operating Voltage
6. Specialized Processing Units

7. Price

1. **Performance:** The first and foremost consideration in selecting the processor is its performance. The performance speed of a processor is dependent primarily on its architecture and its silicon design. Evolution of fabrication techniques helped packing more transistors in same area there by reducing the propagation delay. Also presence of cache reduces instruction/data fetch timing. Pipelining and super-scalar architectures further improves the performance of the processor. Branch prediction, speculative execution etc. are some other techniques used for improving the execution rate. Multi-cores are the new direction in improving the performance.

   Rather than simply stating the clock frequency of the processor which has limited significance to its processing power, it makes more sense to describe the capability in a standard notation. MIPS (Million Instructions per Second) or MIPS/MHz was an earlier notation followed by Dhrystones and latest EEMBC's Core Mark. Core Mark is one of the best ways to compare the performance of various processors.

   Processor architectures with support for extra instruction can help improving performance for specific applications. For example, SIMD (Single Instruction/Multiple Data) set and Jazelle – Java acceleration can help in improving multimedia and JVM execution speeds.
   So size of cache, processor architecture, instruction set etc. has to be taken in to account when comparing the performance.

2. **Power:** Increasing the logic density and clock speed has adverse impact on power requirement of the processor. A higher clock implies faster charge and discharge cycles leading to more power consumption. More logic leads to higher power density there by making the heat dissipation difficult. Further with more emphasis on greener technologies and many systems becoming battery operated, it is important the design is for optimal power usage.

   Techniques like frequency scaling – reducing the clock frequency of the processor depending on the load, voltage scaling – varying the voltage based on load can help in achieving lower power usage. Further asymmetric multiprocessors, under near idle conditions, can effectively power off the more powerful core and load the less powerful core for performing the tasks. SoC comes with advanced power gating techniques that can shut down clocks and power to unused modules.

3. **Memory:** Usually, designers make the decision to use internal or external memory after they define the required amounts of code space and data memory. Internal memory is typically the most cost effective memory type, but it is also the least flexible. For this reason, designers must determine future growth possibilities and whether there is an upgrade path to microcontrollers with larger code space. Since cost is always a factor, the microcontroller with the least amount of memory to fit the application is typically selected. Therefore, care must be taken when predicting code size, since an increase in code size might require a different microcontroller.

4. **Peripheral Set:** Every system design needs, apart from the processor, many other peripherals for input and output operations. Since in an embedded system, almost all the processors used are SoCs, it is better if the necessary peripherals are available in the chip itself. This offers various benefits compared to peripherals in external IC's such as optimal power architecture, effective data communication using DMA etc. So it is important to have peripheral set in consideration when selecting the processor.

5. **Operating Voltages:** Each and every processor will have its own operating voltage condition. The operating voltage maximum and minimum ratings will be provided in the respective data sheet or user manual.

   While higher end processors typically operate with 2 to 5 voltages including 1.8V for Cores/Analogue domains, 3.3V for IO lines, needs specialized PMIC devices, it is a deciding factor in low end micro-controllers based on the input voltage. For example it is cheaper to work with a 5V micro-controller when the input supply is 5V and 3.3 micro-controllers when operated with Li-on batteries.

6. **Specialized Processing Units:** Apart from the core, presence of various co-processors and specialized processing units can help achieving necessary processing performance. Co-processors execute the instructions fetched by the primary processor thereby reducing the load on the primary. Some of the popular co-processors include

   Floating Point Co-processor: RISC cores supports primarily integer only instruction set. Hence presence of a FP co-processor can be very helpful in application involving complex mathematical operations including multimedia, imaging, codecs, signal processing etc.
   Graphic Processing Unit: GPU (Graphic Processing Unit) also called as Visual processing unit is responsible for drawing images on the frame buffer memory to be displayed. Since human visual perception needed at-least 16 Frames per second for a smooth viewing, drawing for HD displays involves a lot of data bandwidth. Also with increasing graphic requirements such as textures, lighting shadesetc, GPU's have become a mandatory requirements for mobile phones, gaming consoles etc.

   Various GPU's like ARM's MALI, Power, and OpenGLetc are increasing available in higher end processors. Choosing the right co-processor can enable smooth design of the embedded application.

   Digital Signal Processor: DSP is a processor designed specifically for signal processing applications. Its architecture supports processing of multiple data in parallel. It can manipulate real time signal and convert to other domains for processing. DSP's are either available as the part of the SoC or separate in an external package. DSP's are very helpful in multimedia applications. It is possible to use a DSP along with a processor or use the DSP as the main processor itself.

7. **Price:** Various considerations discussed above can be taken in to account when a processor is being selected for an embedded design. It is better to have some extra buffer in processing capacities to enable enhancements in functionality without going for a major change in the design. While engineers (especially software/firmware engineers) will want to have all the functionalities, price will be the determining factor when designing the system and choosing the right processor.

1.2 ARM

1.2.1 Introduction:

Advanced RISC Machine (ARM) designs microprocessor technology that lies at the heart of advanced digital products, from mobile phones and digital cameras to games consoles and automotive systems, and is leading intellectual property (IP) provider of high-performance, low-cost, power-efficient RISC processors, peripherals, and system-on-chip (SoC) designs through

involvement with organizations such as the Virtual Socket Interface Alliance (VSIA) and Virtual Component Exchange (VCX). ARM also offers design and software consulting services. ARM's architecture is compatible with all four major platform operating systems: Symbian OS, Palm OS, Windows CE, and Linux. As for software, ARM also works closely with its partners to provide optimized solutions for existing market segments. These benefits are making the ARM company a complete solution provider. With over forty partners licensed to use its architecture, ARM enables Original Equipment Manufacturers (OEM) to realize an accelerated time-to-market through complete product offerings, such as Prime Cell Peripherals, embedded software IP, development tools, training, and support The Company offers a complete solution that is essential to the manufacturing process. Although ARM does not manufacture processors itself, ARM licenses its cores to semi-conductor manufacturers to be integrated into ASIC standards and then the company in using test chips manufactured by its partners to measure and validate the functionality of the core.

ARM is able to accelerate OEM time-to-market by capitalizing on its architecture. By providing the IP and supporting services, customers can gain a jump on their design cycle and obtain a competitive edge in their targeted market segment. At that point, the architecture is portable to further product generations or applications as all code creation is directly compatible with any future architecture produced by ARM.

ARM's Global Technology Partner Network is the largest in the industry, spanning from Semiconductor manufacturers to distributors. ARM has worked diligently to ensure that the partnerships provide proven solutions in real-time operating systems (RTOS), EDA tools, development systems, applications software, and design consulting, all built around the ARM Architecture. The ARM Company is working to establish standards, not just within the company, but across the industry by taking advantage of leadership opportunities in the creation of standards. ARM is the industry standard embedded microprocessor architecture, and is a leader in low-power high performance cores. ARM also has a large partner network supporting the entire design and development cycle. ARM is a full-solutions provider, supporting a broad range of applications.

1.2.2 Basic of ARM architecture:

ARM architecture is not synonymous with the single organization. But there is certain commonality across the different variants.

Basic ARM Organization.

As shown in Fig 1.1 ARM Organization consists of register bank. It is connected to the ALU by two buses A and B. A is connected directly to ALU and B is connected through Barrel shifter. This Barrel shifter can actually preprocess the data which can come from one of this source registers; and the Barrel shifter can shift to the left, shift to the right or even rotate the data before it is fed to the ALU.Now, since all of these blocks i.e.ALU, Barrel shifter is also combinational circuit. So, the entire, all these operations that is operation that ALU carries out as well as operation that Barrel shifter carries out can take place in one cycle itself and that actually splits up to the operation execution speed.

Register bank can generate the address also. In fact the PC address is, PC also is part of the register bank and that can generate the address. As well as the other register banks, can be made use of for generation for manipulation of address. Because registers are in a way symmetric they can have both address as well as the data and they can be operated in a symmetric way. The PC generates the address for the instruction.

Other operations can also be done using these registers. Instruction decodes and control provides a control signal. Address bus is 0 to 31 that means it is a 32 bit. Data buses are also 32 bits, so it is basically a 32 bit processor. It can operate on 32 bit operands and the addresses that it generates are also 32 bit. Register bank has a very prominent role.

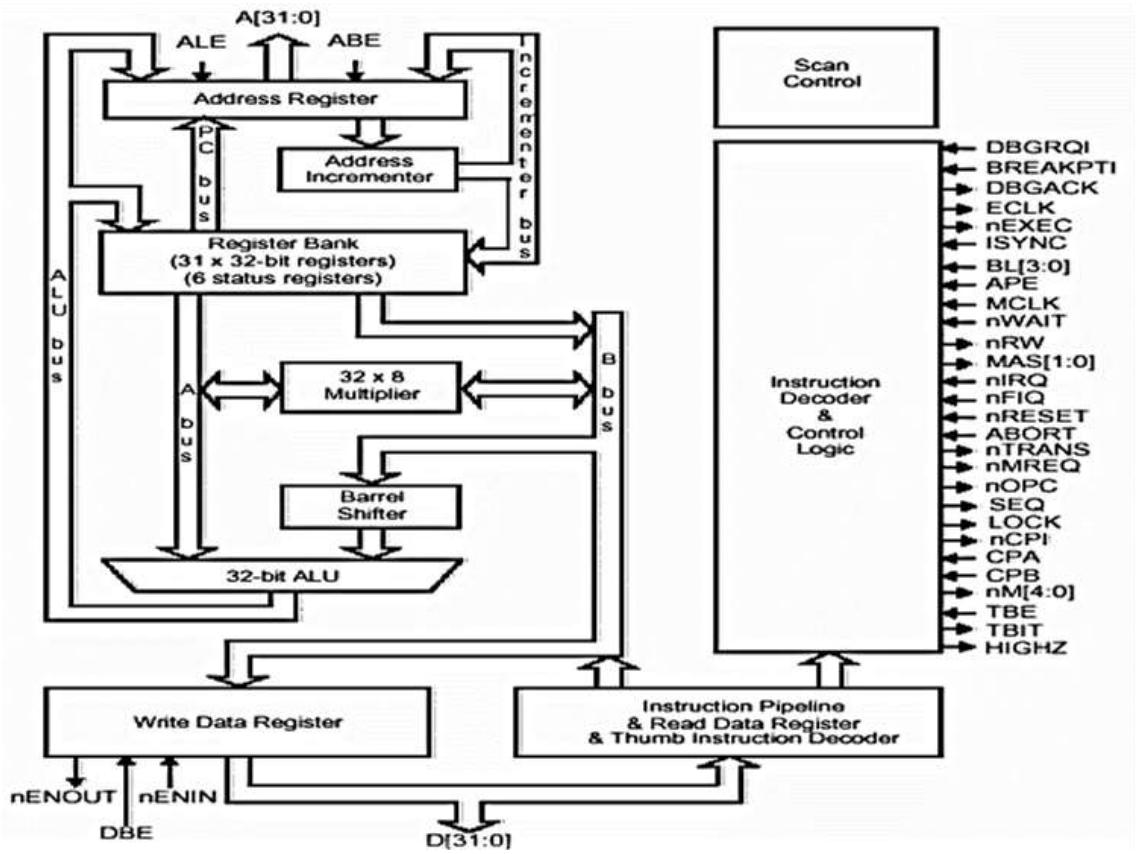


Fig 1.1 ARM7 TDMI Core Diagram

All registers are 32 bits because data bus is 32 bit, operating at 32 bit operands as well as addresses are also 32 bits. There are 16 data registers in user mode and 2 data registers are visible.
User mode is a common operating mode. Used by user when running program on ARM.

Data registers are typically r0 to r15 and in fact in ARM, all registers are refer to by r followed by a number. So, here we are talking about data registers r0 to r15 which are visible in the user mode. Out of these registers, 3 registers perform special function they are r13, r14 and r15. R13 is a stack pointer, so this stack pointer refers to the entry point on the stack and this is critical for implementation of a stack in the memory. R14 is a link register. This link register is a register where return address is put whenever a subroutine is called. Here, we have got a single link register and in the link register the return address is put in. Then r15 is the program counter and obviously the current instruction what is being executed will be pointed to by the content of r15.

Now, depending on the context registers r13 and r14 can also be used as general purpose registers. In addition there are 2 status registers. CPSR, (current program status register) and SPSR s (saved program status register). These are basically the status registers which are not data registers. So, here in this registers effectively the status of the current execution is being captured. In fact this status can include status of your program as well as that of the processor.

And when it is operating in your 32 bit it is assume that all instructions are word aligned. That means all 32 bit instructions start at 32 bit boundary. And what does that imply, that implies that PC value is stored effectively in bits from 2 to 31, bit numbers 2 to 31, with bits 1, 0 effectively undefined or not really useful for referring to an instruction. Now, obviously this discussion refers to one fact that 32 bit address in ARM refers to byte locations. Each byte with associated with a unique address so, talking about 32 bit boundaries means effectively talking about what blocks of 4 bytes. So, if there is one instruction starting at location 0 then that instruction will occupy location 0, 1, 2 as well as 3. The next instruction would be located at 4 so, therefore these 2 bits, the least significant bits of PC that is r15 or in a way do not care for operations. So, that is why PC value is effectively stored in bits from 2 to 31.

Status register CPSR: CPSR is the current program status register; it has got a number of bits. Again it will be a 32 bit register; it is not that all bits are used at the same time. The condition code flags which occupy the higher that MSB that is most significant bits in the status register; they are standard flags which reflect various arithmetic conditions. Negative flag results from ALU which is typically the most significant bit, it is associated with the most significant bit. If it is one then it can be interpreted as a negative result when we are doing signed arithmetic set, Z indicates 0, C is the carry and V is overflow. There is this sticky overflow flag, this is with reference to saturation arithmetic. There are two levels of interrupts. With Interrupt, disable bits.

So, user can enable or disable these two levels of interrupts by using these 2 bits. This T- bit indicates whether processor is in thumb mode or not thumb mode because when user have an embedded 16 bit processor into the 32 bit architecture, we shall be making use of this T bit to know whether operating in the thumb mode or ordinary 32 bit mode and rest are mode bits and these mode bits really defined what is called the mode of processors operation. User can use about 16 data registers, in program and normal operation and that is user mode. These modes are specified by these bits.

Saturation: Saturation means when we reach the maximum value or the minimum value because of an arithmetic operation which may have overflow or underflow.
Processor modes are either privileged or non-privileged mode. In a privileged mode, it is expected to have full read-write access to the CPSR. In a non-privileged mode only read access to the control field of CPSR but read-write access to the condition flags.

Implication of these privileged and non- privileged modes: In a privileged mode what can happen actually, in a privileged modes as you can change the control bits that means you can have a full read as well as write access of the control bits. You can actually change the processor mode, you can enable, disable the interrupts. So, this is a privileged operation. In a non- privileged mode, these control fields can be simply read but cannot be changed, but the condition flags which can change because of an arithmetic operation would normally reflect the status of the arithmetic operation and that should be remain write enable even in non-privileged modes.
So, typically you will find that when we talk about these kind of operations, a typically user program is expected to run in a non- privileged mode because in user program is normally not expected to change the control bits.

In privileged mode typically user will expect the OS or the supervisory cell to run. Since user is targeting for ARM for more sophisticated applications, typically there would be an OS running in an ARM based system under which user programs are expected to execute. The OS is typically expected to be running in privileged mode and user applications running in non- privileged mode.

In fact ARM has got 7 modes and these 7 modes can be now classified as privileged and non-privileged. In fact the privileged modes are abort, first interrupt request, supervisor system and another is undefined.

Supervisor mode is a state in which processor goes in after reset and generally it is a mode in which the OS kernel is supposed to operate because obviously when the processor is reset, the first thing that its excepted to execute is an operating system code and not user application of program. So, this is a supervisor mode in which the processor goes in when the reset happens. The other two privileged modes are system mode and undefined mode. In a system mode, is a special version of user mode that allows full read-write access of CPSR.

It is also targeted for supervisory applications; many of the OS routines can be configured to run in the system mode. The undefined mode, processer enters this undefined mode when it encounters an undefined instruction that means when user is trying to use an illegal op-code for undefined instruction, the instruction undefined for particular processor, and then it goes into an undefined. ARM has got 37 registers in all and typically 20 registers are hidden from program at different times.

So, they are not visible registers and they are actually called banked registers and this banked registers becomes available only when processors is in a particular mode. In fact processors modes other than system mode have a set of associated banked registers that are subset of these 16 registers that we have talked about in the user mode. These banked registers have one-to-one mapping with the user mode registers.

In the user mode there are the 16 data registers which are available, and the current program which is getting executed, that status would get reflected in the CPSR register. Now, if the processor goes into some other mode, FIQ is first interrupt; IRQ is interrupt request mode. Now, in an FIQ mode, what we will find that have got banked register r8, r9, r10, r11, r12 becoming available as well as r13 and r14.

It implies that if programmer is having an interrupt service routine which is operating in FIQ that is which is basically serving in the interrupt, in the first interrupt mode, it can use r8, r9 to r14 without bothering about what happens to the original content of these registers.

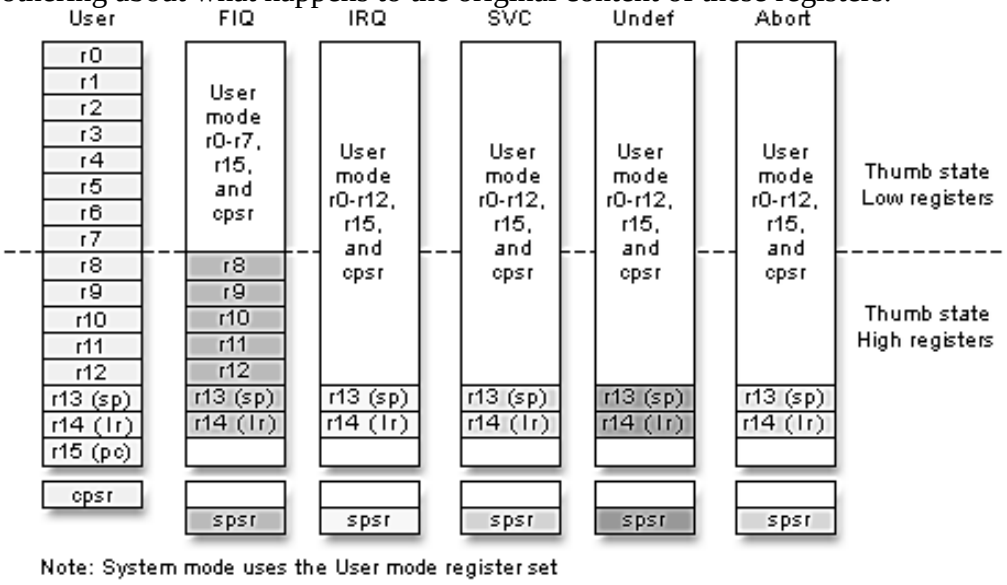


Fig 1.2 Register organization

Register organization: There are 37 total registers divided among seven different processor modes. Figure 1.2 shows the bank of registers visible in each mode. User mode, the only non-privileged mode, has the least number of total registers visible. It has no SPSR and limited access to the CPSR. FIQ and IRQ are the two interrupt modes of the CPU. Supervisor mode is the default mode of the processor on start up or reset. Undefined mode traps unknown or illegal instructions when they are passed through the pipeline. Abort mode traps illegal memory accesses as a result of fetching instructions or accessing data. Finally, system mode, which uses the user mode bank of registers, was introduced to provide an additional privileged mode when dealing with nested interrupts. Each additional mode offers unique registers that are available for use by exception handling routines. These additional registers are the minimum number of registers required to preserve the state of the processor, save the location in code, and switch between modes. FIQ mode, however, has an additional five banked registers to provide more flexibility and higher performance when handling critical interrupts. When the ARM core is in Thumb state, the registers banks are split into low and high register domains. The majority of instructions in Thumb state have a 3-bit register specifier. As a result, these instructions can only access the low registers in Thumb, R0 through R7. The high registers, R8 through R15, have more restricted use. Only a few instructions have access to these registers.

TDMI: T-D-M-I stands for
Thumb, which is a 16-bit instruction set extension to the 32-bit ARM architecture, referred as states of the processor.
"**D**" and "**I**" together comprise the on-chip debug facilities offered on all ARM cores.
These stand for the **D**ebug signals and Embedded **I**CE logic, respectively.
The "**M**" signifies the support for 64-bit results and an enhanced multiplier, resulting in higher performance. This multiplier is now standard on all ARMv4 architectures and above.

Thumb 16-bit Instructions:
With growing code and data size, memory contributes to the system cost. The need to reduce memory cost leads to smaller code size and the use of narrower memory. Therefore ARM developed a modified instruction set to give market-leading code density for compiled standard C language. There is also the problem of performance loss due to using a narrow memory path, such as a 16-bit memory path with a 32-bit processor. The processor must take two memory access cycles to fetch an instruction or read and write data. To address this issue, ARM introduced another set of reduced 16-bit instructions labeled Thumb, based on the standard ARM 32-bit instruction set. For Thumb to be used, the processor must go through a change of state from ARM to Thumb in order to begin executing 16-bit code. This is because the default state of the core is ARM. Therefore, every application must have code at boot up that is written in ARM. If the application code is to be compiled entirely for Thumb, then the segment of ARM boot code must change the state of the processor. Once this is done, 16-bit instructions are fetched seamlessly into the pipeline without any result. It is important to note that the architecture remains the same. The instruction set is actually a reduced set of the ARM instruction set and only the instructions are 16-bit; everything else in the core still operates as 32-bit. An application code compiled in Thumb is 30% smaller on average than the same code compiled in ARM and normally 30% faster when using narrow 16-bit memory systems.

1.2.3 ARM7TDMI Processor Core

Architecture version 4T:

1 3-stage pipeline
2 Unified bus architecture
3 32-bit ARM ISA plus 16-bit Thumb extension
4 Forward compatible code
5 Embedded ICE on-chip debug
6 Hard Macro cell IP
7 Smallest Die Size: 0.53 mm2 on 0.18 μm process
8 Up to 110 MHz on TSMC standard 0.18 μm
9 Industry leading 0.25 mW/MHz

The ARM7TDMI has a core based on the fourth version of the ARM architecture. This implementation uses a three stage pipeline - a standard fetch-decode-execute organization. It features a unified cache, as well as the Thumb extension permitting 32-bit and 16-bit operation. It is completely forward compatible, meaning that any code written for this core will be compatible with any new core releases, such as ARM9 or ARM10. This core also includes the on-chip debug extension discussed in the previous training module. The core is successful mainly because of the extremely small but high performance processor - slightly more than 70,000 transistors in all with extremely low power consumption.

The ARM7TDMI family is popular with applications where small die size, high performance, and low power consumption help reduce system costs, especially when the system does not require cache. Applications include cellular phones, MP3 players, and mass storage.

ARM7TDMI applications:

The standard ARM7TDMI processor core is a 'hard' macrocell, which is to say that it is delivered as a piece of physical layout, customized to the appropriate process technology. The ARM7TDMI-S is a synthesizable version of the ARM7TDMI, delivered as a high-level language module which can be synthesized using any suitable cell library in the target technology. It is therefore easier to port to a new process technology than is the hard macrocell.

The synthesis process supports a number of optional variations on the processor core functionality. These include:

a. Omitting the Embedded ICE cell;
b. Replacing the full 64-bit result multiplier with a smaller and simpler multiplier that supports only the ARM multiply instructions that produce a 32-bit result.

Either of these options will result in a smaller synthesized macrocell with reduced functionality. The full version is 50% larger and 50% less power-efficient than the hard macrocell.

The ARM7TDMI processor core has found many applications in systems with simple memory configurations, usually including a few kilobytes of simple on-chip RAM.

Example is a mobile telephone handset where the same chip usually incorporates sophisticated digital signal processing hardware and associated

1.3 Arduino:

1.3.1 Introduction: Arduino is an open-source hardware and software platform, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices. Its products are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of

Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form or as do-it-yourself (DIY) kits.
Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards or breadboards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers can be programmed using C and C++ programming languages. In addition to Using traditional compiler tool chains, The Arduino project provides an integrated development environment (IDE) based on the Processing language project.

Arduino UNO R3 board: The Arduino Uno R3 is a microcontroller board based on a removable, dual-inline-package (DIP) ATmega328 AVR microcontroller.

Features:
1. 14 Digital IO pins (pins 0–13) these can be inputs or outputs, which is specified by the sketch you create in the IDE.
2. 6 Analogue In pins (pins 0–5) These dedicated analogue input pins take analogue values (i.e., voltage readings from a sensor) and convert them into a number between 0 and 1023.
3. 6 Analogue output pins (pins 3, 5, 6, 9, 10, and 11) these are actually six of the digital pins that can be reprogrammed for analogue output using the sketch user can create in the IDE.
4. The board can be powered from user's computer's USB port, most USB chargers, or an AC adapter (9 volts recommended, 2.1mm barrel tip and center positive). If there is no power supply plugged into the power socket, the power will come from the USB board, but as soon as user can plug a power supply, the board will automatically use it. Programs can be loaded on to it from the easy-to-use Arduino computer program.

The Arduino has an extensive support community, which makes it a very easy way to get started working with embedded electronics. The R3 is the third, and latest, revision of the Arduino Uno shown in Fig 1.3.

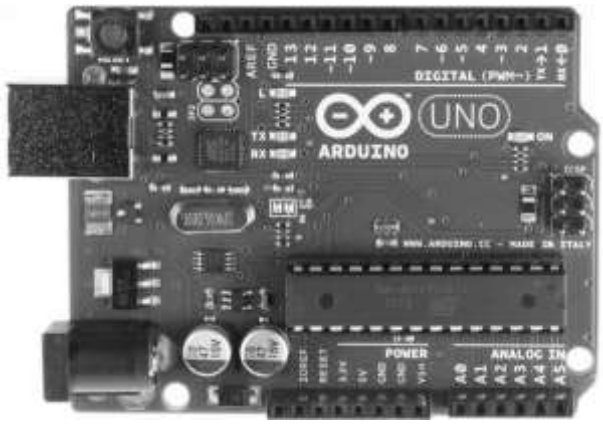


Fig 1.3Arduino R3 UNO Board

Table 1.1 Atmel chips used in Arduino boards

Chip Number	On-Chip Flash	RAM	I/O pins	Pin numbers	Arduino Board
ATmega16	16K	1K	14	28	Nano or Uno
ATmega328	32K	2K	14	28	Nano or Uno

ATmega328p	(p) stands for low (Pico) Power consumption other features same as 328				
ATmega2560	256K	4K	54	100	Mega

1.3.2 AVR Overview

The AVR is a modified Harvard architecture machine, where program and data are stored in separate physical memory systems that appear in different address spaces, but having the ability to read data items from program memory using special instructions

Basic families:

AVRs are generally classified into following:

Tiny AVR — The AT tiny series

1 0.5–16 kB program memory
2 6–32-pin package
3 Limited peripheral set

MegaAVR — The ATmega series

1 4–256 kB program memory
2 28–100-pin package
3 Extended instruction set (multiply instructions and instructions for handling larger program memories)
4 Extensive peripheral set

XMEGA — The ATXmega series

1 16–384 kB program memory
2 44–64–100-pin package (A4, A3, A1)
3 32-pin package : XMEGA-E (XMEGA8E5)
4 Extended performance features, such as DMA, "Event System", and cryptography support.
5 Extensive peripheral set with ADCs

Application-specific AVR

MegaAVRs with special features not found on the other members of the AVR family, such as LCD controller, USB controller, advanced PWM, CAN, etc.

FPSLIC (AVR with FPGA)

1 FPGA 5K to 40K gates
2 SRAM for the AVR program code, unlike all other AVRs
3 AVR core can run at up to 50 MHz

32-bit AVRs

In 2006 Atmel released microcontrollers based on the 32-bit AVR32 architecture. They include SIMD and DSP instructions, along with other audio- and video-processing features. This 32-bit family of devices is intended to compete with the ARM-based processors. The instruction set is similar to other RISC cores, but it is not compatible with the original AVR or any of the various ARM cores.

1.2.3 AVR ATmega328 Microcontroller Pin Diagram and High-Level Block Diagram:

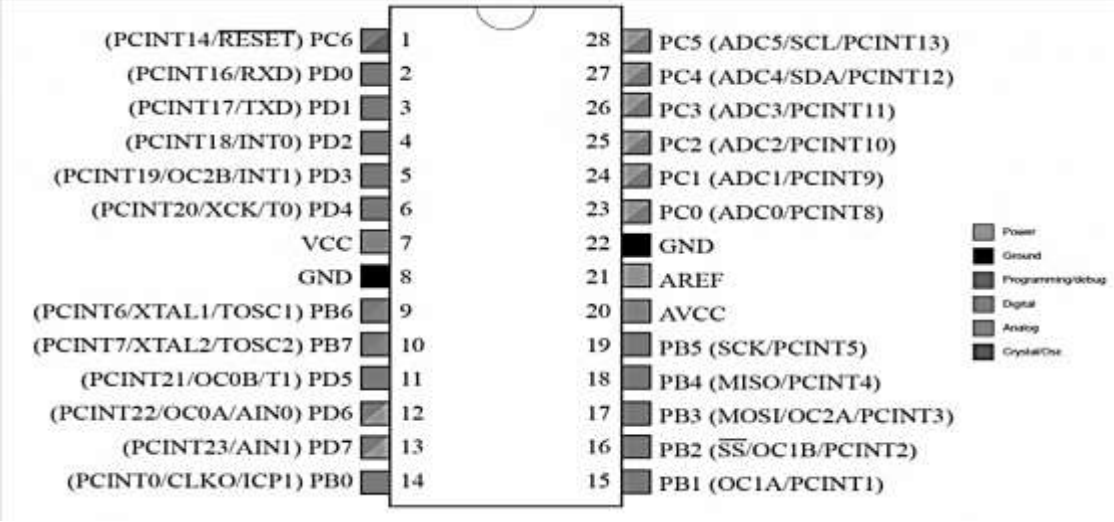


Fig 1.4 ATmega 328 Pin Diagram

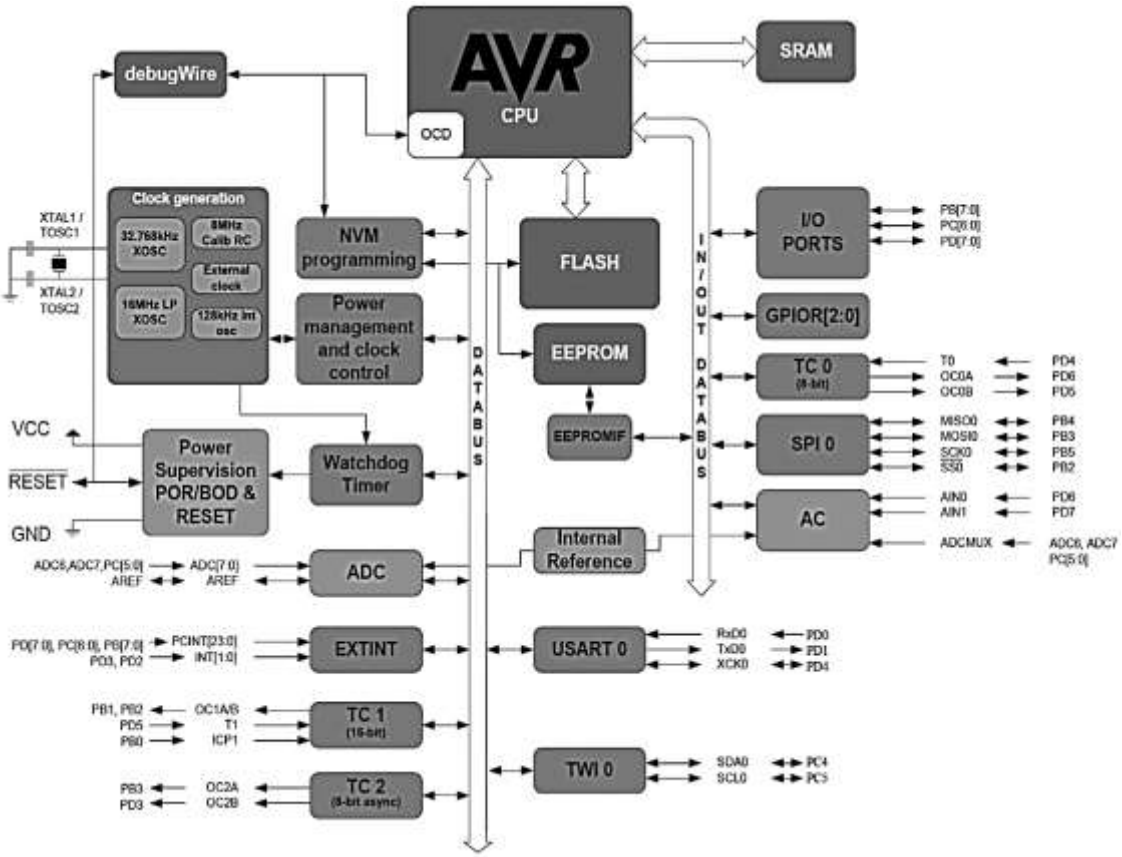


Fig 1.5 ATmega 328 block diagram

Device architecture: Flash, EEPROM, and SRAM are all integrated onto a single chip, removing the need for external memory in most applications. Some devices have a parallel external bus option to allow adding additional data memory or memory-mapped devices. Almost all devices (except the smallest TinyAVR chips) have serial interfaces, which can be used to connect larger serial EEPROMs or flash chips.

Program memory

Program instructions are stored in non-volatile flash memory. Although the MCUs are 8-bit, each instruction takes one or two 16-bit words.

The size of the program memory is usually indicated in the naming of the device itself (e.g., the ATmega64x line has 64 kB of flash, while the ATmega32x line has 32 kB).

There is no provision for off-chip program memory; all code executed by the AVR core must reside in the on-chip flash. However, this limitation does not apply to the AT94 FPSLIC AVR/FPGA chips.

Internal data memory

The data address space consists of the register file, I/O registers, and SRAM.

Internal registers

The AVRs have 32 single-byte registers and are classified as 8-bit RISC devices.

In the tinyAVR and megaAVR variants of the AVR architecture, the working registers are mapped in as the first 32 memory addresses (0000_{16}–$001F_{16}$), followed by 64 I/O registers (0020_{16}–$005F_{16}$). In devices with many peripherals, these registers are followed by 160 "extended I/O" registers, only accessible as memory-mapped I/O (0060_{16}–$00FF_{16}$).

Actual SRAM starts after these register sections, at address 0060_{16} or, in devices with "extended I/O", at 0100_{16}.

Even though there are separate addressing schemes and optimized opcodes for accessing the register file and the first 64 I/O registers, all can still be addressed and manipulated as if they were in SRAM.

The very smallest of the tinyAVR variants use a reduced architecture with only 16 registers (r0 through r15 are omitted) which are not addressable as memory locations. I/O memory begins at address 0000_{16}, followed by SRAM. In addition, these devices have slight deviations from the standard AVR instruction set. Most notably, the direct load/store instructions (LDS/STS) have been reduced from 2 words (32 bits) to 1 word (16 bits), limiting the total direct addressable memory (the sum of both I/O and SRAM) to 128 bytes. Conversely, the indirect load instruction's (LD) 16-bit address space is expanded to also include non-volatile memory such as Flash and configuration bits; therefore, the LPM instruction is unnecessary and omitted.

In the XMEGA variant, the working register file is not mapped into the data address space; as such, it is not possible to treat any of the XMEGA's working registers as though they were SRAM. Instead, the I/O registers are mapped into the data address space starting at the very beginning of the address space. Additionally, the amount of data address space dedicated to I/O registers has grown substantially to 4096 bytes (0000_{16}–$0FFF_{16}$). As with previous generations, however, the fast I/O manipulation instructions can only reach the first 64 I/O register locations (the first 32 locations for bitwise instructions). Following the I/O registers, the XMEGA series sets aside a 4096 byte range of the data address space, which can be used optionally for mapping the internal EEPROM to the data address space (1000_{16}–$1FFF_{16}$). The actual SRAM is located after these ranges, starting at 2000_{16}.

GPIO ports:

Each General Purpose Input Output (GPIO) port on a tiny or mega AVR drives up to eight pins and is controlled by three 8-bit registers: DDR*x*, PORT*x* and PIN*x*, where *x* is the port identifier.

1. DDR*x*: Data Direction Register configures the pins as either inputs or outputs.

2. PORT*x*: Output port register. Sets the output value on pins configured as outputs. Enables or disables the pull-up resistor on pins configured as inputs.
3. PIN*x*: Input register, used to read an input signal. On some devices (but not all, check the datasheet), this register can be used for pin toggling: writing a logic one to a PIN*x* bit toggles the corresponding bit in PORT*x*, irrespective of the setting of the DDR*x* bit.

AVRXmega have additional registers for push/pull, totem-pole and pull-up configurations.

EEPROM:

Almost all AVR microcontrollers have internal EEPROM for semi-permanent data storage. Like flash memory, EEPROM can maintain its contents when electrical power is removed.

In most variants of the AVR architecture, this internal EEPROM memory is not mapped into the MCU's addressable memory space. It can only be accessed the same way an external peripheral device is, using special pointer registers and read/write instructions, which makes EEPROM access much slower than other internal RAM.

However, some devices in the Secure AVR (AT90SC) family use a special EEPROM mapping to the data or program memory, depending on the configuration. The XMEGA family also allows the EEPROM to be mapped into the data address space.

Since the number of writes to EEPROM is not unlimited — Atmel specifies 100,000 write cycles in their datasheets — a well-designed EEPROM write routine should compare the contents of an EEPROM address with desired contents and only perform an actual write if the contents need to be changed.

Note that erase and write can be performed separately in many cases, byte-by-byte, which may also help prolong life when bits only need to be set to all 1s (erase) or selectively cleared to 0s (write).

Program execution:

Atmel's AVRs have a two-stage, single-level pipeline design. This means the next machine instruction is fetched as the current one is executing. Most instructions take just one or two clock cycles, making AVRs relatively fast among eight-bit microcontrollers.

The AVR processors were designed clock speed to be optimized with the efficient execution of compiled C code in mind and have several built-in pointers for the task.

MCU speed:

The AVR line can normally support clock speeds from 0 to 20 MHz, with some devices reaching 32 MHz Lower-powered operation usually requires a reduced clock speed. All recent (Tiny, Mega, and XMega, but not 90S) AVRs feature an on-chip oscillator, removing the need for external clocks or resonator circuitry. Some AVRs also have a system clock prescaler that can divide down the system clock by up to 1024. This prescaler can be reconfigured by software during run-time, allowing the.

Since all operations (excluding multiplication and 16-bit add/subtract) on registers R0–R31 are single-cycle, the AVR can achieve up to 1 MIPS per MHz, i.e. an 8 MHz processor can achieve up to 8 MIPS. Loads and stores to/from memory take two cycles, branching takes two cycles. Branches in the latest "3-byte PC" parts such as ATmega2560 are one cycle slower than on previous devices.

Development:

AVRs have a large following due to the free and inexpensive development tools available, including reasonably priced development boards and free development software. The AVRs are sold under various names that share the same basic core, but with different peripheral and memory combinations. Compatibility between chips in each family is fairly good, although I/O controller features may vary.

Features:

Current AVRs offer a wide range of features:

1. Multifunction, bi-directional general-purpose I/O ports with configurable, built-in pull-up resistors
2. Multiple internal oscillators, including RC oscillator without external parts
3. Internal, self-programmable instruction flash memory up to 256 kB (384 kB on XMega)
4. In-system programmable using serial/parallel low-voltage proprietary interfaces or JTAG
5. Optional boot code section with independent lock bits for protection
6. On-chip debugging (OCD) support through JTAG or debug WIRE on most devices
7. The JTAG signals (TMS, TDI, TDO, and TCK) are multiplexed on GPIOs. These pins can be configured to function as JTAG or GPIO depending on the setting of a fuse bit, which can be programmed via ISP. By default, AVRs with JTAG come with the JTAG interface enabled.
8. Debug WIRE uses the /RESET pin as a bi-directional communication channel to access on-chip debug circuitry. It is present on devices with lower pin counts, as it only requires one pin.
9. Internal data EEPROM up to 4 kB
10. Internal SRAM up to 16 kB (32 kB on XMega)
11. External 64 kB little endian data space on certain models, including the Mega8515 and Mega162.
12. The external data space is overlaid with the internal data space, such that the full 64 kB address space does not appear on the external bus and accesses to e.g. address 0100_{16} will access internal RAM, not the external bus.
13. In certain members of the XMega series, the external data space has been enhanced to support both SRAM and SDRAM. As well, the data addressing modes have been expanded to allow up to 16 MB of data memory to be directly addressed.
14. AVRs generally do not support executing code from external memory. Some ASSPs using the AVR core do support external program memory.
15. 8-bit and 16-bit timers
16. PWM output (some devices have an enhanced PWM peripheral which includes a dead-time generator)
17. Input capture that record a time stamp triggered by a signal edge
18. Analog comparator
19. 10 or 12-bit A/D converters, with multiplex of up to 16 channels
20. 12-bit D/A converters
21. A variety of serial interfaces, including
22. I²C compatible Two-Wire Interface (TWI)
23. Synchronous/asynchronous serial peripherals (UART/USART) (used with RS-232, RS-485, and more)
24. Serial Peripheral Interface Bus (SPI)
25. Universal Serial Interface (USI): a multi-purpose hardware communication module that can be used to implement an SPI, I^2C or UART interface.
26. Brownout detection
27. Watchdog timer (WDT)

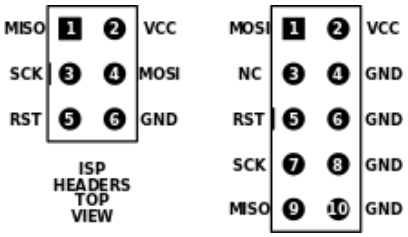
28. Multiple power-saving sleep modes
29. Lighting and motor control (PWM-specific) controller models
30. CAN controller support
31. USB controller support
32. Proper full-speed (12 Mbit/s) hardware & Hub controller with embedded AVR.
33. Also freely available low-speed (1.5 Mbit/s) (HID) bit banging software emulations
34. Ethernet controller support
35. LCD controller support
36. Low-voltage devices operating down to 1.8 V (to 0.7 V for parts with built-in DC–DC up converter)
37. Pico Power devices
38. DMA controllers and "event system" peripheral communication.
39. Fast cryptography support for AES and DES

1.3.4 Programming interfaces:

There are many means to load program code into an AVR chip. The method to program AVR chips varies from AVR family to family. Most of the methods described below use the RESET line to enter programming mode. In order to avoid the chip accidentally entering such mode, it is advised to connect a pull-up resistor between the RESET pin and the positive power supply.

ISP:

The in-system programming (ISP) programming method is functionally performed through SPI, plus some twiddling of the Reset line. As long as the SPI pins of the AVR are not connected to anything disruptive, the AVR chip can stay soldered on a PCB while reprogramming. All that is needed is a 6-pin connector as shown in Fig 1.6 (a) and programming adapter. This is the most common way to develop with an AVR. Also sometimes 10 pin connector is used as shown in Fig 1.6(b)



(a) 6 Pin (b) 10 pin

Fig 1.6 ISP header

The Atmel AVRISP MKII device connects to a computer's USB port and performs in-system programming using Atmel's software.

AVRDUDE (AVR Downloader/UploadEr) runs on Linux, FreeBSD, Windows, and Mac OS X, and supports a variety of in-system programming hardware, including Atmel AVRISP MKII, Atmel JTAG ICE, older Atmel serial-port based programmers, and various third-party and "do-it-yourself" programmers.

Bootloader:

Microcontrollers are usually programmed through a programmer unless you have a piece of firmware in your microcontroller that allows installing new firmware without the need of an external programmer. This is called a boot loader.

Most AVR models can reserve a boot loader region, 256 Byte to 4 KB, where re-programming code can reside. At reset, the bootloader runs first and does some user-programmed determination whether to re-program or to jump to the main application. The code can re-program through any interface available, or it could read an encrypted binary through an Ethernet adapter like PXE.

OptibootBootloader is a Small and Fast Bootloader used for Arduino and other Atmel AVR chips.

ROM:
AVRs are available with a factory mask-ROM rather than flash for program memory. Because of the large up-front cost and minimum order quantity, a mask-ROM is only cost-effective for high-production runs.

Debugging interfaces:
The AVR offers several options for debugging, mostly involving on-chip debugging while the chip is in the target system.

Debug WIRE:
Debug WIRE is Atmel's solution for providing on-chip debug capabilities via a single microcontroller pin. It is particularly useful for lower pin count parts which cannot provide the four "spare" pins needed for JTAG. The JTAGICE MKII and the AVR Dragon support debug WIRE. Debug WIRE was developed after the original JTAGICE release, and now clones support it.

JTAG:
The Joint Test Action Group (JTAG) feature provides access to on-chip debugging functionality while the chip is running in the target system. JTAG allows accessing internal memory and registers, setting breakpoints on code, and single-stepping execution to observe system behavior.

1.4 Arduino IDE:
1.4.1 Arduino IDE: Arduino IDE, the piece of software you run on your computer. You use the IDE to create a sketch (a little computer program) that you upload to the Arduino board. The sketch tells the board what to do.

Features:
1. **Cross-platform** - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
2. **Simple, clear programming environment** - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.
3. **Open source and extensible software** - The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.

Sketch:
A *sketch* is a program written with the Arduino IDE. Sketches are saved on the development computer as text files with the file extension **.ino**. Arduino Software (IDE) pre-1.0 saved sketches with the extension **.pde**.
The programming cycle on Arduino is basically as follows:

» Plug your board into a USB port on your computer.
» Write a sketch that will bring the board to life.
» Upload this sketch to the board through the USB connection and wait a couple of seconds for the board to restart.
» The board executes the sketch that you wrote.

1.4.2 Arduino C/C++ program functions:

- `setup()`: This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch. It is analogous to the function `main ()`.
- `loop()`: After `setup()` function exits (ends), the `loop()` function is executed repeatedly in the main program. It controls the board until the board is powered off or is reset. It is analogous to the function `while(1)`

Special symbols
Arduino includes a number of symbols to delineate lines of code, comments, and blocks of code.
; (semicolon) every instruction (line of code) is terminated by a semicolon. This syntax lets you format the code freely. You could even put two instructions on the same line, as long as you separate them with a semicolon. (However, this would make the code harder to read.)
Example:
delay (100);
{} (curly braces)
This is used to mark blocks of code. For example, when you write code for the *loop()* function, you have to use curly braces before and after the code.

Example:
void loop() {
Serial.println("MSBTE");
}

C/Arduino:
These are portions of text ignored by the Arduino processor, but are extremely useful to remind yourself (or others) of what a piece of code does. There are two styles of comments in Arduino:
// single-line: this text is ignored until the end of the line
/* multiple-line: you can write a comments in here*/

Constants:
Arduino includes a set of predefined keywords with special values. HIGH and LOW are used, for example, when you want to turn on or off an Arduino pin. INPUT and OUTPUT are used to set a specific pin to be either and input or an output true and false indicate exactly what their names suggest: the truth or false hood of a condition or expression.

Variables:

Variables are named areas of the Arduino's memory where you cans tore data that you can use and manipulate in your sketch. As the name suggests, they can be changed as many times as you like. Because Arduino is a very simple processor, when you declare a variable you have to specify its type. This means telling the processor the size of the value you want to store.

Here are the *datatype* that are available: Boolean Can has one of two values: true or false.

Char holds a single character, such as A. Like any computer, Arduino stores it as a number, even though you see text. When chars are used to store numbers, they can hold values from –128 to 127.

Control Structures:

Arduino includes keywords for controlling the logical flow of your sketch.

if . . . else

This structure makes decisions in your program. *If* must be followed by a question specified as an expression contained in parentheses. If the expression is true, whatever follows will be executed. If it's false, the block of code following else will be executed. It's possible to use just *if* without providing an *else* clause.

Example:

```
if (val == 1) {
digitalWrite(LED,HIGH);
}
```

for

Lets you repeat a block of code a specified number of times.

Example:

```
for (int i = 0; i < 10; i++) {
Serial.print("MSBTE");
}
```

switch case

The *if* statement is like a fork in the road for your program. *switch case* is like a massive roundabout. It lets your program take a variety of directions depending on the value of a variable. It's quite useful to keep your code tidy as it replaces long lists of *if* statements.

Example:

```
switch (sensorValue) {
case 23:
digitalWrite(13,HIGH);
break;
case 46:
digitalWrite(12,HIGH);
break;
default: // if nothing matches this is executed
digitalWrite(12,LOW);
digitalWrite(13,LOW);
}
```

while

Similar to *if*, this executes a block of code while a certain condition is true.

Example:

```
// blink LED while sensor is below 512
sensorValue = analogRead(1);
```

```
while (sensorValue< 512) {
digitalWrite(13,HIGH);
delay(100);
digitalWrite(13,HIGH);
delay(100);
sensorValue = analogRead(1);
}
```

do . . . while

Just like *while*, except that the code is run just before the the condition is evaluated. This structure is used when you want the code inside your block to run at least once before you check the condition.

Example:

```
do {
digitalWrite(13,HIGH);
delay(100);
digitalWrite(13,HIGH);
delay(100);
sensorValue = analogRead(1);
} while (sensorValue< 512);
```

Arithmetic and formulas:

You can use Arduino to make complex calculations using a special syntax.+ and – work like you've learned in school, and multiplication is represented with an * and division with a /.

There is an additional operator called "modulo" (%), which returns the remainder of an integer division. You can use as many levels of parentheses as necessary to group expressions. Contrary to what you might have learned in school, square brackets and curly brackets are reserved for other purposes (array indexes and blocks, respectively).

Examples:

```
a = 2 + 2;
light = ((12 * sensorValue) - 5 ) / 2;
remainder = 3 % 2; // returns 2 because 3 / 2 has remainder 1
```

Comparison Operators:

When you specify conditions or tests for *if*, *while*, and *for* statements, these are the operators you can use:

== equal to
!= not equal to
<less than
>greater than
<= less than or equal to
>= greater than or equal to

Boolean Operators:

These are used when you want to combine multiple conditions. For example, if you want to check whether the value coming from a sensor is between 5and 10, you would write:

```
if ((sensor => 5) && (sensor <=10))
```

There are three operators: and, represented with &&; or, represented with ||; and finally not, represented with!.

Input and output functions:

Arduino includes functions for handling input and output. User have already seen some of these in the example programs throughout the book.

pinMode(pin, mode)

ReconFigures a digital pin to behave either as an input or an output.

Example:

pinMode(7,INPUT); // turns pin 7 into an input

digitalWrite(pin, value)

Turns a digital pin either on or off. Pins must be explicitly made into anoutput using *pinMode*before *digitalWrite*will have any effect.

Example:

digitalWrite(8,HIGH); // turns on digital pin 8

intdigitalRead(pin)

Reads the state of an input pin, returns HIGH if the pin senses somevoltage or LOW if there is no voltage applied.

Example:

val = digitalRead(7); // reads pin 7 into val

intanalogRead(pin)

Reads the voltage applied to an analog input pin and returns a numberbetween 0 and 1023 that represents the voltages between 0 and 5 V.

Example:

val = analogRead(0); // reads analog input 0 into val

analogWrite(pin, value)

Changes the PWM rate on one of the pins marked PWM.*pin*may be 11,10,9, 6, 5, 3. *Value* may be a number between 0 and 255 that represents the scale between 0 and 5 V output voltage.

Example:

analogWrite(9,128); // Dim an LED on pin 9 to 50%

shiftOut(dataPin, clockPin, bitOrder, value)

Sends data to a *shift register*, devices that are used to expand the number of digital outputs. This protocol uses one pin for data and one for clock.*bitOrder*indicates the ordering of bytes (least significant or most significant) and *value* is the actual byte to be sent out.

Example:

shiftOut(dataPin, clockPin, LSBFIRST, 255);

unsigned long pulseIn(pin, value)

Measures the duration of a pulse coming in on one of the digital inputs. This is useful, for example, to read some infrared sensors or accelerometers that output their value as pulses of changing duration.

Example:

time = pulsein(7,HIGH); // measures the time the next

// pulse stays high

Time functions:
Arduino includes functions for measuring elapsed time and also for pausing the sketch.
unsigned long millis()
Returns the number of milliseconds that have passed since the sketch started.
Example:
duration = millis()-lastTime; // computes time elapsed since "lastTime"
delay(ms)
Pauses the program for the amount of milliseconds specified.

Example:
delay(500); // stops the program for half a second
delayMicroseconds(us)
Pauses the program for the given amount of microseconds.

Example:
delayMicroseconds(1000); // waits for 1 millisecond

Table 1.2 Summary of Arduino Functions Used for I/O

Function	**Description**	**Syntax**
pinMode();	Designate the pin as OUTPUT or INPUT	pinMode(pin#, mode);
digitalWrite();	Write a LOW or HIGH to a pin	digitalWrite(pin#, value);
digitalRead();	Read the status of pin	digitalRead(pin#);
delay();	Create a delay in millisecond	delay(ms);

1.5 Arduino Interfacing:
LED Interfacing:

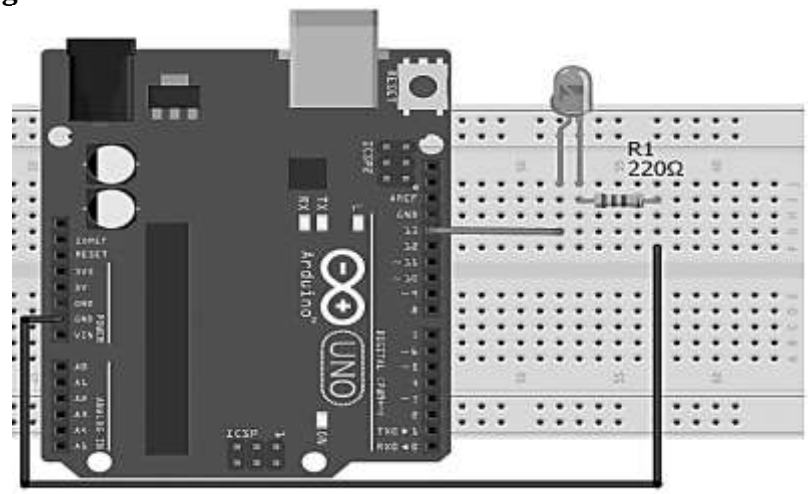


Fig 1.7 Interfacing of LED to Arduino board

LED (Red) attached to pin 13 on an Arduino compatible board with ground as shown in Fig 1.7. Most Arduino boards contain a light-emitting diode (LED) and a current limiting resistor connected between pin 13 and ground, which is a convenient feature for many tests and program functions.

Functions `pinMode()`, `digitalWrite()`, and `delay()`, which are provided by the internal libraries included in the IDE environment.
The following program will blink LED with certain delay.

```
#define LED_PIN 13                  // Pin number attached to LED.

voidsetup(){
pinMode(LED_PIN,OUTPUT);// ConFigure pin 13 to be a digital output.
}
voidloop(){
digitalWrite(LED_PIN,HIGH);// Turn on the LED.
delay(1000);// Wait 1 second (1000 milliseconds).
digitalWrite(LED_PIN,LOW);// Turn off the LED.
delay(1000);// Wait 1 second.
}
```

Relay Interfacing:
Relay interfacing to Arduino Board is shown in Fig1.9

```
//Relay is turned on for 5 seconds and then off.

void setup()
{
// Initialise the Arduino data pins for OUTPUT
  pinMode(RELAY, OUTPUT);
}
  void loop()
{
   digitalWrite(RELAY,LOW);           // Turns ON Relays
   delay(5000);                       // Wait 5 seconds
   digitalWrite(RELAY,HIGH);          // Turns Relay Off
}
```

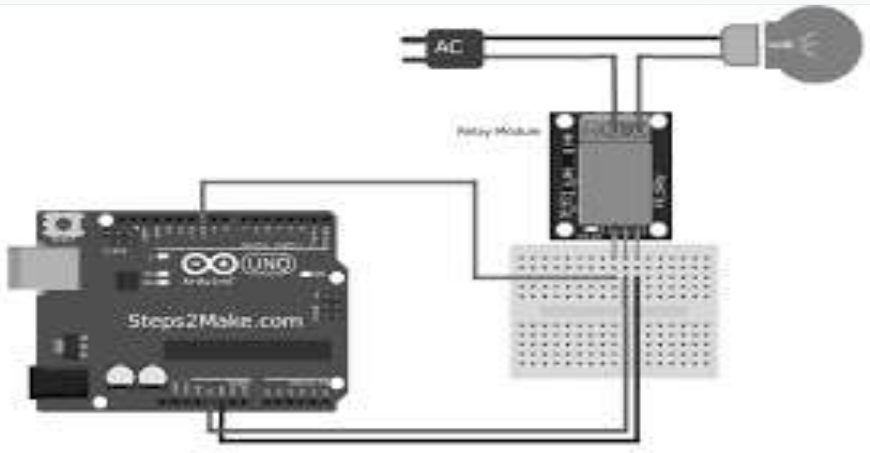


Fig 1.8 Interfacing of Relay to Arduino board

DC motor Interfacing:
DC motor interfacing to Arduino Board is shown in Fig 1.9

A direct current, or DC, motor is the most common type of motor. DC motors normally have just two leads, one positive and one negative. If you connect these two leads directly to a battery, the motor will rotate. If you switch the leads, the motor will rotate in the opposite direction.

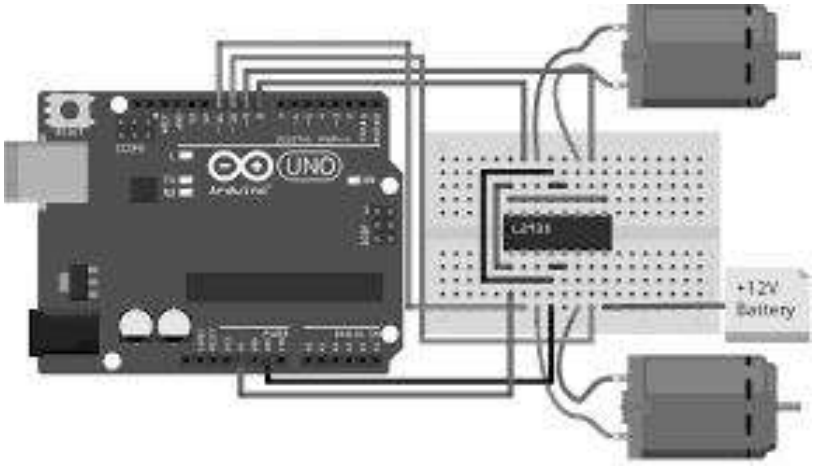


Fig 1.9 Interfacing of DC motor to Arduino board

To control the direction of the spin of DC motor, without changing the way that the leads are connected, you can use a circuit called an H-Bridge. An H bridge is an electronic circuit that can drive the motor in both directions. H-bridges are used in many different applications, one of the most common being to control motors in robots. It is called an H-bridge because it uses four transistors connected in such a way that the schematic diagram looks like an "H."

Since user will be controlling only one motor in this tutorial, we will connect the Arduino to IN1 (pin 5), IN2 (pin 7), and Enable1 (pin 6) of the L298 IC. Pins 5 and 7 are digital, i.e. ON or OFF inputs, while pin 6 needs a pulse-width modulated (PWM) signal to control the motor speed. IN1 pin of the L298 IC is connected to pin 8 of the Arduino while IN2 is connected to pin 9. These two digital pins of Arduino control the direction of the motor. The EN A pin of IC is connected to the PWM pin 2 of Arduino. This will control the speed of the motor.

1. Connect 5V and ground of the IC to 5V and ground of Arduino.
2. Connect the motor to pins 2 and 3 of the IC.
3. Connect IN1 of the IC to pin 8 of Arduino.
4. Connect IN2 of the IC to pin 9 of Arduino.
5. Connect EN1 of IC to pin 2 of Arduino.
6. Connect SENS A pin of IC to the ground.
7. Connect the Arduino using Arduino USB cable and upload the program to the Arduino using Arduino IDE software or Arduino Web Editor.
8. Provide power to the Arduino board using power supply, battery or USB cable.

The motor should now run first in the clockwise (CW) direction for 3 seconds and then counter-clockwise (CCW) for 3 seconds.

Code:

```
constintpwm = 2 ; //initializing pin 2 as pwm
constint in_1 = 8 ;
constint in_2 = 9 ;
 //For providing logic to L298 IC to choose the direction of the DC motor
void setup()
{
```

```
pinMode(pwm,OUTPUT) ; //we have to set PWM pin as output
pinMode(in_1,OUTPUT) ; //Logic pins are also set as output
pinMode(in_2,OUTPUT) ;
}
void loop()
 {
//For Clock wise motion , in_1 = High , in_2 = Low
digitalWrite(in_1,HIGH) ;
digitalWrite(in_2,LOW) ;
analogWrite(pwm,255) ;
 /*setting pwm of the motor to 255 we can change the speed of rotaion by
chaningpwm input but we are only using arduino so we are using higest value
to driver the motor */
//Clockwise for 3 secs
delay(3000) ;
//For brake
digitalWrite(in_1,HIGH) ;
digitalWrite(in_2,HIGH) ;
delay(1000) ;
//For Anti Clock-wise motion - IN_1 = LOW , IN_2 = HIGH
digitalWrite(in_1,LOW) ;
digitalWrite(in_2,HIGH) ;
delay(3000) ;
//For brake
digitalWrite(in_1,HIGH) ;
digitalWrite(in_2,HIGH) ;
delay(1000) ; }
```

1.6 Graphics Processing Unit (GPU):

Introduction:

The graphics processing unit (GPU) has become an integral part of today's mainstream computing systems. Over the past six years, there has been a marked increase in the capabilities of GPUs.

Need of GPU:

A graphics processing unit (GPU) is a microprocessor that is designed especially for processing 3D graphics. GPU is designed to provide additional computational power that is customized specifically to perform the 3D task. GPU is the heart of modern graphics cards; it relieves the CPU (Central Processing Unit) from graphics processing load. GPU is a dedicated graphic processor with memory. GPU is used to manipulate and display computer graphics. GPU is used to accelerate the creation of images in a frame buffer used to a display on a device. GPU is a specialized processor designed to accelerate graphics rendering. GPU's can process many PCs of data simultaneously making them useful for machine learning, video editing and gaming application. GPU's may be integrated in Computer CPU or offered as a discrete hardwired unit. GPU use parallel processing.

Features:

1. GPU use multiprocessing. It can handle large amount of data in many threads, i.e. GPU is multi-threaded processor.
2. GPUs are capable of performing operations like floating point arithmetic's and vector point operations. GPU have larger number of ALU's compared to those of CPU's.
3. It is capable of graphics rendering for display of electronics device.
4. It can perform rapid mathematical calculations so used for texture mapping, graphics & images.

5. GPUs accelerate rendering of real time 2D and 3D, MPEG decoding applications.
6. Applications support for high intensity graphic software such as Auto CAD.
7. GPU's can perform calculations in parallel so can-do real-time operations.
8. Support for YUV (Y-Luminance or Brightness, U-Blue projection, V-Red Projection) color space.
9. Hardware overlays.
10. Performance of GPU's are measured in FLOPS i.e. Floating point operations per seconds to create more interesting visual effects and realistic scenes with advance lighting and shadowing techniques.

Architecture of GPU:

A single GPU device consists of multiple Processor Clusters (PC) that contain multiple Streaming Multiprocessors (SM) as shown in Fig 1.10. Each SM accommodates a layer-1 instruction cache layer with its associated cores. Typically, one SM uses a dedicated layer-1 cache and a shared layer-2 cache before pulling data from global GDDRAM (Graphics DDR SDRAM) memory. Its architecture is tolerant of memory latency. Latency is a measure of speed of memory.

Compared to a CPU, a GPU works with fewer, and relatively small, memory cache layers. As GPU has more transistors dedicated to computation meaning it cares less how long it takes the retrieve data from memory. The potential memory access 'latency' is masked as long as the GPU has enough computations at hand, keeping it busy.

A GPU is optimized for data parallel throughput computations.

Looking at the numbers of cores it quickly shows user the possibilities on parallelism that is it is capable of. If one device contains 80 SM's, each containing 64 cores making a total of 5120 cores!

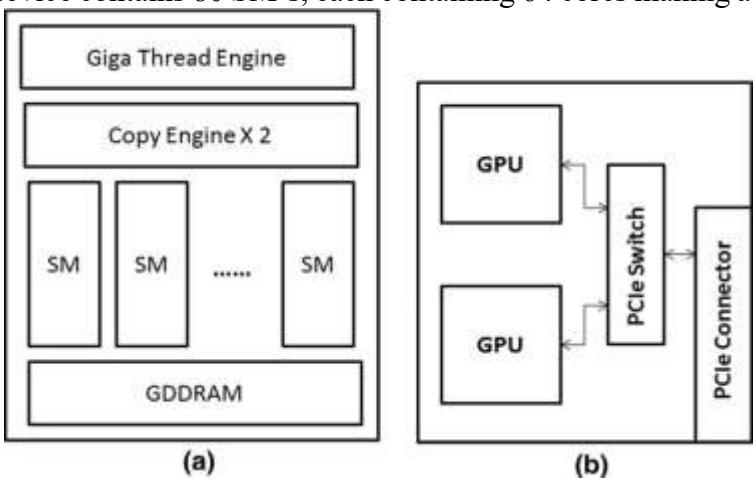


Fig 1.10 Block diagram of GPU

Tasks aren't scheduled to individual cores, but to processor clusters and SM's. That's how it's able to process in parallel. Now combine this powerful hardware device with a programming framework so applications can fully utilize the computing power of a GPU.

High Performance Computing (HPC) is the use of parallel processing for running advanced application programs efficiently, reliably and quickly.

This is exactly why GPU's are a perfect fit for HPC workloads. Workloads can greatly benefit from using GPU's as it enables them to have massive increases in throughput.

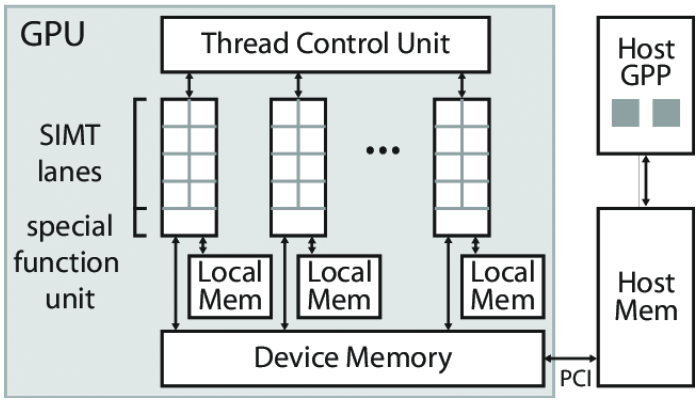


Fig a **Fig b**

Fig 1.11 Basic GPU Architecture

Working of GPU:

Memory in Graphics controller circuits is integrated into the CPU chip as shown in Fig 1.11 a. The memory controller is connected to the DRAM via the memory bus. The Graphic controller GPU is connected via different high-speed bus called as PCI express Fig 1.11 b. These days modern PC's include an expansion card called a graphics card or adapter. It is specifically designed to handle graphics operations freeing the CPU for other tasks.

A graphics card has its own memory to store the data that is currently data processing and act as a buffer between CPU and display. This memory is called as VRAM or video RAM as the frame buffer. The amount of memory on graphic card is typically 8 to 10 Giga Bytes. It's similar to DRAM used in Computer main memory but it's highly optimized for Bandwidth so it's much faster. It has wider memory bus and more channels than regular DRAM. It also uses less power and generates less heat.

Through external connections Graphics card is connected to a monitor these may include interfaces for HDMI, DVI (display video only) and display port.
The most important unit of graphics card is GPU. Often the card is referred as GPU. To keep GPU cool during operation cooling fans are fitted on the top of card.

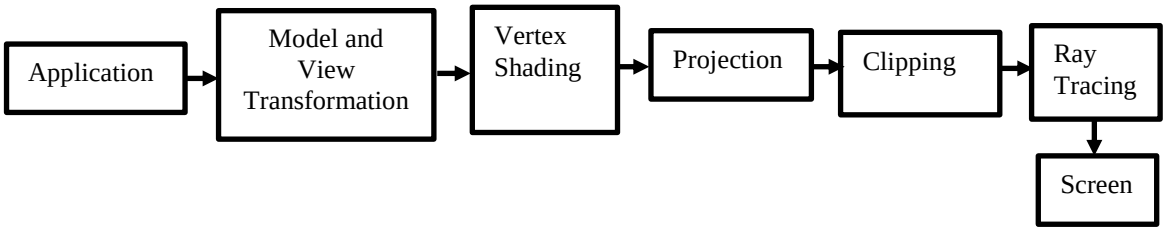


Fig 1.12. Graphics pipeline

GPU is designed primarily to handle graphics pipeline which is also known as rendering pipeline. The Graphics pipeline is shown in Fig 1.12. The graphics pipeline is a series of stages that take a huge amount of numerical data about a 3D world and convert it into a 2D image that can be displayed on a flat screen namely color information for each and every pixel. When it comes to interactive computer games and virtual reality this involves millions of calculations every second. Because the scene may be changing at an incredible rate in response to the inputs from the players. This is called real time rendering. The majority of calculations involve are geometry of one kind or another. In a 3D scene each model is made up of polygons usually triangles, with 3 points known

as vertices. The coordinates of the millions of vertices in a 3D scene are stored as vectors. Matrix arithmetic's is used to manipulate these vectors.

Object Moving, rotating, resizing, shading, smoothing, projecting and ray tracing are the work of modern GPU. Compared to CPU, a GPU is designed to perform very few operations but very quickly indeed. A GPU therefore consists of 100's of light weight cores, called as shader cores. Each working on its own share of the millions of data streams being processed in parallel. Because many of the cores are performing same operations simultaneously but with different data, instruction decoding can be done for cluster of core all at once hence a cluster of core can share one control unit, this is known as the single instruction multiple data (SIMD). If anyone core is held up because it is waiting for data then it can very quickly switch to another instruction stream to maximize the throughput.
Like CPU, the GPU also have various levels of Cache memory. A cluster of cores will share a level 1 cache and all of the cores will share level 2 cache.

Some GPUs have cores and cache memory dedicated to specific task in graphics pipeline for example for applying materials and texture to a model.

The GPU main role is to render images, however, to do this, it requires space to hold the information which is required to make the full completed image, therefore it uses RAM (Random Access Memory) to store this data. The data consists of each pixel associated with the image, as well as its color and its location on the screen.

A pixel can be defined as a physical point in a raster image, which is a dot matrix data structure that represents a rectangular grid of pixels (points of color).The RAM can also hold completed images until it's time for them to be displayed, which is called as a frame buffer.

In order for the monitor to display the image in analogue form, the RAM will be directly connected to a DAC (digital-to-analogue convertor), which will translate the image into an analogue signal that the monitor can use. Some systems have more than one RAM-DAC, which can improve performance and support the use of more than one monitor.

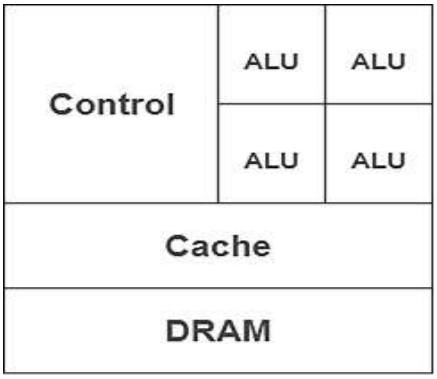
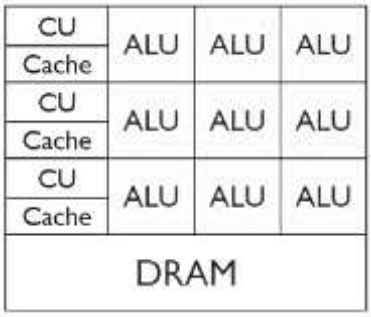
1) **Frame rate:** A good measurement of how well a GPU works is the frame rate, which is measured in frames per second (FPS). This frame rate dictates how many completed images can be rendered on display per second.
2) To compare, the human eye can process around 25 frames per second, however fast action games must process at least 60 frames per second to provide a smooth game scroll and flow.
3) **Texture Mapping:** Number of texture mapping units in a design dictates its maximum textural output and how fast it can "address" and "map" the textures onto the objects.
4) **Render Outputs:** Render outputs means the outputs of GPU is all assembled into an image to be displayed on the system i.e. a phone, TV.

Types of GPUs: There are two types of GPU: Integrated and Discrete.

1) Integrated/Embedded GPU: The term-integrated graphics refers to a computer where the GPU is built on the same chip as the CPU (on the same "die"). As integrated GPU has benefits such as: energy efficiency, small in size, and less costly than the discrete GPU. Integrated GPUs utilize the system RAM, rather than having their own RAM like discrete GPUs. The integrated GPUs don't generate much heat nor consume as much power as discrete GPUs, they also cost less to purchase.

2) **Discrete GPU:** A discrete GPU is a dedicated graphics card, which is completely separate from the CPU. The graphics card encapsulates the GPU, which can be used to process elements and instructions separately from the CPU. A discrete graphic card comes with their own form of video RAM (VRAM, video random access memory), this attribute gives the discrete GPU quick access to image data. This graphics card generated a lot of heat, hence require a healthy power supply.

Table 1.4 Comparison of CPU and GPU Architecture

Sr. No.	CPU	GPU
1.	CPU consumes or needs more memory than GPU.	While it consumes or requires less memory than CPU.
2.	The speed of CPU is less than GPU's speed.	While GPU is faster than CPU's speed.
3.	The speed of CPU is less than GPU's speed.	While it contains more weak cores.
4.	CPU is suitable for serial instruction processing.	While GPU is suitable for parallel instruction processing.
5.	CPU emphasis on low latency.	While GPU emphasis on high throughput.
6.	In CPU there is common Cache and Control Unit present for cores. 	In GPU there are separate Cache and Control Unit present each individual cores. 

GPU applications:

A Graphics Processor Unit (GPU) is mostly known for the hardware device used when running applications that have heavy graphics, i.e. 3D modelling software or VDI, Virtual Desktop infrastructures. In the consumer market, a GPU is mostly used to accelerate gaming graphics. Today, GPGPU's (General Purpose GPU) are the choice of hardware to accelerate computational workloads in modern High-Performance Computing (HPC).

HPC in itself is the platform serving workloads like Machine Learning (ML), Deep Learning (DL), and Artificial Intelligence (AI). Using a GPGPU is not only about ML computations that require image recognition anymore. As calculations on tabular data is also required in healthcare, insurance, financial industry verticals etc.

GPUs are used in embedded systems, mobile phones, personal computers, workstations, and consoles. While Graphics Processing Units (GPUs) are commonly used to render computer graphics for video games, there are a number of uses for GPUs other than gaming. GPUs can be used for video editing, 3D graphics rendering, and much more. With a high processing throughput, GPUs can process more data than their Central Processing Unit (CPU) counterparts, making them uniquely suited for highly demanding tasks such as machine learning and cryptocurrency mining.

Applications of GPUs other than gaming are as follows:

1. **Video Editing:** Modern graphics cards support software used for video encoding, a process by which video data is prepared and formatted prior to playback. Video encoding is a resource intensive process that can take a prohibitively long amount of time to complete if only a CPU is used. With a GPU, video encoding can be done relatively quickly without overburdening system resources. With video formats supporting higher and higher resolutions, an adequate GPU is an essential tool for the modern video editor.

2. **3D Graphics Rendering:** 3D graphics are commonly used for video games, now-a-days increasingly used in other forms of media such as films, television shows, commercials, and digital art displays. Similar to video editing, the creation of high-resolution 3D graphics can be a resource intensive and time-consuming process, hence an adequate GPU is an essential.

   Modern film studios often depend on GPU technology to generate ever increasingly lifelike and dynamic computer images, making the hardware a vital part of the movie-making process. Digital artists employ GPU-enabled computers to create abstract displays that could not be created in physical space, allowing them to create works of art unlike anything seen before. With the proper combination of hardware performance and artistic vision, GPUs can be a powerful creative resource for any media operation.

3. **Machine Learning:** Modern GPUs are used in machine learning. Machine learning is a form of data analysis that automates the construction of analytic models. Machine learning involves systems that use data to learn, identify patterns and make decisions independent from human input. Due to the highly resource-intensive nature of machine learning, GPUs are an essential component.
   Considered a building block of artificial intelligence, machine learning is a computationally demanding process as it necessitates the input of large volumes of data for analysis. This analysis is performed by software known as machine learning algorithms. These algorithms then build models based on what is called training data or sample data**.** The resulting models are then used to form predictions or make decisions without any need for human input. This methodology has seen widespread implementation in fields ranging from medicine to email filtering, making machine learning a crucial yet frequently overlooked aspect of modern data infrastructures.

4. **GPU Technology for Unmanned Applications:** General Purpose GPU (GPGPUs) may be installed on drones and robots to facilitate SIGINT (signals intelligence) and ISR (intelligence, surveillance and reconnaissance) functions such as image recognition and classification. Typical example of GPGPU Card for Drone image processing is as shown in Fig 1.13. This allows unmanned vehicles to perform a range of autonomous tasks such as target following, autonomous navigation, and detect-and-avoid (DAA). GPGPU computing can also handle the large amounts of data intake and processing required for drone swarming and formation flight.

Fig 1.13Condor-GR5-RTX5000 3U VPX GPGPU Card for Drone image processing by EIZO

General purpose GPUs may also be used to provide drones and robots with the ability to navigate in GPS- and GNSS-denied environments. Algorithms such as SLAM (simultaneous localization and mapping) can allow vehicles to map and travel autonomously within their environment by making use of data from sensors such as LiDAR and cameras.

UGVs (unmanned ground vehicles) can make use of GPGPU processing not only for autonomous navigation and obstacle avoidance, but also for specialized tasks such as IED (improvised explosive device) recognition. Similarly, USVs (unmanned surface vessels) can use it for missions such as mine hunting.

Suggested References:

Sr. No	Keyword	QR code	Weblink
1	Advanced Processor Technology		https://slideplayer.com/slide/8290583/
2	ARM Processor		https://en.wikipedia.org/wiki/ARM_architecture_family
3	ARM processor		https://www.youtube.com/watch?v=4VRtujwa_b8
4	Arduino Guide		https://www.arduino.cc/en/Guide
5	GPU Architectures		https://courses.cs.washington.edu/courses/cse471/13sp/lectures/GPUsStudents.pdf

Sr. No	Keyword	QR code	Weblink
6	GPU Architectures		https://core.vmware.com/resource/exploring-gpu-architecture
7	GPU Applications		https://www.inmotionhosting.com/support/product-guides/private-cloud/additional-resources/uses-for-gpus-other-than-gaming/

Sample Question:

Sr. No.	Question
1.	_____ is also known as Visual Processing Unit. A. Central Processing Unit B. Graphics Processing Unit. C. Floating Point Coprocessor D. Digital Signal Processor
2.	ARM stands for _____ A. Advanced Rate Machines B. Advanced RISC Machines C. Artificial Running Machines D. Aviary Running Machines
3.	The GPIO stand for_____. A. General Purpose Inner Outer Propeller B. General Purpose Input Output Processor C. General Purpose Interested Old People D. General Purpose Input Output Pins
4.	ALU of ARM7TDMI is_____bit. A. 8 B. 32 C. 64 D. 10
5.	____ number of digital pins are there on the UNO board. A. 14 B. 12 C. 16 D. 20
6.	The function of link register in ARM7TDMI is_____ A. To store return address whenever subroutine is called B. To store address of I/O device C. Multiplex the address and data lines D. Perform addition.
7.	The function of register r15 in ARM7TDMI is as A. Program Counter(PC) B. Current Program Status Register(CPSR) C. Saved Program Status Register (SPSR) D. Arithmetic Logic Unit (ALU)

Sr. No.	Question
8.	In the ARM Nomenclature **ARMxTDMI,** D and M signifies A. Division and Multiplier units are not present B. Division and Multiplier units are present C. Debugger and Multiplier units are not present D. Debug and Fast Multiplier units are present
9.	In ARM processor when Interrupt occurs ARM processor goes into following mode A. FIQ mode B. Abort mode C. Supervisor mode D. Undefined mode
10.	The function of Barrel shifter is A. Shift Operation in same instruction cycle B. Shift operation in 2 instruction cycle C. Shift operation in 3 instruction cycle D. Shift operation in 3 instruction cycle
11.	A program written with the IDE for Arduino is called _____. A. IDE source B. Cryptography C. Sketch D. Source code
12.	Arduino IDE consists of 2 functions namely: A. Build() and loop() B. Setup() and build() C. Setup() and loop() D. Loop() and build and setup()
13.	The command which is called once when the program starts: A. loop() B. setup() C. input() D. output()
14.	Default bootloader for the Arduino UNO is_____ A. Opti boot loader B. AIR-boot C. Bare box D. GAG
15.	Select proper microcontroller used in Arduino UNO. A. ATmega32114 B. ATmega2560 C. ATmega328p D. AT91SAM3x8E
16.	GPU stands for: A. Grouped Processing Unit B. Graphics Processing Unit C. Graphical Performance Utility D. Graphical Portable Unit
17.	A normal human eye can process around_____ frames per second A. 25

Sr. No.	Question
	B. 50 C. 60 D. 70
18.	Fast action games must process at least _____ frames per for smooth game scroll and flow. A. 25 B. 50 C. 60 D. 70
19.	A process in which the video data is prepared and formatted prior to playback is known as: A. 3D graphics rendering B. Video Editing C. Graphics Processing. D. Signal Processing.
20.	The processor that can process large amount of data suited for Machine learning and Cryptocurrency mining is: A. IO processor B. Digital Signal Processor C. Graphics Processor D. Coprocessor

UNIT 2: Electronic System Manufacturing Processes

Teaching Hrs. 8 **Marks 10**

Course Outcome- Suggest the relevant techniques in electronic system manufacturing Processes

To attain above course outcome candidate must able to:

2a. Enlist the advantages of SMD.
2b. Explain end to end electronic system manufacturing process.
2c. Suggest specifications to select typical machines for electronic system manufacturing.
2d. Enlist environmental standards for electronic system manufacturing process.

Unit focus on following major points:

2.1 Surface Mount Devices: Introduction, need, advantages and applications.
2.2 Modern Electronic Assembly and Manufacturing process: Various machines used in End-to-End manufacturing process with their features and functions. Pick-n-Place machine and Automatic Component Insertion machine. Reflow soldering method.
2.3Environmental standards for electronic manufacturing such as: EPEAT and RoHS Standards.
2.4 Battery [Li-ion, nuclear]: Concepts and applications including E vehicles.

2.1 Surface Mount Devices

2.1.1Introduction:

A surface-mount device (SMD) is an electronic device/components which are directly placed or mounted onto the surface of the PCB. The technology or method for producing electronic circuits using SMD is called Surface-mount technology (SMT).

SMT was developed to minimize the manufacturing cost and to make efficient use of PCB space. It has largely replaced the through-hole technology (THT) especially in devices that need to be small or flat. With SMT both sides of a PCB can be used when required. SMD components can be smaller than THT components since they can have either smaller leads or no leads at all. (Fig. 2.1) This makes it easier to shrink the components size.

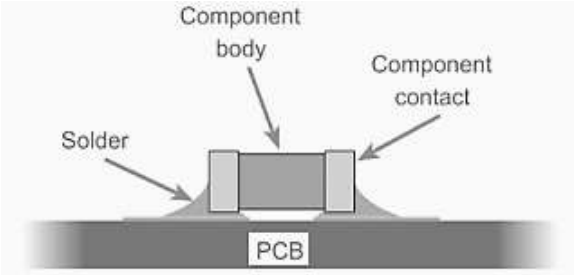


Fig.2.1Surface Mount Technology (Courtesy electronics-notes.com)

2.1.2 Advantages of SMT:

SMT has many advantages over the Through Hole Technique Components.

a. Miniature Components.
b. Higher component density.
c. SMT enable placement of components on both sides of the circuit board.
d. SMT reduced manufacturing cost.
e. Automatic accurate placement of components on circuit board is possible.
f. Better mechanical performance under shock and vibration conditions.
g. Components are mounted using solder paste. It saves time and labor- intensive work.

h. Lower initial cost and time of setting up for mass production, using automated equipment.
i. Simpler and faster automated assembly. Some component placement machines are capable of placing more than 136,000 components per hour.
j. Cost of SMD components is less than the through-hole components.
k. Light weight and very small form factor circuits are possible.

2.1.3 Disadvantages of SMT:

a. As the device complexity increases, the heat generated increases during operation. If the heat not dissipated, the temperature of the device rises, shortening the operational life.
b. SMT is unsuitable for some parts such as transformers, heat-sink power semiconductors, physically large capacitors, fuses, connectors.
c. SMDs' solder connections may be damaged after going through thermal cycling.

2.1.4 Applications of SMD:

a. SMD are used in Flexible PCB and Flex- Rigid PCB.
b. SMD sensors are used in Smart home controls for humidity, air quality and temperature measurement.
c. SMD sensors are used in Electric vehicles power plugs and chargers as they are more compact than wired elements.
d. SMD Network resistors are used in Digital Memory circuits.
e. SMD LEDs are used in domestic and industrial lighting systems, in vehicles, in LED screens, Televisions, projectors etc.
f. SMDs are used in Mobile circuit, Digital camera and keyboard etc.
g. SMDs are used in Drones , automation circuits

2.1.5 SMT Soldering:

Surface mount soldering is the process of creating circuits using surface mount technology (SMT) components that are mounted directly onto the surface of printed circuit boards (PCBs). The two main methods for SMT soldering are:

a. **Wave soldering:** In this method a small bath of molten solder flow which is flowing out causing a small wave. The boards with their components are passed over the wave and the solder wave provide the solder to solder the components. In this process, components need to be held in place, often by a small dot of glue so that they do not move during the solder process.
b. **Reflow soldering**: This is a preferred method now-a-days. Within the PCB assembling, the board has solder applied through a solder screen. Components are then placed onto the board and held in place by the solder paste. The board is then passed through an infra-red heater and the solder is melted to provide a good joint for electrical conductivity and mechanical strength. The modern electronic assembly and manufacturing process uses SMD with Reflow soldering.

2.2 Modern Electronic Assembly and Manufacturing process:

In modern electronic assembly the surface mount devices (SMD) are placed automatically onto the surface of the board.

2.2.1: Design for Manufacturability (DFM):

Before the PCB manufacturing process, the PCB design and its functionality is checked as per the specific requirements. The PCB assembly company checks the PCB design file for any issues that may affect the PCB's functionality or manufacturability. This is called a design for manufacturability check, or DFM check.

The DFM check looks at all the design specifications of a PCB. Specifically, this DFM checks for any missing, redundant or potentially problematic features. Any of these issues may severely and negatively influence the functionality of the final project. For example, one common PCB design flaw is leaving too little spacing between PCB components. This can result in shorts and other malfunctions.

By identifying potential problems before manufacturing begins, DFM checks minimize the manufacturing cost as these checks cut down on the number of scrapped boards. As part of quality at a low cost, DFM checks have become standard with every PCB assembly for an automatic electronic assembly system contributing to high speed and accuracy.

2.2.2: Various machines used in the End-to-End manufacturing process:

The end-to-end electronic assembly and manufacturing process start with the design of PCB and the process is completed with final packaging as shown in block diagram (Fig 2.2)

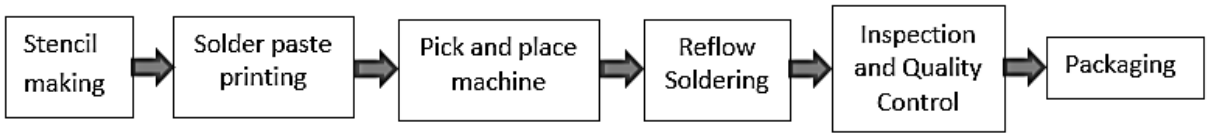


Fig 2.2: Flow diagram of End-to-end Electronic System manufacturing process

Steps for End-to-end Electronic System manufacturing:

Step 1: Stencil making: Stencil is made from the PCB design file. The material used for the stencil is a thin, stainless-steel. It is placed on a board and works like a mask for applying a solder paste to the board. (Fig 2.3)

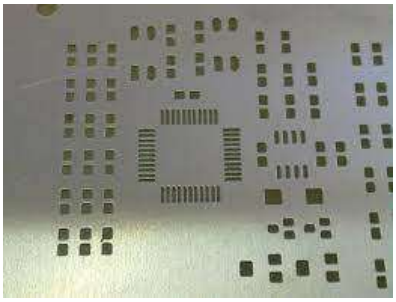


Fig.2.3: PCB stencil

Specifications of stencil Making Machine:

SMT Stencil Types –

A. Framed Stencils (by Laser cut)
B. Frameless Stencils (by Laser cut)
C. Prototyped Stencil (by Laser cut)
D. Electroformed Stencil (by Electroforming Technology-

Table 2.1: Specifications of stencil Making Machine

Sr. No.	Specifications	General Description
1.	Material used for stencil	Stainless Steel
2.	Frame Types	Cast | Space Saver

Sr. No.	Specifications	General Description
3.	Stencil Thickness	0.06 ~ 0.3 mm
4.	Minimum Cut Width	0.05 mm
5.	Maximum Size	736 X736 mm

Step 2: Solder paste printing or dispensing - Solder paste has tiny metal spheres of the alloy mixed with flux, solvents, and thixotropic materials. Methods of applying solder paste are: Stencil printing and Syringe dispensing.

This solder paste applying process is like screen-printing, except instead of a mask, a stencil is placed over the PCB. This allows assemblers to apply solder paste only to certain parts of the PCB. These parts are where components will be placed in the finished PCB. The composition of the solder paste is 96.5% tin, 3% silver and 0.5% copper. The solder paste mixes solder with a flux, which is a chemical designed to help the solder melt and bond to a surface. Solder paste appears as a gray paste and must be applied to the board at exactly the right places and in precisely the right amounts.

Fig.2.4: Solder paste screen printer and solder paste printed PCB.

The machine used for solder paste printing is called screen printer or solder paste printer shown in Fig. 2.4

In the PCB assembly process, in the solder paste printer, a mechanical fixture holds the PCB and solder stencil in place. An applicator then places solder paste on the intended areas in precise amounts. The machine then spreads the paste across the stencil, applying it evenly to every open area. After removing the stencil, the solder paste remains in the intended locations.

Specifications of Solder paste printing machine:

Table 2.2: Specifications of Solder paste printing machine

Sr. No.	Specifications	General Description
1.	Temperature and humidity requirements	25±3Degree Celsius, RH 40 to 70%
2.	Solder paste rolling/sliding speed	Approx. 10-20mm/sec

Step 3: Pick and place machine: After applying the solder paste to the PCB board, the PCB assembly process moves on to the pick and place machine. It is a robotic device, which places surface mount components, or SMDs, on a prepared PCB. The SMDs are then soldered onto the surface of the board in the next step of the PCB assembly process.

The surface mount components are accurately placed onto the pads with the help of pick and place machines, as shown in Fig 2.5.The wet solder paste applied during this process acts as a temporary

adhesive. However, it is important to ensure that the boards are moved gently to prevent misalignment.

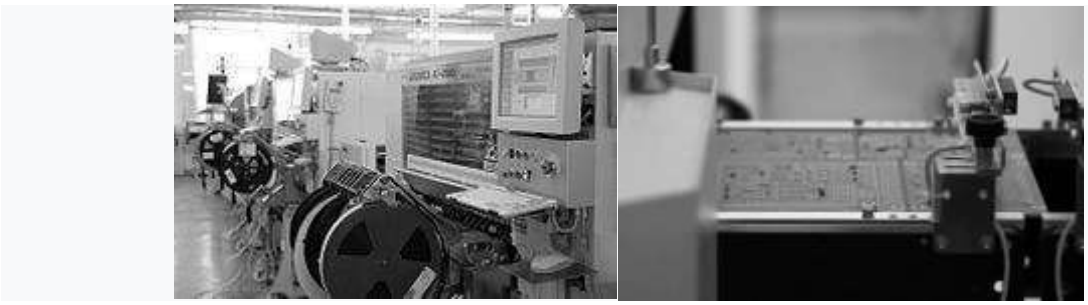


Fig.2.5: Assembly line with SMT placement equipment and Pick n place machine.

These automatic assembly machines are more accurate and more consistent than humans. Machines work around the clock without any fatigue.
The machine starts the pick and place process by picking up a PCB board with a vacuum grip and moving it to the pick and place station. The robot then orients the PCB at the station and begins applying the SMTs to the PCB surface. These components are placed on top of the soldering paste in preprogrammed locations.

SMD reels are available in various values, wattage and tolerance. To handle hybrid and linear SMD components anti-static tools are used.

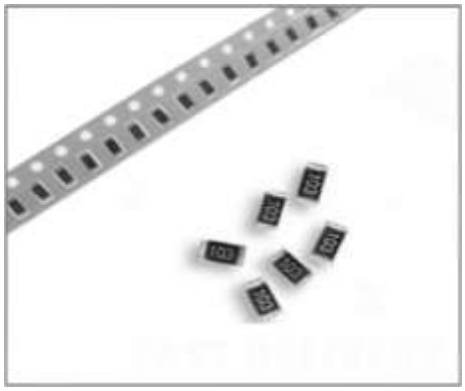


Fig 2.6: SMD resistor Reel

Technical Specifications of Pick and Place Machine:
Types of Pick and Place Machine:

1) According to type of components
   a) For leaded component
   b) For unleaded or SMDs
2) According to mounting
   a) Table mounted
   b) Floor mounted

Table 2.3 Technical Specifications of Pick and Place Machine

Sr No	Parameter	General Descriptions
1	System Items	Content Mounting system
2	Mounting head number	2

Sr No	Parameter	General Descriptions
3	Pieces Mounting accuracy	0.025 mm
4	Mounting angle	0^0 to 360^0
5	Theoretical velocity	7500 pcs/h
6	Normal mounting	6000 pcs/h
7	Nozzle type	Juki nozzle
8	Element for mounting	RC (0402, 0603, 0805, 1206, etc)LED lamp (0603, 0805, 3014, 5050, etc)Chip (SOT, SOP, QFN, BGA, etc)
9	Substrate minimum size	10×10 mm
10	Substrate maximum size	320×450 mm
11	Substrate thickness	≤2 mm
12	Substrate warp allowed value	<1 mm
13	Feeder	8 mm 20 bit 12mm 4 bit 16mm 2 bit 24mm 1 bit
14	Y axis moving range	410 × 490 mm
15	Z axis moving range	10 mm
16	Z axis rotation angle	0^0 to 360°
17	Operating software	Embedded system Compatible file format CSV, TXT.
18	Host size	L 800 × W 780 × H 380 mm
19	Feeder size	L 235 × W 700 × H 245 mm
20	Power supply	AC220V±10V 50 Hz 150 W

E.g. SMT component size for placement is indicated as 0603, where 06 mm is a length and 03mm width of component

Step 4: Reflow Soldering

Once the solder paste and surface mount components are all in place, they need to remain there. This means the solder paste needs to solidify, adhering components to the board. PCB assembly accomplishes this through a process called "reflow".

The boards are passed through a reflow oven, as shown in Figure 2.7. It is also called reflow soldering machine or SMT reflow oven) which subjects the boards to infrared radiation, after which the solder paste melts and solder joints are formed.

After the pick and place process concludes, the PCB board is then transferred to a conveyor belt. This conveyor belt moves through a large reflow oven. This oven consists of a series of heaters which gradually heat the board to temperatures around 250 degrees Celsius or 480 degrees Fahrenheit. This is hot enough to melt the solder in the solder paste.

Once the solder melts, the PCB continues to move through the oven. It passes through a series of cooler, which allows the melted solder to cool and solidify in a controlled manner. This creates a permanent solder joint to connect the SMDs to the PCB.

Many PCB assemblies require special consideration during reflow, especially for two-sided PCB assembly. Two-sided PCB assembly needs stenciling and reflowing each side separately. First, the side with fewer and smaller parts is stenciled, placed and reflowed, followed by the other side.

Fig.2.7: Commercial reflow oven

The Thermal profile of a typical Reflow Soldering machine is shown in Fig 2.8. The preheat zone involves heating the entire assembly at a controlled rate between 1-4°C to temperatures from 100^0 C to 150°C. The rate of heating in this zone is critical to avoid thermal shock to the components.

The soak zone holds the temperature at a steady level for up to two minutes between 150 to 170°C. This allows fluxes to activate and for the temperature to stabilize throughout all components.

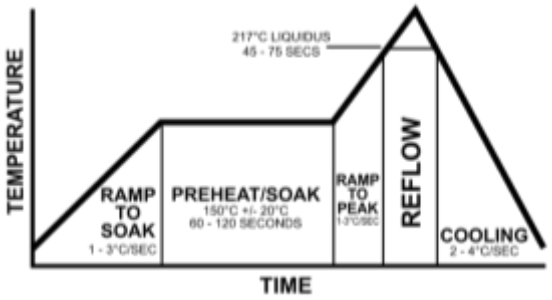


Fig 2.8: Thermal Profile of Reflow Soldering Machine

The reflow zone heats the assembly to a temperature higher than the solder's melting point for 30 to 60 seconds to ensure reflow for every soldered lead.

The cooling zone lowers the temperature at a controlled rate between 1 to 4°C to evenly form solid solder interconnections between components and the board, with ideal grain size and structural strength.

Technical Specifications of Reflow Soldering Machine:

Types of Reflow Soldering Machine:

1) According to type of loading method
   a) Manual
   b) Automatic
   c) Semiautomatic
2) According to heating system
   a) IR heater
   b) Vapor phase ovens

Selection Criteria for Reflow Soldering Machine:

a) Thermal performance
b) Throughput
c) Maximum temperature rating
d) Heating technology
e) Reflow oven type
f) Entrance clearance
g) Maximum PCB width and height
h) Speed of conveyor
i) Conveyor design
j) Process gas
k) Computer software and PC interface
l) Power supply
m) Software
n) Reliability
o) Serviceability
p) Maintenance downtime

Table 2.4 Technical Specifications of Reflow Soldering Machine:

Sr No	Parameter	General Description
1	Dimension	W850 mm D 500 mm H 1350mm
2	Process Area	W 200mm D 250 mm H 60 mm
3	Heating system	IR heater Temperature upto 4000 C
4	Cooling System	Water cooled Plate
5	Temperature sensor	Thermocouple
6	Vacuum Pump	Corrosion proof Dry pump
7	Vacuum gauge	Capacitance diaphragm gauge
8	Reducing Agent	Formic acid

Step 5: Inspection and Quality Control:

Once the surface mount components are soldered in place after the reflow process, the assembled board needs to be tested for functionality. Often, movement during the reflow process will result in poor connection quality or a complete lack of a connection. A common side effect of this movement is shorts, as misplaced components can sometimes connect portions of the circuit that should not connect.

Automatic Optical Inspection (AOI) machine runs a number of quality checks for the boards visually, such as component alignment and checking for solder bridges (Fig 2.9). The boards then proceed to further testing.

Fig.2.9: Photograph of AOI Machine

Automatic Optical Inspection:
Automatic optical inspection is used for inspection of large batches of PCB Assembly. An automatic optical inspection machine, also known as an AOI machine, uses a series of high-powered cameras to "see" PCBs. These cameras are arranged at different angles to view solder connections. Different quality solder connections reflect light in different ways, allowing the AOI to recognize a lower-quality solder. The AOI does this at a very high speed, allowing it to process a high quantity of PCBs in a relatively short time.

Whether an inspection finds one of these mistakes or not, the next step of the process is to test the part to make sure it does what it's supposed to do. This involves testing the PCB connections for quality. Boards requiring programming or calibration require even more steps to test proper functionality.

Such inspections can occur regularly after the reflow process to identify any potential problems. These regular checks can ensure that errors are found and fixed as soon as possible, which helps both the manufacturer and the designer save time, labor and materials.
A final inspection will test the PCB for its functionality. This inspection is known as a "functional test". The test puts the PCB through its paces, simulating the normal circumstances in which the PCB will operate. Power and simulated signals run through the PCB in this test while testers monitor the PCB's electrical characteristics. Thus PCBs are tested for the desired operation and performance

If any of these characteristics, including voltage, current or signal output, shows unacceptable fluctuation or hit peaks outside of a predetermined range, the PCB fails the test. The failed PCB can then be recycled or scrapped, depending on the company's standards.
Testing is the final and most important step in the PCB assembly process, as it determines the success or failure of the process. This testing is also the reason why regular testing and inspection throughout the assembly process is so important.

Another method of defect detection is Automatic X Ray Inspection

Table 2.5 Comparison of the major defect detection capabilities of AOI and AXI

DEFECT TYPE	AOI capabilities	AXI capabilities
Soldering defects		
1. Open circuits	Yes	Yes
2. Solder bridges	Yes	Yes
3. Solder shorts	Yes	Yes
4. Insufficient solder	Yes (not heel of joint)	Yes
5. Solder void	N0	Yes
6. Excess solder	Yes	Yes
7. Solder quality	No	Yes
Component defects		
1. Lifted lead		
2. Missing component	Yes	Yes
3. Misaligned or misplaced component	Yes	Yes
4. Incorrect component value	No	No
5. Faulty component	No	No

Automated X-ray inspection, AXI has an important place in many electronics PCB manufacturing organizations. AXI is able to provide a fast and in-depth and accurate inspection of PCBs passing through the production facility and in this way provide real-time feedback that enables the production system to be optimized to enable high quality reliable circuits to be produced. Although more expensive than some other forms of inspection, AXI has many advantages

Desired Features:

1. 15 Megapixels high speed Industrial camera and High resolution Lens.
2. Graphic programming, easy to program.
3. Barcode reader inside, every products are storied with the barcode information, the inspection products are traceable.
4. Real time monitoring of production line, no need stop when inspection, the inspection is finished when the board passing.
5. All production line equipment can be centralized management through the central server, also can collect all the test data and information of the production line, convenient for the management.
6. The machine can automatically recognize the board without barcode and automatic inspect.

Specifications of AOI machine:

Table 2.6: Automatic Optical Inspection Machine Specifications

Sr. No.	Specifications	General Description
1.	Camera Resolution	15 micro mm,20 micro mm
2.	Field of view (FOV) size	30mm x 30mm, 40mm x 40mm
3.	Inspection speed	22.9-36.6 sq.cm/sec
4.	Illumination	IR- RGB LED dome style
5.	Max measurement height	5mm

Step 6: Cleaning and packaging:

After the PCB assembly process**,** soldering paste leaves behind some amount of flux, while human handling can transfer oils and dirt from fingers and clothing to PCB surface. Once all is done, the results can look a little dingy (dirty and dark), which is both an aesthetic and a practical issue.

After months of remaining on a PCB, flux residue starts to smell and feel sticky. It also becomes somewhat acidic, which can damage solder joints over time. Also the residue and fingerprints on PCBs should be cleaned before shipments. For these reasons, washing the product after finishing all the soldering steps is important.

A stainless-steel, high-pressure washing apparatus using deionized water is the best tool for removing residue from PCBs. Washing PCBs in deionized water poses no threat to the device. This is because the ions in regular water do damage to a circuit. The deionized water is therefore harmless to PCBs as they undergo a wash cycle.

After washing, a quick drying cycle with compressed air the finished PCBs is ready for packaging and shipment.

2.2.3 Flexible PCB:

Flexible PCB's can be bended allowing greater freedom in the design and operation of the application. Flexible PCBs can also adapt to small or irregularly shaped spaces. Another advantage of flexible circuits is that they take up less space, reducing the weight on the application's motherboard. The optimal use of the available spaces allows also for better thermal management, reducing the amount of heat to be dissipated.

Flexible PCB in wearables:

The wearable devices typically require a light weight, small size, environmental protection, heat protection, durability, and flexibility. Wearables use a rigid flexible PCB for interconnection of points or mechanical moving parts. At high frequencies, small impedance mismatches can create big signal distortions and communication issues, so impedance matching (recall Maximum Power theorem) of circuit will be critical to reducing signal loss. Bends in the rigid flexible PCB must also be precise to perfectly line up and not put stress on the connection points, increasing the potential of failure. Utilizing a flexible PCB approach will mitigate the risks that come with rigid PCB and their interconnect points.

2.2.4 Anti-Static Work Environment:

Electrostatic discharge (ESD) is the release of static electricity when two objects come into contact. A static discharge causes a sudden flow of electrons from one charged object to another object in contact.

Examples of ESD include lightening and the shock user sometimes feel when user touches another object like a metal door knob.

Now-a-days there is increasing demand for electronic devices with ESD control products. Technological advancements in the electronics industry, such as the miniaturization of PCBs and components, have increased the damage caused by electrostatic discharge. This discharge is very less but the heat released causes the most damage to the devices. This heat can cause the electronic devices and components to malfunction at any stage for example: during device manufacture, handling, assembly, testing, field operation, the shipping process, etc. ESD can occur without users feeling any sense of shock and happens while working inside the devices, while handling a cord or other hardware. Therefore, static control becomes very important during electronics manufacturing.

ESD is a major contributor of device failure within electronics systems. According to Industry experts estimate, the average product loss due to static discharge could be in the range 8% to 33%.

Methods to control and prevent ESD:

Some precautions should be taken to reduce the damage caused by ESD while manufacturing, assembling and repairing electronic devices.

1. Wearing a grounded wrist strap is highly recommended to reduce the risk of creating an ESD incident. It should be worn correctly, with proper contact with the skin to bring down contact resistance. Since it is connected to the ground, the wrist strap will quickly shield any charge the body generates. Thus, it protects sensitive components from ESD damage.
2. Repairing of components or the manufacture of PCBs should be done in an ESD-safe and cleanroom environment.

3. Use ESD-safe mats on tables or workbenches to reduce static electricity. These mats are designed with electrically conductive carbon fibers. As a result, the ESD is not very active on the surface of the mat, which in turn neutralizes it.
4. For very sensitive Electrostatic Protection Area (EPA) employees should wear anti-static clothing to prevent ESD shock and shield sensitive components. Such clothing includes T-shirts, sweatshirts, conductive shoes, sole grounders, high visibility jackets, etc.
5. Jewellery and other static producing accessories should not be used in this area. This precaution will help to reduce ESD accumulation.
6. Use of anti-static tools and equipment avoids the conduction of electrical charge. Avoid working on the electronic devices during an electrical storm (bust of current), as it can increase ESD risks.
7. Anti-static bags are efficient in storing the equipment in a safe environment. These bags are also used for packaging PCBs when they are being transported.
8. ESD air ionizers remove static charge and particulate matter from the air, which cannot be grounded from the workstation.

2.3 Environmental Standards for Electronic System Manufacturing:

Need of Environmental standards:

a. As the fastest growing global waste stream, the environmental impact of electronics manufacturing is a critical issue which must be addressed.
b. Waste from PCB generated decades back keep harming environment for years. PCB waste, which is made of hazardous substances that includes heavy metals like mercury, lead, cadmium and many other chemicals affects human health and life adversely.
c. According to the European Environment Agency (EEA), the amount of waste electrical and electronic equipment (widely known as WEEE or e-waste) in Europe alone is over 10 million tons per year.
d. To address the above given issues there is need to study Environmental standards for electronic manufacturing.

Environmental evaluation of manufacturing systems

a. To enable environmental evaluation of manufacturing systems, various types of data from the manufacturing activity is needed.
b. Standards help to clearly define data so that it can be used to perform unambiguous environmental evaluations.

2.3.1Types of Environmental standards for electronic manufacturing:

I. Restriction of Hazardous substances (RoHS):

a. In 2002, the European Union instigated RoHS directive, some substances that are hazardous have been prohibited from use in packaging electronic circuits and electrical products.
b. RoHS directive has seen two upgrades, which includes the RoHS 2 and RoHS 3.
c. It helps in restricting manufacturers from making use of any hazardous material, most especially those found on electronic and electrical components
d. As per **RoHS** it is illegal manufacturing electronic or electrical equipment containing restricted materials, as well as materials that can harm the environment.
e. Materials that are Restricted under the RoHS Compliance

Six major materials cannot be used in PCB beyond the given limits due to the restriction caused by RoHS compliance. These include Lead, Mercury, polybrominated biphenyls, Hexavalent Chromium, polybrominated diphenyl ethers, and phthalates like DIBP, BBP, DEHP.

This compliance specifies the highest levels these materials can be in a PCB as well as other electronics.

i. Mercury < 100 ppm(parts per million)
ii. Cadmium <100 ppm
iii. Lead <1000 ppm
iv. Hexavalent Chromium<1000 ppm
v. Polybrominated Biphenyls <1000 ppm
vi. Polybrominated Diphenyl Ethers <1000 ppm
vii. Benzyl butyl phthalate <1000 ppm
viii. Diisobutyl phthalate <1000 ppm
ix. Dibutyl phthalate <1000 ppm
x. Bis (2-Ethylhexyl) phthalate <1000 ppm

II. Electronic Product Environmental Assessment Tool (EPEAT):

a. The Electronic Product Environmental Assessment Tool (EPEAT) is a tool was originally developed under a grant from the U.S. Environmental Protection Agency (EPA).
b. EPEAT is managed and operated by staff contracted from the Green Electronics Council.
c. The Electronic Product Environmental Assessment Tool (EPEAT) is a method for purchasers (governments, institutions, consumers, etc.) to evaluate the effect of a product on the environment and helps manufacturers promote environmentally sustainable products.
d. EPEAT is based on a set of performance criteria. It assesses various lifecycle environmental aspects of a device and ranks products as Gold, Silver or Bronze based on a set of environmental performance criteria.
e. EPEAT-registered products must meet environmental performance criteria that address materials selection, supply chain greenhouse gas emissions reduction, design for circularity and product longevity, energy conservation, end-of-life management and corporate performance.
f. The Electronic Product Environmental Assessment Tool (EPEAT) is a global eco-label for the IT sector.

EPEAT currently covers the following product categories:

a. Computers and Displays
b. Imaging Equipment
c. Mobile Phones
d. Photovoltaic Modules and Inverters (PVMI)
e. Televisions
f. Servers

Fig2.10: EPEAT evaluates products according to specific criteria into three tiers of environmental performance – Bronze, Silver and Gold.

2.4 Battery:

A battery is an energy source consisting of one or more electrochemical cells and two terminals called an anode and a cathode. Electrochemical cells transform chemical energy into electrical energy. Inside the battery is an electrolyte, often consisting of soluble salts or acids, it serves as a conductive medium, allowing the electric charge to travel through the battery.

2.4.1 Working of battery:

When a battery is disconnected, the charge at the positive and negative ends is equal, meaning there is no electric current. When connected to an outside resistance or device, the battery experiences an imbalance in charge that pushes electrons through the device's conductive material to the positive end of the battery. But while the electrons—or the negative charge—are what moves through the circuit, the electric current is measured following the positive charge's direction, which flows from the positive to the negative end inside the battery, and vice versa outside it.

Depending on its voltage and load, a single battery can power anything such as car's motor, computer, cellphone, light bulb etc. Fig 2.11 shows use of batteries in different devices.

Fig 2.11: Uses of Primary and Secondary battery

2.4.2 Classification of batteries:

Batteries are classified as either primary or secondary batteries, according to the type of electrochemical cells they are made of.

Primary Batteries:

a. Primary batteries, also known as non-chargeable batteries, are disposable batteries that can only be used once. That is because the chemical reactions that produce electricity in their electrochemical cells cannot be reversed.
b. Disposable batteries are widely used because they are convenient, cheap, require little to no maintenance and are reliable in an emergency.

Fig 2.12: Primary batteries

Secondary Batteries:

a. Secondary batteries are rechargeable batteries that can be used more than once but have a set life expectancy.
b. Because of their durability and ability to provide larger amounts of energy, they are often used in larger devices such as laptops, tablets, and even cars.

Secondary rechargeable batteries:

They are divided according to their chemical composition and the state of the electrolyte into wet- and dry-cell batteries.

Wet-cell batteries:

a. Wet-cell batteries are the oldest type of rechargeable battery which contains liquid electrolyte with two electrodes submerged into it, acting as the battery's anode and cathode.
b. Wet-cell batteries are often used in demanding industries such as aviation, electric storage, cell phone towers, and electric utilities as they are affordable and durable in the right circumstances.

Dry-cell batteries:

a. Dry-cell batteries are not entirely dry. The electrolyte is in paste form with enough moisture to allow electrons flow.
b. These are the rechargeable type often used in portable electronics like phones and laptops as they are considered to be safer.

Fig 2.13: Secondary batteries

Other types include nickel-metal hybrid (NiMH), nickel-zinc (NiZn), and nickel-cadmium (NiCd) cells. NiCd batteries are still widely used in medical equipment and power tools because of their longer lifespan.

Table: 2.7 Comparative study of rechargeable batteries

Features	**Nickel-Cadmium(Ni-Cd)**	**Nickel Metal Hydride (NiMH /Ni-MH)**	**Lithium-ion (Li-ion/ LIB)**
Cathode Material	Nickel hydroxide ($Ni(OH)_2$)	Nickel hydroxide ($Ni(OH)_2$)	Lithium Metal Oxide
Anode Material	Cadmium hydroxide ($Cd(OH)_2$)	Hydrogen	Graphite
Electrolyte Material	Potassium hydroxide (KOH)	Potassium hydroxide (KOH)	Lithium salt, LiPF6 in an organic solution
Battery Voltage	1.2 V	1.6 V	3.5 V
Battery cycle count	500 cycles	600 cycles	2000+ cycles
Memory Effect	Good	Reduced	No
Self-Discharge / month	High (15%-20%)	High (20%-30%)	Low (5%-10%)
Toxic	Toxic	Less Toxic	Less Toxic
Cost	Less expensive	Moderate	High Cost
Battery Images			

Li-Ion Battery:

For the portable DC power many times rechargeable batteries like Lithium-ion (Li-ion/ LIB) are the most popular types used commercially. A Lithium-ion battery is commonly called as Li-ion battery or abbreviated as LIB. It is a rechargeable electrochemical battery converting chemical energy into electrical energy and vice versa.

Operating Principle of Lithium-ion (Li-ion/ LIB):

a. Most lithium batteries (Li-ion) used in computer, communication, and consumer electronics products use cathodes made of lithium compounds, such as lithium cobalt oxide ($LiCoO_2$), lithium manganese oxide ($LiMn_2O_4$), and lithium nickel oxide ($LiNiO_2$). The anodes are generally made of graphite

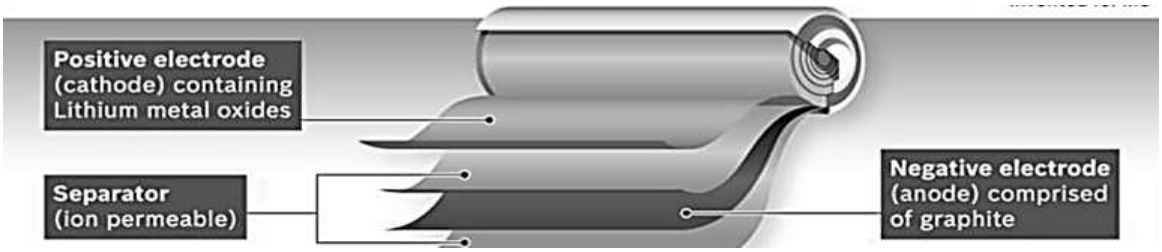


Fig 2.14: Lithium-ion battery

b. All lithium-ion batteries work in broadly the same way, the anode and cathode store the lithium. The electrolyte carries positively charged lithium ions from the anode to the cathode and vice versa through the separator.
c. As shown in fig 2.14when the battery is charging up, the lithium-cobalt oxide, (positive electrode) releases some of its lithium ions, which move through the electrolyte to the graphite (negative electrode) and remain there.
d. The battery stores energy during this process.
e. When the battery is discharging, the lithium ions move back across the electrolyte to the positive electrode, producing the energy that powers the load.
f. In both charging and discharging cases, electrons flow in the opposite direction to the ions around the outer circuit.

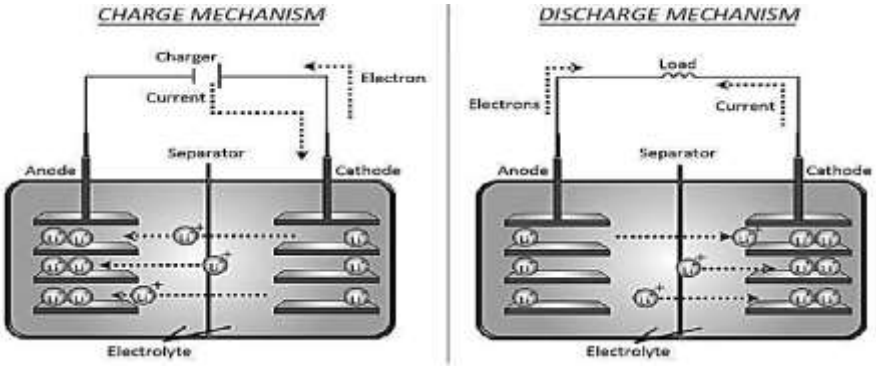


Fig 2.15: Charging and Discharging of Li-ion battery

(*Courtesy:* *Rechargeable Energy Storage Systems for Plug-in Hybrid Electric Vehicles—Assessment of Electrical Characteristics Noshin Omar, Mohamed Daowd)*

Advantages of Lithium-Ion Batteries

a. Low to Minimum Maintenance

A huge price of maintenance and ownership is possessed by most of the other cells like the Nickel Cadmium batteries.

b. Low Self Discharge

The self-discharge rate, a common phenomenon in batteries, when kept idle, is very low. It is like being negligent in most cases.

c. High Energy Density

The high energy density of the lithium-ion battery is one of the biggest benefits of lithium-ion batteries. The high current output is maintained by the Lithium-ion charges and they can remain longer between charges too during that time, making it the best-suited battery for most modern needs.

d. Uses

Commercial lithium-ion batteries are utilized in electric vehicles and consumer electronics in the vast majority.

2.4.3 Applications of Li-Ion Batteries

a. As Lithium-ion batteries are present in all kinds of sizes and shapes makes them a perfect candidate for power needs without the system's size being of any importance.
b. Power solutions are offered by the Lithium-ion batteries from the energy storage solutions to the portable energy solutions, across the spectrum.
c. Energy Storage Systems
d. Electric Mobility
e. Laptops, mobiles, and others usually utilized consumer electronic goods.
f. UPS/Power backups.
g. Drone Power supply.

Lithium-ion battery in Electric Vehicle:

An electric vehicle (EV) is a vehicle powered by an AC motor that is powered by electricity. The motor turns the wheels and the wheels, in turn, move all four tires.

An electric vehicle has an electric motor battery. When the driver presses the accelerator, the electric motor turns and makes the car go. The battery stores energy from the electric motor and converts it into electricity for the electric motor.

EV is a car that uses electricity to power its wheels. It doesn't have a combustion engine, which means there's no engine noise or exhaust. They use rechargeable batteries and are often referred to as plug-in hybrids or all-electric vehicles.

Need of Batteries in Electric Vehicle:

Electric vehicles have several advantages over traditional gasoline-powered vehicles. They are more environmentally friendly, require less maintenance than gas-powered cars, and produce less pollution than other forms of transportation like buses or trains.

Electric car batteries power the motors. They're cheaper than other transportation options and they can be recharged quickly using electricity from renewable sources such as solar panels or wind turbines.

Working of electric vehicle (e-vehicle) batteries:

a. The energy storage system in electric cars comes in the form of a battery. Battery type can vary depending on if the vehicle is all-electric (AEV) or plug-in hybrid electric (PHEV).
b. Current battery technology is designed for extended life (typically about 8 years or 100,000 miles). Some batteries and can last for 12 to 15 years in moderate climates, or eight to 12 years in extreme climates. There are four main kinds of batteries used in electric cars: lithium-ion, nickel-metal hydride, lead-acid, and ultra-capacitors.
c. All-electric vehicles have an electric traction motor in place of the internal combustion engine used in gasoline-powered cars. AEVs use a traction battery pack (usually a lithium-ion battery) to store the electricity used by the motor to drive the vehicle's wheels.
d. The traction battery pack is the part of the car that must be plugged in and recharged, and its efficiency helps determine the overall range of the vehicle.

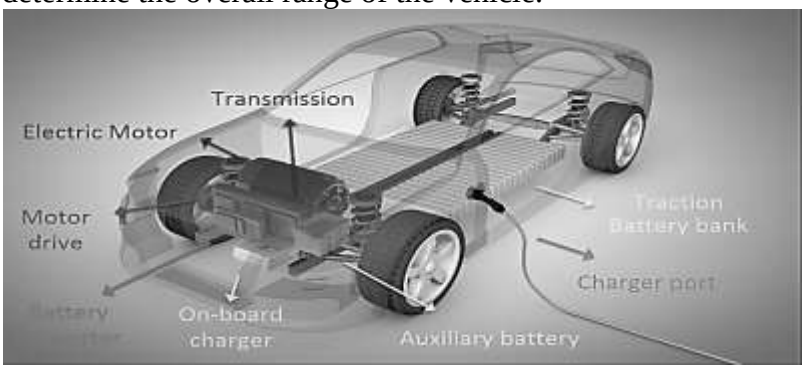


Fig 2.16: Parts of E-vehicle

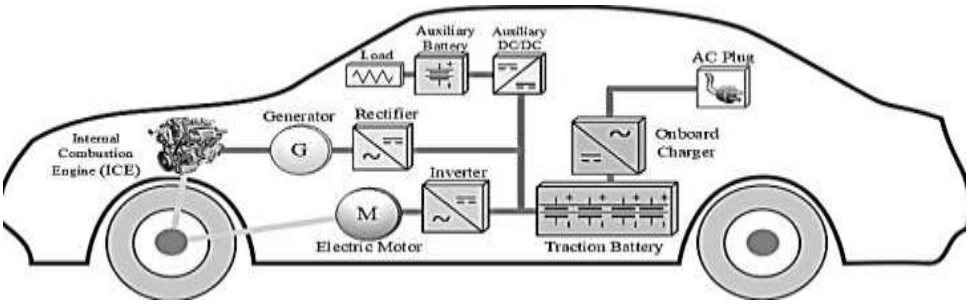


Fig 2.17: Internal components of E-vehicle car

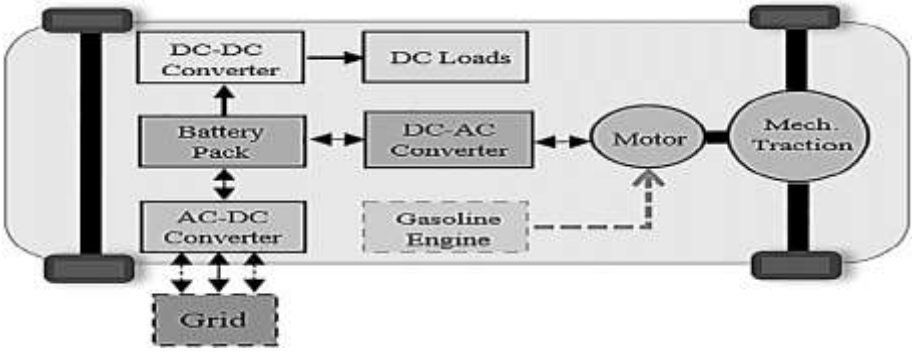


Fig 2.18: Internal blocks diagram of E-vehicle car

e. In plug-in hybrid electric vehicles, the electric traction motor is powered by a traction battery pack much like an AEV. The primary difference is that the battery also has a combustion engine.

PHEVs run on electric power until the battery is depleted and then switch over to fuel which powers an internal combustion engine.

f. The battery, usually lithium-ion, can be recharged by being plugged in, through regenerative braking, or by using the internal combustion engine. The combination of battery and fuel gives PHEVs a longer range than their all-electric counterparts.

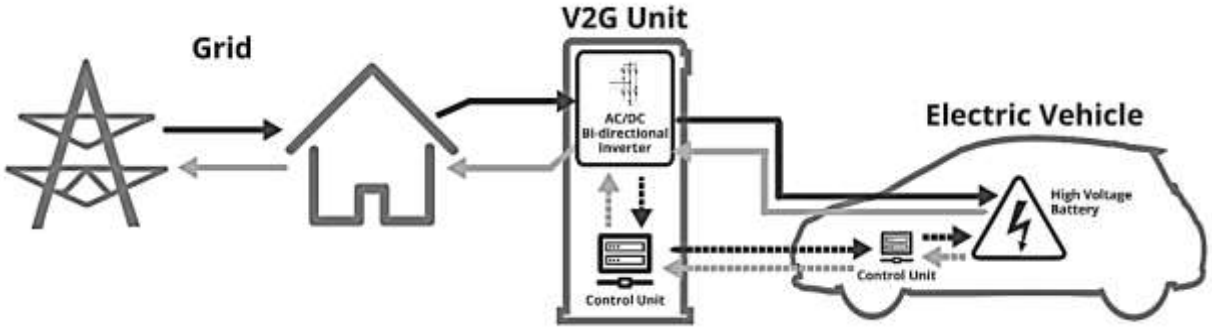


Fig 2.19: Charging of Electric Vehicle (EV) V2G: Vehicle to grid

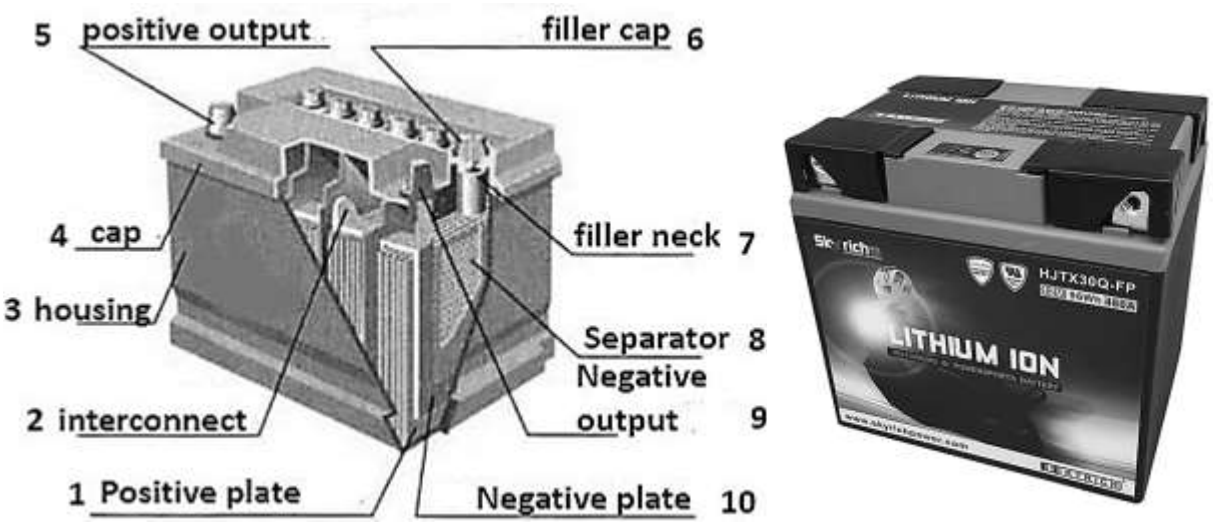


Fig 2.20: Parts of battery used in E-vehicle

Challenges of electric vehicle batteries:

a. One of the main challenges is charging time. It can take a long time to charge an electric vehicle battery, which can be a major inconvenience for drivers.
b. Making sure that electric vehicle batteries are safe. There can be incidents of batteries catching fire, so manufacturers need to find ways to make them safer.
c. Electric vehicle batteries are expensive. This is one of the biggest obstacles to the widespread adoption of electric vehicles. Manufacturers need to find ways to make them more affordable for consumers.

Application of battery in drone:

A drone is an unmanned aircraft. Drones are more formally known as unmanned aerial vehicles (UAVs) or unmanned aircraft systems. Essentially, a drone is a flying robot that can be remotely controlled or fly autonomously using software-controlled flight plans in its embedded systems, that work in conjunction with onboard sensors and a global positioning system (GPS).

Fig 2.21: Drone (UAV: unmanned vehicle)

Drones have a large number of components, including:

a. Electronic speed controllers, which control a motor's speed and direction;
b. Flight controller
c. GPS module
d. Battery
e. Antenna
f. Receiver
g. Cameras
h. Sensors, including ultrasonic sensors and collision avoidance sensors;
i. Accelerometer, which measures speed; and
j. Altimeter, which measures altitude.

The most common batteries used in drones are lithium polymer (LiPo) batteries. LiPo batteries are composed of a lithium-based cathode and anode separated by a polymer electrolyte.

LiPo batteries differ from other lithium-ion (Li-ion) batteries in that they have a solid polymer electrolyte component rather than a liquid electrolyte.

LiPo Battery Capacity:

Battery capacity is given in mAh or Ah and can be used to estimate flight time. Battery capacity is more specifically defined as the number of hours of current or power the battery can provide. Common units are the ampere-hour (Ah) and the watt-hour (Wh). If a battery has a capacity of 1 Ah, load draw 1 A of current for one hour. If the capacity is 1 Wh, the battery would provide 1 W of power for one hour. The energy density of LiPo batteries ranges from 140 - 200+ Wh/kg in terms of weight and 250 - 350+ Wh/L for volume. Volume energy density is important to consider when building a drone so the battery fits on the frame, but for performance calculations, the energy density by weight is more relevant.

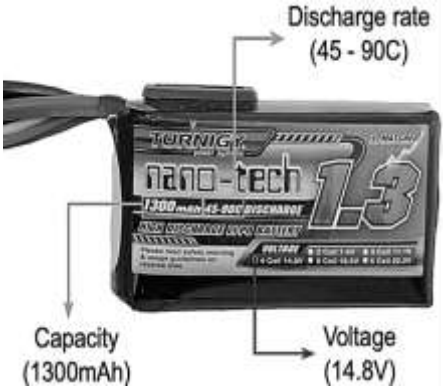


Fig 2.22 a: LiPo battery

Fig 2.22 b: Sample drone parts showing LiPo battery

Nuclear Battery-Next Generation Battery:

Small, compact and smart devices of next generation require new batteries with increased functionality, reliability and long life.

The nuclear battery can be defined as, a device that uses electric energy from decomposing a radioactive isotope for producing electricity. So there is no panic about harmful radiation. The lifespan of these batteries is up to decades and very efficient as well.

A nuclear battery also called as atomic battery, tritium battery or radioisotope generator can be the solution for this need.

Nuclear battery is a device which uses energy from the emission of a radioactive isotope to generate electricity. As half-life period of radioactive materials is in terms of decades, it is capable to provide power for 10 to 20 years. For example, the radioactive isotope, Tritium isotope, has half-life of 12.32 years while Ni-63 isotope has half-life of 100 years which shows that nuclear batteries equipped with theses isotopes can provide electricity for a much longer period. This is a unique feature of nuclear battery.

These batteries generate electricity from nuclear energy, but they do not use a chain reaction (chain reaction is normally used in nuclear reactor to generate electricity from nuclear energy).

Fig 2.23: A Nuclear battery. Credit: Elena Khavina/MIPT

Fig 2.24: Nuclear-Diamond Battery developed in Bristol

Radioactive isotopic material required for the nuclear battery can be obtained from radioactive waste of the nuclear fission reaction from the nuclear reactor. Thus nuclear batteries can be also useful for the disposal of waste from the nuclear reactors.

These batteries can be the solution for the bulky chemical batteries which need to be replaced frequently.

However, high initial cost of production and observing the regional and country specific laws regarding use and disposal of radioactive fuels can be a hurdle in its commercial use. These batteries need to gain social acceptance for its application

Applications of Nuclear Battery:

a. They are used in **s**pace applications due to its compact size and light weight and long lasting reliable voltage supply independent of atmospheric conditions.
b. Nuclear batteries can be used in cardiac pacemaker to avoid frequent battery replacement problem for the patients.
c. Nuclear powered laptop battery can offer long life time with less need of frequent charging.
d. Nuclear batteries are used in different applications like a power source because of their enhanced reliability, high energy density & long lifetime.
    i. These are extensively used in military, space, medical and underwater applications.
    ii. Pacemakers
    iii. Spacecraft
    iv. Underwater systems
    v. Automated scientific stations in remote areas
    vi. Military and Medical applications

Advantages of Nuclear batteries:

a. Reliable
b. Less weight with high energy density
c. Life span is decades
d. The greenhouse effect can be reduced
e. Obtained energy is maximum
f. Waste generation is less
g. Nuclear battery's economic viability can be determined by balancing the power benefits & safety measures.

Disadvantages of Nuclear batteries

a. When the battery is in the experimental phase, the production cost is high
b. Conversion methods of energy are not advanced

Suggested Resource:

Sr. No.	Keyword	QR Code	Web link
1	SMT Solder Paste Screen Printer		http://www.electronicsandyou.com/blog/smt-solder-paste-screen-printer-machine-for-solder-paste-screen-printing.html
2	PCB Assembly Process		https://www.pcbcart.com/article/content/pcb-assembly-process.html
3	Electronics-manufacturing standards		https://www.raypcb.com/electronics-manufacturing-standards/
4	Electronic Product Environmental Assessment Tool		https://en.wikipedia.org/wiki/Electronic_Product_Environmental_Assessment_Tool
5	Importance of ESD		https://www.electronicsb2b.com/headlines/the-importance-of-esd-safe-products/
6	Automotive Applications for Li-Ion Batteries		https://nanografi.com/blog/automotive-applications-for-lithiumion-batteries/#:~:text=Tens%20to%20thousands%20of%20individual,into%20the%20whole%20battery%20pack.
8	Introduction to Battery		https://www.techopedia.com/definition/16316/battery
9	Nuclear Battery		https://www.elprocus.com/nuclear-battery/

Sample Questions:

Sr. No.	Question
1	In Li-ion battery, the _____is/are lithium ion based A. Positive electrode B. Negative electrode C. Positive and negative electrode D. Electrolyte
2	The main benefit of solid electrolytes is that there is no _____ which is a serious _____for batteries with liquid electrolytes. A. Risk of leak, safety issue B. Conductivity, conduction issue C. Non-conductivity, non-conductivity issue D. Conductivity, non-conductivity issue
3	Both glassy and ceramic electrolytes can be made more ionically conductive by substituting _____for oxygen. A. Nitrogen B. Carbon dioxide C. Sulphur D. Hydrogen
4	SMD has largely replaced the _____ especially in devices that need to be small or flat. A. pin technology B. through-hole technology C. plated technology D. hole technology
5	Compared to other batteries, nuclear batteries are very ____ but have an extremely ____and high energy density A. Cheap, long life B. Costly, long life C. Cheap short life D. Costly, short life
6	In the PCB assembly process, in the solder paste printer, a mechanical fixture holds the PCB and _____in place. A. Solder stencil B. Solder paste C. Solder flux D. Solder gun
7	_____account for most non-connector components on PCBs today. A. SIP B. SMD C. Pin- up components D. Plug -in components
8	_____is a more appropriate inspection method for larger batches of PCB Assembly. A. Automatic optical inspection B. Manual inspection C. Automatic X-ray inspection. D. Operator inspection

9	With growing global manufacturing waste of electronics manufacturing _____ has to be addressed on priority. A. Environmental impact. B. political impact C. social impact D. financial impact
10	WEEE or e-waste is - A. The amount of waste mechanical and electronic equipment B. The amount of waste biological and electronic equipment C. The amount of waste surgical and electronic equipment D. The amount of waste electrical and electronic equipment
11	_____ and _____standards are used for certifying manufacturing material. A. RoHS and EPEAT B. FPEAT and RoHS C. IEEE and ASCII D. TRIA and EPEAT
12	EPEAT evaluates products into three tiers of environmental performance: A. Bronze, Silver and Mercury B. Bronze, Nickel and Gold. C. Bronze, Silver and Gold. D. Bronze, Platinum and Gold.
13	Batteries are classified as either primary or secondary batteries, according to the type of: A. mechanical part B. electrical assembly C. instruments used D. electrochemical cells
14	The most common batteries used in drones are _____batteries. A. Sodium polymer (PbPo) B. cadmium polymer (CdPo) C. Nickel polymer (NiPo) D. lithium polymer (LiPo)
15	Using SMD _____density components can be placed on both sides of the circuit board. A. higher B. Lower C. Medium D. none of above
16	The _____check looks at all the design specifications of a PCB. A. AOI B. DFM C. ESD D. SMD

17	Wearing a _____is highly recommended to reduce the risk of creating an ESD incident. A. band B. sweatshirts C. shoes D. grounded wrist strap
18	EPEAT do not audits which of the following product categories: A. Computers and Displays B. Imaging Equipment C. Mobile Vanity D. Mobile Phones
19	Wearables use a rigid flexible PCB for interconnection of points or mechanical _parts. A. Moving B. Stationary C. Both a & b D. None of above
20	If SMD component has two leads and for placement it is specified as 0603 , then 0603 means A. Length is 06 mm with width 3mm B. Length is 03 mm with width 6 mm C. 06 Ohm with 03 A rating D. 06 Volt with 03 A rating

Unit 3: Next Generation Telecom Network

Expected Course Outcome: Suggest different telecom network for given application

Teaching Hrs. 12 **Marks 16**

To attain above course outcome candidate must able to

a. Explain the function of given Network components.
b. Describe the Spectrum in Telecom sector.
c. Compare given Mobile Network with respect to given parameter.
d. Explain the Multi-Protocol Label Switching in NGN core.
e. Explain the given component used in FTTH.
f. Describe the features of OTN.

This unit mainly focuses on following major points:

3.1 NGN architecture: Features, Functional block diagram, Network components: Media Gateway, Media Gateway Controller, and Application Server.

3.2 NGN Wireless Technology: Telecom network Spectrum: Types [licensed and unlicensed], Mobile Network Evolution (3G to 5G), Comparative features,

3.3 NGN Core: Features, Multi-Protocol Label Switching (MPLS): Concepts, Features and Advantages.

3.4 Fiber to the Home (FTTH): Architecture, Features, and Components: Optical Line Termination (OLT), Optical Network Unit (ONU).

3.5 Next generation transmission system: Optical Transport Network variants: Synchronous Transfer Module STM1, STM4, STM16, STM64 and STM256 Features: bit rates and capacity, OTN Standards.

Introduction:

Next Generation Network (NGN) is a new concept and becoming more and more important for future telecommunication networks. Next Generation Network (NGN) is a packet-based network able to provide telecommunication services and able to make use of multiple broadband, Quality of service (QoS)-enabled transport technologies. It supports mobility. In NGN, service related functions are independent from underlying transport-related technologies. It enables unfettered access for users to networks and to competing service providers. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users.

The general idea behind the NGN is that one network transports all information and services (voice, data, and all sorts of media such as video) by encapsulating these into IP packets, similar to those used on the Internet. NGNs are commonly built around the Internet Protocol, and therefore the term all IP is also sometimes used to describe the transformation of formerly telephone-centric networks toward NGN.

3.1 NGN Architecture:

3.1.1 NGN Basic terms:

1) NGN: NGN is a packet-based network able to provide telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies in which service related functions are independent from underlying transport related technologies.
2) NGN Application: A software entity residing on an application server that contributes to the delivery of an end user service.
3) Application network interface (ANI): Interface which provides a channel for interactions and exchanges between applications and NGN elements. The ANI offers capabilities and resources needed for the realization of applications.
4) Application programming interface (API): An API provides a set of interfaces from an application environment to an execution environment. The execution environment provides services to the application environment.
5) NGN service stratum: NGN part which provides the user functions that transfer service-related data and functions. It control and manage service resources and network services to enable user services and applications.
6) NGN transport stratum: NGN part which provides the user functions that transfer data and the functions. It controls and manages transport resources to carry such data between terminating entities.
7) Open service environment capabilities: Capabilities provided by an open service environment to enable enhanced and flexible service creation and provisioning based on the use of standards interfaces.
8) Service: A set of functions and facilities offered to a user by a provider.
9) Authorized account: A profile of the entity which a NGN end user can subscribe for accessing the information via messaging exchange. Authorized means the account is sanctioned and recognized by the service provider (third-party provider) and it is always available to be accessed. The profile is a numeric string which includes the identity of the entity and the service information of the entity.
10) Authorized account messaging service: A messaging service through which third-party provider can register to an authorized account and interact with the account subscribers via messaging exchange.

3.1.2 Connectivity to the NGN:

Fig. 3.1 shows the different connectivity, direct or indirect (i.e., through another network), that a NGN may support.

1. The User-Network Interface (UNI) is used to provide connectivity to terminal equipment's, user networks and corporate networks. The UNI supports both a control level type of interaction and a media level type of interaction.
2. The Network-Network Interface (NNI)) is used to provide connectivity to:
    - Other NGNs (at the service stratum and/or transport stratum level);
    - Other IP-based networks;
    - PSTN/ISDN

The NNI supports both a control level type of interaction and a media level type of interaction.

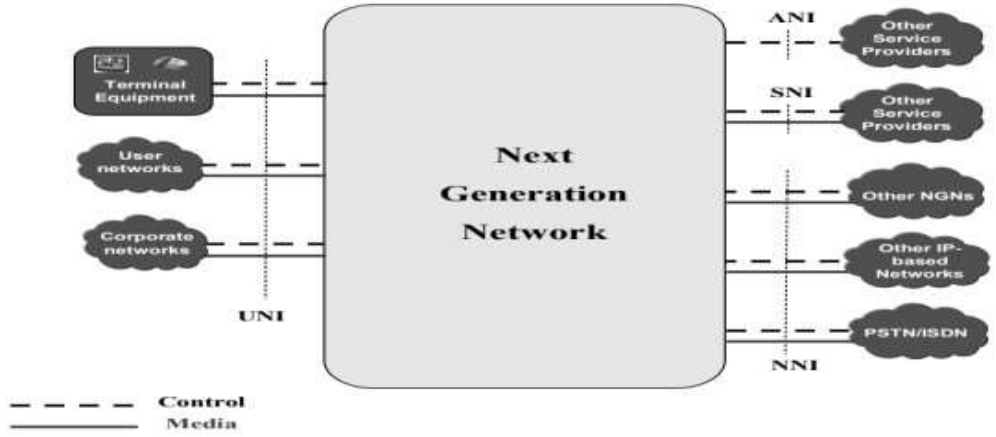


Fig. 3.1: Connectivity to NGN [ITU-T Y.2011]

3. The Application Network Interface (ANI) is an interface which provides a channel for interactions and exchanges between a NGN and applications. The ANI offers capabilities and resources needed for realization of applications. The ANI supports only a control plane level type of interaction without involving media level (or data plane) interaction. The ANI is used to provide connectivity to other service providers, and their applications. An NGN operator can also be an application provider as it may support "in-house" applications.
4. The Service Network Interface (SNI) is an interface which provides a channel for interactions and exchanges between a NGN and other service providers. The SNI supports both a control plane level type of interaction and a media level (or data plane) type of interaction.

3.1.3 NGN Applications:

The next generation network (NGN) is expected to implement various functions for creating various kinds of broadband services, such as end-to-end quality control, unicast communication functions, multicast communication functions, and interactive communication functions.

Major applications are:

1) Intelligent Call Routing (ICR)**:** Intelligent Call Routing is a core network application that allows the execution of a service flow (the business logic of decision nodes) by the underlying routing engine. When a caller makes a phone call to a number, it triggers the right service flow provisioned in ICR based on the dialed number and call treatment is done as per the decision nodes – e.g. connect to IVR menu, play announcement based on time of day, origin or time-based routing, fetch information from external Database, execute commands or call APIs, route the call to operator or call center,
2) Advanced Toll Free: The Advanced Toll-Free or Free Phone service is a core network application that allows callers to make a free phone call to a service-subscriber by dialing a special service
3) Voice Virtual Private Network (VPN) service
4) Number Portability
5) Flexi charge (Real time Rating and Charging)
6) Call Screening Service
7) Emergency Calling Services
8) Call Diversion Service (CDIV)
9) Interactive Voice Response (IVR)
10) Single Number Service (SNS)

11) Caller ID on TV
12) Call Intercept Service (CIS)
13) ZIP Code Routing (ZCR)

3.1.4 NGN Features:

1) NGN Support for a wide range of converged services between fixed/mobile Networks. A fundamental characteristic of NGN is the ability to deliver a wide variety of services including voice, video, audio and visual data, via session and interactive based services in unicast, multicast and broadcast modes. Furthermore, wire line and wireless technologies can be used interchangeably for delivery of services. The NGN can be used in a consistent manner anytime and anywhere across various environments using converged terminal equipment (i.e., those terminals capable of accepting all services) in a digital environment. The concurrent delivery of all content types will allow their simultaneous presentation on single terminal equipment (TE) or on separate devices as required.
2) NGN provides End-to-end Quality of Service (QoS): The NGN aims to provide high quality broadband communication by controlling the quality of service (QoS) on end to end basis.
   The NGN supports a wide range of QoS enabled services:
   a) Bearer service QoS classes;
   b) QoS control mechanisms;
   c) QoS control functional architecture;
   d) QoS control/signaling.
3) NGN provides *e*nd-to-end Packet-based Transfer (machine2machine, human2human ,human2machine)with Broadband capabilities approximately > 2Mbps
4) Technologies used at access and transport layers are broadband in nature. 3G WCDMA, 4G LTE Advance is used at wireless access whereas FTTH, xDSL technology used at wire line access
5) MPLS is used at transport layer in NGN Core.
6) Separation of control functions (routing of payload)among bearer(payload: voice, data) capabilities, call/session
7) Decoupling of service provision: One of the main characteristics of NGN is the decoupling of services and transport, allowing them to be offered separately and to evolve independently. Therefore in the NGN architectures, there will be a clear separation between the functions for the services and the functions for the transport. NGN allows the provisioning of both existing and new services independently of the network and the access type used**.**
8) The separation is represented by two distinct blocks or stratum of functionality. The transport functions reside in the transport stratum and the service functions related to applications reside in the service stratum as shown in Fig.3.2

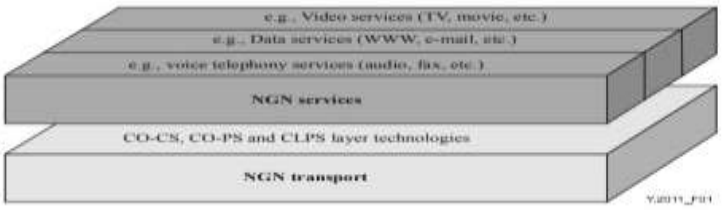


Fig. 3.2: Separation of services from transport in NGN [Courtesy: (T-REC-Y.2011-200410-I!!PDF-E%20ITU-T Y.2001]

9) Interworking with legacy (old) networks via open interfaces**:** Many services have to be operated across a hybrid combination of NGN and non NGN technologies. In such cases

interworking between NGNs of different operators and between NGN and existing networks such as PSTN (Public Switched Telephone Network), ISDN (Integrated Services Digital Network) and GSM (Global System for Mobile communications) is provided by means of gateways.

10) NGN Provides Generalized mobility: It is the ability for the user or other mobile entities to communicate and access services irrespective of changes of the location (anywhere in world) or technical environment.(technology independent)
11) Unrestricted access by users to different service providers**:** User can access services of different service providers along with own service provider.
12) Variety of identification schemes: Since the NGN consists of interconnected heterogeneous networks, using heterogeneous user access and devices the NGN should provide a seamless capability, independent of access method and network, the NGN should address Numbering, Naming and Addressing. NGN can identify different naming and numbering scheme such as: telephone scheme, IPV4, IPV6, E.164.
13) NGN compliant with all regulatory requirements, for example concerning emergency communications, security, privacy, lawful interception, etc.
14) Reliability: Every communication device is highly reliable. To improve reliability provision of redundant configuration for communication circuits and equipment's is maintained.
15) NGN is Layered Architecture having four layers:
    a) Access Layer
    b) Transport /Core Layer
    c) Control Layer
    d) Service Layer

3.1.5 NGN Architecture

The recommended architecture of NGN combines the features of all networks.

Fig. 3.3 shows an overview of the NGN functional architecture. The NGN functional architecture supports the UNI, NNI, ANI and SNI reference points. The NGN architecture supports the delivery of multimedia services and content delivery services, including video streaming and broadcasting.

The aim of the NGN is to serve as a PSTN and ISDN replacement.

The NGN functions are divided into:

- Service stratum (layer) functions
- Transport stratum (layer) functions.

To provide services, several functions in both the service stratum and the transport stratum are needed, as illustrated in Fig 3.3. The delivery of services/applications to the end-user is provided by utilizing the application support functions and service support functions, and related control functions.

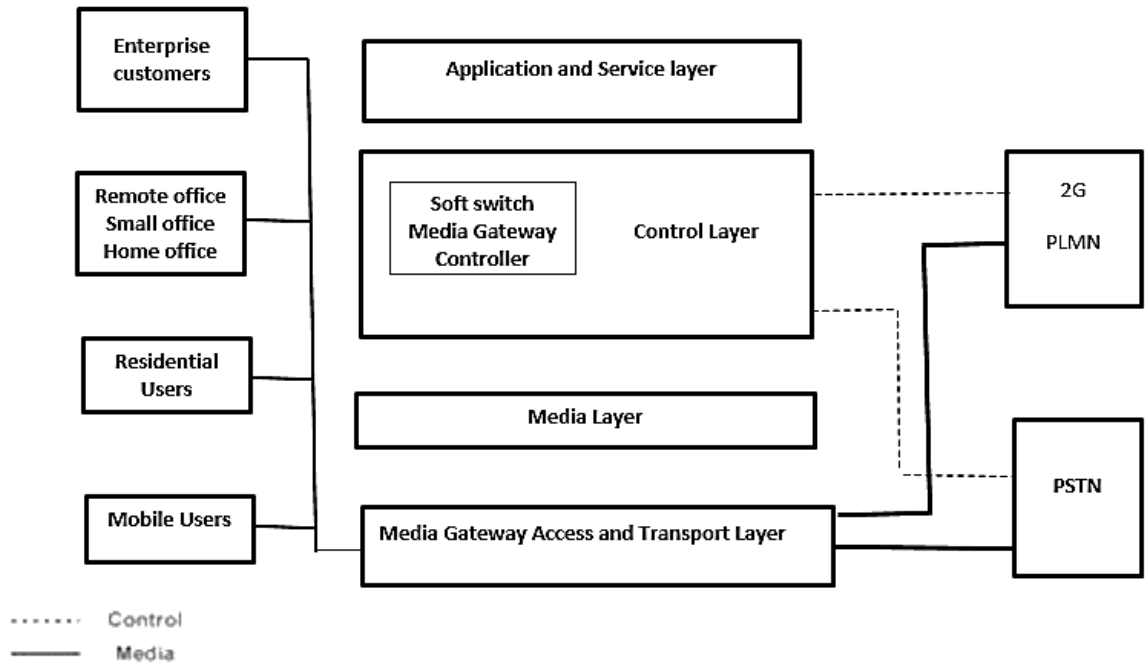


Fig 3.3 NGN Architecture

Transport stratum functions

The transport stratum functions include transport functions and transport control functions.

1) Transport functions: The transport functions provide the connectivity for all components and physically separated functions within the NGN. These functions provide support for unicast and/or multicast transfer of media information, as well as the transfer of control and management information. Transport functions include access network functions, edge functions, core transport functions, and gateway functions.

2) Transport control functions: The transport control functions include resource and admission control functions, network attachment control functions as well as mobility management and control functions.

3) Access network functions: The access network functions take care of end-user's access to the network as well as collecting and aggregating the traffic coming from these accesses towards the core network. These functions also performs QoS control mechanisms dealing directly with user traffic, including buffer management, queuing and scheduling, packet filtering, traffic classification, marking, policing, and shaping. In addition, the access network provides support for mobility. The access network includes access-technology dependent functions, e.g., for W-CDMA technology and xDSL access.
   Depending on the technology used for accessing NGN services, the access network includes functions related to:
   a) Cable access;
   b) xDSL access;
   c) Wireless access (e.g., [b-IEEE 802.11] and [b-IEEE 802.16] technologies and 3G Radio Access Network (RAN access)
   d) Optical access.

4) Gateway functions: The gateway functions provide capabilities to interwork with end-user functions and/or other networks, including other types of NGN and many existing networks, such as the PSTN/ISDN, the public Internet, and so forth. Gateway functions can be controlled either directly from the service control functions or through the transport control functions

5) Resource and admission control functions (RACF): Within the NGN architecture, the resource and admission control functions (RACF) act as the arbitrator between service control functions and transport functions for QoS. The RACF provides an abstract view of transport network infrastructure to service control functions (SCF) and makes service stratum functions agnostic to the details of transport facilities, such as network topology, connectivity, resource utilization and QoS mechanisms/technology.

6) Network attachment control functions (NACF)**:** The network attachment control functions (NACF) provide registration at the access level and initialization of end-user functions for accessing NGN services. They also announce the contact point of NGN functions in the service stratum to the end user.

The NACF provides the following functionalities:

a. Dynamic provisioning of IP addresses and other user equipment configuration parameters.
b. By endorsement of user, auto-discovery of user equipment capabilities and other parameters.
c. Authentication of end user and network at the IP layer (and possibly other layers). Mutual authentication between the end user and the network attachment is performed.
d. Authorization of network access, based on user profiles.
e. Access network configuration, based on user profiles.

Service stratum functions

Functional grouping in the service stratum includes:

a) The service control and content delivery functions including service user profile functions.
b) The application support functions and service support functions.

1) Service control functions (SCF)**:** The service control functions (SCF) include resource control, registration and authentication- authorization functions at the service level for both mediated and non-mediated services. They can also include functions for controlling media resources, i.e., specialized resources and gateways at the service-signaling level.

2) Content delivery functions (CDF): The content delivery functions (CDF) receive content from the application support functions and service support functions, store, process, and deliver it to the end-user functions using the capabilities of the transport functions, under control of the service control functions.

3) Application support functions and service support functions (ASF and SSF): The application support functions and service support functions (ASF and SSF) include functions such as the gateway, registration, authentication and authorization functions at the application level. These functions are available to the "applications" and "end-user" functional groups. Through the UNI, the application support functions and service support functions provide reference points to the end-user functions. Application interactions with the application support functions and service support functions are handled through the ANI reference point.

4) End-user functions: No assumptions are made about the diverse end-user interfaces and end-user networks that may be connected to the NGN access network. End-user equipment may be either mobile or fixed.
5) Management functions: These functions provide the capabilities to manage the NGN in order to provide NGN services with the expected quality, security, and reliability. All the NGN components are centralized controlled.

3.1.6 NGN Network components:

The Fig 3.4 shows the conceptual diagram of NGN network components with VoIP functional architecture.

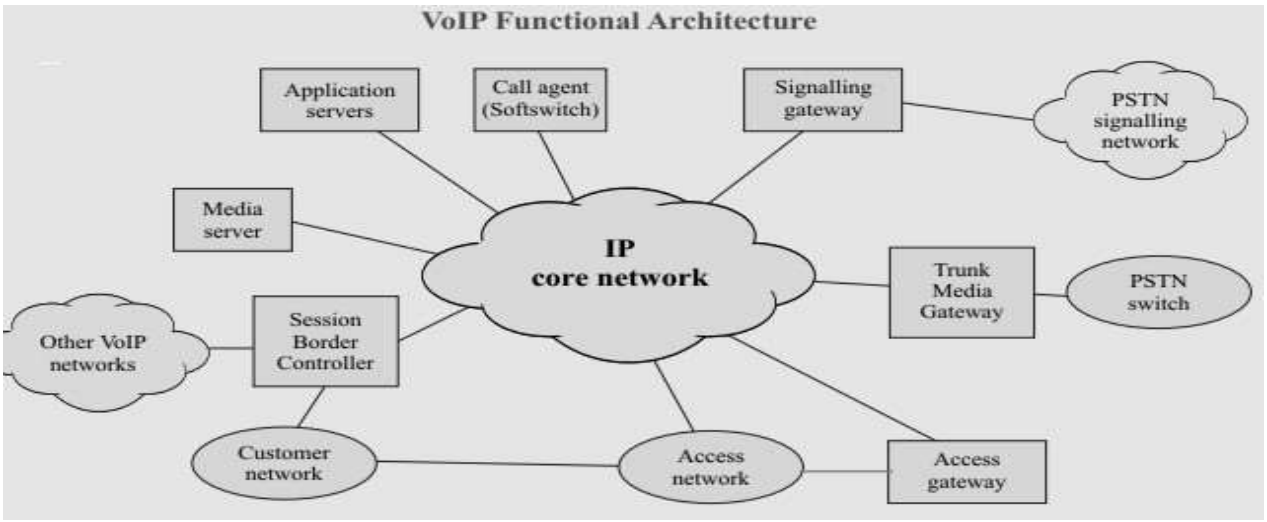


Fig. 3.4: NGN Network Components

1) Media Gateway Controller (MGC): Media gateway controllers are also known as Soft switches and Call controllers, Wireless Call Server or Call Agents. The MGC is located in the service provider's network in control layer and provides call logic and call control functions, typically maintaining call state for every call in the network. Many MGCs interact with application servers to supply services that are not directly hosted on MGCs.

2) Media Gateway: Media Gateways are located in access layer of NGN. Media Gateway performs following functionality:
   a. Access gateway (AG)
   b. Trunk Media gateway (TMG)
   c. Signaling gateway (SG)
   d. Border Gateway (BGW)/ Session Border Controller(SBC)

3) Access gateway (AG): The AG is located in the service provider's network. It supports the line side interface to the core IP network for use by phones, devices, and PBXs. This element provides functions such as media conversion (circuit to Packet, Packet to circuit) and echo control.

4) Trunk Media gateway (TMG): The TMG supports a trunk side interface to the PSTN and/or IP routed flows in the packet network. It supports functions such as packetisation, echo control etc.

5) Signaling gateway (SG): The SG provides the signaling interface between the VoIP network and the PSTN signaling network. It terminates SS7 links and provides Message Transport Part (MTP) Level 1 and Level 2 functionality. Each SG communicates with its associated Call Agent (CA) to support the end-to-end signaling for calls.

6) Border Gateway (BGW)/ Session Border Controller (SBC): It is deployed at the edge and core of a service provider's network to control signaling and media streams as they enter and exit the network.
   a) The “edge” is any IP-IP network border such as between a service provider and a customer or between a service provider and an enterprise network.
   b) The “core” is any IP-IP network border such as between two service providers.

   SBC provides functions such as security, denial of Service attacks, overload control, Network Address Translation and Firewall Traversal, Lawful Interception, Quality of Service (QoS) management, Protocol Translation, call accounting etc.

7) Access network (AN): The access network provides connectivity between the customer premises equipment and the access gateways in the service provider's network. There are various access methods:
   a) TDM direct access,
   b) Switched TDM,
   c) Broadband access (cable, DSL),
   d) IP managed Internet service, etc.

8) IP core network: The primary function of the IP core network is to provide routing and transport of IP packets. The IP core has the added value of architecturally isolating the gateways, and their associated access networks, from the MGC and associated service intelligence.

9) Media Server**:** The Media Server is located in the service provider's network and uses a control protocol such as H.248 or SIP, under the control of the MGC or application server, to provide announcements and tones, and collect user information.

10) Application Server**:** The Application Server is located in the service provider’s network and provides the service logic and execution for one or more applications or services that are not directly hosted on the MGC. Typically the MGC routes calls to the appropriated AS for features the MGC does not support.

NGN components are connected to the practical NGN network as shown in fig 3.5.

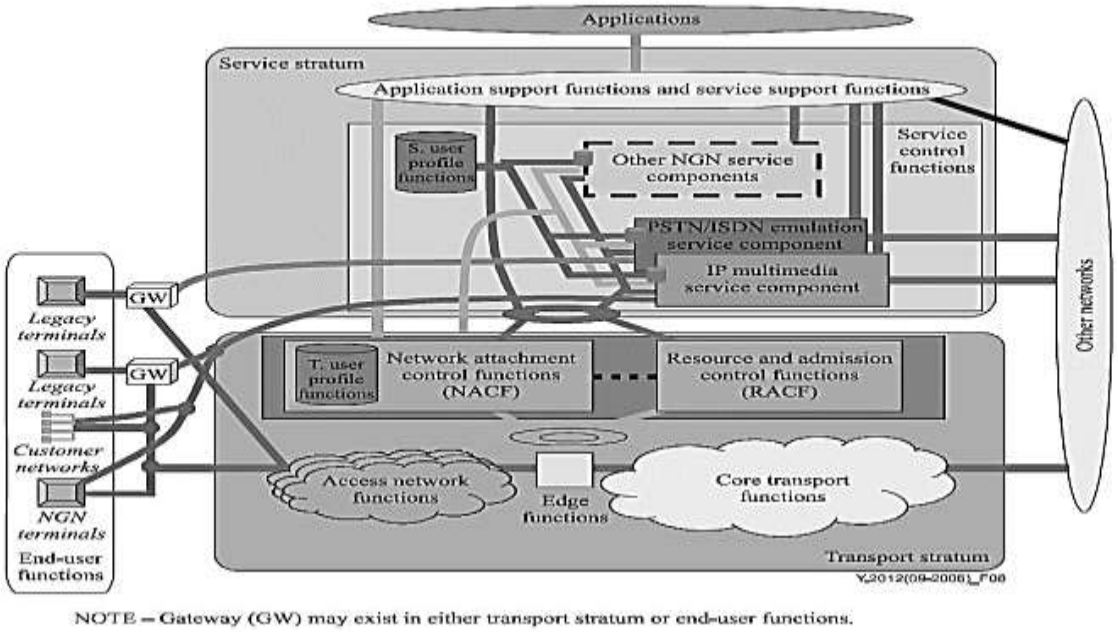


Fig 3.5: NGN Components **(Courtesy: T-REC-Y.2012-200609-S!!PDF-E)**

3.2 NGN Wireless Technology

3.2.1 Licensed and Unlicensed Radio Bands

The radio spectrum is the part of the electromagnetic spectrum with frequencies from 30 Hz to 300 GHz. Electromagnetic waves in this frequency range, called radio waves, are widely used in modern technology, particularly in telecommunication. Radio Spectrum, in general, can be categorized into two types, licensed radio bands and unlicensed radio bands.

Licensed radio bands-To use this radio bands, a license must be obtained from a government agency. This requirement is true of all users of these radio spectrums. A few of the uses of licensed radio bands are as follows:

Table 3.1: Licensed Radio Bands

Sr.No	Type	Frequency Range
1	AM Broadcast a. Short Wave b. Medium Wave c. Long Wave	 1.711MHz-30.0 MHz 520MHz – 1610 MHz 148.5KHz-283.5KHz
2	FM Broadcast	87.5 MHz-108.0 MHz
3	Cellular Phone	840 MHz, 900 MHz

Unlicensed radio bands: Unlicensed radio bands have been allocated to certain users by the government or any individual can use it, but to be able to use and broadcast on these bands, user do not need to have a license; user only need to create compliant devices that are to be used. Regulations exist around these bands.

Some of the types of unlicensed radio bands are as follows:

Table 3.2: Unlicensed Radio Bands

Sr.No	Type	Frequency
1	Industrial, Scientific and Medical [ISM] Band Includes several Medical monitors and Industrial devices.	900 MHz, 2.4 GHz, 5 GHz.
2	Unlicensed National Information Infrastructure (U-NII) Defines specifications for the use of wireless devices such as WLAN access points and routers	5GHz Band

Standard Bodies: IEEE 802.11 networks have several choices of wireless bands that are available to them to use, without the requirement to lease the frequencies from the government.

Following groups and standards bodies have helped to develop standards so that all users can be good neighbors with others who use those radio bands.

Table 3.3: Standard Organization Bodies

S No	Abbreviation	Full Form	Function
1	FCC	Federal Communications Commission	Manages and sets standards with regard to the spectrum use
2	IEEE	Institute of Electrical and Electronics Engineers	A leading standards organization which publishes standards that are adopted across industries
3	ETSI	European Telecommunications Standards Institute	Another standards organization that has contributed many worldwide standards
4	ITU-R	International Telecommunication Union, Radio communication Sector	With the FCC, defines how WLANs should operate from a regulatory perspective, such as operating frequencies, antenna gain, and transmission power
5	WLANA	WLAN Association	Provides information resources related to WLANs with regard to industry trends and usage.
6	WPC	The Wireless Planning and Coordination	National Radio Regulatory Authority responsible for Frequency Spectrum Management, including licensing and caters for the needs of all wireless users (Government and Private) in the India. It exercises the statutory functions of the Central Government and issues licenses

			to establish, maintain and operate wireless stations

3.2.2 Mobile Network Evolution (3G to 5G):

In the last few decades, Mobile Wireless Communication networks have experienced a remarkable change. The mobile wireless Generation (G) generally refers to a change in the nature of the system, speed, technology, frequency, data capacity, latency etc. Each generation have some standards, different capacities, new techniques and new features which differentiate it from the previous one .The first generation (1G) mobile wireless communication network was analog used for voice calls only. The second generation (2G) is a digital technology and supports text messaging. The third generation (3G) mobile technology provided higher data transmission rate, increased capacity and provide multimedia support. The fourth generation (4G) integrates 3G with fixed internet to support wireless mobile internet, which is an evolution to mobile technology and it overcome the limitations of 3G. It also increases the bandwidth and reduces the cost of resources. 5G stands for 5^{th} Generation Mobile technology and is going to be a new revolution in mobile market which has changed the means to use cell phones within very high bandwidth. User never experienced ever before such high value technology which includes all type of advance features and 5G technology will be most powerful and in huge demand in near future.

The GSM technology was continuously improved to provide better services which led to development of advanced Technology between 2G and 3G. Fig 3.6 shown GSM architecture.

1. Provides phone calls
2. Send/receive e-mail messages
3. Web browsing Speed : 64-144 kbps
4. Camera phones

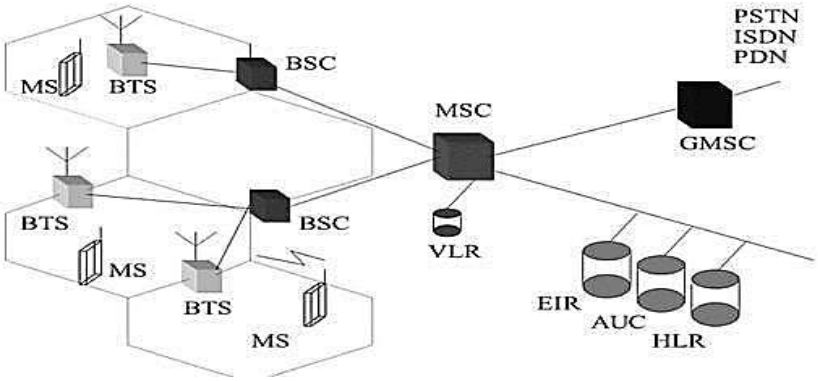


Fig 3.6: GSM System Architecture

GSM components functions are elaborated in Table 3.4.

Table 3.4: GSM Components Functions

Sr. No	GSM Components	Functions
1	Network switching system (NSS)	NSS is a GSM element that provides flow management and call processing for mobile devices moving between base stations
2	Mobile Services Switching Center (MSC)	Mobile Switching Center is integral to the GSM network architecture's central network space. The MSC supports call switching across cellular phones and other fixed or mobile network users. It also monitors cellular services, including registration, location updates, and call forwarding to a roaming user.
3	Home Location Register (HLR)	It is a set of data items used for storing and managing subscriptions. It provides data for each consumer as well as their last known position. The HLR is regarded as the most significant database because it preserves enduring records about users.
4	Visitor Location Register (VLR)	VLR is a database that provides subscriber information necessary for the MSC to service passengers. This includes a short-term version of most of the data stored in the HLR.
5	Equipment Identity Register (EIR)	It is the component that determines if one can use particular mobile equipment on the system. This consists of a list of every functioning mobile device on the system, with each mobile device recognized by its own International Mobile Equipment Identity (IMEI) number.
6	Authentication Center (AuC)	The AUC is a unit that offers verification and encryption factors to ensure the user's identity and the privacy of every call. The verification center is a secure file that contains the user's private key in the SIM card.
7	Mobile station (MS)	The mobile station is a cell phone with a display, digital signal processor, and radio transceiver regulated by a SIM card that functions on a system. Hardware and the SIM card are the two most essential elements of the MS. The MS (Mobile stations) is most widely recognized by cell phones, which are components of a GSM mobile communications network that the operator monitors and works.
8	Base station system (BSS)	It serves as a connection between the network subsystem and the mobile station.
9	Base Transceiver Station (BTS)	The BTS is responsible for radio connection protocols with the MS and contains the cell's radio transceivers. Each network cell has transceivers and antennas that make up the BTS. Based on the cell's consumer density, every BTS includes anywhere from one to sixteen transceivers.
10	Base Station Controller (BSC)	The BSC is responsible for managing the radio resources of one or more BTS(s). This manages radio channel configuration and handovers. The BSC serves as the link seen between mobile and MSC. It allocates and emits MS frequency bands and time slots. Additionally, the BSC is responsible for intercell handover and transmits the BSS and MS power within its jurisdiction.

Third Generation (3G) Mobile Technology:

3G is based on GSM and was launched in 2000. The aim of this technology was to offer high speed data. The original technology was improved to allow data up to 14 Mbps and more using packet switching. It uses Wide Band Wireless Network with which clarity is increased. It also offers data services, access to television/video, new services like Global Roaming. It operates at a range of 2100MHz and has a bandwidth of 15-20MHz used for High-speed internet service, video chatting.

The main features of 3G are:

a) Increased bandwidth (Speed 2 Mbps**)** and data transfer rates to accommodate web-based applications and audio and video files.
b) Typically called smart phones**,** intelligent device
c) Provides faster communication
d) High speed web/more security/video conferencing/3D gaming
e) Large capacities and broadband capabilities such as TV streaming/mobile TV/Phone calls

3G mobile system was called as UMTS (Universal Mobile Telecommunication System) which includes 2 technology WCDMA or CDMA2000. Fig 3.7 shows the WCDMA network diagram.

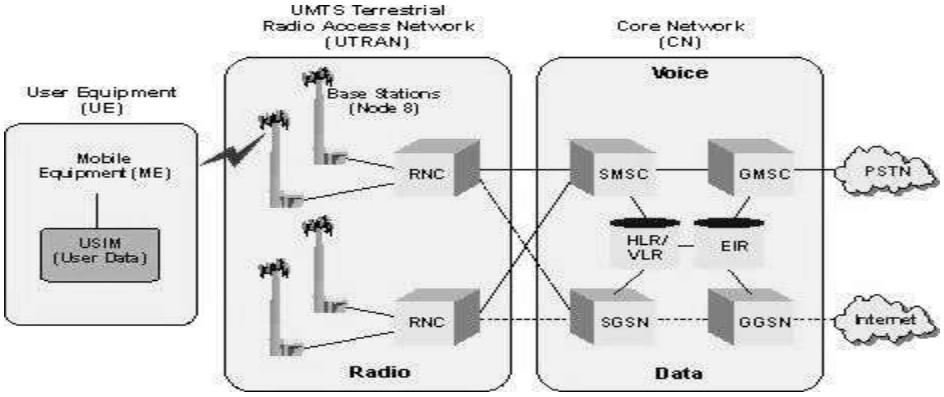


Fig. 3.7 WCDMA Network Diagram

Fourth Generation (4G) Mobile Technology:

4G offers a downloading speed of 100Mbps. 4G provides same feature as 3G and additional services like Multi-Media Newspapers, to watch T.V programs with more clarity and send Data much faster than previous generations .

LTE (Long Term Evolution) is considered as 4G technology. 4G is being developed to accommodate the QoS and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth. Fig 3.8 shows 4G network architecture.

The main features of 4G are:

a) Uplink speed (UE to node B) 100 Mbps and Download link speed (node B to UE) 200 Mbps.
b) When user is using mobile at fixed position or is moving from one place to other 4G is capable to provide 10Mbps-1Gbps speed
c) High quality streaming video **[**HDTV content, Digital Video Broadcasting (DVB)]
d) Combination of Wi-Fi and Wi-Max
e) High security as compared to 3G

f) Provide any kind of service at any time as per user requirements anywhere
g) Integrated Expanded multimedia services i.e. voice,video,data can be integrated for (internet, telephone, TV broadcasting, wearable devices)
h) Low cost per-bit
i) As compared to 3G more battery requirement.
j) Hard to implement.
k) Need complicated hardware
l) Expensive equipment required to implement next generation network

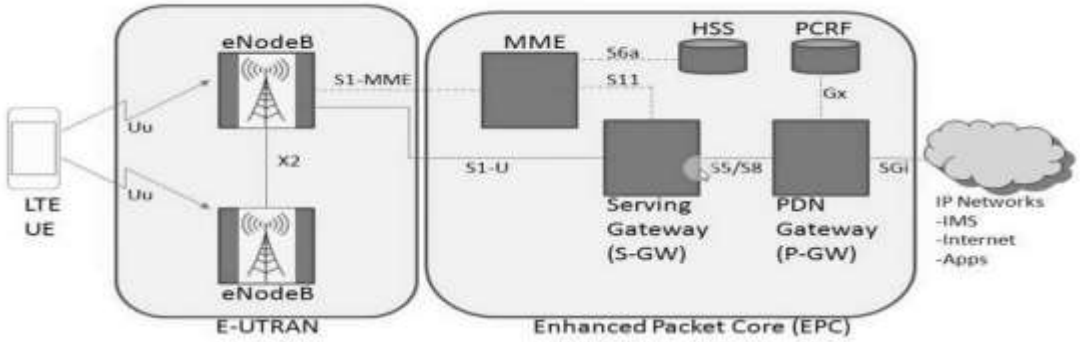


Fig 3.8. 4G Network Architecture

Table 3.5: 4G Network Components Functions

Sr. No	Components	Function
1	Home Subscriber Server (HSS)	The component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.
2	Packet Data Network (PDN)	Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world i.e. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.
3	Serving gateway (S-GW)	The acts as a router, and forwards data between the base station and the PDN gateway.
4	Mobility Management Entity (MME)	MME controls the high-level operation of the mobile by means of signaling messages and Home Subscriber Server (HSS).
5	Policy Control and Charging Rules Function (PCRF)	PCRF is a component which is not shown in the above diagram but it is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW

Fifth Generation (5G) Mobile Technology:

5G refer to Fifth Generation Mobile technology has initiated implementation in 2022 in India. Facilities that might be seen with 5G technology includes far better levels of connectivity and coverage. The main focus of 5G will be on World-Wireless World Wide Web (WWWW).

The main features of 5G are:

a) It is highly supportable to WWWW (Wireless World Wide Web)
b) High speed, high capacity to provide large broadcasting of data in GBps.
c) Multi-media newspapers, watch TV programs with the clarity (HD Clarity)
d) Faster data transmission that of the previous generation
e) Support interactive multimedia, voice, streaming video, internet and other such as wearable devices.
f) More effective and attractive

The current trend of 5G technology has a following feature:

a) 5G technology offer high resolution for cell phone user and bi- directional large bandwidth sharing.
b) 5G technology is providing large broadcasting of data in Gigabit which supporting almost 65,000 connections.
c) The uploading and downloading speed of 5G technology touching the peak
d) The 5G technology also support virtual private network.
e) The 5G terminals will have software defined radios and modulation schemes as well as new error control schemes that can be downloaded from the Internet.
f) In 5G, each network will be responsible for handling user-mobility, while the terminal will make the final choice among different wireless/mobile access network providers for a given service. Such choice will be based on open intelligent middleware in the mobile phone.
g) The remote diagnostic is a great feature offered by 5G, through which a user can get better and fast solution.

Challenges Facing by 5G:

a) Integration of various standards: One of the big challenges facing 5G is standardization. There are already multiple groups working to come up with standards around interoperability, backward compatibility with older technologies (4G, 3G), and making sure the network will be future-proof.
b) Common Platform: There is no common architecture for interconnecting various engineering practices. One common governing body is required, which creates a common platform for all engineering practices to regularize the interconnectivity issues as well as knowledge sharing
c) Building the infrastructure: It is a huge task, with issues around spectrum and installing new antennas. 5G is likely going to rely, at least in part, on higher-frequency bands. There is more space in those airwaves available, but at such high frequencies, signals can’t travel nearly as far as they can over the frequencies used for 4G, resulting in a poor connection.
d) Obstacles: Like buildings, trees and even bad weather can also cause interference. To offset that, carriers will need to install more base stations to ensure better coverage, and use antenna technologies like MIMO.

Table 3.6: Comparison of All Generations of Mobile Technologies:

Technology	**1G**	**2G**	**3G**	**4G**	**5G**
Start/ Development	1970-80	1990-2004	2004-10	2010-12	Soon (probably by 2020)
Data bandwidth	2 Kbps	64 Kbps	2 Mbps	1 Gbps	Higher than 1 Gbps
Technology	Analog	Digital	CDMA-2000, UMTS,EDGE	Wi max, Wi-Fi, LTE	WWWW
Core network	PSTN	PSTN	Packet Network	Internet	Internet
Multiplexing	FDMA	TDMA/ CDMA	CDMA	CDMA	CDMA
Technology	**1G**	**2G**	**3G**	**4G**	**5G**
Switching	Circuit	Circuit /Packet	Packet (except Air interference)	All Packet	All Packet
Primary service	Analog phone calls	Digital phone calls and Messaging	Phone calls and Messaging, data. Integrated high quality audio, video and data	Dynamic integration of access, variable Devices. All IP service (including voice messages)	Dynamic integration of access, variable devices with air interference. High speed, High capacity and provide large broadcasting of data in Gbps
Key differentiator	Mobility	Secure, Mass adoption	Better Internet experience	Faster broadband Internet ,lower Latency	Better coverage and no dropped calls ,much lower latency, Better performance

3.3 NGN Core

MPLS (Multi-protocol label switching) is used at core transport layer in NGN network. MPLS provides faster switching, propagation delay is less.

3.3.1 MPLS Overview

In NGN, a packet of a connectionless network layer protocol travels from one router to the next, each router makes an independent forwarding decision for that packet. That is, each router analyzes the packets header, and each router runs a network layer routing algorithm and independently chooses a next hop for the packet, based on its the packet's header.

Packet headers contain considerably more information than is needed simply to choose the next hop. Choosing the next hop can therefore be thought of as the composition of two functions.

a. The first function partitions the entire set of possible packets into a set of Forwarding Equivalence Classes (FECs).

b. The second maps each FEC to a next hop.

3.3.2 MPLS Basics

Elements of MPLS: Fig 3.9 shows the MPLS architecture.

1) Labels: A label is a short, fixed length, locally significant identifier which is used to identify a FEC. The label which is put on a particular packet represents the Forwarding Equivalence Class to which that packet is assigned. Most commonly, a packet is assigned to a FEC based on its network layer destination address. Each IP destination network has a different label which has local significance. Label for a destination network changes in each hop.

2) Label Switch Router :
   A label switch router (LSR) is a router that supports MPLS. It is capable of understanding MPLS labels and of receiving and transmitting a labeled packet on a data link. Three kinds of LSRs exist in an MPLS network:
   a. Provider Edge [PE] Router/Ingress LSRs: Ingress LSRs receive a packet that is not labeled yet, insert a label (stack) in front of the packet, and send it on a data link.
   b. Provider Edge [PE] Router/Egress LSRs: Egress LSRs receive labeled packets, remove the label(s), and send them on a data link. Ingress and egress LSRs are edge LSRs.
   c. Core Edge [CE] Router/Intermediate LSRs: Intermediate LSRs receive an incoming labeled packet, perform an operation on it, switch the packet, and send the packet on the correct data link.

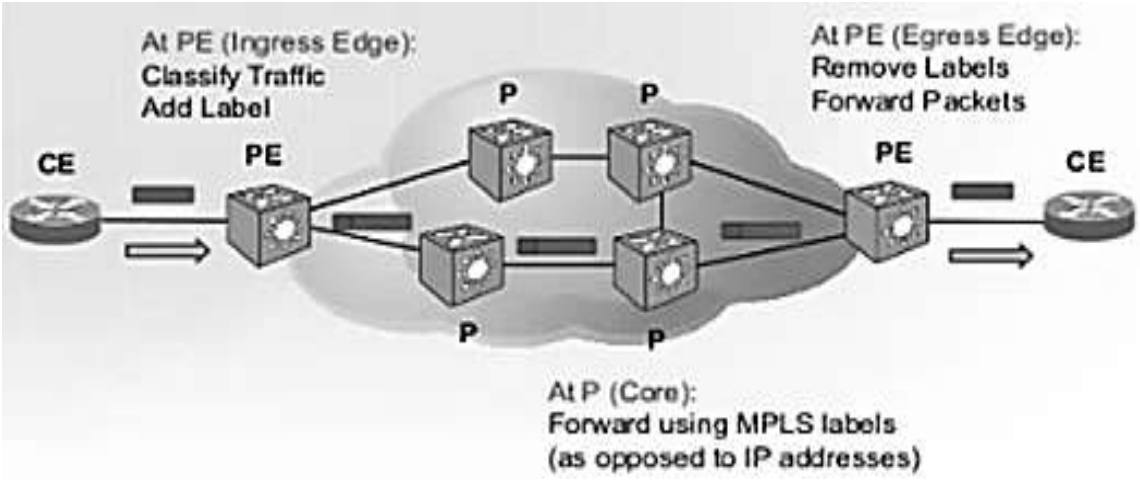


Fig 3.9 MPLS Architecture

   d. Upstream and Downstream LSRs:
      An LSR can do the three operations: PUSH/adding labels, POP/remove labels, or SWAP/interchanging labels.
      i. It must be able to pop one or more labels (remove one or more labels from the top of the label stack) before switching the packet out.
      ii. An LSR must also be able to push one or more labels onto the received packet.
      iii. If the received packet is already labeled, the LSR pushes one or more labels onto the label stack and switches out the packet.
      iv. If the packet is not labeled yet, the LSR creates a label stack and pushes it onto the packet. An LSR must also be able to swap a label. This simply means that when a labeled

packet is received, the top label of the label stack is swapped with a new label and the packet is switched on the outgoing data link.

v. An LSR that pushes labels onto a packet that was not labeled yet is called an imposing LSR because it is the first LSR to impose labels onto the packet.
vi. One that is doing imposition is ingress LSR. An LSR that removes all labels from the labeled packet before switching out the packet is a disposing LSR.
vii. One that does disposition is an egress LSR.

e. Label Switch path: A label switched path (LSP) is a sequence of LSRs that switch a labeled packet through an MPLS network or part of an MPLS network. Basically, the LSP is the path through the MPLS network or a part of it that packets take. The first LSR of an LSP is the ingress LSR for that LSP, whereas the last LSR of the LSP is the egress LSR. All the LSRs in between the ingress and egress LSRs are the intermediate LSRs. LSP is unidirectional. The flow of labeled packets in the other direction right to left between the same edge LSRs would be another LSP.

3.3.3 MPLS Features:

1 QoS enabled MPLS transport network will provide real time and data transport application.
2 MPLS increases operator revenue.
3 MPLS offers high transport efficiency by using hybrid technology (packet switching and circuit switching)
4 MPLS offers high reliability and operational simplicity.
5 MPLS provide control and deterministic usage of network resources, end-to-end control to engineer network paths and to efficiently utilize network resources.
6 In MPLS network management is simple
7 It ensures smooth interworking of the packet transport network with other existing/legacy packet networks.
8 MPLS header length is of 32 bits, in which label length is 20 bits, 3 bits for service quality and 8bits for Time to live (no of hops in network) and 1 bit for stacking the labels.

3.4 Fiber to the Home (FTTH)/Wireline technology:

The optical section of a local access network system can be either active or passive and its architecture can be either point-to-point or point-to-multipoint. Figure 3.10 shows the architectures considered, such as fiber to the home (FTTH), fiber to the cell sites (FTTCell), fiber to the building/curb (FTTB/C) and fiber to the cabinet (FTT Cab).

The differences among these FTTx options are mainly due to the different services supported and the different locations of the ONUs.

With above FTTx scenario following service categories have been considered:

1 Asymmetric broadband services: Asymmetric broadband services means the Bandwidth is allocated as per requirement e.g., digital broadcast services, VoID, Internet, distant learning, telemedicine, etc.
2 Symmetric broadband services: In Symmetric broadband services the bandwidth on both transmitter and receiver side is equal e.g., telecommunication services for small business customers, tele consulting, etc.
3 PSTN and ISDN. The access network must be able to provide in a flexible way the narrowband telephone services with the appropriate timing for the introduction.

3.4.1 FTTH Functional Component:

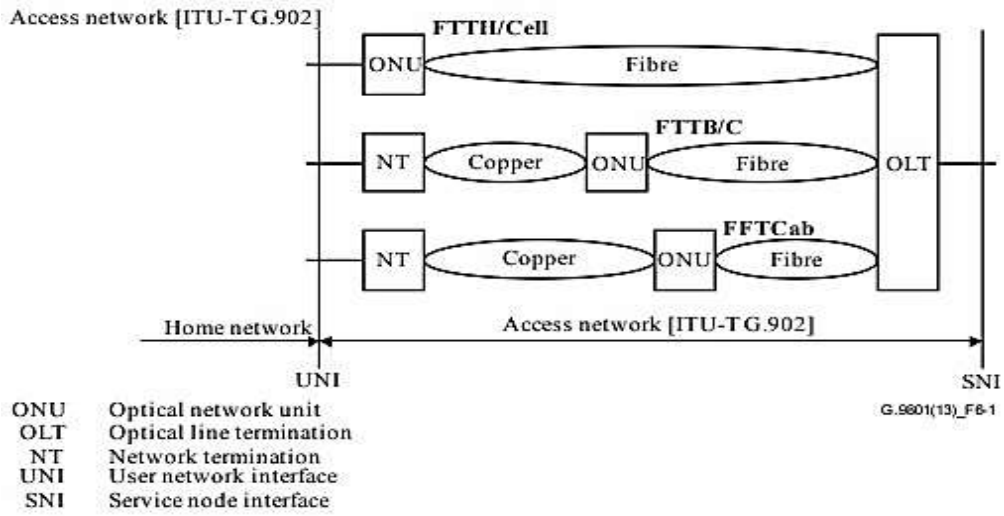


Fig 3.10 FTTH Architecture

The two directions for optical transmission in the Optical Distribution Network are identified as:

i. Downstream direction for signals travelling from the Optical Line Termination to the Optical Network Unit's.
ii. Upstream direction for signals travelling from the ONU's to the OLT.

The system consists of Optical Line Termination (OLT), Optical Network Unit (ONU) and fiber cable which has a Passive Optical Network (PON) configuration with a passive optical splitter. One fiber is passively split between multiple ONU's who share the capacity of one fiber. Because of the passive splitting, special actions are required with respect to privacy and security.

Table 3.7: FTTH Components Functions

Sr. No	FTTH Components	Functions
1	User Network Interface [UNI]	UNI is the physical interface boundary between the user (subscriber) and the service provider.
2	Service node interface [SNI]	SNI is the interface between the service node (SN) and the access network.
3	Optical Line Termination [OLT]	Optical Line Termination (OLT) interface is over the SNI to service nodes, and to the Optical Network. The OLT is responsible for managing all the network-specific aspects of the ATM transport system. The ONU and OLT provide transparent ATM transport service between the UNIs and the SNI over the optical network
4	Optical Network Unit [ONU]	The Optical Network Unit interfaces over the Optical Network to the OLT, and to the UNI. Together with the OLT, the ONU is responsible for providing transparent ATM transport service between the UNI and the SNI. Convergence layer, and ATM layer.
5	Optical Distribution Network [ODN]	The Optical Distribution Network provides the optical transmission means from the OLT towards

Sr. No	FTTH Components	Functions
		the users and vice versa. It utilizes passive optical components

3.4.2 FTTH Features:-

a. Indoor ONU's can be considered, resulting in more favorable environmental conditions.
b. No change of intermediate ONU is required to upgrade access network capabilities to accommodate future evolution of broadband and multimedia services.
c. Maintenance is easy, because it requires maintenance only for fiber systems, and all fiber systems are regarded as more reliable than hybrid fiber-metallic ones.
d. FTTH is a driver for the development of advanced optoelectronics technologies. The greater volume in production of optical modules will also accelerate the reduction in cost. The ODN offers one or more optical paths between one OLT and one or more ONUs.

3.5 Next Generation Transmission System:

Synchronous Digital Hierarchy (SDH):

Synchronous digital hierarchy (SDH) are standardized protocols that transfer multiple digital bit streams synchronously over optical fiber using lasers or highly coherent from light emitting diodes (LEDs). At low transmission rates data can also be transferred via an electrical interface.

SONET and SDH, which are essentially the same, were originally designed to transport circuit mode communications (e.g., E1, E3) from a variety of different sources, but they were primarily designed to support real-time, uncompressed, circuit-switched voice encoded in PCM format.

SDH allowed for the simultaneous transport of many different circuits of differing origin within a single framing protocol. SDH is not a communications protocol in itself, but a transport protocol.

Table 3.8: SDH Data Rates

SONET Level (Optical)	SONET Frame Format (Electrical)	SDH Level and Frame Format	Payload Bandwidth (Kbit/s)	Line Rate (Kbit/s)
OC-1	STS-1	STM-0	50,112	51,840
OC-3	STS-3	STM-1	150,336	155,520
OC-12	STS-12	STM-4	601,344	622,080
OC-24	STS-24	--	1,202,688	1,244,160
OC-48	STS-48	STM-16	2,405,376	2,488,320
OC-192	STS-192	STM-64	9,621,504	9,953,280
OC-768	STS-768	STM-256	38,486,016	398,131,20
OC-3072	STS-3072	STM-1024	153,944,064	159,252,480

Table 3.9 Transmission Technology Features

Sr.No.	Technology	Bit Rate	Features
1	SDH	51.84Mbps39.13Gbps	Performance Monitoring, Fault Detection, Connection Channel and Multiplexing features available.
2	WDM/DWDM	Up to 400 Gbps	All SDH features available. Higher bit rate achieved with WDM/DWDM Multiplexing.

3	OTN	Up to 400 Gbps	All features DWDM available. Operation, Network Management and Protection facility available.

Table 3.10 OTN STANDARDS

ITU-T Standards	Description
G.878	OTN architecture
G.709	Frame format and payload mapping (Ethernet ,storage, SDH/SONET)
G.798	Characteristics of optical transport network hierarchy equipment functional blocks
G.873.1	Optical transport networks (OTN): Linear protection

Suggested Resources:

Sr. No.	Keyword	QR Code	Weblink
1.	TRAI Publications		https://www.trai.gov.in/notifications/publication
2.	NGN Overview		https://www.itu.int/en/ITU-T/studygroups/2013-2016/03/Documents/201405-miniworkshop/05-Chaesub-Lee.pdf
3.	NGN Basics		https://www.slideshare.net/NiranjanPoojary/ngn-basics
4.	Video Lecture on MPLS		https://www.youtube.com/watch?v=t2WpMsk18yU
5.	Evolution of Mobile Generation		https://www.semanticscholar.org/paper/EVOLUTION-OF-MOBILE-GENERATION-TECHNOLOGY%3A-1G-TO-5G-Vora/82bb15f1dcc9bf669601d3957cbe9b6178eab097?p2df
6.	Telecommunication Engineering center Study Papers		https://tec.gov.in/study-papers

Sample Question:

Sr. No.	Question
1.	In NGN the interface used to provide connectivity to terminal equipment's is A. UNI B. ANI C. NNI D. SNI
2.	In NGN ,the interface not supporting media interaction is A. UNI B. ANI C. NNI D. SNI
3.	Number of layer in NGN architecture are A. 7 B. 6 C. 5 D. 4
4	Within the NGN architecture, the _____act as the arbitrator between service control functions and transport functions for QoS. A. RACF B. NACF C. Gateway functions D. Transport Functions
5.	In NGN communication is possible A. Within a city B. Within a state C. Within a country D. Anywhere in world
6.	The data bandwidth rate in 4G is A. 2MBps B. 64KBps C. 2 KBps D. 1GBps
7.	The multiplexing technique used in 3G is A. CDMA B. FDMA C. TDMA D. Not from above
8.	In GSM Database that provides subscriber information necessary for the MSC to service passengers A. Home Location Register B. Visitor Location Register C. Equipment Identity Register

	D. Base Station
9.	____ multiplexing is used in 4G. A. FDMA B. CDMA C. TDMA D. FDMA/CDMA
10	In licensed radio bands, medium wave frequency range between_____ A. 1.711 MHz to 30MHz B. 520MHz to 1610MHz C. 148.5MHz to 283.5MHz D. 87.5MHz to 108 MHz
11	In licensed radio bands, short wave frequency range between_____ A. 1.711 MHz to 30MHz B. 520MHz to 1610MHz C. 148.5MHz to 283.5MHz D. 87.5MHz to 108 MHz
12	In licensed radio bands, FM Broadcast frequency range between_____ A. 1.711 MHz to 30MHz B. 520MHz to 1610MHz C. 148.5MHz to 283.5MHz D. 87.5MHz to 108 MHz
13	In Fourth Generation (4G) Mobile _____ technology is used. A.Digital B.CDMA-2000 C.Wi-Max D.WWWW
14	In Fifth Generation (5G) Mobile _____ technology is used. A. Digital B. CDMA-2000 C. Wi-Max D. WWWW
15	Technology provides Phone calls, Messaging, Data Integrated Audio and Data. A.2G B.3G C.4G D.5G
16	The protection Scheme in an OTN network is defined by: A.G 709 B.G 873.1 C.G 798 D.G 872

17	SDH is ____layer protocol. A. Session B. Transport C. Service D. Application
18	Data Speed in 5G is A. More than 1Gbps B. 64Kbps C. 2Mbps D. 4 Kbps
19	TTL in MPLS label is A. Transistor to Transistor Logic B. Time to Live C. Technology Transfer Layer D. Through the Line
20	Synchronous Digital Hierarchy provides the feature like: A. Performance Monitoring. B. Network Management C. Protection facility D. WDM Multiplexing.

Unit 4: Digital Factory

Expected Course Outcome: Suggest the relevant IoT technologies for Digital Factory.

Teaching Hrs. 10 **Marks 16**

To attain above course outcome candidate must able to:

1. Explain the principle of IoT used in given application.
2. Explain the architecture of IoT.
3. Explain the importance of IoT in given application.
4. Explain the importance of Industrial revolution I4.0
5. Suggest the suitable type of ML for given AI application.

This Unit mainly focus on following major points:

4.1 Internet of Things IoT: Introduction, Functions of Cyber Physical system Components.
4.2 Architectures: IoT Sensor to cloud data routes.
4.3 Applications of IoT in Industries: Automotive, Discreet Manufacturing, Telecom and Agro Industries.
4.4 I4.0/IIoT/ Smart Manufacturing: Introduction/ Evolution from I1.0 to I4.0, Applications and benefits of I4.0, Compare I3.0 with I4.0, Architecture of I4.0
4.5 Artificial Intelligence/ Machine Learning (AI/ML): Definitions of AI, Applications and advantages of AI, Definition and Types of ML such as Supervised, Unsupervised and Reinforcement. Relationship between DL, ML and AI. Agents in AI: Single Agent and Multi Agent.

Introduction:

A digital factory uses digital technology for modeling, communications and to operate the manufacturing process. This arrangement of technology allows managers to configure, model, simulate, assess and evaluate items, procedures and system before the factory is constructed. The digital factory gives answers for configuration, design, screen and control of a production system.

It adopts the combination of physical technology and cyber technology and deeply integrates previously independent discrete systems making the involved technologies more complex and precise than they are now.

In the implementation of digital factory, the Industrial Internet of Things (IIoT) is employed to integrate the underlying equipment resources. Accordingly, the manufacturing system has abilities of perception, interconnection and data integration. The data analysis and scientific decision are used to achieve production scheduling, equipment service and quality control of products in digital factory. Further, the Internet of services is introduced to virtualize the manufacturing resources from a local database to the cloud server. Through the human-machine interaction, the global collaborative process of intelligent manufacturing oriented to the order-driven market is built. Therefore, the digital factory represents an engineering system that mainly consists of three aspects: interconnection, collaboration and execution. The main aim of digital factory is to convert modern factory into smart factory.

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

Things: A thing, in the context of the Internet of things (IoT), is an entity or physical object that has a unique identifier, an embedded system and the ability to transfer data over a network. Things can be a part of domestic, process or manufacturing areas like smart TV, PLC, CNC machine etc. IoT evolved from machine-to-machine (M2M) communication, i.e., machines connecting to each other via a network without human interaction. M2M refers to connecting a device to the cloud, managing it and collecting data. Taking M2M to the next level, IoT is a sensor network of billions of smart devices that connect people, systems and other applications to collect and share data. As its foundation, M2M offers the connectivity that enables IoT.

The IoT is also a natural extension of SCADA (supervisory control and data acquisition), a category of software application program for process control, the gathering of data in real time from remote locations to control equipment and conditions. SCADA systems include hardware and software components. The hardware gathers and feeds data into a computer that has SCADA software installed, where it is then processed and presented it in a timely manner. The evolution of SCADA is such that late-generation SCADA systems developed into first-generation IoT systems.

Major components of IoT system:

1. **Physical object:** with embedded software into hardware
2. **Hardware:** Consisting of microcontroller, firmware, IoT sensors, control unit, actuators, and communication modules.
3. **Communication Module:** Software consisting of device APIs and device interface for communication over the network and communication circuits, ports and middleware for creating communication stacks using IPv4, IPv6, ZigBee and other protocols
4. **Software:** For actions on messages, information and commands which devices receives and drives actuators which enables actions such as glowing light, on off domestic or industrial equipment's**.**

Examples of IoT: The first most smart and interactive IoT device is the ATM, Others are smart watches, fitness trackers, sleep monitors, heart monitors.

An IoT ecosystem: consists of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments as shown in Fig 4.1.

IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data.

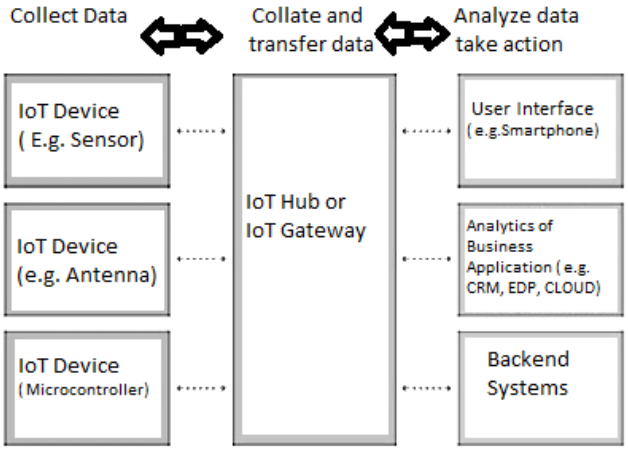


Fig 4.1: IoT System

The connectivity, networking and communication protocols used with these web-enabled devices largely depend on the specific IoT applications deployed.

Importance of IoT:

1. The IoT helps people live and work smarter as well as gain complete control over their lives and also offers smart devices to automate homes.
2. IoT provides businesses with a real-time look into how their companies' systems really work, delivering insights into everything from the performance of machines to supply chain and logistics operations.
3. IoT enables companies to automate processes and reduce labor costs.
4. It also cuts down on waste and improves service delivery, making it less expensive to manufacture and deliver goods as well as offering transparency into customer transactions.
5. IoT touches every industry, including healthcare, finance, retail and manufacturing.
6. Smart cities help citizens reduce waste and energy consumption and connected sensors are even used in farming to help monitor crop and cattle yields and predict growth patterns.

As such, IoT is one of the most important technologies of everyday life and it will continue to pick up steam as more businesses realize the potential of connected devices to keep them competitive.

Advantages of IoT:

1. Ability to access information from anywhere at any time on any device.
2. Improved communication between connected electronic devices.
3. Monitor their overall business processes.
4. Improve the customer experience.
5. Save time and money.
6. Enhance employee productivity.
7. Integrate and adapt business models.
8. Make better business decisions.
9. Generate more revenue.
10. IoT encourages companies to rethink the ways they approach their businesses, industries and markets and gives them the tools to improve their business strategies
11. Transferring data packets over a connected network saves time and money.
12. Automating tasks helps improve the quality of a business' services and reduces the need for human intervention.

Disadvantages of IoT:

1. As the number of connected devices increases and more information is shared between devices, the potential that a hacker could steal confidential information also increases.
2. Enterprises may eventually have to deal with massive numbers of IoT devices and collecting and managing the data from all those devices will be challenging.
3. If there's a bug in the system, it's likely that every connected device will become corrupted/ effected.
4. Since there's no international standard of compatibility for IoT, it's difficult for devices from different manufacturers to communicate with each other.

4.1.1 Cyber Physical system components:

Cyber-Physical Systems (CPSs): Cyber-Physical Systems represent systems, where computations are tightly coupled with the physical world, meaning that data obtained from physical layer is the core component that drives computation. Industrial automation systems, wireless sensor networks, mobile robots and vehicular networks are just a sample of cyber-physical systems. CPS's have limited computation and storage capabilities due to their tiny size and being embedded into larger systems. CPSs extend their capabilities by taking advantage of the emergence of cloud computing and the IoT.

IoT Sensors:

IoT connectivity is enabling all types of physical sensors to send their data directly to virtual dashboards with close to no human interaction. This is the only possible due to recent advanced technologies such as cellular IoT and LPWAN which are radically changing the way sensors are used; from occasional measurements to continuous, real-time remote monitoring across multiple industrial and consumer applications. So, sensor is not a new thing they are mainly used to measure variables.

A sensor is a device capable of detecting changes in an environment. A sensor is able to measure a physical phenomenon and transform it into an electric signal that can represents the magnitude of the conditions being monitored. Those conditions may be light, heat, sound, distance, pressure, or some other more specific situation, such as the presence or absence of a gas or liquid.

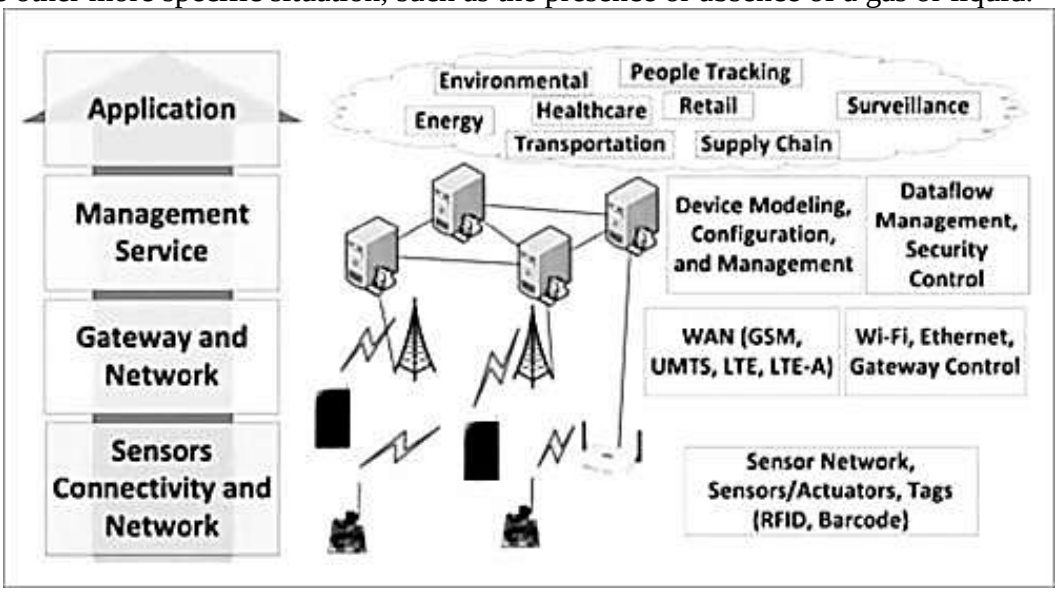


Fig. 4.2: IoT architecture layers

As shown in Fig 4.2, the bottom layer of the IoT system consists of sensor connectivity and network to collect information. This layer is an essential part of the IoT system and has network connectivity to the next layer, which is the gateway and network layer.

The main purpose of sensors is to collect data from the surrounding environment. Sensors, or 'things' of the IoT system, form the front end. These are connected directly or indirectly to IoT networks after signal conversion and processing. But all sensors are not the same and different IoT applications require different types of sensors. For instance, digital sensors are straightforward and easy to interface with a microcontroller using Serial Peripheral Interface (SPI) bus. But for analogue sensors, either analogue-to-digital converter (ADC) or Sigma-Delta modulator is used to convert the data into SPI output.

Edge Gateway:

The main function of the Edge (IoT) Gateway:

a. Forwarding packets between LAN and WAN on the IP layer
b. Performs application layer functions between IoT nodes and other entities
c. Enables local, short-range communication between IoT devices

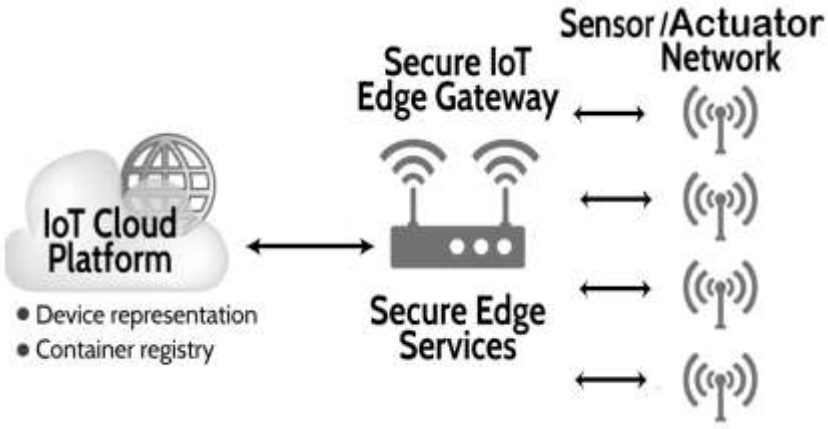


Fig 4.3: Edge gateway

An IoT gateway is a physical device or software program that serves as the connection point between the cloud and controllers, sensors and intelligent devices as shown in Fig 4.3.

All data moving to the cloud, or vice versa, goes through the gateway, which can be either a dedicated hardware appliance or software program. An IoT gateway may also be referred to as an intelligent gateway or a control tier.

Some sensors generate tens of thousands of data points per second. A gateway provides a place to preprocess that data locally at the edge before sending it on to the cloud. When data is aggregated, summarized and tactically analyzed at the edge, it minimizes the volume of data that needs to be forwarded on to the cloud, that have a big impact on response times and network transmission costs.

Another benefit of an IoT gateway is that it can provide additional security for the IoT network and the data it transports. Because the gateway manages information moving in both directions, it can protect data moving to the cloud from leaks and IoT devices from being compromised by malicious outside attacks with features such as tamper detection, encryption, hardware random number generators and crypto engines.

Cloud:
Cloud has the responsibility of accepting large amount of information from the IoT gateway, store and process them into actionable resources and send them to the user interface (web app/mobile app/dashboard).

There is an inextricable link between IoT and Cloud. The data collected by the sensors is quite huge in the case of an industrial application of IoT and a gateway is not capable of processing and storing it. This data is stored in cloud (a secure database) and processed in an affordable and scalable way. (Refer Fig 4.4)

The cloud is connected to the IoT gateway through the internet and receives all the data fed to the gateway by the sensors. There are a few protocols that connect gateways to the IoT cloud applications and the most common among them is Message Queuing Telemetry Transport (MQTT).

Sensors collect and feed data at all times and this huge chunk of data after the aggregation and some pre-processing is transferred to the cloud for storage and processing

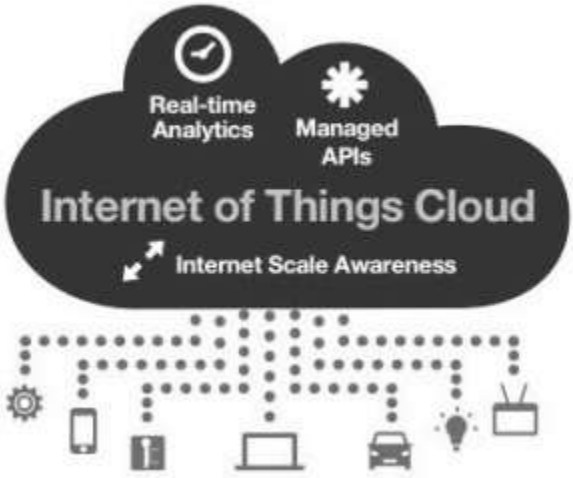


Fig 4.4: Cloud basics

Depending on the nature of the IoT implementation the cloud may have varying degrees of complexity. In simple applications, the cloud may consist of a database that stores the data collected by the IoT as well as the information of the users who possess the right to access/modify the data.

In bigger and more complex implementations the IOT cloud applications may also have the capability of machine learning, performing analytics, generating reports and more.

IoT Cloud Applications:
Cloud is where the real action takes place. IoT cloud application along with the APIs and other interfaces manage the data and commands to and from the sensors or the gateways. Different APIs need to be integrated so that the data is read and stored accurately.

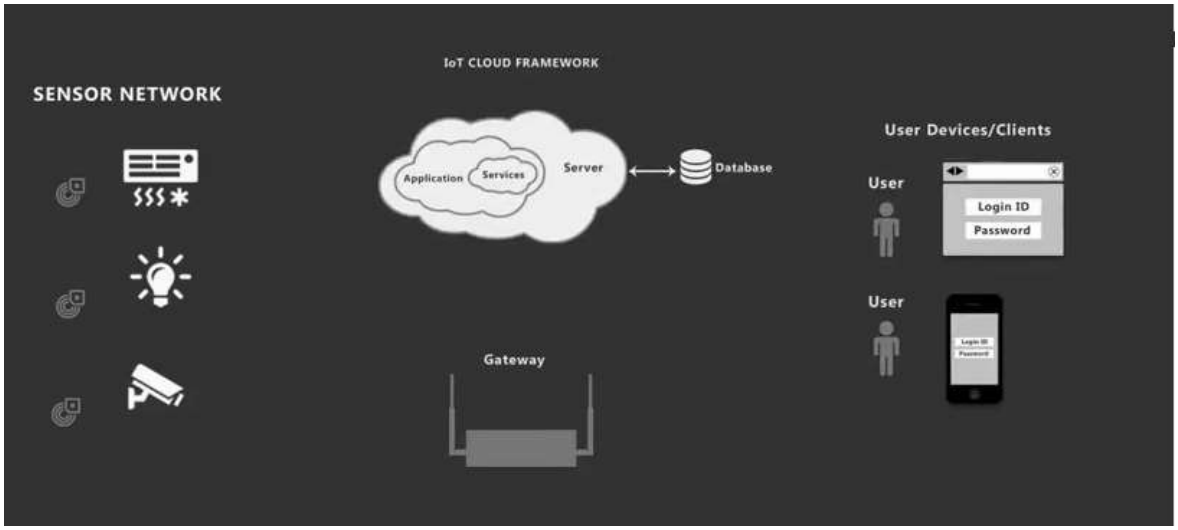


Fig 4.5: Cloud Application

Some of the protocols such as MQTT, Web socket, CoAP, and AMQP are used to develop a powerful and secure interface that facilitates seamless communication between the sensors and the cloud. In order to ensure that there is no data loss during heavy inflow of data, a robust database is designed as well.

Benefits of Cloud in an IoT ecosystem:

1. Caters the data storage and processing demands of IoT:
   IoT has huge potential and in near future, all kinds of physical entities connected to each other. This would require raw computing power and only cloud can provide that.
2. Advanced analytics and monitoring:
   With 'things' now being connected, there would be a need for constant analysis and monitoring in order to ensure seamless IoT experience to the users. Advanced cloud application development will ensure that the cloud is equipped with such capabilities.
3. Smoother inter-device connectivity:
   In an IoT, the sensors not only talk to the users, they also interact with each other. IoT Cloud applications along with the IoT gateway ensure that different sensors and actuators are able to talk to each other without any incompatibility.

4.2: IoT Data routes:

Before revealing the IoT data routes it is important to understand, IoT architecture layers and elements such as sensors, protocols, actuators, cloud services, and layers.

IoT Architecture Layers: Basically, there are three IoT architecture layers:

1. The client side (IoT Device Layer)
2. Operators on the server side (IoT Getaway Layer)
3. A pathway for connecting clients and operators (IoT Platform Layer)

In fact, addressing the needs of all these layers is crucial on all the stages of IoT architecture. Being the basis of feasibility criterion, this consistency makes the result designed really work. In addition, the fundamental features of sustainable IoT architecture include functionality, scalability, availability, and maintainability. Without addressing these conditions, the result of IoT architecture is a failure. Therefore, all the above-mentioned requirements are addressed in 4 stages of IoT architecture described here — on each separate stage and after completing the overall building process.

IoT Architecture:
The 4 Stage IoT architecture consists of:
1. IoT Sensors and actuators
2. Internet getaways and Data Acquisition Systems
3. Edge IT
4. Data center and cloud.
The detailed presentation of these stages can be found on the Fig 4.6.

Stage 1. Networked things (wireless IoT sensors and actuators):
The outstanding feature about sensors is their ability to convert the information obtained in the outer world into data for analysis. In other words, it's important to start with the inclusion of IoT sensors in the four stages of an IoT architecture framework to get information in an appearance that can be actually processed.

For actuators, the process goes even further — these devices are able to intervene the physical reality. For example, they can switch off the light and adjust the temperature in a room.
Because of this, sensing and actuating stage covers and adjusts everything needed in the physical world to gain the necessary insights for further analysis.

Stage 2. IoT Sensor data aggregation systems and analog-to-digital data conversion:
Even though this stage of IoT architecture still means working in a close proximity with sensors and actuators, Internet getaways and data acquisition systems (DAS) appear here too. Specifically, the later connect to the sensor network and aggregate output, while Internet getaways work through Wi-Fi, wired LANs and perform further processing.

The vital importance of this stage is to process the enormous amount of information collected on the previous stage and squeeze it to the optimal size for further analysis. Besides, the necessary conversion in terms of timing and structure happens here.
In short, Stage 2 makes data both digitalized and aggregated.

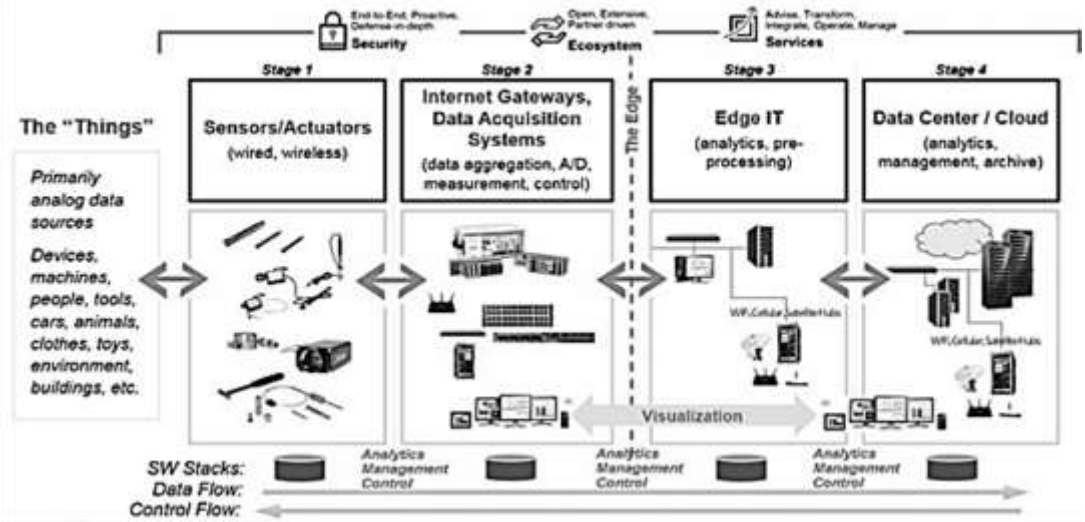


Fig 4.6: 4 Stage IoT Solutions Architecture

Stage 3. The appearance of edge IT systems:
During this moment among the stages of IoT architecture, the prepared data is transferred to the IT world. In particular, edge IT systems perform enhanced analytics and pre-processing here. For example, it refers to machine learning and visualization technologies. At the same time, some additional processing may happen here, prior to the stage of entering the data center.

Likewise, Stage 3 is closely linked to the previous phases in the building of an architecture of IoT. Because of this, the location of edge IT systems is close to the one where sensors and actuators are situated, creating a wiring closet. At the same time, the residing in remote offices is also possible.

Stage 4. Analysis, management, and storage of data:
The main processes on the last stage of IoT architecture happen in data center or cloud. Precisely, it enables in-depth processing, along with a follow-up revision for feedback. Here, the skills of both IT and OT (operational technology) professionals are needed. In other words, the phase already includes the analytical skills of the highest rank, both in digital and human worlds. Therefore, the data from other sources may be included here to ensure an in-depth analysis.

After meeting all the quality standards and requirements, the information is brought back to the physical world but in a processed and precisely analyzed appearance already.

Stage 5:
In fact, there is an option to extend the process of building a sustainable IoT architecture by introducing an extra stage in it. It refers to initiating a user's control over the structure — if only user result doesn't include full automation, of course. The main tasks here are visualization and management. After including Stage 5, the system turns into a circle where a user sends commands to sensors/actuators (Stage 1) to perform some actions and the process starts all over again.

4.2.1 IoT Sensor to Cloud various Data routes:
In the world of industrial automation, applying human-machine interface (HMI) to control and monitor machines, processes and even smart buildings has been a common practice for many years. These industrial HMIs, sometimes called operator interface terminals (OITs), are good at what they do but have traditionally required significant engineering effort for development, deployment and maintenance. They also typically include many proprietary elements and require ongoing expenditures for software and licensing.

Automation engineers are increasingly taking advantage of available "smart" systems in the field, including IoT (IoT) devices. These devices have lots of useful data to offer and frequently need monitoring, and are sometimes used as inputs to real-time control systems. But the traditional methods of connecting these remote devices through standard industrial systems is difficult and costly.

However, a next generation of HMI and SCADA hardware and software addresses these and other challenges. By using the latest commercial and open-source technologies, these products free users to focus on connecting with smart systems, getting data, transforming it into actionable information, and visualizing it when and where we want.

IoT Sensor-PLC-SCADA-Cloud data route:
The "classic" approach involves several steps and linkages to make edge data available up to the cloud as shown in Fig 4.7. These connections are difficult to configure initially, but they are also challenging to maintain over time, with required maintenance beginning at the periphery and progressing inward.

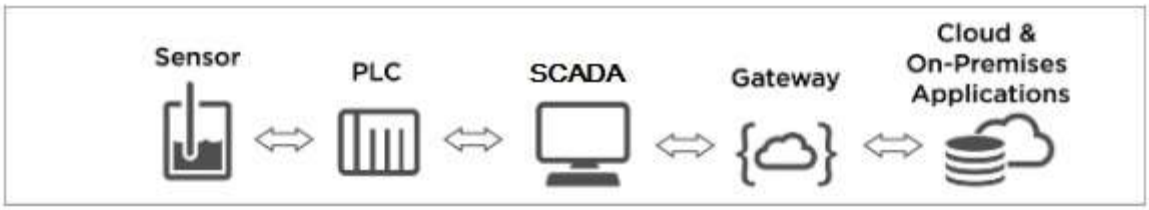


Fig 4.7: IoT Sensor –PLC-SCADA- Cloud Data route

First, the field device is likely wired or networked to a local programmable logic controller (PLC), since this is often the nearest programmable system to the edge component. The PLC requires some device-specific communication driver or instructions to obtain the data, which may involve choosing the desired points and mapping them in a spreadsheet-like format.

Next, the PLC data is networked up to a PC-based HMI or SCADA system, with either approach requiring configuration of data tags, drivers and polling rate assignments. In turn, the HMI or SCADA needs additional configuration or programing steps to transport the data into a cloud-based database, where it can be made more widely available.

Drawbacks: All these tasks are feasible and commonly employed, but they have many downsides:

1. Typical PLCs and communications drivers may be proprietary,
2. Requires costly configuration software and licenses.
3. Even with the right hardware and software in hand, designers require specialized knowledge of devices, programming and networking.
4. The last networking link from the project site to the cloud demands dedicated attention to go through firewalls and maintain security.

IoT Sensor- Server-Cloud Data Route:

An IoT system has a three-level architecture: devices, gateways and data systems as shown in Fig 4.7. The data moves between these levels via four types of transmission channels.

1. **Device to device (D2D)**: Direct contact between two smart objects when they share information instantaneously without intermediaries. For example, industrial robots and sensors are connected to one another directly to coordinate their actions and perform the assembly of components more efficiently. This type of connection is not very common yet, because most devices are not able to handle such processes.

2. **Device to gateway**: Telecommunications between sensors and gateway nodes. Gateways are more powerful computing devices than sensors. They have two main functions: to consolidate data from sensors and route it to the relevant data system; to analyze data and, if some problems are found, return it back to the device. There are various IoT gateway protocols that may better suit this or that solution depending on the gateway computing capabilities, network capacity and reliability, the frequency of data generation and its quality.

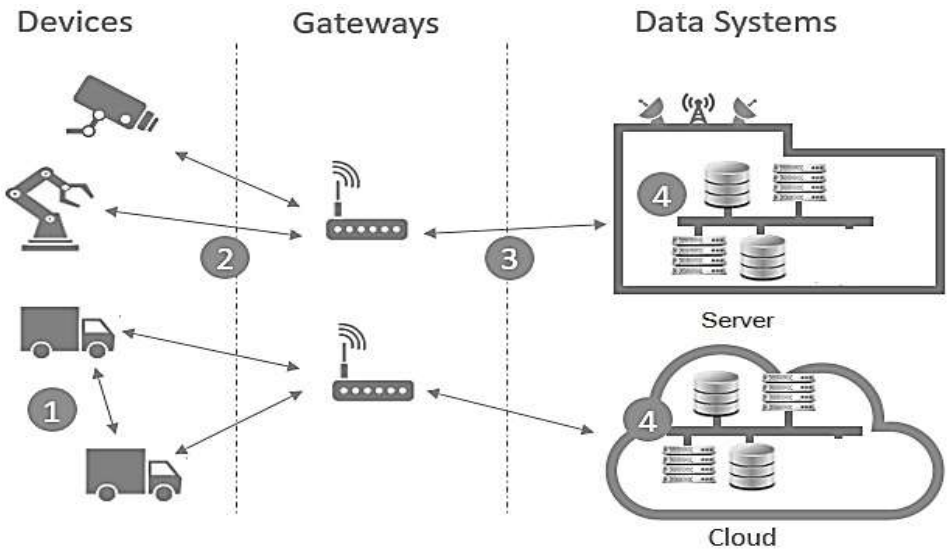


Fig4.7: IoT Sensor – Server-Cloud Data route

3. **Gateway to data systems:** Data transmission from a gateway to the appropriate data system. To select the protocol one should analyze data traffic (frequency of burstiness and congestion, security requirements and how many parallel connections are needed).

4. **Between data systems**: Information transfer within data centers or clouds. Protocols for this type of connection should be easy to deploy and integrate with existing apps, have high availability, capacity and reliable disaster recovery.

IoT Sensor to Edge gateway to Cloud Gateway:

The IoT is becoming an indispensable part of our daily lives. Enabling functions like these and others perhaps more critical requires an ecosystem that consists of many components working seamlessly together.

The architecture can be organized by function into several layers or tiers shown in Fig 4.8:

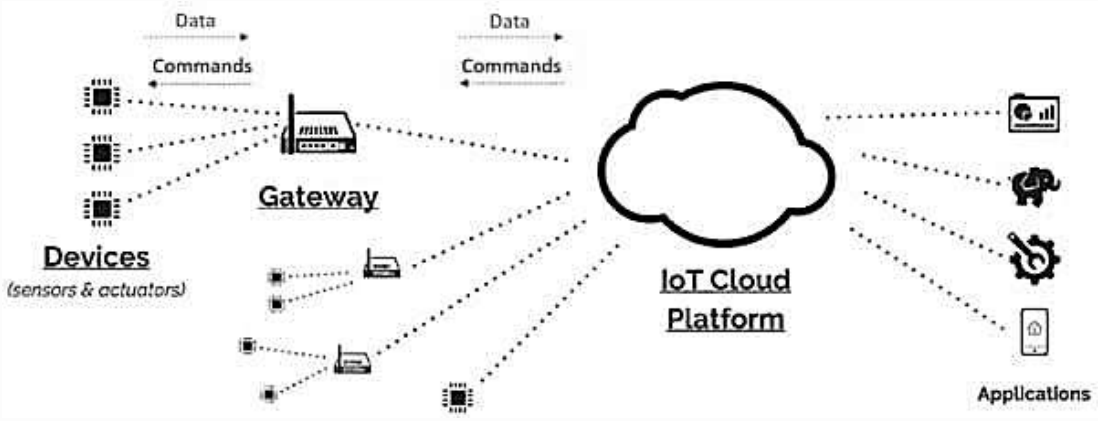


Fig 4.8: IoT Sensor to Edge Gateway to Cloud Architecture

a. **The Device layer** (also called the edge tier) typically contains three elements: Sensors measuring real-world data; actuators affecting changes to the real world; and transceivers transmitting sensor data and receiving actuator commands.

b. **The Data way tier** acts as a secure intermediary between these sensors and actuators and the Cloud. An IoT gateway is an integral part of the IoT ecosystem, handling communication with local sensors and remote users as well as a suite of other functions.
c. **The Cloud tier** handles overall monitoring and management of the IoT ecosystem. It interfaces with multiple gateways and performs analytics on the collected and stored data.
d. **The Application layer** is the interface to the end user, allowing access and control of IoT products and services

4.3 IoT Applications:

Use of IoT in Agriculture:

Improving farm productivity is essential for increasing farm profitability and meeting the rapidly growing demand for food that is fueled by rapid population growth across the world. Farm productivity can be increased by understanding and forecasting crop performance in a variety of environmental conditions.

Fig 4. 9: IoT use in Agriculture

Emerging IoT technologies, such as IoT devices (e.g., wireless sensor networks, network-connected weather stations, cameras, and smart phones) can be used to collate vast amount of environmental and crop performance data, ranging from time series data from sensors, to spatial data from cameras, to human observations collected and recorded via mobile smart phone applications. Such data can then be analyzed to filter out invalid data and compute personalized crop recommendations for any specific farm. IoT based farming as shown in Fig 4.9 can automate the collection of environmental, soil, fertilization, and irrigation data, automatically correlate such data and filter-out invalid data from the perspective of assessing crop performance. Then compute crop forecasts and personalized crop recommendations for any particular farm.

Major activities of farming can be smartly monitored, controlled and managed using IoT as follows:

a. **Crop Water Management**: In order to perform agriculture activities in efficient manner, adequate water is essential. Agriculture IoT is integrated with Web Map Service (WMS) and Sensor Observation Service (SOS) to ensure proper water management for irrigation and in turn reduces water wastage.
b. **Precision Agriculture:** High accuracy is required in terms of weather information which reduces the chances of crop damage. Agriculture IoT ensures timely delivery of real time data in terms of weather forecasting, quality of soil, cost of labor and much more to farmers.

c. **Integrated Pest Management or Control (IPM/C):** Agriculture IoT systems assures farmers with accurate environmental data via proper live data monitoring of temperature, moisture, plant growth and level of pests so that proper care can be taken during production.
d. **Food Production & Safety:** Agriculture IoT system accurately monitors various parameters like warehouse temperature, shipping transportation management system and also integrates cloud based recording systems.

Benefits of IoT in Agriculture:

The following are the benefits of IoT in Agriculture:

1. IoT enables easy collection and management of tons of data collected from sensors and With integration of cloud computing services like Agriculture fields maps, cloud storage etc., data can be accessed live from anywhere and everywhere enabling live monitoring and end to end connectivity among all the parties concerned.
2. IoT is regarded as key component for Smart Farming as with accurate sensors and smart equipment's, farmers can increase the food production
3. With IoT productions costs can be reduced to a remarkable level which will in turn increase profitability and sustainability.
4. With IoT, efficiency level would be increased in terms of usage of Soil, Water, Fertilizers, and Pesticides etc.
5. With IoT, various factors would also lead to the protection of environment.

Smart Farming Based Agriculture IoT Stick: It is regarded as IoT gadget focusing on Live Monitoring of Environmental data in terms of Temperature, Moisture and other types depending on the sensors integrated with it. Agricultural IoT stick as shown in Fig 4.10 provides the concept of "Plug and Sense" in which farmers can directly implement smart farming by as such putting the stick on the field and getting Live Data feeds on various devices like Smart Phones, Tablets etc. and the data generated via sensors can be easily shared and viewed by agriculture consultants anywhere remotely via Cloud Computing technology integration. IoT stick also enables analysis of various sorts of data via Big Data Analytics from time to time.

Fig 4.10: Agricultural IoT Stick

Use of IoT in Automotive:

IoT has a significant impact on automotive industry. Not long ago, the idea of IoT in the automotive sector was being seen as a futuristic theoretical concept and today we are already seeing possibilities of connected cars, driverless cars and application of IoT in the car ecosystem. This includes smart parking, environment, supply chain, transport governing bodies. It is also used

in related automotive segments such as Car services/applications, Vehicle communications, IoT in Intelligent Transportation, IoT based Supply Chain Management in Automotive Industry and New Generation Cars.
IoT is at the heart of this digital transformation in Auto sector. It connects people, machines, vehicles, auto parts, and services to streamline the flow of data, enable real-time decisions, and improve automotive experiences. Leading automotive manufacturers, suppliers, and dealers have started investing heavily in IoT and are gaining returns in the form of efficient inventory management, real time promotions that grow sales, reduced operational expenses and increase in revenue. They are beginning to change their business processes and recognize that, in time, IoT will touch every area of automotive operations and customer engagement.

Todays advanced car is one big IoT device with a lot of IoT properties inbuilt. Applications are developed that use data collected by connected cars in many ways.

Example, traffic control systems can provide real-time data collected from connected cars to avoid traffic jams and accidents. Automotive components manufacturers can benefit from data about wear and tear to pre-order the components to be replaced and notify customers before there are equipment failures. Car sharing mobile apps can use real-time location data to encourage car pools.

Also, in insurance systems, premium rates would be based on geolocation of vehicles and driving behavior of drivers.

Figure 4.11 shows these and many more developments on IoT in Automotive sector these include:

a. **Connected Car:** Automobile manufacturing companies, telecommunication service providers and software companies are coming together to build the Connected Car/ Internet enabled car. A connected car is a car which using its onboard sensors and internet connectivity enhances the in-car experience of its users. Connected car, just doesn't mean the capacity to surf the internet on the move, but the communication between cars, communication of cars with other devices. As of date, there are only a small number of cars which are internet enabled but it is expected that the number will rise considerably in future.
b. **Car Services/Applications: Infotainment:** Infotainment refers to a system in vehicles that delivers a combination of information and entertainment content/services. Typical features are – providing navigation features while driving, managing audio/visual entertainment content, delivering rear-seat entertainment, and connectivity with smart phones for hands free experience with the help of voice commands. With rapid growth in smart phone and Cloud technologies, consumers are demanding for live streaming of music and Internet radio.
c. **Vehicles and Smartphones Integration:** Using the On-Board Diagnostics (OBD) port, which is like computer which monitors emissions, mileage, speed, and other useful data information regarding engine and other crucial vehicle parameters can be displayed on the driver's smartphones and same can be sent to service provider for analysis. Alerts related to the car like Open doors, Lights ON and Hand brake ON and performing actions on certain vehicle parts such as Lock/Un-lock vehicle doors, roll windows up/down and AC temperature +/- are becoming seamless.

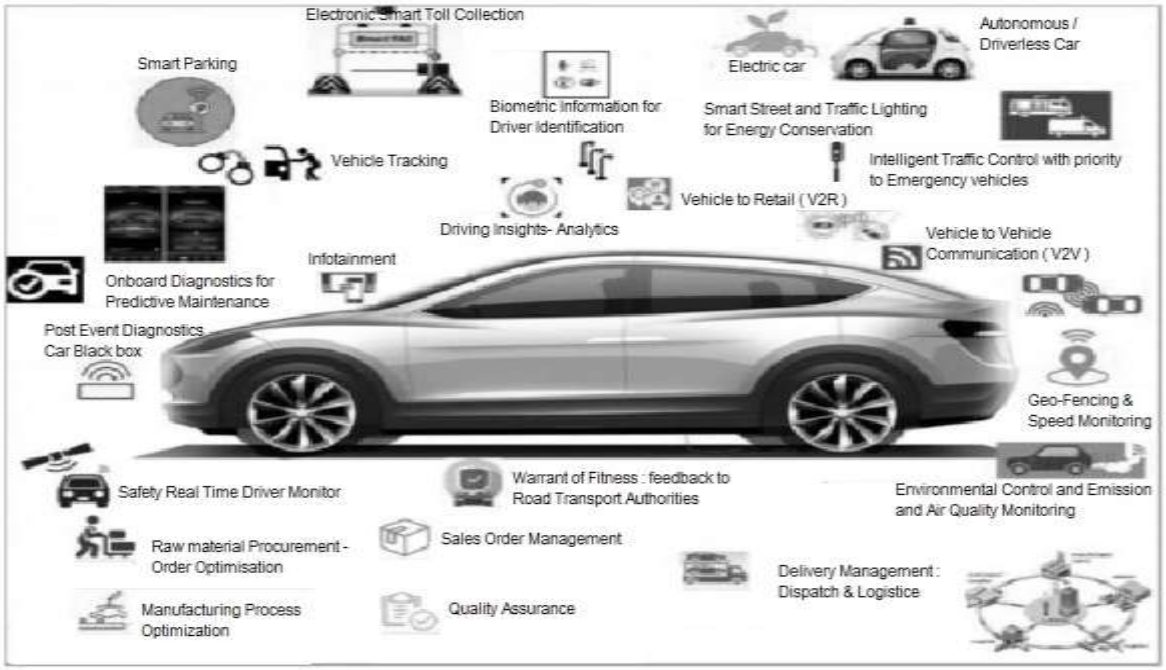


Fig 4.11: Application of IoT in Automotive

d. **Driving Insights – Analytics:** Smartphones sensors such as GPS, Gyroscope or Orientation sensor and Accelerometer can be used to model the driving behavior. It can detect driving patterns such as sharp turns, sudden acceleration, hard braking, drifting and speeding. This can be used to profile the driver as safe or aggressive, to rate and compare different drivers and share such data with insurance companies for customized premiums.

e. **On-Board Diagnostics for Predictive maintenance:** The On-Board Diagnostics port is commonly used in automobile service and maintenance for self-diagnosis and reporting of any issues that may occur, or have occurred within the system. Using this, information such as emissions, mileage, faults, vehicle and engine speed, engine temperature, fluid levels, gear shifts, battery status, etc. can be monitored and information can be sent to vehicle owners and service stations giving them a better picture of the car performance.

f. **Safety: Real Time Driver Monitor:** Advanced sensor based technologies to detect and monitor behavior and fatigue levels of driver are emerging which makes the cars more intelligent for avoiding accidents on roads. Systems are being developed for real time monitoring of vehicles which controls the speed of the vehicle and fatigue level of the driver to prevent accidents. The primary components of such a system are microcontrollers along with some sensors like eye blink, gas, impact sensors, alcohol detecting sensor and fuel sensors. GPS and Google Maps API‟s is used to track the location of the vehicle which can sent to a predefined number in the system.

g. **Geo-fencing and Speed Monitoring:** The geo fencing and speed monitoring applications can be used to inform the car owner if the vehicle has gone out of the predefined geographical area or is being driven faster than a preset threshold speed. Speed of the vehicle can be measured speed sensors and geo-fencing can be achieved with the help of GPS.

h. **Law: Stolen Vehicle Tracking** GSM and GPS based Vehicle Tracking System is used for tracking device which is hidden in the vehicle to monitor and track the location of vehicles .Satellite signals will be received by a remotely located application server and then position coordinates with latitude and longitude are determined. Exact position of the vehicle can be determined from these coordinates and using the GSM system, thus vehicle can be notified.

i. **Biometrics Information for Driver identification:** Biometrics refers to the physical, biological or behavioral characteristics of a person. It can be used to identify and authenticate a driver. Biometric identifiers include face recognition, fingerprints or voice recognition.

j. **Vehicle Communications:** As more and more connected cars emerge and in-vehicle embedded connectivity becomes common, a whole new paradigm of vehicle communications is set to unfold.

1. Vehicle to Vehicle (V2V)
2. Vehicle to Infrastructure(V2X)
3. Vehicle-to-Retail Industry (V2R)

Other applications of IoT in automotive are

a) In Intelligent Transportation: Electronic Smart Toll Collection
b) Smart Parking
c) Energy Conservation: Smart Street & Traffic Lighting
d) Post Event Diagnostics: Car Black Box.
e) Intelligent traffic control with priority for emergency vehicles
f) Warrant of Fitness certificate of vehicle: Feedback to Road Transport Authorities for required safety inspections.
g) Environmental Control: Emissions and Air Quality Monitoring.
h) IoT Based Supply Chain Management in Automotive Industry

Use of IoT Discrete manufacturing:

Discrete manufacturing is an industry term for the manufacturing of finished products that are distinct items capable of being easily counted, touched or seen. Discrete manufacturing involves parts and systems like nuts and bolts, brackets, wires, assemblies and individual products. A discrete unit is a separate part of something larger. The crankshaft is a discrete part of a car engine. Almost every item sold in stores is an example of discrete manufacturing.

Examples of discrete manufacturing could include:

1. Vehicles
2. Aircraft
3. Smartphones
4. Computers
5. Cookware
6. Clothing
7. Cabling

Discrete manufacturing can be characterized by unit production; where units can be produced with high complexity and low volume, like aircrafts or computers, or low complexity and high volume, like nuts or bolts.

Discrete manufacturers have the opportunity to adapt processes with IoT to lower costs, optimize operations, reduce resource consumption, improve productivity, enhance customer service, and manage the supply chain. Similarly, they can also use IoT to drive product-related benefits, such as improving product quality, increasing uptime, and using actual performance data to drive future design changes in the next generation of products.

As IoT provides the basis for an increasing amount of automated data acquisition, manufacturers will be able to adapt their processes and their products not just for incremental improvements but also for transformation of the product, service, and business model. IoT gives manufacturers the

opportunity to create "intelligent" products that can sense, learn, and predict customer needs as well as interconnect with other product ecosystems.

Discrete Manufacturing Industry challenges are:
1. Connected products,
2. Connected supply chain, and
3. Smart manufacturing.

These challenges are overcome with IOT.

IoT and Today's Connected Products: The key benefits resulting from the promise of connected products are as follows:
1. Documenting actual product performance, creating early warning and detection signals, and enabling closed loop feedback to drive quality improvements in future products.
2. Easing the transition to new services that should bring substantially higher margins and greater customer satisfaction levels

IoT and the Connected Supply Chain: The key benefits resulting from the connected supply chain are as follows:
1. Managing inventory positions throughout an increasingly complex logistics network, with greater visibility into actual inventory
2. Increased fulfillment execution capabilities, including the use of smaller, more localized warehouses located closer to customers.

IoT and Smart Manufacturing: The key benefits resulting from smart manufacturing are as follows:
1. Increasing reliability and quality through ongoing access to operational intelligence
2. Connecting shop-floor decisions with corporate-level objectives, whether they are primarily focused on lowering costs, increasing customer service, or increasing revenue

Thus IoT is making easier to track information about products and processes and more automation will provide greater efficiency, eventually reducing costs and boosting profit margins and more productivity.

Use of IoT in Telecom:

The IoT is transforming the world around us, especially in telecommunications. This fourth industrial evolution also driven by Artificial Intelligence (AI), robotics, 3D printing, and other emerging technologies will irrevocably change the way machines interact with humans and each other.

It is predictions that over 20 billion connected things will be in use worldwide by 2020, putting service providers in a race to tailor their strategies, data services, and telecom infrastructure to make the most of this trend.

IoT in telecommunications will be defined by the ability to deliver high-value, scalable data-driven services that prioritize cost and convenience, while making a positive impact on people’s lives. The market leaders will be the telecom providers that partner with customers, domain specialists, and platform providers to co-create the next generation of IoT networks

Data-driven networks

Service quality, reliability, and intelligent dynamic capacity allocation are critically important to IoT services such as autonomous cars, heart-rate monitors, and insulin pumps. Improved network analytics capabilities will allow providers to perform real-time and predictive IoT network maintenance to improve services and keep costs down. This data-driven approach will become a core enabler of intelligent, automated networks that incorporate next-generation technologies like 5G, SDN, NFV, and service cloudification.

Security and privacy

Problems of security and privacy will be particularly challenging in the age of IoT in telecommunications. As there are more devices in a network, there are more points of vulnerability. Additionally, their computational and energy constraints could make higher-level security measures difficult to implement.

The concept of a distributed network, rather than a centralized one with a single point of failure, could greatly benefit IoT security. Additionally, as network intelligence evolves, it's likely that devices and networks will become knowledgeable enough to be able to proactively identify, locate, and neutralize any harmful threats. The development of uniform regulatory standards for the collection and usage of IoT data will also be important as IoT and Machine-to-Machine (M2M) communications pave the way to the Internet of Everything (IoE).

Telecom infrastructure management

Sharing telecom infrastructure is becoming increasingly popular around the world as changes to regulations lower the barriers to entry and increase competition among providers. Passive infrastructure sharing is a core part of this, given the fact that building and maintaining telecom infrastructure is capital-intensive. The need will only grow as 5G wireless leads to networks that are increasingly decentralized, segmented, and built atop small-cell infrastructure.

IoT will play a key role in not just 5G network services, but also surveillance and monitoring of this next-generation infrastructure. An IoT-enabled Tower Operations Center (TOC) integrates on-site IoT sensors with cloud-based analytics to extract and analyze cell-tower data. This results in increased tower up-time, reduced operational costs, more efficient OSS and BSS, improved site security and intrusion detection, and more efficient energy/power management.

The degree of remote monitoring allows tower and infrastructure companies to monitor alarms and manage key performance indicators via a centralized console. In turn, this allows better overall management of critical passive infrastructure at cell sites, while freeing up IoT telecom professionals to concentrate on better network planning and resourcing.

4.4 I4.0/IIoT/Smart Manufacturing:

4.4.1: Introduction/Evolution from I1.0 to I4.0:

Evolution: Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum and author of The Fourth Industrial Evolution describes an industrial evolution as the appearance of "new technologies and novel ways of perceiving the world which triggered a profound change in economic and social structures." The Industrial evolutions are shown in Fig 4.12.

1. The first industrial evolution began with the mechanization and mechanical power generation in 1800s. It brought the transition from manual work to the first manufacturing processes;

mostly in textile industry. It is characterized by use of water and steam to mechanize production, an improved quality of life was a main driver of the change.

2. The second industrial evolution was triggered by electrification that enabled industrialization and mass production.
3. The third industrial evolution is characterized by the digitalization with introduction of electronics, IT and automation. In manufacturing this facilitates flexible production, where a variety of products is manufactured on flexible production lines with programmable machines.
4. The fourth industrial evolution is the IoT, robotics, Augmented Reality (AR) Virtual Reality (VR) and Artificial Intelligence (AI) are changing the way we live and work. It began at the turn of this century and builds on the digital evolution. It is characterized by a much more global and mobile Internet, by smaller and more powerful sensors that have become cheaper, and by artificial intelligence and machine learning

The world is at the cusp of the fourth industrial evolution. It is current and developing environment in which disruptive technologies and trends such as the Internet, AI, IoT, Autonomous Vehicles, 5G Telephony, Nanotechnology, Bio-Technology, Robotics, Quantum 3D printing, Cloud Computing and the like marked the era of 4th industrial evolution..

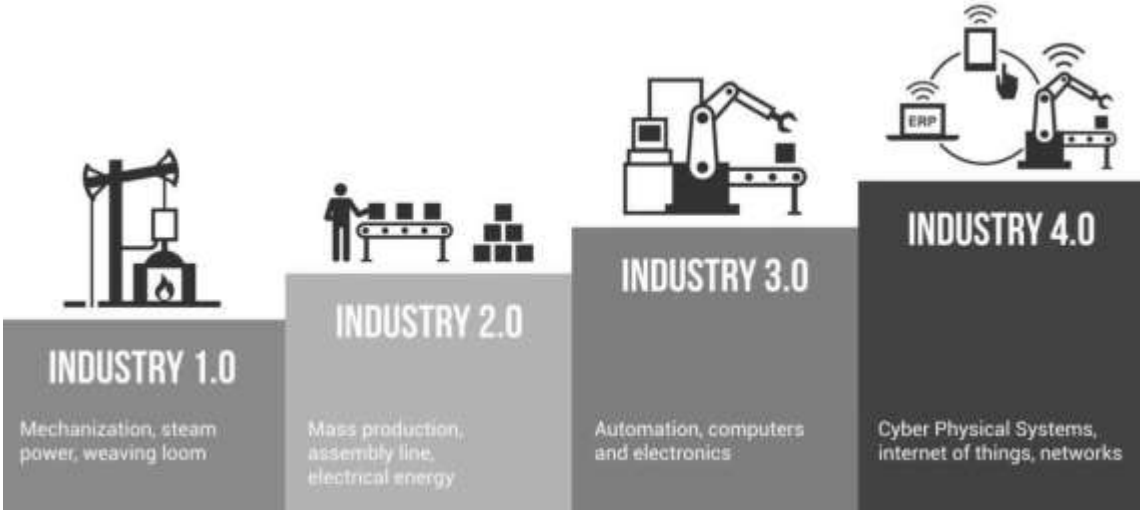


Fig 4.12: The industrial evolutions from 1 to 4.

First Industrial Evolution: Agrarian societies to Mechanized production:

The first industrial evolution, began in the 18th century involved a change from mostly agrarian societies to greater industrialization as a consequence of the steam engine and other technological developments. It is marked by a transition from hand production methods to machines through the use of steam power and water power. It is started with use of steam power and mechanization of production. It is also called as the Age of Mechanical Production. Its effects had consequences on textile manufacturing, which was first to adopt such changes, as well as iron industry, agriculture, and mining. What before produced threads on simple spinning wheels, the mechanized version achieved eight times the volume in the same time using Steam power**.**

The use of it for industrial purposes was the greatest breakthrough for increasing human productivity. Instead of weaving looms powered by muscle, steam-engines was used for power**.** Through the advent of the steam engine, the focus has shifted from agriculture to textile manufacturing. But with steam power, those agrarian societies gave way to urbanization.

Developments such as the steamship or the steam-powered locomotive brought about further massive changes because humans and goods could move great distances in fewer hours. The world began to rely on steam power and machine tools, while steamships and railroads revolutionized how people got from A to B and what emerged as the new center of community life? Ultimately, advancing industrialization created a middle class of skilled workers. Cities and industries grew more quickly than ever before, and economies grew along with them.

Second Industrial Evolution: The Age of Science and Mass Production

The Second Industrial Evolution better known as the technological evolution is the period between 1870 and 1914. It began with the discovery of electricity and assembly line production**.** Henry Ford took the idea of mass production from a slaughterhouse in Chicago: The pigs hung from conveyor belts and each butcher performed only a part of the task of butchering the animal. Henry Ford carried over these principles into automobile production and drastically altered it in the process. By the early part of the 20th century, Henry Ford's company was mass producing the groundbreaking Ford Model T, a car with a gasoline engine built on an assembly line in his factories.

While before one station assembled an entire automobile, now the vehicles were produced in partial steps on the conveyor belt **-** significantly faster and at lower cost**.** It was made possible with the extensive railroad networks and the telegraph which allowed for faster transfer of people and ideas. It is also a period of great economic growth, with an increase in productivity. It, however, caused a surge in unemployment since many workers were replaced by machines in factories.

Things started to speed up with a number of key inventions. Think gasoline engines, airplanes, chemical fertilizer. All inventions that helped us go faster and do more. But advancements in science weren't limited to the laboratory. Scientific principles were brought right into the factories. Most notably, the assembly line, which effectively powered mass production.

People follow the jobs, and the early 1900s saw workers leaving their rural homes behind to move to urban areas and factory jobs. By 1900, 40% of the population lived in cities, compared to just 6% in 1800. Along with increasing urbanization, inventions such as electric lighting, radio, and telephones transformed the way people lived and communicated.

Third Industrial Evolution: Digital Evolution

The Third Industrial Evolution called the digital evolution involved the development of computers and Information Technology (IT) since the middle of the 20th century. This began in the 70's of the 20th century through partial automation using memory-programmable controls and computers**.** Since the introduction of these technologies, user can now able to automate an entire production process **-** without human assistance. Known examples of this are robots that perform programmed sequences without human intervention.

The third industrial evolution or Industry 3.0 occurred, after the end of the two big wars, as a result of a slowdown with the industrialization and technological advancement compared to previous periods. It is also called digital evolution. The global crisis in 1929 was one of the negative economic developments which had an appearance in many industrialized countries from the first two evolutions.

The production of Z1 (electrically driven mechanical calculator) was the beginning of more advanced digital developments. This continued with the next significant progress in the

development of communication technologies with the supercomputer. In this process, where there was extensive use of computer and communication technologies in the production process. Machines started to abolish the need for human power in life.

Beginning in the 1950s, the third industrial evolution brought semiconductors, mainframe computing, personal computing, and the Internet—the digital evolution. Things that used to be analog moved to digital technologies, like an old television you used to tune in with an antenna (analog) being replaced by an Internet-connected tablet that lets you stream movies (digital).

The move from analog electronic and mechanical devices to pervasive digital technology dramatically disrupted industries, especially global communications and energy. Electronics and information technology began to automate production and take supply chains global.

Fourth Industrial Evolution: Cyber Physical Systems, IoT and Networks:

The Fourth Industrial Evolution **is** characterized by the application of information and communication technologies to industry and is also known as **"Industry 4.0".** It builds on the developments of the Third Industrial Evolution but considered as new era because of the explosiveness of its development and the disruptiveness of its technologies.

Origin of Industry 4.0 concept comes from Germany, since Germany has one of the most competitive manufacturing industries in the world and is even a global leader in the sector of manufacturing equipment. Industry 4.0 is a strategic initiative of the German government that traditionally supports development of the industrial sector. In this sense, Industry 4.0 can be seen also as an action towards sustaining Germany's position as one of the most influential countries in machinery and automotive manufacturing.

The basic concept was first presented at the Hannover fair in the year 2011. Since its introduction, Industry 4.0 is in Germany a common discussion topic in research, academic and industry communities at many different occasions. The main idea is to exploit the potentials of new technologies and concepts such as:

1. Availability and use of the internet and IoT,
2. Integration of technical processes and business processes in the companies,
3. Digital mapping and virtualization of the real world,
4. 'Smart' factory including 'smart' means of industrial production and 'smart' products.

Besides being the natural consequence of digitalization and new technologies, the introduction of Industry 4.0 is also connected with the fact that, many up to now exploited possibilities for increasing the profit in the industrial manufacturing are almost exhausted and new possibilities have to be found. Namely the production costs were lowered with introduction of just-in-time production, by adopting the concepts of lean production and especially by outsourcing production to countries with lower work costs. When it comes to the decreasing costs of industrial production, Industry 4.0 is a promising solution.

Advantages and reasons for the adoption of this concept including:

1. A shorter time-to-market for the new products,
2. An improved customer responsiveness,
3. Enabling a custom mass production without significantly increasing overall production costs,
4. More flexible and friendlier working environment, and
5. More efficient use of natural resources and energy.

Production systems that already have computer technology are expanded by a network connection and have a digital twin on the Internet so to speak. These allow communication with other facilities and the output of information about themselves. This is the next step in production automation. The networking of all systems leads to "cyber-physical production systems" and therefore smart factories**,** in which production systems**,** components and people communicate via a network and production is nearly autonomous**.**

The advent of 5G telecommunication technologies will make real-time downloads possible. This will enable a whole host of things, such as a majority of driverless cars plying on the roads, and talking to each other using the IoT. The autonomous vehicle, enabled by 5G technology, will result in a lower demand for automobiles and release parking space for parks. When combined with an increasing population of non-polluting electrical vehicles, it will benefit the environment.

The electrical vehicles will be powered by renewable energy, and the use of fossil fuel would reduce. The cost of solar panels is likely to drop. Real-time speeds using 5G would allow devices to be connected and to communicate with each other through the IoT. Thus cars on the road will talk to each other, avoiding accidents. Machines in factories will talk to each other, leading to productivity gains.

Benefits of Industry 4.0:

The main benefits of industry 4.0 are:

1. **Improved Efficiency and thus Productivity:** Industry 4.0 technologies enable you to do more with less. That is, user can produce more and faster while allocating your resources more cost-effectively and efficiently. User production lines will also experience less downtime because of enhanced machine monitoring and automated/semi-automated decision-making. Overall Equipment Effectiveness will improve as your facility moves closer to becoming an Industry 4.0 Smart Factory.

   Multiple areas of user production line will become more efficient as a result of Industry 4.0-related technologies. These efficiencies are less machine downtime, the ability to make more products and make them faster. Other examples of improved efficiency include faster batch changeovers, automatic track and trace processes, and automated reporting. New Product Introductions also become more efficient as does business decision making and more.

2. **Flexibility and Agility:** The benefits of Industry 4.0 also include enhanced flexibility and agility. For example, it is easier to scale production up or down in a Smart Factory. It is also easier to introduce new products to the production line as well as creating opportunities for one-off manufacturing runs, high-mix manufacturing, and more.

3. **Better Customer Experience:** Industry 4.0 also presents opportunities to improve the service you offer to customers and enhance the customer experience. For example, with automated track and trace capabilities, you can quickly resolve problems. In addition, you will have fewer issues with product availability, product quality will improve, and you can offer customers more choice.

4. **Increased Knowledge Sharing and Collaborative Working:** Traditional manufacturing plants operate individually and in isolation. This results in minimal collaboration or knowledge sharing. Industry 4.0 technologies allow your production lines, business processes, and departments to communicate regardless of location, time zone, platform, or any other factor. This enables, for example, knowledge learned by a sensor on a machine in one plant to be disseminated throughout your organization.
   Best of all, it is possible to do this automatically, i.e. machine-to-machine and system-to-system, without any human intervention. In other words, data from one sensor can instantly make an improvement across multiple production lines located anywhere in the world.

5. **Cost Reduction:** Becoming a Smart Factory does not happen overnight, and it won't happen on its own. To achieve it, you need to invest, so there are upfront costs. However, the cost of manufacturing at your facilities will dramatically fall as a result of Industry 4.0 technologies, i.e. automation, systems integration, data management, and more.
   Primary drivers for these reduced costs include:
   a. Better use of resources
   b. Faster manufacturing
   c. Less machine and production line downtime
   d. Fewer quality issues with products
   e. Less resource, material, and product waste
   f. Lower overall operating costs

6. **Better return on Investment:** Industry 4.0 technologies are transforming manufacturing across the world. The benefits of Industry 4.0 and potential return on investment are what is truly important, though. To stay competitive and equip your production lines for the future, the time to think about the next stage of your Industry 4.0.

7. **Machine downtime reductions:** Predictive maintenance in Industry 4.0 means that equipment failure will be identified before it occurs. Systems can spot repetitive patterns that precede failures, notify your teams and have them schedule an inspection. Such systems also learn over time, becoming capable to spot even more granular changes and help you continuously optimize your production process.

8. **Improved supply/demand matching:** Cloud-based inventory management solutions enable better interactions with suppliers. Instead of operating in "individual silo", user can create seamless exchanges and ensure that user have:
   a. High service-parts fill rates;
   b. High levels of product uptime with minimal risk;
   c. Higher customer service levels.
   By pairing user inventory management system with a big data analytics solution, user can improve his demand forecasts by at least 85%. User can also perform real-time supply chain optimization and gain more visibility into the possible bottlenecks, protruding your growth.

Challenges in implementation of Industry 4.0:

1. Economic
   a. High economic costs
   b. Business model adaptation
   c. Unclear economic benefits/ excessive investment.

2. Social
    a. Privacy concerns
    b. Surveillance and distrust
    c. General reluctance to change by stakeholders
    d. Threat of redundancy of the corporate IT department
    e. Loss of many jobs to automatic processes and IT-controlled processes, especially for blue collar workers
3. Administrative/policy:
    a. Lack of regulation, standards and forms of certifications
    b. Unclear legal issues and data security
4. Organizational/ Internal
    a. IT security issues, which are greatly aggravated by the inherent need to open up those previously closed production shops
    b. Reliability and stability needed for critical machine-to-machine communication (M2M), including very short and stable latency times
    c. Need to maintain the integrity of production processes
    d. Need to avoid any IT snags, as those would cause expensive production outages
    e. Need to protect industrial know-how (contained also in the control files for the industrial automation gear)
    f. Lack of adequate skill-sets to expedite the transition towards the fourth industrial evolution
    g. Low top management commitment
    h. Insufficient qualification of employees

Comparison I3.0 with I4.0:

Sr. No	**Feature**	**I4.0**	**I3.0**
1	Characterized by	A fusion of technologies across physical, digital and biological spheres. Physical – Autonomous Vehicles, 3D Printing, Advanced Robotics, New Materials etc. Digital – IoT, Block chain, AI etc. Biological – Molecular biology and genetics, application of engineering principles to biology, , 3DBio printing etc.	Digital evolution. rise of telecommunications technologies and computers and IT
2	Technologies used	For smart automation technology used is Cyber physical systems, IOT, IIoT, smart factory, Cloud**,** Big Data Analytics, and AI.	For automation technology used is mainly PLC's and Robots.
3	Automation level	in Industry 4.0 machines work autonomously without the intervention of a human	Industry 3.0 the machines are only automatized.
4	Impact	The impact of the fourth industrial evolution is global and is on all the aspects of human life	Impact is limited to geographical and manufacturing industry only

Sr. No	Feature	I4.0	I3.0
		i.e. Economy, Business, Governments, Society, and Individuals.	
5	Efficiency, Productivity and performance	By combining machine-to-machine communication with industrial big data analytics, ir4.0 is driving unprecedented levels of efficiency, productivity, and performance.	Due to limitation of technological advancements lower Efficiency, Productivity and performance
6	Implemented by	Cyber physical systems, IoT, Smart factory, Big data, Cloud, Cyber security.	Production, planning and control, IT support, ERP, MES and data management.
7	Scope	Real time, Interconnected global system.	Not real and global in nature
8	Example	If the CNC Milling machine is in the Industry 4.0 the tool changes are automatic at the same time the spindle speeds and all other parameters essential to carry out the process are recorded by the hundreds of sensors present in the machine and the optimum settings are done on its own based on the large amount of data there is to compare and optimize the process. i.e. No human intervention	If a CNC Milling machine is in the era of Industry 3.0, the tool changes can be done automatically but the speed at which the spindle should run is to be observed by the operator and the corrections should be made by him. I.e. Human intervention/ assistance.

IoT Layered Architecture:-

The IoT is a technology which is currently emerging and it can be viewed as a network of objects connected via. Internet, which aims to increase the availability of Internet at anyplace and any time through integration of the physical objects (embedded with software, sensors, actuators etc.) into the information network which enables these objects to collect data and exchange it.

IoT is the ability to connect, communicate with, and remotely manage an incalculable number of networked, automated devices, from the factory floor to the hospital operating room to the residential basement. It is a scenario in which storage, computing and communication technologies are embedded in everyday objects. Processing, storage and communication capabilities attached to an object turns object into a service for which users pay per use.

Since the IoT was proposed in 1999, it has been in continuous development and expansion, but there are no uniform definition standards. The IoT concept broadly refers to RFID, infrared sensors, GPS, laser scanners and other information sensing devices, according to the agreed protocol, to achieve any time, any place, any object information exchange and communication in order to achieve intelligent identification, locate, track, monitor and manage a network. The IoT has full perception, reliable transmission, intelligent processing and other features.

IoT was making extensive use of, and made throughout the wisdom industry, wisdom agriculture, intelligent transportation, smart security, environmental protection, wisdom health care, government livelihood management, intelligent home, food safety and so on. Although the IoT industry has been in rapid development in recent years, there is still no large-scale applications in reality. There is no uniform construction standards, norms things access and integration management platform.

The three-layer framework of IoT is widely considered and it is consisting of perception layer, network layer and application layer. Although the three-layer framework describes the architecture of the IoT from the technical level, but not fully shows the characteristics and reference of the IoT. Now some applications require the closed-loop system, and the IoT is an open-loop global network system, so its application and promotion still faces many difficulties and challenges.

The Five-Layer Architecture of IoT:
Architecture of IoT is consisting of perception layer, network access layer, network layer, application support layer and presentation layer, as shown in Fig 4.13.

Perception/Edge layer: The perceptual layer is the foundation of IoT, is the interface between the layer of physical world and information world. It uses radio frequency identification technology, bar code technology, sensor technology, positioning technology, or other information sampling technology to complete the information collection, and with the help of controlling the objects of perception by the actuator, implement the infection control between the physical space and information space. Its main components include two-dimensional code label, code reader-writer, RFID tags and RFID reader-writer, cameras, and all kinds of sensors. So, the IoT perception layer has the main functions of information perception and original data collection, necessary auxiliary complete downward at the end of the control object. Therefore, the main function of perception layer of IoT is information and data collection, when necessary, assist to complete the control objects of perception.

Network access layer: The network access layer is mainly composed of the base station node and the network access gateway. It complete the network control and the data fusion of each node in the perception layer, or forward the information from the above layers (The network transmission layer or the application layer). When the perception layer's nodes complete networking, the perception layer's nodes need to upload data, and send the data to the base station node. The base station node will receive the data, and complete the connection with the network transmission layer by the access gateway. When the application layer and the network layer needs to downlink data, the base station node sends data to each node in the perception layer after the network access gateway receiving the data from the network transmission layer, then complete the forwarding information and interaction between the perception layer and the network transmission layer. The current access methods in the network access layer mainly include WIFI, Ad hoc, Mesh, ZIGBEE, industrial bus. It collect the information by various cognitive tools, or to preliminary process and network access.

Network transmission layer: The network transmission layer is mainly used to realize the transmission and exchange of information, provide the basis transmission network for the necessary of applications and services within a wide range, including the satellite communication network, the mobile communication network, the optical fiber communication network and the local independent private network and so on. It is a problem in the network layer that the neutral

access and seamless integration between different network and means of communication, and how to form the transmission and exchange capacity with end-to-end.

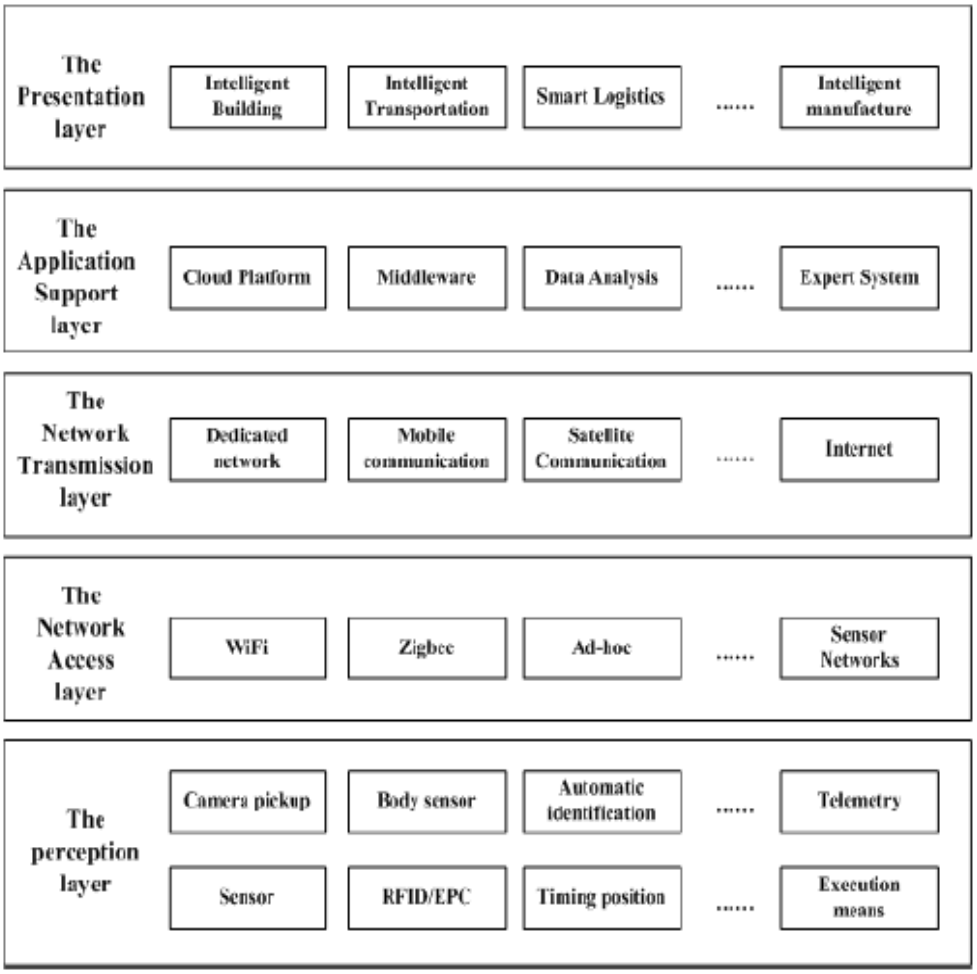


Fig 4.13: Five Layer Architecture of IoT

Application support layer: With the support of the information technology, cloud computing technology, middleware technology, database technology, expert system and so on, the application support layer complete public intelligent analysis and storage of data information, realize information processing, and all kinds of intelligent application sharing and exchanging.

Application presentation layer: The application presentation layers task is the development of a variety of applications of IoT base on the data processing of the application support layer, and uses the technology with multimedia, virtual reality, human-computer interface to build the interface of intelligent application between the IoT and the user, implement present and application of all kinds of intelligent information.

Industrial IoT (IIoT):

Industrial domain is different from consumer domain. It has specialized communications protocols, security requirements, QoS and device life cycles. Initially, IIoT applications referred to any application that relied on an Internet- (or Intranet-) capable sensor and actuator networks. Many web, industrial automation, embedded and wireless sensor network applications are usually grouped under the umbrella of IIoT. While IoT has maintained its position covering domain of

home automation and consumer electronics, IIoT extended it to include industrial domain with all its implications. The key enabler of both is connectedness (networked).

The IIoT integrates with a wider array of communication protocols. IIoT based low power wireless networks may require real-time performance with time triggered variations of IEEE 802.15.4. Hence, IIoT applications must handle changes in and introduction of new communications protocols. Security is an important aspect for networked systems, such as IIoT. The open connectedness of IIoT applications make them vulnerable and require protection from various threats.

The traditional security triad of confidentiality, integrity and availability still apply to the IIoT, and now privacy must also be included. Traditionally, industrial computer networks rely on network segregation with highly controlled network access or an "air gap" between factory floor and IT networks. This includes using firewalls to control what connections are allowed to pass between network segments, for example network traffic entering and leaving the factory may be fully denied.

IIoT applications have monetary consequences and could expose commercially sensitive information. Authenticity and terms and conditions must be taken seriously. IIoT applications operating in continuous production require QoS agreements and monitoring. QoS refers to the non-functional requirements of an application. The QoS concerns could be battery life time, bandwidth, round trip delay, redundancy, backup, resilience, recovery or more. QoS is an important issue for IIoT therefore it must comply stricter limits.

The life-cycles of IIoT applications differ to those of IoT. By comparison IIoT applications must pass thorough testing, simulation, validation and verification prior to deployment. The deployment environment of IIoT applications requires integration with areas, such as legacy systems and devices, simulators, intelligent robotics, big data, analytics and augmented reality etc. In addition, IIoT must not introduce cyber security vulnerabilities to other areas, such as robotics. Therefore, a software architecture style must account not only for IIoT but also the surrounding domains.

Comparison of IoT and IIoT:

Sr No.	Parameters	IoT	IIoT
1.	Devices	IoT includes devices located in consumer or commercial settings: offices, business, and homes.	IIoT includes devices located in industrial settings: factory floor, automation control, HVAC, energy grid.
2.	Reliability	Moderate requirements: ease of use, short product life cycles.	Stringent requirements than the consumer IoT: Hi-reliability, harsh environments, high product life cycles.
3.	Security	Require identify and privacy.	Requires robust security protecting against access.
4.	Function	Synonymous with functions that benefit end users-human life style.	Provide basic operational roles and requirements many are independent of human intervention.

Sr No.	Parameters	IoT	IIoT
5.	Availability	Function in environment of updates, add-ons, apps, charging and random rebooting.	Requires high availability and up time. Unscheduled patching and rebooting is not tolerated.
6.	Failure	Retry, replace.	Resilient, fail in place.
7.	Connection	Connects people to people or people to internet.	Peer-Peer and M2M.
8.	Protocol	For the most part is IP.	Based upon numerous protocols standards based and proprietary.
9.	Market	Green Field new device uptake is almost immediate.	Brownfield new device uptake must be phased in.
10.	Area of focus	Commercial or consumer convenience	Monitoring and managing systems for high stake industries- defense, Manufacturing, Health Care and others.
11	Focus development.	Smart Devices.	Sophisticated Machines.
12	Degree of application	Sensitive sensors, Advanced controls and Analytics.	Simple application with low risk impacts.
13	Scalability	Low scale networks.	Large scale networks.
14	Precision and Accuracy	Critically Monitored.	Synchronized to milliseconds.
15	Programmability	Easy off-site programming.	Remote on-site reprogramming required to support new processes.
16	Output	Convenience	Economic Growth.
17.	Resilience	Not required.	Must be automated to support fault tolerance.
18.	Maintenance	Consumer preferred.	Scheduled and Organized.

Industry 4.0 Architecture*:*

Industry 4.0 is the German initiative that aims to bring about challenges of the fourth industrial evolution. It undertakes to bring together advances in digital technologies. Starting with a focus on the smart factory concept. It now includes concepts such as big data and analytics, CPS, cloud, fog and edge computing, IIoT, augmented reality, intelligent robotics, additive manufacturing, and simulation and cyber security. Each of these fields are being developed within their own areas. But combining the technologies together and creating a cohesive technological environment is a challenge.

Industry 4.0 has proposed the Reference Architecture Model for Industry (RAMI) 4.0 as shown in Fig 4.14. It is a reference architecture that joins life-cycle, software concerns and the automation pyramid into a cube view. The RAMI 4.0 shows the need for recognizing the multi-dimensional relationship between engineering domains within industrial automation. RAMI 4.0 makes explicit the need for all hierarchy components to share some burden of the software layer distribution. To address the standardization issue, a Reference Architecture Model for the Industry 4.0 was developed in Germany

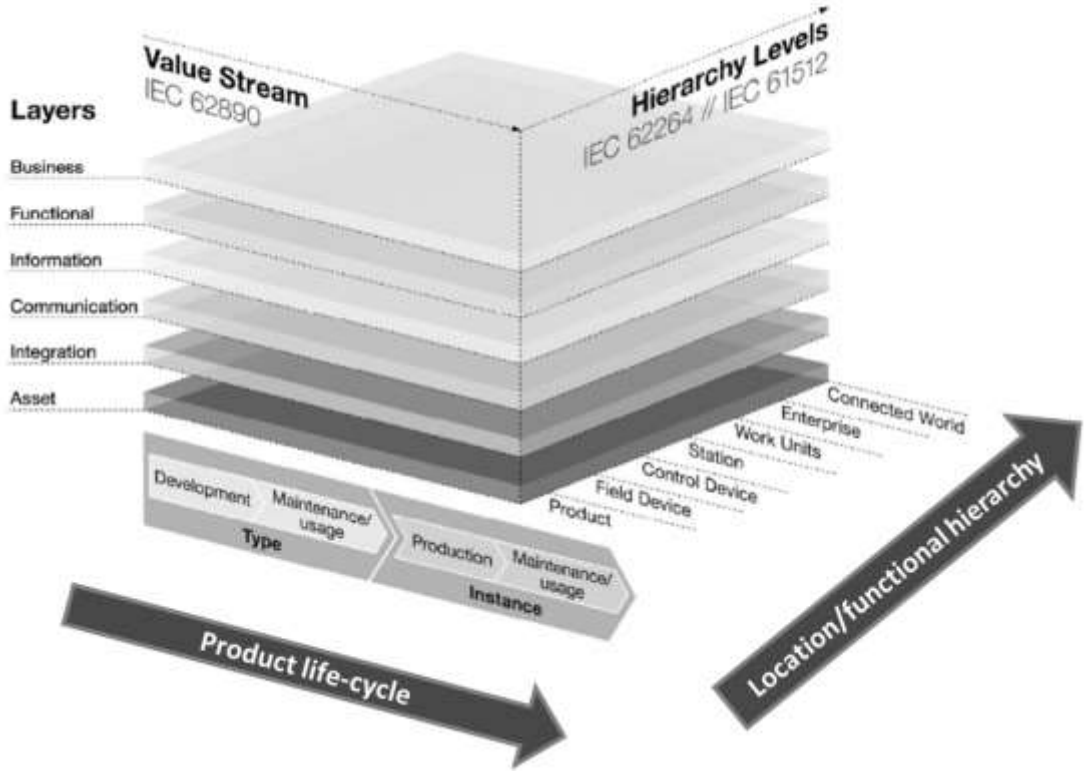


Fig 4.14: Proposed Reference I4.0 Architecture.

This is a meta-model so it describes the aspects that play an important role in the Industry 4.0 production system. It is based on the internationally accepted Smart Grids architecture model introduced in year 2014. Two additional bottom layers are added to address specific aspects of Industry 4.0.

The three dimensional RAMI4.0 should enable:

a) Identification of the existing standards,
b) Identification and closure of gaps and loopholes in the existing standards,
c) Identification of overlaps in the existing standards.

1. The first dimension of the RAMI4.0 addresses two elements, type and instance. As long as an idea, a concept, or a product is still a plan and is not available/realized yet, it is called type.
2. The second dimension of the model deals with location, functional hierarchy from the product to the connected world (as the last stage of Industry 4.0 development with all enterprises, customers and suppliers connected).
3. The third dimension of the RAMI4.0 model is organized in functional layers as follows
   a. An assets layer includes physical components such as robots, conveyer belts, PLCs, documents, archives, but also non-physical objects such as software and ideas.
   b. An integration layer provides information for assets in a form that can be digitally processed. It includes elements connected to IT such as sensors, integration to HMI and computer-aided control of technical processes.
   c. A function of the communication layer is standardization of communication using uniform data format and predefined protocols. It also provides services for the integration layer.
   d. An information layer is processing and integrating available data into useful information.
   e. A functional layer includes formal descriptions of functions. Also ERP functions belong to this layer.
   f. A business layer includes mapping of the business model and links between different business processes.

Thus the vertical axis representing software concerns, the horizontal axis representing life cycle stages, and the diagonal axis represents automation hierarchy.

RAMI4.0 is in Germany registered as DIN SPEC 91345 and it is as such a first compilation of the essential technological elements of Industry 4.0. It is perceived as a precondition for deployment of Industry 4.0 concept in practice and also as a model that requires international acceptance.

4.5 Artificial Intelligence (AI):

Definition: AI is defined as the study of making machines and humans do things intelligently. AI is combination of computer science, physiology and philosophy. Basically, AI is combination of science of human intelligence and an engineering discipline (Smart physical systems).

Advantages of AI:

1. Accuracy in operations
2. Multivariable/multiparameter-based systems can be easily designed
3. Operation and Controlling of systems become easier
4. Output of any system can be predicted.
5. Human errors in different operations (Industrial/commercial) gets reduced
6. Digital assistance is possible
7. AI systems will be available for 24×7 real time operations.
8. Huge Data/information can be stored
9. Faster decisions.
10. Depending upon the computational time, algorithm capacity and processor capacity the AI programs can be designed or changed. Means design is flexible.
11. Reliable and cost effective design is possible.

Applications of AI:

1) Bio-informatics
2) Brain-Machine interface
3) Handwriting recognition and speech recognition.
4) Cheminformatics
5) Medical diagnosis
6) Complex aided diagnosis: Breast cancer, lung, colon, prostate cancers, Alzheimer's cancer
7) Computer vision: Autonomous, robots, object recognition
8) Robot locomotion
9) Driverless cars
10) Text mining: Business intelligence, life sciences, National security etc.
11) Spam detection and filter
12) Appropriateness of image data and text data
13) Smart machines: Intelligent systems that uses Wi-Fi, sensors, RF-IDs to receive data and make diagnosis via cellular networks
14) Search engines.
15) Reservation and Transportation systems
16) Use in different manufacturing and production processes
17) Robotic systems

Machine Learning:

Definition: Machine learning (ML) has been defined by different scientists and researchers in different ways. It is a modern platform of learning. ML focuses on development of computer programs that can access data and use it learning for themselves.

In 1959 Arthur Samuel, defined that “Ml provides a computer with ability to learn without being explicitly programmed." Marvin Minsky, a pioneering mathematician, scientist, and computer engineer has denied as “concept of learning as a process that makes useful changes in our minds."

ML is also defined as "It is the science of getting computers to learn and act like humans do, and improve their learning over time in autonomous fashion, by feeding data and information to them (computers) in the form of observations and real world interactions."

ML deals with computer technology/machines that facilitate users across the world to store and process large amount of data which is in distributed manner.

ML is to program a machine to learn from previous experience/data points/every attempt and thereby to improve the outcome. This means that we need huge amount of data/stored data on to which process/es is to be done or to infer some results. The massive/huge amount of data encompasses numbers, words, images, clicks, rules, details of any object(s) etc. in detail manner.

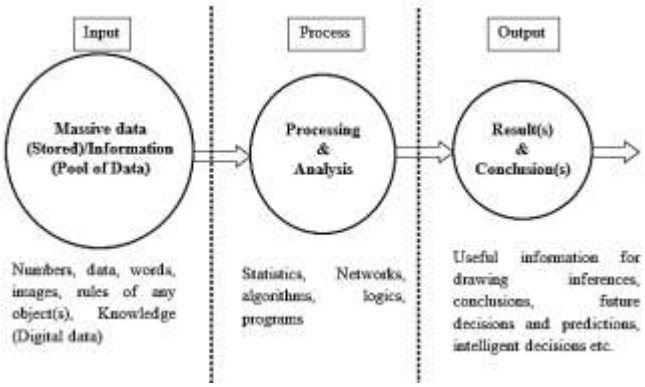


Fig 4.15: Concept of Machine Learning

As shown in Fig 4.15 the massive input data is collected and is then processed and analysed. Different statistical methods, tools, algorithms, logics, programs are used on this data for processing and analysis. After this, some results/conclusions have been obtained. This result is useful for drawing some interferences and making some decisions. This phenomenon is applicable in different applications in industries, medicines, banks, trading, and computer networks. Thus, ML helps to accelerate understanding and learning efficiency of human being.

Relationship between ML and AI:

Fig.4.16 shows the relationship between ML and AI by means of diagram. In AI, an intelligent software is based on statistical learning methods (algorithms).

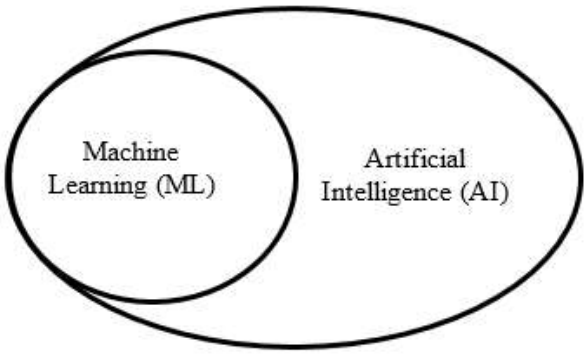


Fig. 4.16: Relationship between ML and AI

These methods are developed by using Machine Learning (ML) or ML algorithms which needs databases or pool of data or learning data. It includes data bases, data mining, statistics, pattern recognition, and neuro computing and knowledge discovery from data (KDD). AI techniques are based on ML algorithms. This signifies that ML needs/requires data from various sources through different techniques which are called as Machine Learning Techniques. Machine Learning model is a mixture of these techniques which are discussed in preceding section. Basically, there are three broad categories/types of machine learning techniques through which the data or learning "signal" or "feedback" or "learning data" is available to learning system.

Types of ML:

Supervised Learning: In every learning method, the basic objective is to learn an unknown function $f(X) = y$; where X is an input vector and y is desired output vector. In this labelled training data is available. It is a model generated from labelled data. Here, X is input/training data consisting vector X. y is output vector 'y' of labels/tags. The training data comprises set of training examples. Thus, each example is a pair of an input object/vector and desired output value/vector i.e. called as supervised signal. Hence, we need training examples. Here, supervisor/teacher/domain expert is available to monitor or label the data. This type of learning us called as supervised learning because:

a. The output vector 'y' is comprising label for each training example present in training data i.e. 'X'.
b. The output vector is provided by the supervisor/teacher. These supervisors are humans because the accuracy and precision in the learning data and reliable source of information. In some cases machines can be used as supervisor.

Applications: Some of applications of supervised learning are bioinformatics, pattern recognition, Cheminformatics, speech recognition, spam detection, handwriting recognition etc.

Algorithms used: Following two types of algorithms are used in supervised machine learning
(1) Regression
(2) Classification. Analytical learning, ANN, BP, Boosting, Bayesian Statistics etc. may also be used.

Unsupervised Learning: In unsupervised learning the supervisors or training data is not available. We have unlabelled data only and it is necessary to find out the hidden structures in the data. In this type no information is available about the correct outputs. Manual label inputs are not used. We don't have labelled data because of following reasons-

(a) Inherent nature of data itself
(b) Non-availability of manual of labelling due to some reasons (expertise, payment or any other)
(c) collection of data from different collection devices which is unprecedented rate.
(d) Difficult to judge the big data which is available in large variety, volume and with high velocity. Means here supervisor/teacher is not available to label the data.

Techniques/Algorithms used: In Unsupervised learning are:
(1) Clustering
(2) Anomaly detection
(3) Association
(4) Neural network models such as SOM and ART are used
(5) Expectation-Minimization (EM algorithm
(6) Method of Moments
(7) Blind signal separation techniques-Principal component analysis, Independent component analysis, Non-negative matrix factorization, singular value decomposition.

Reinforcement Learning (RL): In this type of learning, the decision-making system or agent or software agent (program) receive reward or feedback or punishment at the end of sequence of steps. This feedback may be positive and negative. In this method, it is necessary to decide the steps to receive the feedback which may be reward or blame at the final result i.e. on solving the algorithm or program or agent for an environment.

It deals with dynamic environment e.g. 1) driving a car towards a goal 2) playing a game with opponent.

The learning agent/program interacts with the environment in discrete time steps and receives the rewards. Accordingly, the agent receives as much as possible rewards. It includes problems having long-term rewards and short-term rewards between which trade-off takes place.

Algorithms used:
1) Temporal difference learning
2) Q-learning
3) SARSA
4) Fictitious play
5) Learning classifier system
6) Optimal control
7) Multi-agent system
8) Distributed AI.

Deep Learning (DL): It is a subset of machine learning based upon a set of algorithm that attempt to model high-level abstractions in data by using model architectures with complex structures or composed of multiple non-linear transformations.
DL is a specific kind of ML.
DL architectures are;
(a) Deep neural networks (DNN)
(b) Artificial neural networks (DNN)
(c) Deep Belief networks (DBN)
(d) Convolutional neural networks (CNN)
(e) Deep Boltzmann machines (DBM).

Relationship between DL, ML and AI:
Fig 4.17 depicts the representation of DL-ML-AI. Here, DL is a subset of ML. ML and DL are subsets of AI

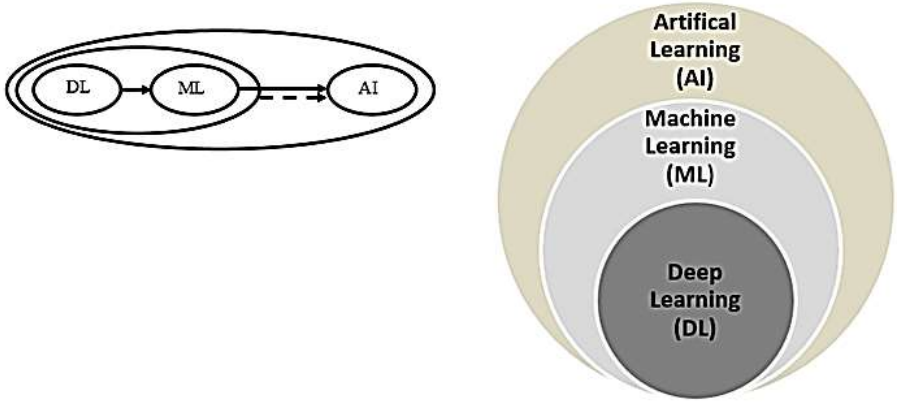


Fig. 4.17: Relationship between DL, ML and AI

a. DL uses neural networks which permits machines to train in performing task. It is a subset of ML.
b. ML uses techniques/models/algorithms to improve the performance of machine at task. It is a subset of AI. ML learns via these experiences.
c. AL uses computers to mimic human operations/intelligence. It uses ML as subset. Uses intelligent machines and programs. DL algorithms are based on pattern processing i.e. information processing patterns mechanism to identify different patterns like our human brain.

Agents in AI:
Basically, AI system composed of agent and environment. Agent is capable of interacting with its working environment. An environment is the surrounding or area or space around agent. Agent takes inputs from environment through sensors and delivers output/actions through actuators. Agent is a system that takes -decisions, course of action to accomplish the activities according to objectives. Agent may be software agent, robotic agent, computational agent, biological (human) agent. Software agent may be a computer program(s).

Single Agent System:
Fig. 4.18 shows block diagram of Single Agent System. Here, agent is a part of an environment. The agent has own goal, actions domain and knowledge. The agent is connected to sensors and actuators (effectors) in the environment.
The agent has:
(a) Autonomy and abilities to solve the problems.
(b) Controlling facilities
(c) Synchronous abilities.

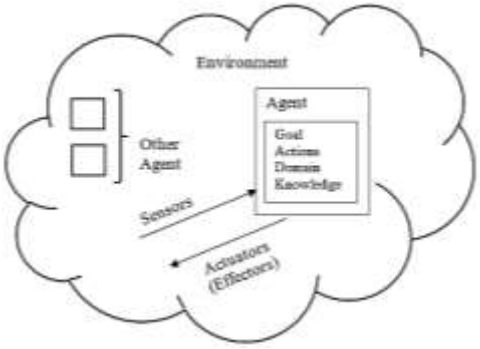


Fig. 4.18: Single Agent System

Multiagent System (MAS):

Fig. 4.19 shows block diagram of Multi Agent System (MAS). It is called as Multiagent system because it uses number of software agents. In this system, multiple intelligent agents are connected to each other to solve the problems which are difficult to solve by a single agent.

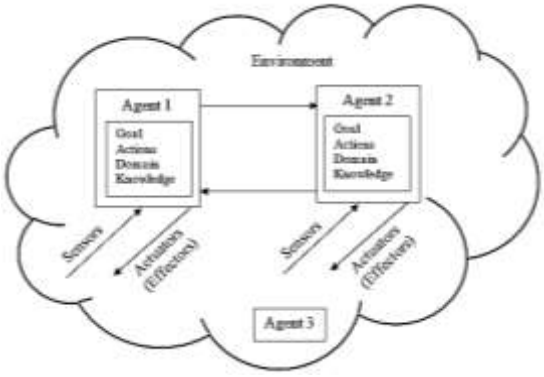


Fig. 4.19: Multi-Agent System

The individual agent has "autonomy" but not have full global view and capabilities to solve the problems. It has asynchronous computation capabilities and decentralized behavior. It is used in computer games, films, online trading, transportation, logistics, on-line examination, ATM Process,

Case Study

Smart City Street Light and Monitoring

City Street light can be controlled through smart embedded device having sensing and computing power which will communicate central coordinator and command station through internet. Here streetlights are grouped together having sensing, computing and communication circuit on each streetlight lamp post. Each group connects to a group controller or coordinator through Bluetooth or ZigBee. Each controller further connects to command and control station through internet.

The station receives data of each streetlight from a group in specific period or intervals. This data may be about status of these streetlights related to nonfunctional/ faulty lights, nearby traffic conditions, daylight whether cloudy, dark, and normal and so on.

The station remotely programs the group controller to take appropriate action as per the condition of traffic or light. It also send data related to faulty light and its location for remedial action. This

way each group of city streetlight is controlled through coordinator, controller and command station through internet.

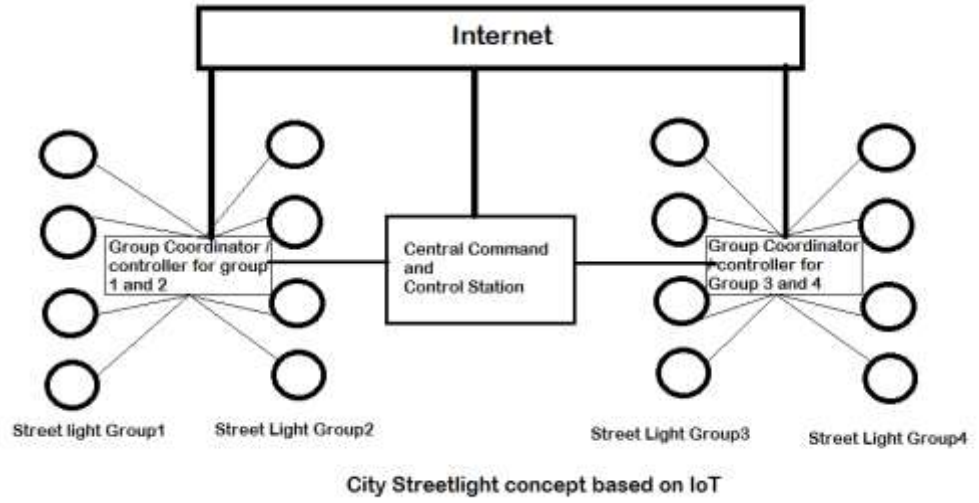


Fig 4.20 Street Light using IoT

Fig4.20 shows the concept of streetlight using IoT. Here lamppost hosts a streetlight, wireless sensor network (WSN) actuator and sensors. Sensors sends messages about status of lamp, ambient light and traffic. Actuator makes light on or off.

When light is above threshold then lights are switched on. The WSN sensors deployed detects presence of traffic and its density. If traffic is not present the lights are switched off. This saves energy. Traffic density data is communicated to traffic signal monitoring service. The WSN transceiver also accepts data from other services such as Wi-Fi service, security service, traffic signaling service and retransmits to network of WSN and then to access points. Thus lamppost may act as information network or active node in service network.

Each transceiver at the lamppost receive and retransmits in real time. Events messages alerts, triggers and notifications from a number of services can transmit for service such as smart parking, traffic signaling, waste management, weather monitoring, air pollution control services, security services for home, banks and important public spaces, emergency services and hospitals.

Functions of control and monitoring service for city streetlights are:

1. Measure light intensity and monitor city street lights.
2. Measure and monitor traffic parameters in real time intervals
3. Each WSN has program that configure and communicate with WSN network.
4. The WSN network connects a coordinator/controller which has data adaption, store, time, location, IDs stampings and gateway interfaces.
5. Communicates the WSN messages
6. These massages are transmitted at preset intervals to access points which are in turn connected to coordinators.
7. Coordinator generates and communicates alerts, triggers, messages and data after aggregating, computing, processing, filtering and compacting at data adaption layer.
8. Coordinator creates and uploads in real time a database which transfers to the cloud for processing and for cloud data store.
9. An OTP module at the cloud node provides OTP management and upload connectivity programs for gateways.
10. Runs and monitors at data adaption layer for faulty or inaccessible sensor at periodic intervals

11. Integrates data and activates the alerts and triggers.

Suggested Resources:

Sr. No	Keyword	QR Code	Weblink
1.	Introduction to IoT		https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT
2.	Edge Gateway		https://www.sequiturlabs.com/secure-edge-gateway/
3.	Importance of Sensors in IoT		https://electronicsforu.com/technology-trends/tech-focus/IoT-sensors
4.	IoT Gateway		https://whatis.techtarget.com/definition/IoT-gateway
5.	IoT Cloud Computing		https://www.embitel.com/blog/embedded-blog/role-of-cloud-backend-in-IoT-and-basics-of-IoT-cloud-applications
6.	Next Generation of HMI and SCADA		https://www.automation.com/automation-news/article/the-next-generation-of-hmi-and-scada
7.	IoT Protocols		https://solace.com/blog/understanding-IoT-protocols-matching-requirements-right-option/
8.	The Intermediary Between Sensors and the Cloud		https://www.mouser.com/blog/gateways-the-intermediary-between-sensors-and-the-cloud
9.	Beginner Guide to AI ML		https://developer.ibm.com/articles/cc-beginner-guide-machine-learning-ai-cognitive/

Sr. No	Keyword	QR Code	Weblink
10.	Introduction, History & Types of AI		https://www.guru99.com/artificial-intelligence-tutorial.html
11.	Artificial intelligence (AI) vs. machine learning (ML)		https://azure.microsoft.com/en-in/solutions/ai/artificial-intelligence-vs-machine-learning/#introduction

Sample Questions:

Sr. No.	Question
1.	Identify not element an element of IoT? A. People. B. Process. C. Security. D. Things.
2.	Find the name of first recognized IoT Device. A. Smart Watch B. ATM C. Radio D. Video Game.
3.	How many devices (in billion) approximately are estimated to be connected to IoT by 2020? A. 2. B. 75 C. 20 D. 100. E.
4.	IoT Gateway must provide_____ A. Connection point between cloud and controllers. B. Security with hardware. C. Simple and fast installation. D. Data storage.
5.	_____ is the other way of refereeing to IoT devices A. Smart B. Connected. C. Smart and Connected. D. Access devices.
6.	The role of IoT sensor is: A. Collect Data B. Store Data C. Manage Data D. Security.

Sr. No.	Question
7. _	_____are smart devices that uses embedded processors, sensor and communication hardware to collect and send data which is acquired from environment A. Computers B. Network C. Things D. Protocols
8.	_____ is the direct contact between two smart objects when they share information instantaneously without intermediaries A. Device to device B. Device to gateway C. Gateway to data systems D. Between data systems
9.	Agriculture IoT stick is smart gadget work on principle of A. Plug and sense B. Plug and play C. Plug and work D. Plug and socket
10.	Vehicle communication, driverless car, connected cars are the example of IoT in A. Agriculture B. Electronics C. Automotive D. Discrete Manufacturing
11.	Real time driver monitor system to detect monitor fatigue level of driver using IoT in automotive includes A. Sensors to detect eye blinks, gas, impact sensors and alcohol detection B. Sensors for GPS C. Fluid level sensors D. RFID tags
12.	Nut and Bolt manufacturing is an example of discrete manufacturing with A. High complexity and low volume B. Low complexity and high volume C. Low complexity low volume D. High complexity high volume
13.	The industrial revolution is: A. Significant change that affects a single industry only B. New technologies and novel ways of perceiving the world that trigger a profound change in economic and social structures C. An event that happened in a previous century and doesn't affect modern society D. A series of technological advances that may or may not have a profound effect on societies
14.	The series of events best describes the transformations of the first three industrial revolutions are: A. Mechanization of production; introduction of mass production B. Mechanization of production; invention of steamships and railroad

Sr. No.	Question
	C. Discovery of electricity; the growth of mass production D. Mechanization of production; the agrarian revolution
15.	Electrical power and locomotives are the inventions of A. First revolution B. Second revolution C. Third Revolution D. Fourth revolution
16.	Artificial Intelligence is A. A field that aims to make machines and humans more intelligent B. Afield that aims to improve the security C. A field that aims to develop intelligent machines D. A field that aims to mine the data.
17.	For Pattern recognition _____ type of machine learning is required. A. Supervised B. Unsupervised C. Reinforcement D. Semi Supervised
18.	The science of getting computers to learn and act like humans is____ A. Artificial Intelligence B. Machine Learning C. Deep Learning D. Supervised Learning.
19.	Clustering algorithm is used in: A. Supervised B. Reinforcement C. Semi Supervised D. Unsupervised
20.	____uses Neural networks that allow machines to train in performing a task. A. Artificial Intelligence B. Machine Learning C. Deep Learning D. Supervised Learning.

Unit– V Smart World

Expected Course Outcome: Suggest the different electronic systems for smart world.

Teaching Hrs. 8 **Marks 12**

To attain above course outcome candidate must able to

a. Explain the working principle of given electronic system in smart home.
b. Explain the relevant features of smart city.
c. Explain the mechanism of smart city.
d. Explain the given network component function**.**

Unit focus on following major points:

5.1Evolution of smart home, X10 Protocol for Home Automation.
Basic requirements and components for Smart Home: Video Monitoring, Security and Alarm, Door control, Smart lighting and smart metering.

5.2 Basic requirements for Smart City: Smart Transportation, Smart Healthcare, Smart waste, Smart physical safety/Security (IP based CCTV, Fire and Gas detection, Fire extinguishers) and Smart education.

5.3 IOT/M2M Network architecture: Conceptual diagram.

5.4 Domains for operation: Application domain, Network domain, M2M device domain.

5.1 Introduction

A smart home is one that incorporates all the advanced automation systems so as to offer those who live in with the ability to monitor and control various devices such as the refrigerator, washing machine, TV, ovens, the opening and closing of doors and windows, without the need to physically operate the devices and interacting with them remotely through a wireless connection. (Wi-Fi, Bluetooth, or ZigBee) that allows multiple devices connected to each other through an appropriate app (developed and made available by the manufacturers of smart devices) that work as an administrative console.

5.1.1 Need:

Smart home technology provides homeowners with security, comfort, energy efficiency and convenience. The term "smart home" is used to describe a residence that has lighting, appliances, heating, TVs, air conditioning, entertainment audio and video systems, computers, cameras and security systems that can communicate with one another and be remotely controlled from any room in the home, as well as remotely from any location via a smartphone or the internet. Thus smart home provides:

1. Comfort, security and convenience.
2. Remote automation.
3. Conserve the earth's limited resources.
4. Increase the independency and given greater control of home environment.
5. Make it easier to communicate with family.
6. Save time and effort.
7. Improve personal safety.
8. Reduce heating and cooling costs.
9. Increase home's energy efficiency.
10. Alert audibly and visually to emergency situations.
11. Allow to monitor home while away and detect intruders.

5.1.2 Evolution of smart home

In 1923, brilliant Swiss-born architect Le Corbusier (1887–1965) described a house asin “and then slowly, during the 20th century, it turned into reality, with the advent of arrival of convenient, electric power started to strip away the drudgery from all kinds of domestic chores, including washing clothes and dishes and vacuuming the floor. Then, when transistors made electronics more affordable in the mid-20th century, appliances started to control themselves in a very limited way, using built-in sensors and programmers.

Today in the 21st century, that the vision of the fully automated, smart home is actually being realized. This possible because of Internet, due to which it's easy to set up virtually any electric appliance in the home, can be controlled from a Web browser anywhere in the world, known as the Internet of Things.

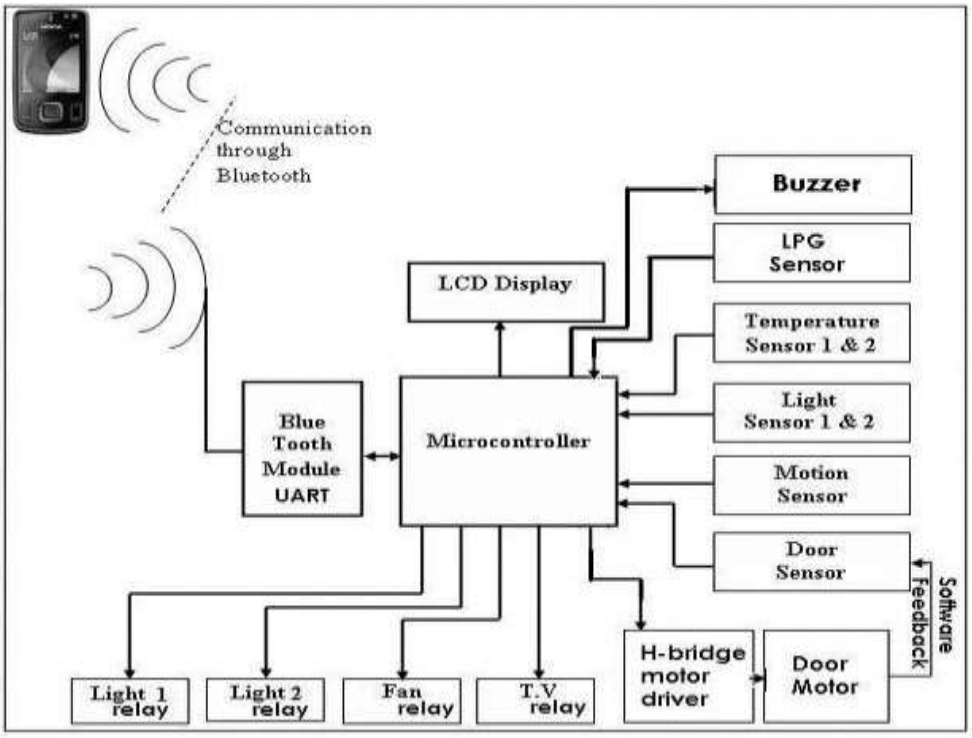


Fig.5.1:-Block diagram of Smart Home

A smart home has various electric and electronic appliances as shown in Fig 5.1 that are wired up to a central computer control system so they can either be switched on and off at certain times for example, heating can be set to come on automatically at 6:00 am on winter mornings or if certain events happen lights can be set to come on only when a photoelectric sensor detects that it's dark.

For a natural-gas-powered central heating system, likely has a thermostat on the wall is switched on and off according to the room temperature, or an electronic programmer that activates it at certain times of day whether or not in the house. Thus the system is hi-tech, with having a robotic vacuum cleaner that constantly crawls around floors sweeping the dust.

Operation- The central controller sends regular switching signals through the ordinary household wiring, effectively treating it as a kind of computer network. Because these signals work at roughly twice the switching frequency of ordinary AC power (which works at 50–60Hz), they don't interfere with it in any way. Each signal contains a code identifying the unit it relates to (a table lamp in living room, perhaps, or a radio in the bedroom) and an instruction such as turn on, turn

off, or (for lamps) brighten, or dim. Although all the control units listen out for and receive all the signals, a particular signal affects only the appliance (or appliances) with the correct code. Apart from appliances that receive signals, can also plug in sensors such as motion detectors, thermostats, and so on, so the system will respond automatically to changes in daylight, temperature or intruders. With most systems, can also switch appliances on and off with a handheld remote control (similar to a TV remote) The remotes either send signals directly to each module using radio wave (RF) signals or communicate with the central controller, which relays the signals accordingly.
X-10 has become one of the international standard for remotely controlling appliances

X10 Protocol for Home Automation: Plug-in X-10 modules
Developed in 1975, the oldest and best-known smart home automation system is called X-10 (sometimes written "X10") and uses ordinary household electricity wiring to switch up to 256 appliances on and off with no need for any extra cables to be fitted. X-10 has become one of the international standard for remotely controlling appliances.

Each appliance is plugged in order to automate into a small control unit (usually called a module) and plug that into an ordinary electrical power outlet. Using a small screwdriver, then adjust two dials on each module. One dial is what's called the house code and set this to be a letter from A through P, so use the house code to link appliances together (for example, so all the lamps on the first floor of home can be controlled as a group). The other dial is set so each individual appliance has a unique identifier known as its unit code, which is a number 1–16. Further, the plug of central controller unit into another electrical socket and program it to switch the various appliances on and off (identifying them through their codes) whichever is required. Wireless router can be used to control an X-10 system as shown in Fig 5.2.

Fig. 5.2: Wireless router

Wireless Internet system
Security is one of the biggest reasons why many people are interested in smart homes. When away at work or on holiday, making the home seem lived in is a good way to deter intruders, a basic X-10 system can turn the lights and the TV on and off at unpredictable times, but if required to push the boat out on security, a wireless, Net-connected system is much better. Effectively, it's a computer-controlled X-10 system with an interface one can access over the Web. With a system like this, one can hook up webcams to watch home/ pets, switch appliances on and off in real time, or even reprogram the whole system.
Example -Harmony Home Automation provides this system.

The remote for setting and control of various operation in Wireless system is shown in Fig 5.3.

Fig 5.3: Remote for setting and control

Features:

1. Control up to minimum four home appliances wirelessly (expandable based on free IO pins).
2. Monitor status of home like temperature inside and outside the home, light intensity inside and outside the home, motion (presence) on the main entrance, LPG leak in the home and status of main door.
3. Open/close main door electrically and wirelessly.
4. As the android application is password protected it automatically adds security to home as it can be controlled by the user only.
5. Automate indoor lightening, outdoor lightening and fan/AC to switch ON/OFF automatically when the light intensity and temperature conditions exceed the programmed threshold values. (This feature, we named it "SENSOMATE").
6. It automatically monitor home against LPG leaks and cases of fire. If it detects something wrong, it automatically switches off all home appliances instantly and immediately opens the door to let the LPG/fire exhaust off home.
7. Has a "SLEEP MODE", once activated will switch light off and program the motion sensor and door sensor to raise alarm if anything goes wrong.
8. At last, as it uses Bluetooth the user can use the android phone within a range from 10-100m.

Fig 5.4:- Home automation

There are many elderly and disabled people, and those with special needs, struggle with simple household tasks. Home automation could make all the difference between them being able to live happily and independently in their own home or having to move into expensive sheltered accommodation.

This application gives them a helping hand, feel secure with the help of motion sensor, give alarm to the guardian at times of emergency, check indoor and outdoor temperatures, Enable/Disable Automatic AC control, Enable/Disable Automatic Room light control and monitor windows/doors. While the nascent smart home market still has plenty of room for growth, examples of smart home technology currently on the market include internet-enabled and controlled refrigerators, smart thermostats like the Nest thermostat, smart lights with light occupancy sensors, and smart door locks and security systems. Most of these smart home devices now include a mobile app for managing them via a smartphone or tablet.

5.2 Basic requirements and components for smart home.

5.2.1 Components -The few of the smart home devices available on today's market:

a. Monitored Security System
b. Security Cameras and Video Surveillance
c. Smart Door Locks
d. Thermostat Control
e. Lighting Control System
f. Intercoms
g. Video Doorbells
h. Home Entertainment
i. Smart TVs
j. Energy Management
k. Garage Door Opener
l. HVAC Units with Climate Control
m. Window Blinds Control
n. Bed Mattress Control
o. Wireless pendants for senior citizens
p. Fire and Gas detection systems

5.2.2 Requirements and Components for Smart Home

Typical block diagram of appliances control is shown in Fig 5.5. Various sensors are placed at different places .It gathers physical conditions such as motion, temperature illumination etc. The parameters are processed using controllers such as Raspberry Pi or Arduino and generates control signals which are used to control the operation of home appliances through switches and relays.

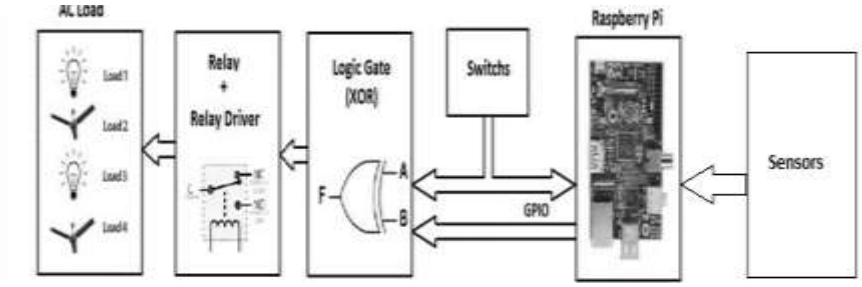


Fig 5.5 Block diagram of Appliances control

5.2.3 Video monitoring

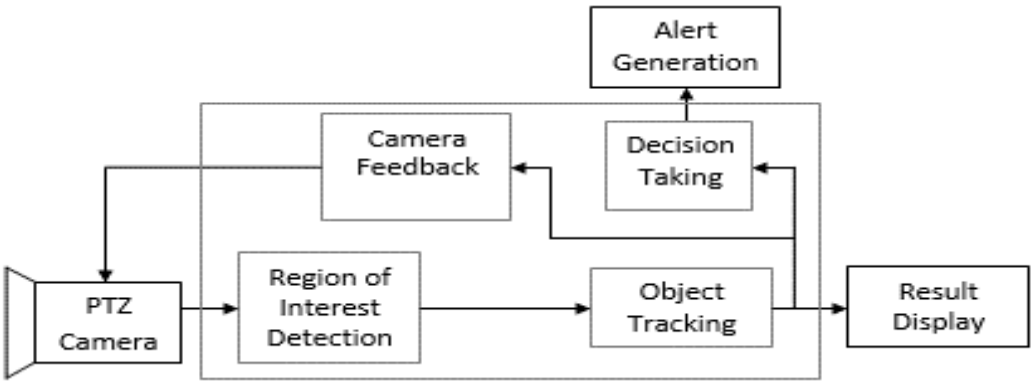


Fig 5.6:- Video recording system

Video monitoring system as shown in Fig 5.6 for home consists of camera (outdoor unit) and displays (indoor unit). Camera can be wired or wireless. Cameras transmitting the capture video through a radio (RF) transmitter. The video is sent to a receiver that is connected to a built-in storage device .Display unit have an easy link to access all of image or video clips.

Video monitoring system can be outfitted with motion sensor technology that is both energy-efficient and more secure. Video monitoring system that include motion detectors will start recording automatically any time they sense movement in range. In the case of pan-and-tilt cameras, the camera lens will automatically point itself in the direction of the motion and record.

5.2.4 Security and Alarm

Alarm Systems: Alarm systems are made up of a combination of different sensors as shown in Fig 5.7 which will trigger an alarm when it detects an action it was specifically built for. Here are some of the basic alarm systems which can install in the home to safeguard family from any outside danger:

Wired / Wireless home alarm systems-Wired alarm systems use a low-voltage current that flows between two points throughout the home's entry points, and breaking the circuit will result in the alarm being triggered; wireless alarm systems use built-in radio frequency transmitters where the signal is transmitted to the control panel and the alarm is activated.

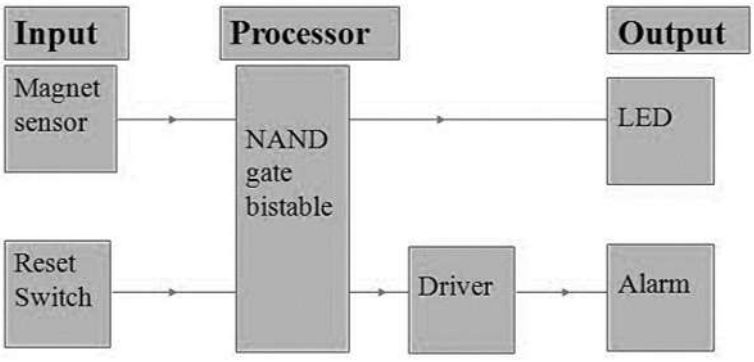


Fig 5.7:- Security and alarm system

Monitored / Unmonitored alarm systems- Alarm systems may be monitored by a call center who will get notified if the alarm gets triggered who will dispatch emergency services, or they may be unmonitored i.e. it'll just set off a loud siren inside and outside the house when the alarm is tripped and will have to take necessary action .

Outdoor / Indoor Siren: The alarm system sirens may be installed indoor, outdoor or both places so that when the alarm is triggered the loud siren will be heard by neighbors as well who can alert the police.

Burglar Alarm System: A combination of different sensors and security cameras make up the burglar alarm system detects an unauthorized entry in home. When the alarm is triggered, an alert is sent to and the police so that immediate action can be taken.

5.2.4 Door control

Smart Door: Smart doors as shown in Fig 5.8 are used nowadays by installing video door phones and smart doorbells. These instruments will help know who is standing outside door before opening it, can even communicate with them about the reason for their visit without the need for physical interaction with them. By making doors smart, can rest assured that family will be safe even from unforeseen dangers.

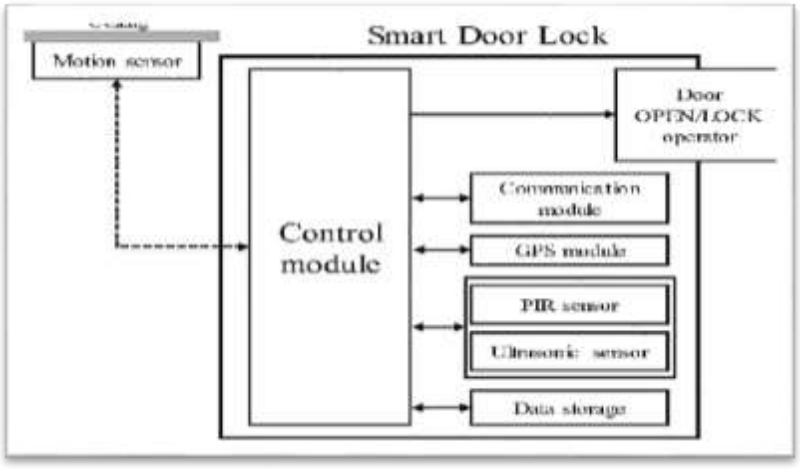


Fig 5.8 -Door control system

5.2.5 Smart lighting

Smart switches are the most cost-effective way to make the lights in home work with a mobile app or smart home system, because it doesn't need to replace every light bulb in the home with a smart one, which is more expensive than replacing a few switches. Controlling lights with voice, have smart lighting systems to make a feel all-powerful. Smart lighting generally uses mesh networking as shown in Fig 5.9 where each smart bulb wirelessly connects to its nearest neighbor. That network is controlled by a hub that plugs into router, enabling other networked devices - such as phone or tablet - to communicate with bulbs. Some systems also have an away from home mode that enables to control the lights when far away, which is handy if just remembered that the lights were left on. Smart light systems can also be accessorized with additional items such as dimmer switches or motion detectors, and in some cases they can be linked to the IFTTT (If This Then That) service to create complex rules that trigger particular recipes for particular things.

Example-Smart lighting systems are controllable with smartphone or tablet apps. Philips' Hue system works with Apple's HomeKit, Amazon's Echo and Google Home, can use those platforms voice assistants to relay the voice commands. Example-saying "Hey Siri, set scene to cinema" or "Alexa, turn the lights off" and seeing it happen. With HomeKit can also control the lights with an Apple Watch. Most smart lighting systems use the same ZigBee wireless networking technology. It's called ZigBee Light Link and it's used by Philips, IKEA and Osram, which should ensure

ongoing compatibility and interoperability between competing systems. Smart light bulbs aren't currently suitable for enclosed light fixtures, as heat can build up in the fixture, which shortens the bulb's life.

Smart Lighting includes-

1. Smart Light Bulbs
2. Smart Dimmers
3. Smart Ceiling fans
4. Smart flash mount lighting
5. Smart lighting kits
6. Smart light switches
7. Smart outdoor lighting
8. Smart outlets
9. Smart plugs

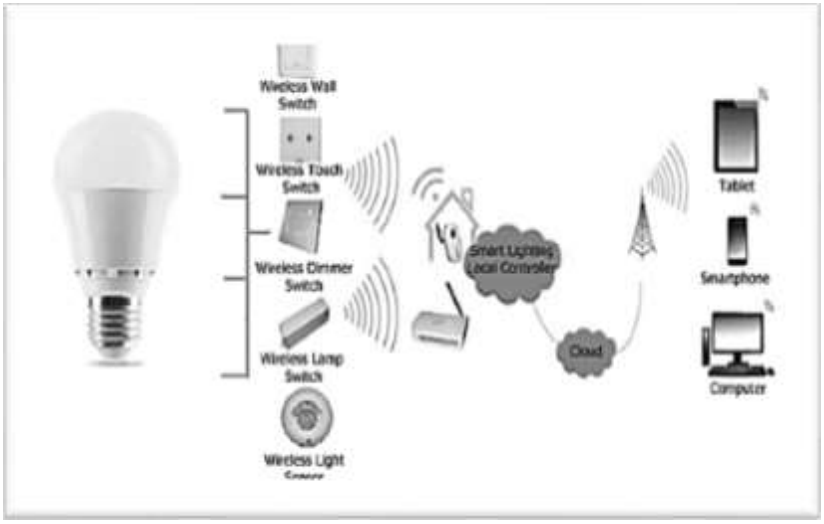


Fig 5.9:-Smart lighting for home and its control

5.2.6 Smart Metering

Introduction: A smart meter is an electronic device that records consumption of electric energy and communicates the information to the electricity supplier for monitoring and billing. Smart meters typically record energy hourly or more frequently, and report at least daily.

Smart meters as shown in Fig 5.9 enables two-way communication between the meter and the central system. Such an advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) in that it enables two-way communication between the meter and the supplier. Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC).

Wireless communication options in common use include cellular communications (which can be expensive), Wi-Fi (readily available), wireless ad hoc networks over Wi-Fi, wireless mesh networks, low power long range wireless (LoRA), ZigBee (low power, low data rate wireless), and Wi-SUN (Smart Utility Networks).

Smart metering offers potential benefits to householders. These include,

a) An end to estimated bills, which are a major source of complaints for many customers
b) A tool to help consumers better manage their energy purchases-stating that smart meters with a display outside their homes could provide up-to-date information on gas and electricity

consumption and in doing so help people to manage their energy use and reduce their energy bills.

An academic study based on existing trials showed that homeowners' electricity consumption on average is reduced by approximately 3-5%.

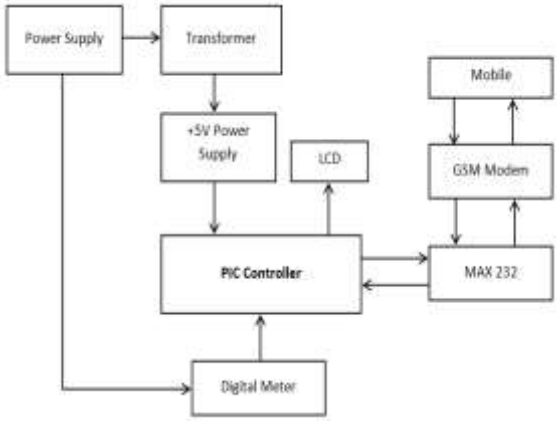


Fig 5.10:- Smart meter system

Advance metering system: -Advanced Metering Infrastructure (AMI) refers to systems that measure, collect, and analyze energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule. Typical advanced metering system is shown in Fig 5.11. These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, meter data management software, and supplier business systems.

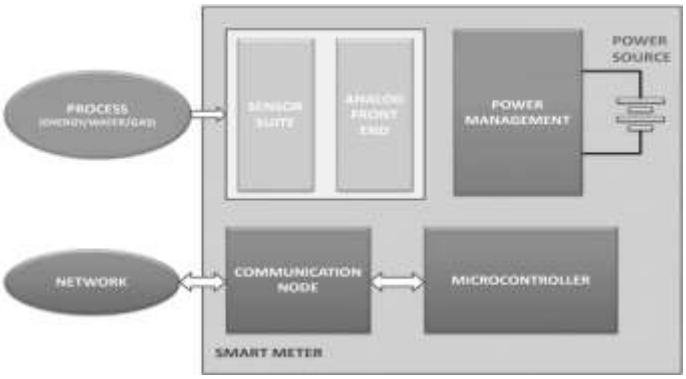


Fig 5.11:- Block diagram Smart Meter

The network between the measurement devices and business systems allows collection and distribution of information to customers, suppliers, utility companies, and service providers. This enables these businesses to participate in demand response services. Consumers can use information provided by the system to change their normal consumption patterns to take advantage of lower prices. Pricing can be used to curb growth of peak demand consumption. AMI differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. Systems only capable of meter readings do not qualify as AMI systems.

5.3 Smart City

5.3.1 Basic requirements for Smart City:

A Smart city is an urban area that uses different types of electronic Internet of things (IoT) sensors to collect data and then use these data to manage assets and resources efficiently. This includes

data collected from citizens, devices, and assets that is processed and analyzed to monitor and manage traffic and transportation systems, power plants, water supply networks, waste management, crime detection, information systems, schools, libraries, hospitals, and other community services.

Requirements:

As shown in Fig 5.12 the basic requirements that makes smart city are:

1. Health and education
2. Sustainable environment
3. Affordable housing, especially for the poor
4. Adequate water supply
5. Assured continuous Electric power supply and backup
6. Sanitation, solid waste management
7. Efficient urban mobility along with public transport and broad highways
8. E-governance and participation of citizens
9. Safety and security, especially senior citizens, women and children
10. Security for banks, ATMs
11. Complete digitization and online trading, IT Connectivity.

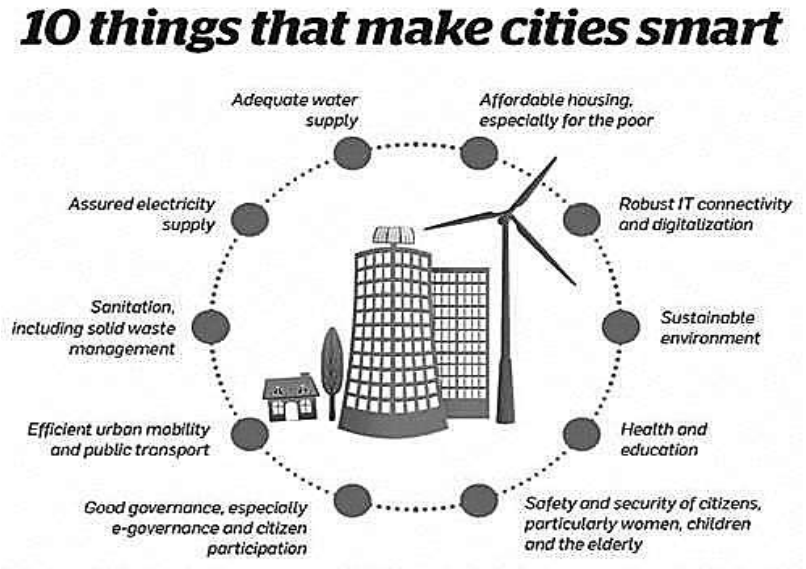


Fig 5.12:- Requirements of smart city

Concept of Smart City:

Development of a smart city can provide various features as shown in Fig 5.13.

New Internet technologies is platform for promoting cloud-based services, the Internet of Things (IoT) real-world user interfaces, use of smart phones and smart meters, networks of sensors and RFIDs, and more accurate communication based on the semantic web, open new ways to collective action and collaborative problem solving.

Online collaborative sensor data management platforms are on-line database services that allow sensor owners to register and connect their devices to feed data into an on-line database for storage and allow developers to connect to the database and build their own applications based on that data.

Large IT, telecommunication and energy management companies launched the Global Intelligent Urbanization initiative to help cities using the network as the fourth utility for integrated city management, better quality of life for citizens, and economic development. *Smarter Cities*

stimulates economic growth and quality of life in cities and metropolitan areas with the activation of new approaches of thinking and acting in the urban ecosystem. Sensor developers and startup companies are continually developing new Smart city applications.

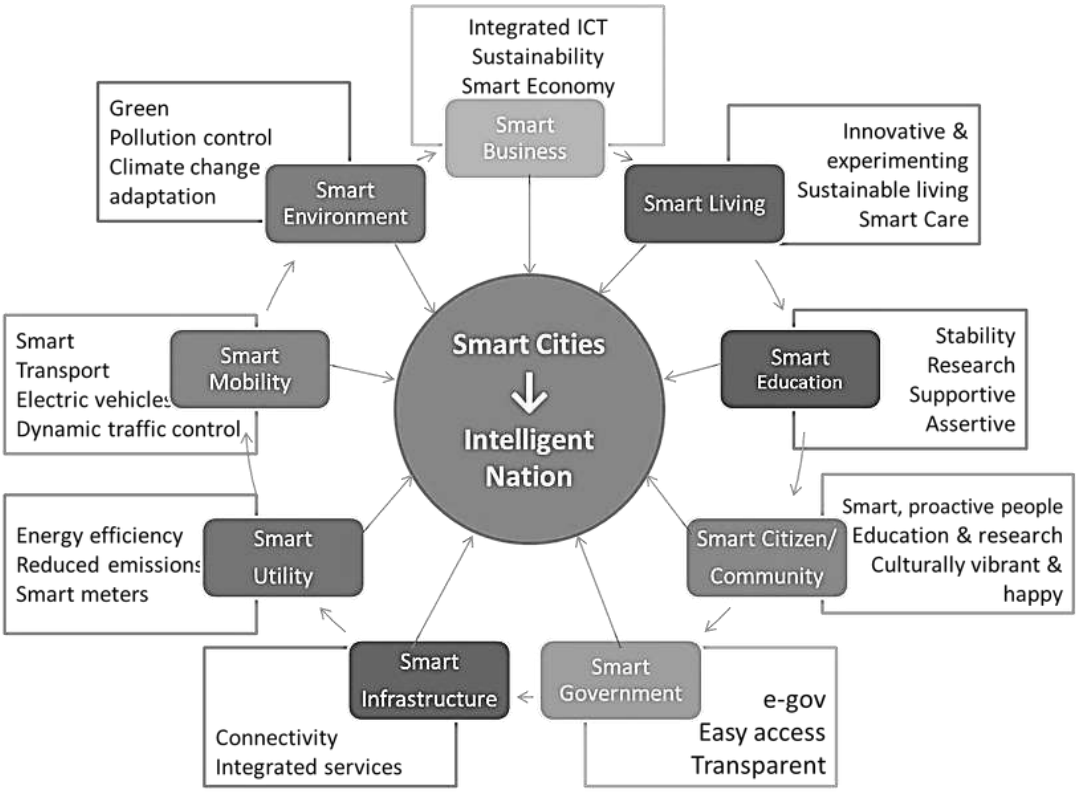


Fig 5.13 : -Features of smart city

Smart city model:

Smart city, also called as community, business cluster, urban agglomeration or region, uses information technologies to:

1. Make more efficient use of physical infrastructure (roads, built environment and other physical assets) through artificial intelligence and data analytics to support a strong and healthy economic, social, cultural development.
2. Engage effectively with local people in local governance and decision by use of open innovation processes and e-participation, improving the collective intelligence of the cities institutions through e-governance, with emphasis placed on citizen participation and co-design.
3. Learn, adapt and innovate and thereby respond more effectively and promptly to changing circumstances by improving the intelligence of the city.

Typical Smart City Model is depicted in Fig 5.14.

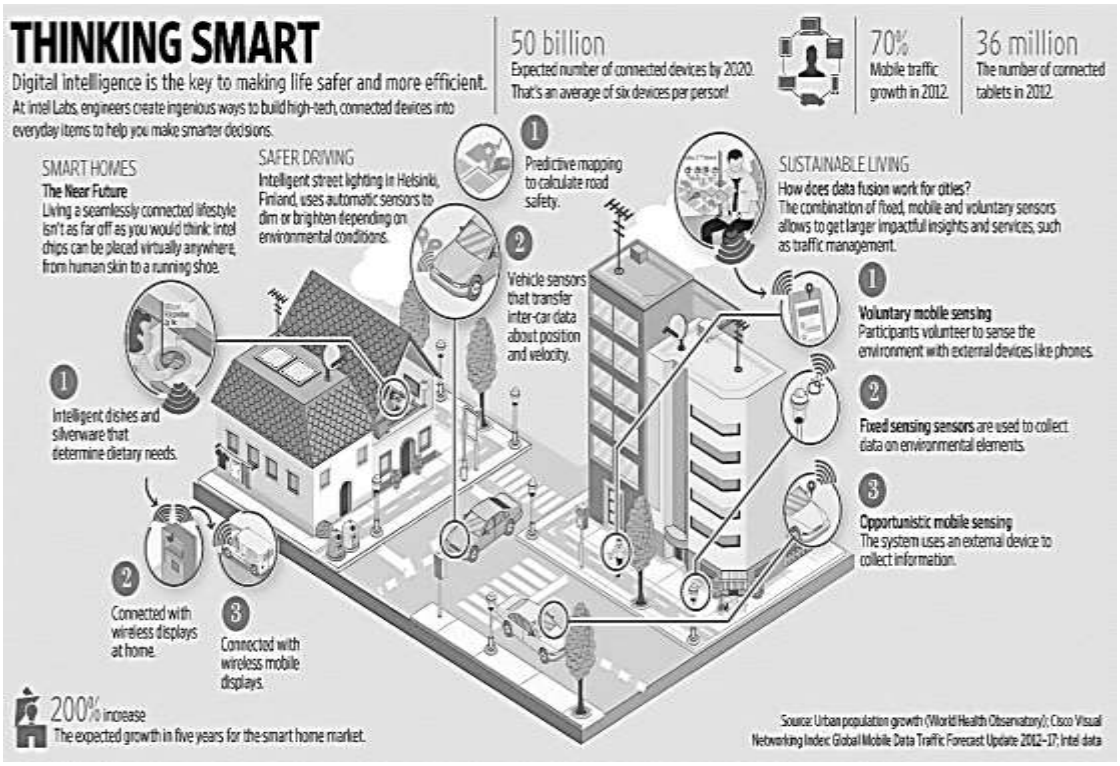


Fig 5.14:- Smart city model

Government of India (GoI) planning and budget for upcoming Smart Cities:

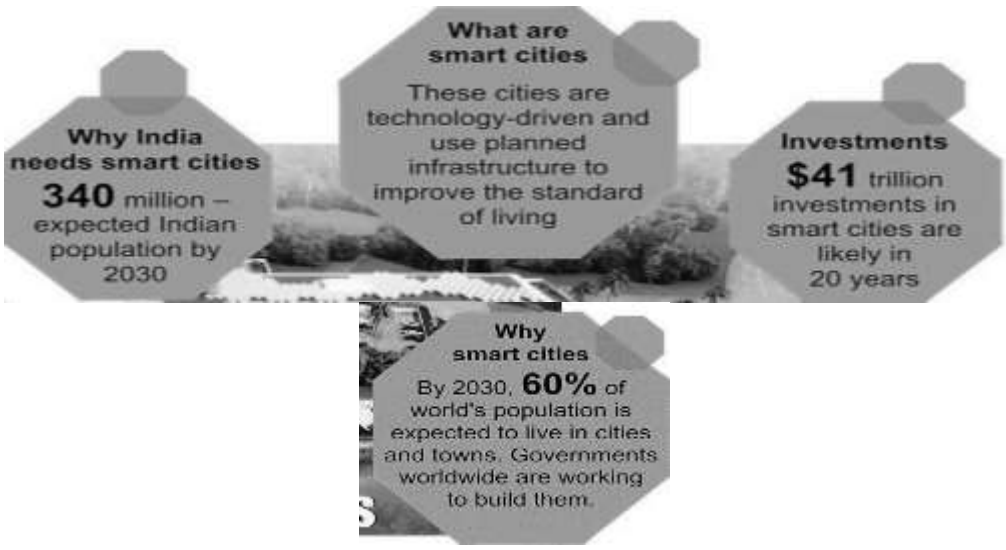


Fig 5.15:- Smart city plan and budget for the future

Current Indian working projects/cities towards smart cities:

Fig 5.16:- Cities under smart city development

5.3.2 Smart Transportation

In 1950, thirty percent of the world's population was urban, expected to grow to 66 percent by 2050. Cities across the world are expanding, so pressures on cities to augment their infrastructure and facilities to accommodate all existing/potential residents and enable them to lead a good quality of life. Smart cities use technology to augment their urban services-transportation, utilities and energy-to improve efficiency, reduce wastage and operate more sustainably. The government of India, too, launched the Smart Cities Mission to develop 100 Indian cities to be sustainable and citizen-friendly. Typical smart city model is depicted in Fig 5.17.

Delivering seamless mobility- Smart transportation is developed on the base of smart infrastructure that includes not only multi-modal connected conveyance but also automated traffic signals, tolls and fare collection. Data integration drives the system, incorporating weather and traffic data, linking emergency services data as well as information from government agencies. Smart services offer different benefits, from smart parking and vehicle locating systems, to route diversion alerts. A central command center can tie together the smart transportation ecosystem, with real-time and updated data, handling passenger information, Optimized on-demand services can ensure that citizens can use all modes of transport according to their needs. Shared mobility solutions can help provide first and last mile connectivity in conjunction with public transportation, they can act as feeder services and improve access to metro/rail or bus services. If public transportation is made robust and accessible through multi-modal shared mobility, citizens can choose it for all their commuting needs be it office travel, travel for daily needs or leisure travel. The number of private vehicles can be reduced, which can contribute to lowering congestion and pollution. Traffic signals, incident management and vehicle health monitoring.

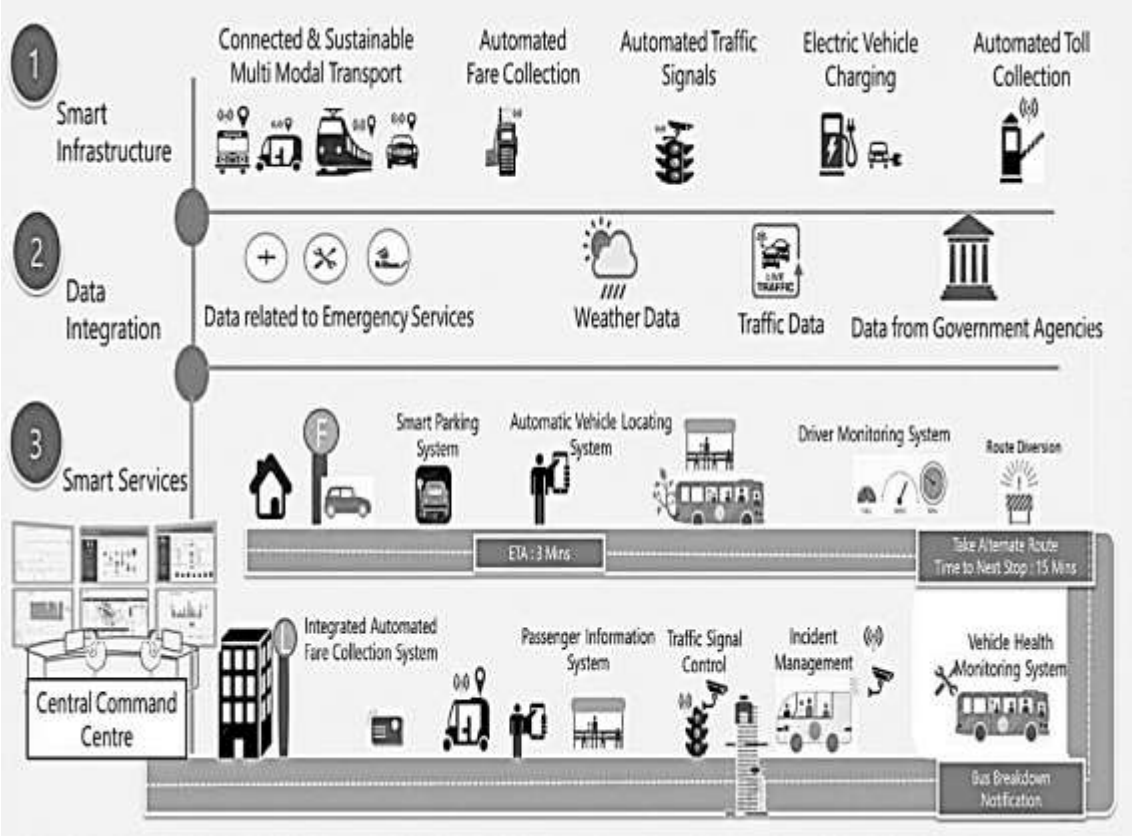


Fig 5.17:- Smart city model

Multi-modal mobility options-through Mobility-as-a-Service (MaaS*):-* MaaS aims to solve the problems associated with urban density and make mobility more efficient and convenient. It offers users access to different modes of transport via a single platform such as a mobile application

Intelligent traffic management-Traffic Demand Modeling: City planners can track data records and area-wise people movement and use this information to build models whereby public transportation gets deployed in areas of maximum people movement to ensure better connectivity. Implementing smart transportation would need the government, transport operators and service providers to collaborate in planning and execution, saving staff-hours through better traffic management, reducing polluting emissions, or increasing Gross Domestic Product (GDP) by reducing the consumption of vehicular fuel and oil imports, smart transportation is here to stay. State DOTs must closely collaborate with local jurisdictions to understand what the communities' critical needs are to help them achieve their goals to provide-

1. Connecting underserved communities to jobs
2. Moving goods in and out of the city
3. Integrating data collection throughout various systems
4. Establishing better parking systems
5. Controlling carbon emissions
6. Improving traffic flow

Example-Transportation in the Smartest City: Singapore plans to improve commuters' overall experience with a wait time for public transport shortened by three to seven minutes and a 92% reduction of overcrowded transportation. By leveraging real-time location intelligence. In their Open Data and Analytics for Urban Transportation project, Singapore's Land Transport Authority (LTA) plans to use data from sensors installed in over 5,000 vehicles to make sure arrival time and

bus availability are sufficient for commuter demand. LTA has also worked to provide travelers with access to real-time data such as bus arrival time, taxi availability, traffic conditions, and carpark availability so they can make informed decisions on how to navigate their surroundings.

5.3.3 Smart Healthcare

Among all the facilities to citizens in a smart city, smart healthcare counts as foremost important facility as a city which has healthy citizens is balanced in every sphere. Smart Health Technology' combines Smart Technology and latest mobile device with health, such as fitness tracker or fitness bands and even health assessment apps in smartphones have gained grand attention amongst fitness enthusiasts. They not only just monitor health but also provide solutions if needed at the right time. Smart Health technology interacts and engages with data produced by those devices which can be analyzed by doctors, researchers and health care professionals for better-personalized diagnosis and solutions. These digital records save cost and time of both patients and hospitals as they not only offer personalized treatments and medications but also give preventive measures through real-time data collection

Role of technologies in Smart Healthcare: Typical Smart Healthcare system is shown in Fig 5.18. Here IoT plays an important role, allows connecting data collected from smart devices and sensors to extract valuable insights, then convey that information to the doctors and staff in real-time, thus improving the effectiveness in the overall healthcare system. When the health data is collected it needs to be analyzed and managed for accurate treatment and here Artificial intelligence and automation are applied.

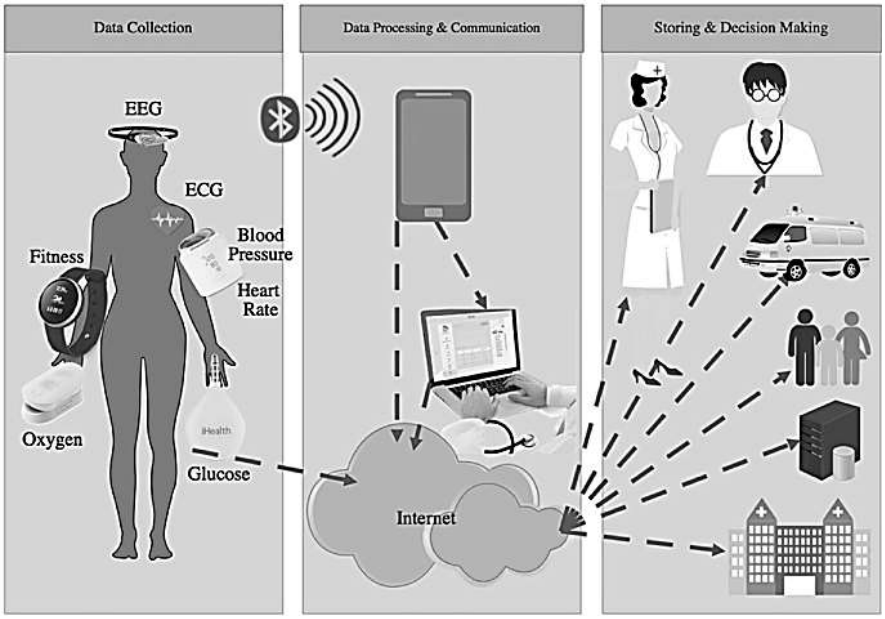


Fig 5.18:- Smart healthcare

E-health delivers health information and services to enable data transmission, storage and retrieval for clinical, educational and administrative purposes. Mobile health (or m-health) is the practice of medicine and public health supported by mobile devices. Speech and hearing systems for natural language processing, speech recognition techniques, and medical devices can aid in speech and hearing (e.g. cochlear implants). Tele-health, tele-medicine, tele-care, tele-coaching and tele-rehabilitation provide various forms of patient care remotely at a distance

Example- Smart Dust-Millimeter-scale self-contained micro-electromechanical devices that include sensors, computational ability, bi-directional wireless communications technology and a power supply. As tiny as dust particles, smart dust motes can be spread throughout buildings or

into the atmosphere to collect and monitor data. Smart dust devices have applications in everything from military to meteorological to medical fields.

5.3.4 Smart Waste

In the field of IoT, the objects communicate and exchange information to provide advanced intelligent services for users, the technology is used to solve the problem of Waste management in smart cities, where the garbage collection system is not optimized.

Waste management is all the activities and actions required to manage waste from its inception to its final disposal. This includes collection, transportation, treatment and disposal of waste together with monitoring and regulation. Domestic waste collection services are often provided by local government authorities such as municipal corporations. The waste is collected at regular intervals by specialized trucks. Waste collected is then transported to an appropriate disposal area. Today cities with developing economies experience exhausted waste collection services, inadequately managed and uncontrolled dumpsites and the problems are worsening. Waste collection method in such countries is an on-going challenge and many struggle due to weak institutions and rapid urbanization.

Need: - Improvement and involvement of technology is required to manage the disposal of waste as:

1. By 2030, almost two-third of the world's population will be living in cities, demanding for development of sustainable solutions for urban life, managing waste is a key issue for the health.
2. Efficient and energy-saving waste management, reducing CO2,air pollution and vehicle exhaust emissions
3. Waste management may swallow up to 50% of a city's budget, but only serve a small part of the population. Sometimes, up to 60%of waste is not being collected, it is often simply burned by the roadside. It can pollute drinking water, it can spread disease to people living nearby.
4. Even with great route optimization, the worker must still physically go to the dustbin to check waste levels. Because of this, trucks often visit containers that do not need emptying, which wastes both time and fuel.
5. Waste management prevents harm to human health and the environment by reducing the volume and hazardous character of residential and industrial waste.
6. Improving proper waste management will reduce pollution, recycle useful materials and create more green energy.

Features

1. The smart, sensor based dustbin will judge the level of waste in it and send the message directly to the municipal corporation.
2. It can sense all the type of waste material either it is in the form of solid or liquid.
3. According to the filled level of the dustbin, the vehicles from the municipal corporation will choose the shortest path with the help of the "TRANSPORTATION SOFTWARE", which will save their time. ϖ It emphasizes on "DIGITAL INDIA".
4. The system is simple. If there is any problem with any equipment in the future, that part is easily replaceable with new one without any difficulty and delay.

Advantages:

1 Less time and fuel consumption as the trucks go only to the filled containers.
2 Decreased noise, traffic flow and air pollution as a result of less trucks on the roads.

3 Our smart operating system enable two way communication between the dust bin deployed in the city and service operator. Therefore the focus is only on collection of route based fill level of the containers.
4 The sensors installed in the containers provide real time information on the fill level. This information helps determine when and where to prioritize collection.
5 In this way both service providers and citizens benefit from an optimized system which results in major cost savings and less urban pollution.
6 Reduces the infrastructure (trucks, containers), operating (fuel) and maintenance costs of the service by up to 30%.
7 Applying this technology to the city optimizes management, resources and costs, and makes it a “SMART CITY”.
8 Historical information on collections helps adapt the deployment of containers to the actual needs of the city, therefore reducing the number of containers that clutter up the road and increasing public parking spaces.
9 It keeps the surroundings clean and green, free from bad odour of wastes, emphasizes on healthy environment and keep cities more beautiful.
10 Reducing manpower required to handle the garbage collection

Smart Waste Management System:
Main Equipment’s used in Smart Waste Management System are shown in Fig 5.19.

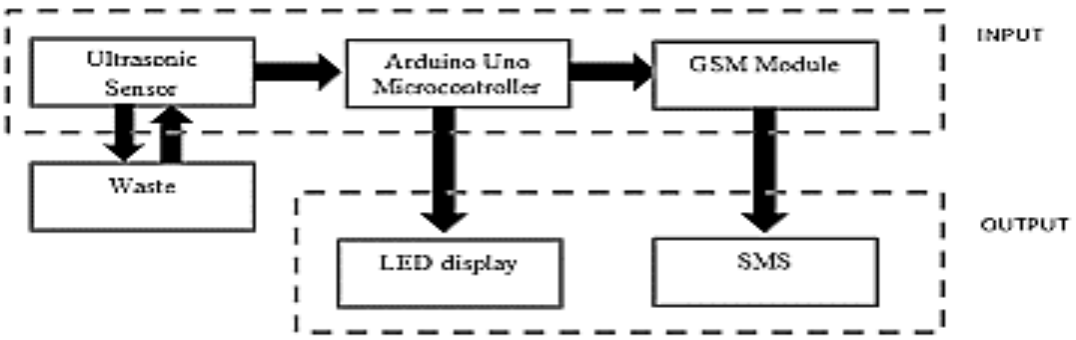


Fig 5.19: –Smart waste System

1. Garbage Container: A waste container as shown in Fig 5.20 is a container for temporarily storing waste, and is usually made out of metal or plastic. The curbside dustbins usually consist of three types: trash cans (receptacles made of metal or plastic), dumpsters (large receptacles similar to skips) and wheelie bins (light, usually plastic bins that are mobile). All of these are emptied by collectors, who will load the contents into a garbage truck and drive it to a landfill, consuming crush facility to be disposed of.

2. Ultrasonic Sensor- A special sonic transducer is used for the ultrasonic proximity sensors shown in Fig 5.21, allows for alternate transmission and reception of sound waves. The sonic waves emitted by the transducer are reflected by an object and received back in the transducer. After having emitted the sound waves, the ultrasonic sensor will switch to receive mode. The time elapsed between emitting and receiving is proportional to the distance of the object from the sensor.

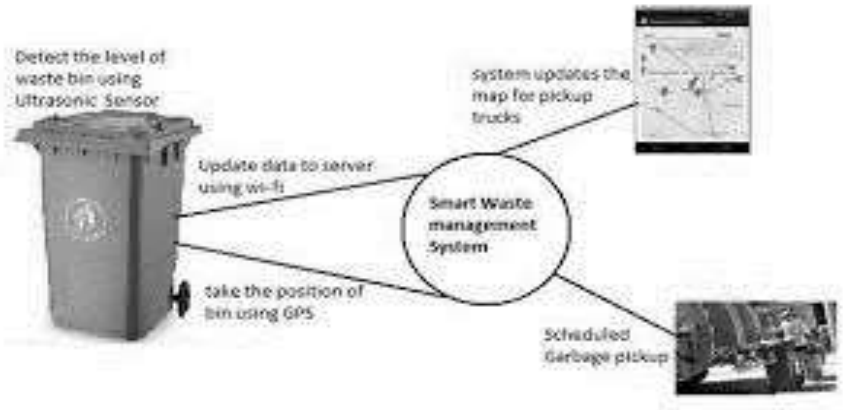


Fig 5.20:- Dustbin features

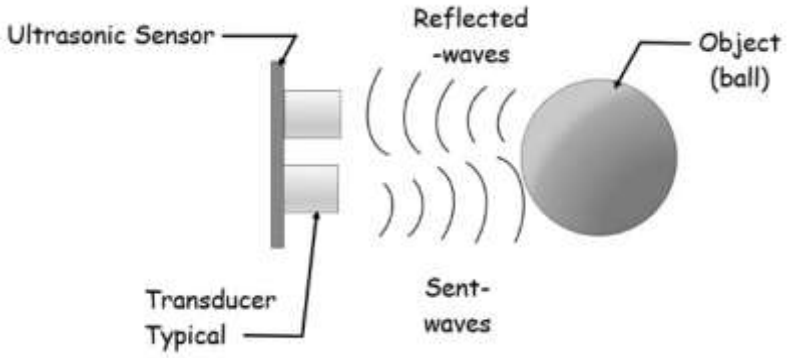


Fig 5.21:-Ultrasonic sensor

3. Arduino Board-: Arduino is a software company, project, and user community that designs and manufactures computer open-source hardware, open-source software, and microcontroller-based kits for building digital devices and interactive objects that can sense and control physical devices. Typical Arduino Board is shown in Fig 5.22.

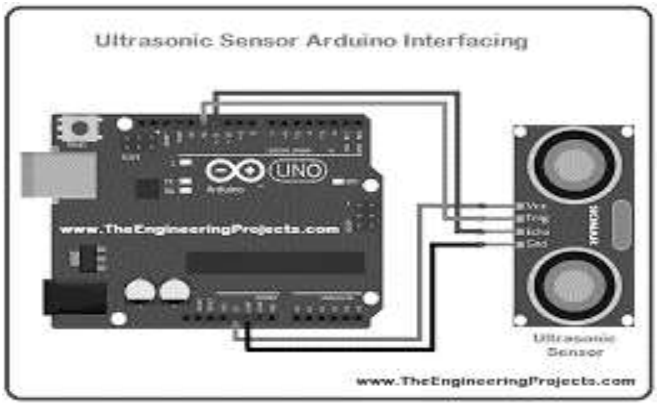


Fig 5.22:- Arduino Board

4. Software of Arduino: The Arduino project provides the Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language Java.

5. GSM Module: A GSM modem or GSM module as shown in Fig 5.23 is a device that uses GSM mobile telephone technology to provide a wireless data link to a network. GSM

modems are used in mobile telephones and other equipment that communicates with mobile telephone networks. They use SIMs to identify their device to the network.

Fig 5.23:- GSM Module

Principle of Sensor: - Ultrasonic sensors generate high-frequency sound waves and evaluate the echo which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object.

Waste Management Model: By using the advanced technologies a smart waste management model can be developed as shown in Fig 5.24.

Fig 5.24:- Waste management model

5.3.5 Smart Physical safety/security

Life safety products Monitoring typically includes

1 Monitored smoke detectors and heat detectors for fire monitoring
2 Carbon monoxide poisoning detectors
3 Flood sensors to detect unwanted water damage in areas like indoor laundry room and basements
4 Medical emergencies.
5 Every home should have at least one of monitored smoke detector which would be placed in the hallway next to the bedrooms. For a multiple story house, it should have at least one monitored smoke detector on each level. Heat detectors should be added to the kitchen, garage

and laundry room. Some homeowners would like to replace the smoke detectors in all bedrooms with a monitored photoelectric smoke and heat detector.

Benefits of fire monitoring:

1 ADT Central Station will call the fire department in the case of a fire emergency
2 Photoelectric smoke detectors detect smoldering smoke before a fire starts. Monitoring for carbon monoxide poisoning is also important as it will notify the ADT Central Station in case home is being filled with this poisonous gas. The monitoring center operator will call and notify the detected carbon monoxide poisoning and dispatch local fire department. This will ensure not to enter into home when it is not safe.
3 Flood sensors are designed to notify water in unwanted areas. Most often these are installed in the laundry room or in the basement that may have issues. This can protect from the massive damage water can cause.

5.3.6 Smart Education

For the past few years, the transformation has taken place in higher education system into smart-education and traditional universities into smart-universities, requirements of the smart-economy and smart-society with the aim of achieving quality training of specialists.

Smart Education as shown in Fig 5.25 provides the flexibility of learning in an interactive educational environment, free access to worldwide content, personalization and adaptation of learning are presented and analyzed. The education based on smart-technology helps to realize inner potential through matching the content of the study course with their own results, and building an individual learning program with an emphasis on their personal qualities of a student.

Fig 5.25:- Smart Education Interactive displays

The upcoming revolution in education system is replacing traditional classroom and learning methods. The implementation of information technology is driving the smart education and learning markets. Educational institutes are adopting advanced teaching methods and tool which includes white boards, projectors and smart notebooks. Implementation of such technology in classroom improves understanding of students and provides clear view about what to learn. Coordination between hardware provider, software innovator and education material provider is making learning easy for students.

The key driver of smart education and learning is the interactive displays hardware, active learning .Increase number of mobile learning applications and professional expertise with technology and towards digital learning are anticipated to drive the smart education and learning market.

E- Learning Features:

By using concept of Smart Education E-learning mechanism is developed providing various features as shown in Fig 5.26.

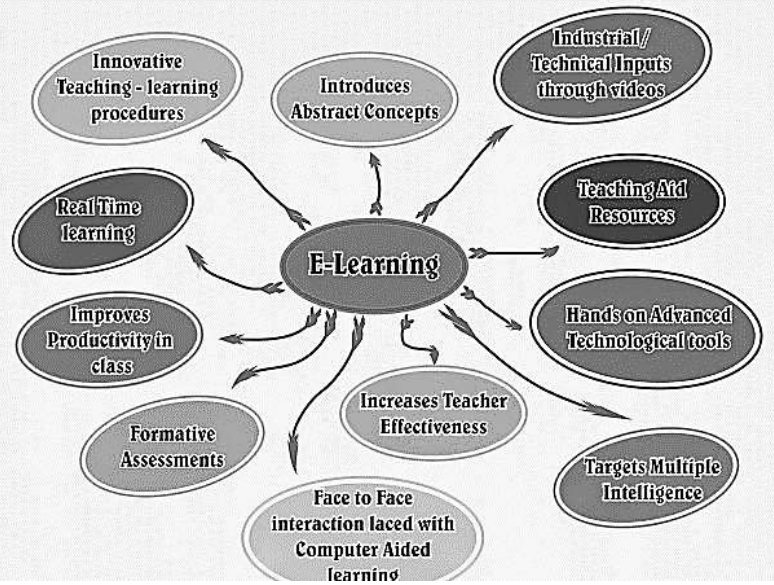


Fig 5.26:- E-learning Features

Smart Education Model is shown in Fig 5.27

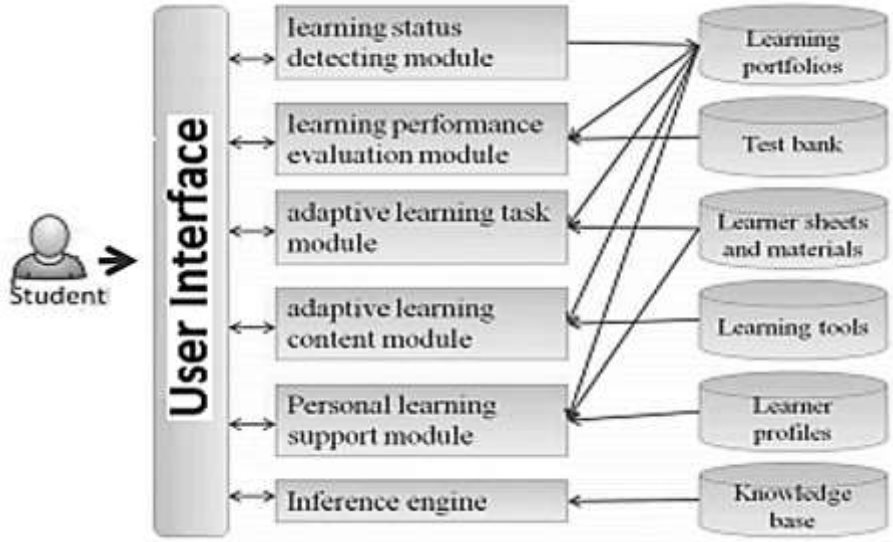


Fig 5.27:-Wireless communication network for smart education

Advantages:

1. Today AR/VR is adopted for more enhanced and detailed learning.
2. Smart classes use all interactive modules like videos and presentations and these visually attractive methods of teaching becomes appealing to students.
3. Smart classes are almost like watching movies as sometimes, animated visuals are used to teach a point
4. Visual is eye-catching and young students can easily relate with them because the audio-visual senses of students are targeted and it helps the students store the information fast and more effectively.
5. Enhanced and Interactive learning experience

6. Easy Access to Online Resources
7. Follows Go Green Concept
8. Time Saving Technology
9. Increased Productivity
10. Smart Boards are Fun.

5.4 IoT/M2M Network architecture:

5.4.1 M2M:

M2M or machine-to-machine is a direct communication between devices using wired or wireless communication channels. M2M refers to the interaction of two or more devices /machines that are connected to each other.

Features of M2M:

1. Low Mobility : M2M Devices move only within a certain region
2. Time Controlled : Send or receive data only at certain pre-defined periods
3. Time Tolerant : Data transfer can be delayed
4. Packet Switched : Network operator to provide packet switched service with or without an MSISDN
5. Online small Data Transmissions: MTC Devices frequently send or receive small amounts of data.
6. Monitoring: Not intend to prevent theft or vandalism but provide functionality to detect the events
7. Low Power Consumption : To improve the ability of the system to efficiently service M2M applications
8. Location Specific Trigger: Intending to trigger M2M device in a particular area.

5.4.2 Conceptual Diagram:

M2M technologies allow wired / wireless system to communicate with devices of same ability. The M2M conceptual diagram is shown in Fig 5.28. M2M uses a device (sensor, meter etc.) to capture an 'event' (motion, meter reading, temperature etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program), that translates the captured event into meaningful information

Controlling electrical appliances like bulbs and fans using RF or Bluetooth from smartphone is simple example of M2M applications.

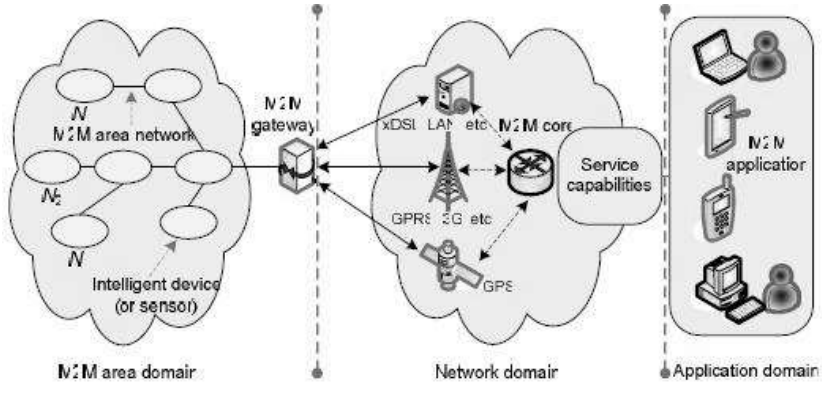


Fig 5.28: M2M conceptual diagram.

5.5: Domains for Operation:

Application domain: The M2M application domain consists of a middleware layer where the collected packets pass through several application services and then are used by the related agencies.

M2M device domain: The M2M devices are responsible for the collection and autonomous transmission of sensor data such as the internal temperature and humidity. The M2M devices are usually connected to small local networks called subnets for the transmission or reception of data to or from the M2M application domains (server domain).

M2M area network domain: The M2M area networks are responsible for establishing the communication path between the M2M devices and the M2M gateways. These networks are usually called subnets which collect and route information from the M2M devices to the M2M gateways. There are several subnets which are used for generating the communication link between the M2M devices and the M2M gateways. Generally, the use of subnets is dependent on the network technology. In fully distributed networks, all M2M devices are connected as peers to the network. One of the nodes which is connected to the network, e.g., via wired or wireless connectivity, acts as a router. *In* client-server networks, all nodes or devices communicate directly with the server. Where as in cooperative networks, all nodes communicate with each other using some intermediate gateways.

Suggested Resources:

Sr No	Keyword	QR Code	Weblink
1	Home Automation		https://en.m.wikipedia.org/wiki/Home_automation
2	Automatic Door Locking System		https://www.ijedr.org/papers/IJEDR1601082.pdf
3	Smart City: Concept and Mission		https://www.youtube.com/watch?v=tKJZxsEeVzk
4	Smart City		https://en.wikipedia.org/wiki/Smart_city
5	Intelligent transportation system		https://en.wikipedia.org/wiki/Intelligent_transportation_system

Sr No	Keyword	QR Code	Weblink
6	M2M Technical reports		https://tec.gov.in/M2M-IoT-technical-reports

Sample Question:

Sr. No.	Question
1.	The oldest and best-known smart home automation system is_____ A. A-10 B. X-10 C. B-10 D. C-10
2.	A smart city is A. A city with all facilities. B. A city run by accountants C. That makes smart use of new technology D. There is no agreed definition for a smart city
3.	The vital component around smart cities is A. The role of the accountant B. The role of central government C. The role of local government D. The role of technology
4.	Smart metering causes A. Increase in precision of billing B. Decrease in precision of billing C. Increase in approximation of billing D. Increase in random estimation of billing
5.	Smart waste deals with _____ A .Garbage collection and disposal B. Reusing and reducing garbage C. Recycling waste D. Dumping trash in landfills.
6.	Smart bins indicate status of bin using _____ A. Garbage Sensors B. Temperature sensors C. Pressure sensors D. Gas sensors
7.	M2M Communication is a communication between A. Machine to Machine B. Motor to Machine C. machine to motor D. motor to moto
8.	Function of device domain in M2M network A. Collection and transmission of sensor data. B .Interpretation of sensor data

Sr. No.	Question
	C. Processing of sensor data. D. Analysis of sensor data
9.	Subnet used for generating the communication link between the M2M devices. A. Devices. B. Gateways. C. Server. D. Router
10.	The component used to capture data from device and relayed to the network____ A. Sensors B. RFID tag C. Actuator. D. Gateway.
11.	In home security system entry of person can be restricted using_____ A. Smart TV B. Smart Door C. Smart Meter D. Smart Lighting System
12.	Identify device used inside home for wireless connection A. Optical Switch B. Wireless Router C. Electrical Switch D. Transformer
13.	Identify system used in smart home from given image. A. Smart lighting and its control B. Smart street and traffic control C. smart dustbin and waste management D. Smart meter and temperature control
14.	M2M technologies allow wired or wireless system to communicate with devices of ability. A. Same B. Completely Different C. Partially different D. Exactly Opposite
15.	Identify the module shown in following figure:  A. ASM Module B. LAN Module C. GSM module D. FSM Module
16.	In a _____networks, all nodes communicate with each other using some intermediate gateways

Sr. No.	Question
	A. Fully distributed B. Client- server C. Cooperative D. Point to point network
17.	In a _____ network all devices are connected as peers in the network. A. Fully distributed B. Client- server C. Cooperative D. Point to point network
18.	Pollution reduction, disposal of unused & recycling of useful materials & creation of green energy is done by_____ A. HVAC management B. Smart healthcare C. Smart Home D. Smart waste management
19.	____ wireless protocol is used for low power and Low data rate applications. A. LoRa B. Wi-SUN C. ZigBee D. W-Fi
20.	____ wireless protocol is used for low power and long range applications. A. LoRa B. Wi-SUN C. ZigBee D. W-Fi

APPENDIX A

Abbreviations and acronyms

AAMS	Authorized Account Messaging Service
ADC	Analog to Digital Converter.
AF	Adaption Function
AG	Access Gateway
AI	Artificial Intelligence.
AMQP	Advanced Message Queuing Protocol.
AMR	Automatic Meter Reading
AMS	Automatic Metering System
AN	Access Network
ANI	Application Network Interface
AOI	Automatic Optic Inspection
API	Application Programming Interface
AR	Augmented Reality
ARM	Advanced RISC Machine
AS	Application Server
ASF	Application Support Function
ASIP	Application Specific Instruction Processor
ASSP	Application Specific System Processor
ATM	Asynchronous transfer mode
AU	Administrative Unit
AVR	Advanced Virtual RISC
BGW	Border Gateway
BOS	Bottom of Stack
BPON	Broadband Passive Optical Network
BSS.	Business Support System
CAPEX	Capital Expenditure
CCTV	Closed Circuit Television
CDF	Content Delivery Function
CDMA	Code-Division Multiple Access
CISC	Complex Instruction Set Computer
CNC.	Computerized Numerical Control.
CoAP:	Constrained Application Protocol.
CPS	Cyber Physical System.
CSP	Chip-Scale Package
DMA	Direct Memory Access
DSL	Digital Subscriber Line
DSP	Digital Signal Processor
DVB	Digital Video Broadcasting
DWDM	Dense Wavelength Division Multiplexing
E2E	End to End

ED	Electro Deposited
EDR	Event Data Recorder
EPON	Ethernet Passive Optical Network
FDMA	Frequency Division Multiplexing
FEC	Forwarding Equivalence Class
FPC	Flexible Printed Circuits
FPC	Flexible Printed Circuits
FPGA	Field Programmable Gate Array
FPSLIC	Field Programmable System Level Integration Circuit
FTTB/C	Fiber to take building /curb
FTTcab	Fiber to take cabinet
FTTcell	Fiber to take cell
FTTH	Fiber to take Home
Gbps	Giga bits per second
GPON	Gigabit Passive Optical Network
GPRS	General Packet Radio Services
GPS.	Global Positioning System
GPU	Graphic Processing Unit
GSM	Global System for Mobile (communications)
HMI.	Human Machine Interface.
HP	Hewlett Packard
HVAC	Heating, ventilation and air conditioning
ICR	Intelligent Call Routing
IEEE	Institution of Electrical and Electronics Engineer
IFPON	Interface over Passive Optical Network
IFTTT	If This Then That
IIoT:	Industrial Internetof Things.
IMS	IP Multimedia Subsystem
IoE:	Internet of Everything.
IoT	Internet of things
IP	Internet Protocol
ISDN	Integrated Service Data Netwok
ISDN-BRI	Integrated Services Digital Network- Basic Rate Interface
ISDN-PRI	Integrated Services Digital Network- Primary Rate Interface
ISP	In System Programming
ITU T	International telecommunication union
JTAG	Joint Test Action Group
LAN	Local area network
LiCoO2	lithium cobalt oxide
Li-ion/ LIB	Lithium-ion
LiMn2O4	lithium manganese oxide
LiNiO2	lithium nickel oxide
LMV	Light Motor Vehicle.

LoRa	Long Range Wide Area Network
LPWAN	Low Power Wide Area Network
LSP	Label Switch Path
LSR	Label switch router
LSW	Label Switch Path
LTE	Long Term Evolution
M2M	Machine To Machine.
MCU	Microcontroller Unit
MGC	Media Gateway Controller
MIPS	Million Instructions Per Seconds
MMCF	Mobility Management and Control Function
MMS	Multimedia Messaging Service
MPLS	Multi Protocol Label Switching
MQTT	Message Queuing Telemetry Transport.
MS	Media Server
MSISDN	Mobile Station International Subscriber Directory Number
MTS	Machine type communication
NACF	Network Attachment Control Function
NAN	Neighborhood Area Network
NAPT	Network Address Port Translation
NB-IoT	Narrow Band LTE for Internet of Things
NE	Network Equipment
NFC	Near Field communication
NFV	Network Function Virtualization
NGN	Next Generation Network
Ni-CD	Nickel-Cadmium
NiMH /Ni-MH	Nickel Metal Hydride
NNI	Network Network Interface
NVM	Non Volatile Memory
NVM	Non Volatile Memory
OBD	On Board Diagnostic.
OC	Optical Circuit
Och	Optical Channel
ODN	Optical Distribution Network
OEM	Original Equipment Manufacturer
OIT.	Operator Interface Terminal
OLED	Organic light-emitting diode
OLT	Optical Line Termination
OMS	Optical multiplex section
ONT	Optical Network Terminator
ONU	Optical Network unit
OPEX	Operational Expenditure
OSE	Open Service Environment

OSS.	Operation Support System
OTS	Optical transmission section
OTT.	Over the Top
OUT	Optical transport unit
PAEK	Poly Aryl Ether Ketone
PAN	Personal Area Network
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PDA	Personal Digital Assistant
PDH	Plesiochronous digital hierarchy
PEEK	Polyether ether ketone
PER	Provider Edge Router
PLC.	Programmable Logic Controller.
PON	Passive Optical Network
POT	Plain old telephone
PR	Provider Router
PSTN	Public Switch Telephone Network
PTF	Polymer Thick-Film
PTH	Plated Through Hole
QoS	Quality of Service
RA	Rolled-Annealed
RACF	Resource and Admission Control Function
RAMI	Reference Architecture Model of Industry
RAN	Radio Access Network
RAN	Radio Access Network
ReRAM	Resistor Switching Random Access Memory
ReRAM	Resistive switching Random Access Memory
RFID	Radio Frequency Identification
RISC	Reduced Instruction Set Computer
RTG	Radioisotope Thermoelectric Generator
RTOS	Real Time Operating System
RTOS	Real Time Operating System
SAN	Storage area network
SBC	Session Border Controller
SCADA	Supervisory Control and Data Acquisition System
SCF	Service control Function
SDH	Synchronous Digital Hierarchy
SDN	Software Defined Network.
SG	Signaling Gateway
SIMD	Single Input Multiple Data
SIP	Session Initiation Protocol
SIP	Session Initiation Protocol
SLA	Service Level Agreement

SLR	Single Lens Reflex
SMD	Surface-Mount Device
SMT	Surface-Mount Technology
SoC	System-On-Chip
SONET	Synchronous optical Network
SOS	Sensor observation Service
SPI	Serial Peripheral Interface.
SSF	Service Support Function
SSF	Service Support Function
SSL	Secure socket layer.
STD	Subscriber Trunk Dial
STM	Synchronous transfer module
SUP	Service User Profile
TAN	Touch Area Network
TCO	Total Cost of Ownership
TDM	Time Division Multiplexing
TDM	Time Division Multiplexing
TDMA	Time Division Multiplexing Access
TE	Terminal Equipment
THT	Through-Hole Technology
TMG	Trunk Media gateway
TOC	Tower operations Centre.
TTL	Time to Live
UE	User Equipment
UID	Unique Identifier.
UMTS	Universal Mobile Telecommunication System
UNI	User Network Interface
URL	Unified Resource Locator
UTF	Unicode Transformation Format
VCR	Video Cassette Recorder
VLSI	Very Large Scale Integration
VoIP	Voice on Internet Protocol
VPN	Virtual Private Network
VR.	Virtual Reality
VR/AR	Virtual Reality/Augmented Reality
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
WDM	Wavelength Division Multiplexing
Wi-Fi	Wireless Fidelity (IEEE 802.11x)
WLAN	Wireless Local Area Network
WMS .	Web Map Service.
WoF	Warrant of Fitness
WPC	Wireless Planning coordination

Appendix B
Answer key of Sample questions

Unit No	Question No	Answer key	Question No	Answer key
1	1	B	11	C
	2	B	12	C
	3	D	13	A
	4	B	14	A
	5	A	15	C
	6	A	16	B
	7	A	17	A
	8	D	18	C
	9	A	19	B
	10	A	20	C
2	1	A	11	A
	2	A	12	C
	3	C	13	D
	4	B	14	D
	5	B	15	A
	6	A	16	B
	7	B	17	D
	8	C	18	C
	9	A	19	A
	10	D	20	A
3	1	A	11	A
	2	B	12	D
	3	D	13	C
	4	A	14	D
	5	D	15	B
	6	D	16	B
	7	A	17	B
	8	B	18	A
	9	B	19	B
	10	B	20	A
4	1	B	11	A
	2	B	12	B
	3	C	13	B
	4	A	14	A
	5	C	15	B
	6	A	16	A
	7	C	17	A
	8	A	18	B
	9	A	19	B
	10	C	20	C

Unit No	Question No	Answer key	Question No	Answer key
5	1	B	11	B
	2	C	12	B
	3	D	13	A
	4	A	14	A
	5	A	15	C
	6	C	16	C
	7	A	17	A
	8	A	18	D
	9	B	19	C
	10	A	20	A

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