UNIT 6: Fundamentals of embedded system and its application in industrial processes

(Lecture 40 to 42)

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Outcome: Analyze the applications of IOT and embedded system in various fields

Fundamentals of embedded system and its application in industrial processes : comparison of microprocessor and micro-controller, types of processors : SOC, ASIC, DSP and FPGA, introduction to embedded system, examples of real-time applications of embedded system : GPOS and RTOS, cyber physical world, role of IOT and cloud computing in condition monitoring of plant processes, health care, agriculture, manufacturing, automobiles and smart grid

EMBEDDED SYSTEM BASICS AND APPLICATION

INTRODUCTION

What is a system?

A system is a way of working, organizing or doing one or many tasks according to a fixed plan, program or set of rules.

A system is also an arrangement in which all its units assemble and work together according to the plan or program.

SYSTEM EXAMPLES

WATCH

It is a time display SYSTEM

Parts: Hardware, Needles, Battery, Dial, Chassis and Strap

Rules

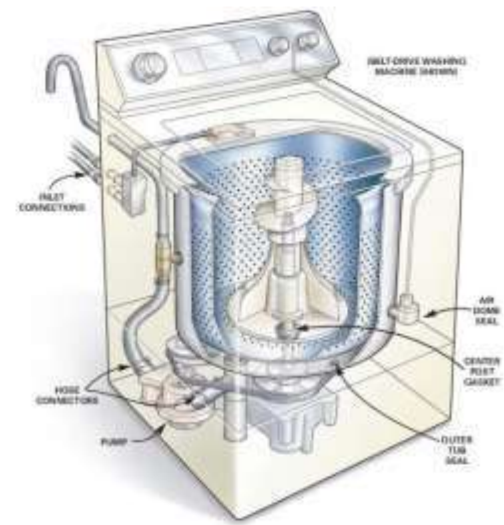
6. All needles move clockwise only
7. A thin needle rotates every second
8. A long needle rotates every minute
9. A short needle rotates every hour
10. All needles return to the original position after 12 hours

SYSTEM EXAMPLES

WASHING MACHINE

It is an automatic clothes washing SYSTEM

Parts: Status display panel, Switches & Dials, Motor, Power supply & control unit, Inner water level sensor and solenoid valve.



Rules

5.Wash by spinning

6.Rinse

7.Drying

8.Wash over by blinking

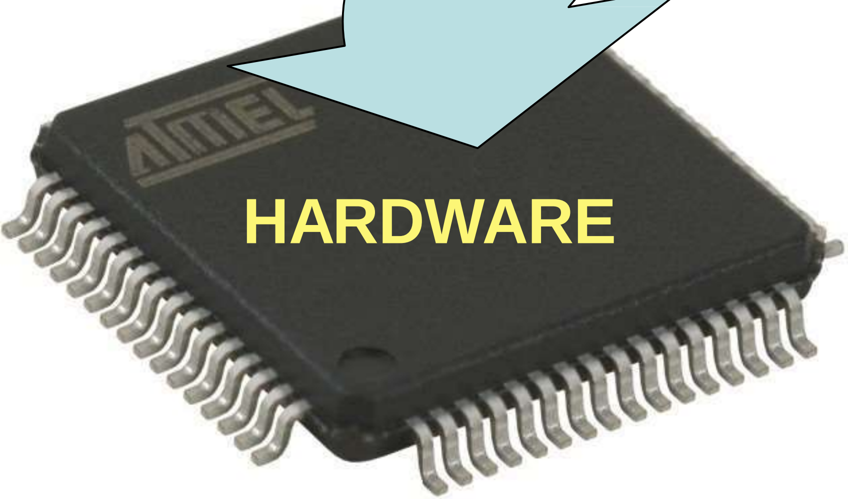
9.Each step display the process stage

10.In case interruption, execute only the remaining

EMBEDDED SYSTEM

Definition: An Embedded System is one that has computer hardware with software embedded in it as one of its important components.

Its software embeds in ROM (Read Only Memory). It does not need secondary memories as in a computer



SOFTWARE PROGRAM

```
#include <16f876a.h>
#use delay (clock=20000000)
#byte PORTB=6
main()
{
set_tris_b(0);
portb=255;        //decimal
delay_ms(1000);
portb=0x55;       //hexadecimal
delay_ms(1000);
portb=0b10101010; //binary
delay_ms(500);
}
```

COMPUTER HARDWARE

A Microprocessor

A Large Memory
(Primary and Secondary)
(RAM, ROM and caches)

Input Units
(Keyboard, Mouse, Scanner, etc.)

Output Units
(Monitor, printer, etc.)

Networking Units
(Ethernet Card, Drivers, etc.)

I/O Units
(Modem, Fax cum Modem, etc.)

COMPONENTS OF EMBEDDED SYSTEM

- **It has Hardware**

  Processor, Timers, Interrupt controller, I/O Devices, Memories, Ports, etc.

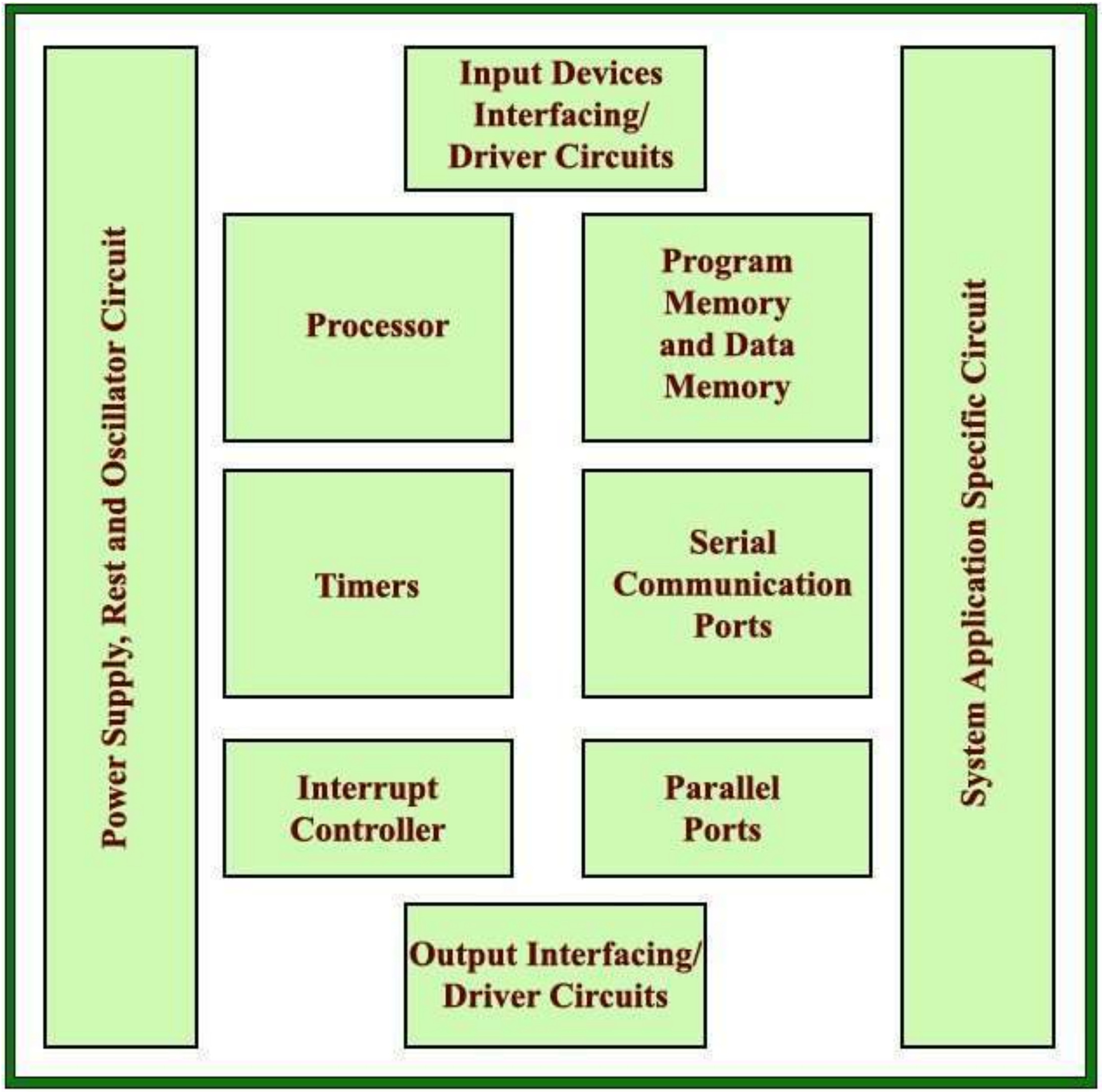
- **It has main Application Software**

  Which may perform concurrently the series of tasks or multiple tasks.

- **It has Real Time Operating System (RTOS)**

  RTOS defines the way the system work. Which supervise the application software. It sets the rules during the execution of the application program. A small scale embedded system may not need an RTOS.

EMBEDDED SYSTEM HARDWARE



EMBEDDED SYSTEM CONSTRAINTS

An embedded system is software designed to keep in view three constraints:

- **Available system memory**
- **Available processor speed**
- **The need to limit the power dissipation**

When running the system continuously in cycles of wait for events, run, stop and wakeup.

What makes embedded systems different?

- Real-time operation
- size
- cost
- time
- reliability
- safety
- energy
- security

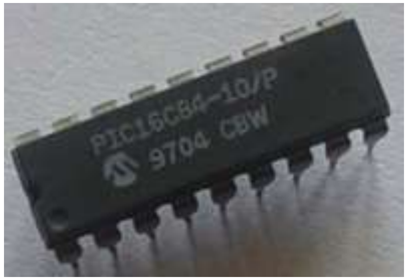
CLASSIFICATIONS OF EMBEDDED SYSTEM

- **Small Scale Embedded System**

- **Medium Scale Embedded System**

- **Sophisticated Embedded System**

SMALL SCALE EMBEDDED SYSTEM



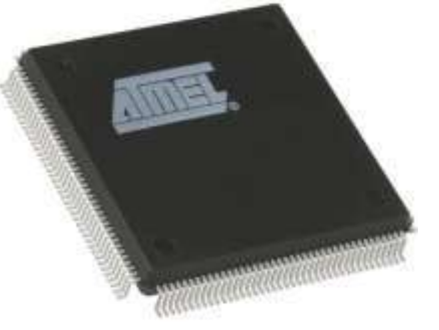
- **Single 8 bit or 16bit Microcontroller.**
- **Little hardware and software complexity.**
- **They May even be battery operated.**
- **Usually “C” is used for developing these system.**
- **The need to limit power dissipation when system is running continuously.**

Programming tools:

Editor, Assembler and Cross Assembler

MEDIUM SCALE EMBEDDED SYSTEM

- **Single or few 16 or 32 bit microcontrollers or Digital Signal Processors (DSP) or Reduced Instructions Set Computers (RISC).**



- **Both hardware and software complexity.**

Programming tools:

RTOS, Source code Engineering Tool, Simulator, Debugger and Integrated Development Environment (IDE).

SOPHISTICATED EMBEDDED SYSTEM

- **Enormous hardware and software complexity**
- **Which may need scalable processor or configurable processor and programming logic arrays.**
- **Constrained by the processing speed available in their hardware units.**

Programming Tools:

For these systems may not be readily available at a reasonable cost or may not be available at all. A compiler or retargetable compiler might have to br developed for this.

PROCESSOR

- A Processor is the heart of the Embedded System.

- For an embedded system designer knowledge of microprocessor and microcontroller is a must.

Two Essential Units:

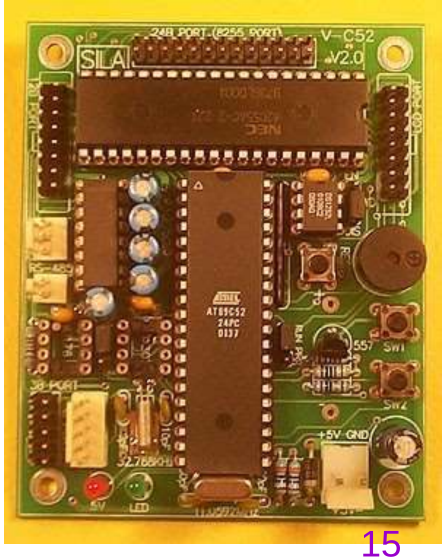
Control Unit (CU),

Execution Unit (EU)

<u>Operations</u>

Fetch

Execute



VARIOUS PROCESSOR

1. General Purpose processor (GPP)

Microprocessor

Microcontroller

Embedded Processor

Digital signal Processor

2. Application Specific System Processor (ASSP)

3. Multi Processor System using GPPs

MICROPROCESSOR

- **A microprocessor is a single chip semi conductor device also which is a computer on chip, but not a complete computer.**

- **Its CPU contains an ALU, a program counter, a stack pointer, some working register, a clock timing circuit and interrupt circuit on a single chip.**

- **To make complete micro computer, one must add memory usually ROM and RAM, memory decoder, an oscillator and a number of serial and parallel ports.**

HISTORY OF MICROPROCESSOR

1st Generation (4 bit processors)
4004 and 4040 4 bit in early 1970 by Intel (Integrated Electronics)

2nd Generation (8 bit processors)
8008 and 8080 8 bit in 1974 Intel with +5 V Input supply 8080 → 8085 8 bit

3rd Generation (16 bit processors)
8086 16 bit. Same as 8086, the 8088 introduced 8088 has only 8 bit data bus (This made it easier to interface to the common 8 bit peripheral devices available at the time)

Followed by:
The 80186 & 80286 (16 bit processor), the 80386 & 80486 (a 32 bit processor), leading to the Pentium range of microprocessors (64 bit processors) available today. The 80x86 and Pentium processors have all been designed for use in personal computer type applications and have large memory maps.

VARIOUS MICROPROCESSORS

Intel

- 4004, 4040
- 8080, 8085
- 8086, 8088,
- 80186, 80188
- 80286, 80386
- x86-64

Motorola

- 6800
- 6809
- 68000
- G3, G4, G5

Zilog

- Z80, Z180, eZ80
- Z8, eZ8

and others

Quick Quiz (Poll 1)

What is true about microprocessor?

A. Microprocessor is a controlling unit of a micro-computer
B. It is fabricated on a small chip capable of performing ALU (Arithmetic Logical Unit) operations
C. It also communicate with the other devices connected to it.
D. All of the above

Quick Quiz (Poll 2)

Which of the following is not a features of a Microprocessor?

A. Versatility
B. Reliability
C. Low Bandwidth
D. Low Power Consumption

Quick Quiz (Poll 3)

An 8-bit microprocessor can process ______ data at a time.

A. 4-bit
B. 8-bit
C. 16-bit
D. All of the above

EMBEDDED SYSTEM BASICS AND APPLICATION

MICROCONTROLLER

- A **microcontroller** is a functional computer system-on-a-chip. It contains a processor, memory, and programmable input/output peripherals.

- Microcontrollers include an integrated CPU, memory (a small amount of RAM, program memory, or both) and peripherals capable of input and output.

VARIOUS MICROCONTROLLERS

INTEL

8031,8032,8051,8052,8751,8752

PIC

8-bit PIC16, PIC18,

16-bit DSPIC33 / PIC24,

PIC16C7x

Motorola

MC68HC11

MICROPROCESSOR Vs MICROCONTROLLER

MICROPROCESSOR	MICROCONTROLLER
The functional blocks are ALU, registers, timing & control units	It includes functional blocks of microprocessors & in addition has timer, parallel i/o, RAM, EPROM, ADC & DAC
Bit handling instruction is less, One or two type only	Many type of bit handling instruction
Rapid movements of code and data between external memory & MP	Rapid movements of code and data within MC
It is used for designing general purpose digital computers system	They are used for designing application specific dedicated systems

EMBEDDED PROCESSOR

- **Special microprocessors & microcontrollers often called, Embedded processors.**

- **An embedded processor is used when fast processing fast context-switching & atomic ALU operations are needed.**

Examples : ARM 7, INTEL i960, AMD 29050.

DIGITAL SIGNAL PROCESSOR

- DSP as a GPP is a single chip VLSI unit.
- It includes the computational capabilities of microprocessor and multiply & accumulate units (MAC).
- DSP has large number of applications such as image processing, audio, video & telecommunication processing systems.
- It is used when signal processing functions are to be processed fast.

Examples : TMS320Cxx, SHARC, Motorola 5600xx

SoCs

A system on a chip is an integrated circuit that integrates all or most components of a computer or other electronic system. These components almost always include a central processing unit, memory, input/output ports and secondary storage – all on a single substrate or microchip, the size of a coin.

A System-on-Chip (SoC) is a silicon chip that contains one or more processor cores — microprocessors (MPUs) and/or microcontrollers (MCUs) and/or digital signal processors (DSPs) — along with on-chip memory, hardware accelerator functions, peripheral functions, and (potentially) all sorts of other "stuff." One way to look at this is that if an ASIC contains one or more processor cores then it's an SoC. Similarly, if an ASSP contains one or more processor cores then it's an SoC.

ASIC

- A microprocessor is intended as a general purpose, programmable device. Whereas an **ASIC** is an Application Specific Integrated Circuit. ... Sometimes, an **ASIC** might include a **processor** core. What is generally referred to as an **ASIC** would be custom made.

- ASIC full form is Application Specific Integrated Circuit. These circuits are application specific .i.e. tailored made ICs for a particular application. These are usually designed from root level based on the requirement of the particular application. Some of the basic application-specific integrated circuit examples are chips used in toys, the chip used for interfacing of memory and microprocessor etc…These chips can be used only for that one application for which these are designed. Presumably, these types of ICs are preferred only for those products which have a large production run. As ASICs are designed from the root level they have high cost and are recommended only for high volume productions.

- An ASIC (application-specific integrated circuit) is a microchip designed for a special application, such as a particular kind of transmission protocol or a hand-held computer. You might contrast it with general integrated circuits, such as the microprocessor and the random access memory chips in your PC.

ASIC

Let’s start with an application-specific integrated circuit (ASIC). As the name suggests, this is a device that is created with a specific purpose in mind. When most people hear the term ASIC, their “knee-jerk” reaction is to assume a digital device. In reality, any chip that is custom-made is an ASIC, irrespective of whether it is analog, digital, or a mix of both. For the purposes of these discussions, however, we shall assume a chip that is either wholly or predominantly digital in nature, with any analog and mixed-signal functions being along the lines of physical interfaces (PHYs) or phase-locked loops (PLLs).

ASICs are typically designed and used by a single company in a specific system. They are incredibly expensive, time-consuming, and resource-intensive to develop, but they do offer extremely high performance coupled with low power consumption.

FPGA

ASICs, ASSPs, and SoCs offer high-performance and low power consumption, but any algorithms they contain — apart from those that are executed in software on internal processor cores — are "frozen in silicon." And so we come to field-programmable gate arrays (FPGAs). The architecture of early FPGA devices was relatively simple — just an array of programmable blocks linked by programmable interconnect.

The great thing about an FPGA is that we can configure its programmable fabric to implement any combination of digital functions we desire. Also, we can implement algorithms in a massively parallel fashion, which means we can perform a humongous amount of data processing very quickly and efficiently.

SoC-classFPGAs

Over time, the capabilities (capacity and performance) of FPGAs increased dramatically. For example, a modern FPGA might contain thousands of adders, multipliers, and digital signal processing (DSP) functions; megabits of on-chip memory, large numbers of high-speed serial interconnect (SERDES) transceiver blocks, and a host of other functions.

OTHER HARDWARE

- **Power Source**
- **Clock Oscillator**
- **Real Time Clock (RTC)**
- **Reset Circuit, Power-up Reset and watchdog timer Reset**
- **Memory**
- **I/O Ports, I/O Buses**
- **Interrupt Handler**
- **DAC and ADC**
- **LCD and LED Display**
- **Keypad/Keyboard**

SOFTWARE

SOFTWARE

- C
- C++
- Dot Net

SIMULATOR

- Masm

COMPILER

- RIDE
- KEIL

APPLICATIONS

- Household appliances:
  - Microwave ovens, Television, DVD Players & Recorders
- Audio players
- Integrated systems in aircrafts and missiles
- Cellular telephones
- Electric and Electronic Motor controllers
- Engine controllers in automobiles
- Calculators
- Medical equipments
- Videogames
- Digital musical instruments, etc.

GPOS and RTOS

GPOS.

General-Purpose Operating System (computer operation)

A **GPOS** is made for high end, general purpose systems like a personal computer, a work station, a server system etc.

A General Purpose Operating **System** (**GPOS**) is an essential component of any mobile device, server, or computer **system**, and is responsible for running all the applications in an installation. Platforms like Linux, Windows, and Mac OS are **GPOS**.

GPOS is great for performing multiple tasks at the same time, but issues with latency and synchronization make them less than ideal for time-sensitive applications.

RTOS

Real Time Operating Systems (RTOS) are software platforms designed for use cases in which time is of the essence, for example, in connected cars. Processing time must be far shorter than in a GPOS, and the execution pattern for applications and processes needs to be predictable. Generally, RTOS runs on smaller, more lightweight hardware than GPOS, as larger hardware configurations tend to be less agile.

RTOS and GPOS

RTOS	GPOS
RTOS has unfair scheduling i.e scheduling is based on priority.	GPOS has fair scheduling i.e it can be adjusted dynamically for optimized throughput.
Kernel is pre-emptive either completely or up to maximum degree.	Kernel is non-preemptive or has long non-preemptive code sections.
Priority inversion is a major issue.	Priority inversion usually remains unnoticed.
It has a predictable behavior.	There is no predictability.
It works under worst case assumptions.	It optimizes for the average case.
It does not have a large memory.	It has a large memory.

Quick Quiz (Poll 1)

8051 microcontrollers are manufactured by which of the following companies?

a) Atmel
b) Philips
c) Intel
d) All of the mentioned

Quick Quiz (Poll 2)

What is true about microcontroller?

A. A microcontroller is a small and low-cost microcomputer
B. It is designed to perform the specific tasks of embedded systems
C. microcontroller consists of the processor, the memory, Serial ports, peripherals.
D. All of the above

Quick quiz (Poll 3)

Which is false about microcontroller?

A. Microcontrollers are used to execute a single task within an application.
B. It consists of CPU, RAM, ROM, I/O ports.
C. Its power consumption is high because it has to control the entire system.
D. It is built with CMOS technology

Quick quiz (Poll 4)

Which of the following is an example of Embedded memory microcontroller?

A. Intel 8031 microcontroller
B. Intel 8051 microcontroller.
C. Intel 8081 microcontroller.
D. Intel 8085 microcontroller.

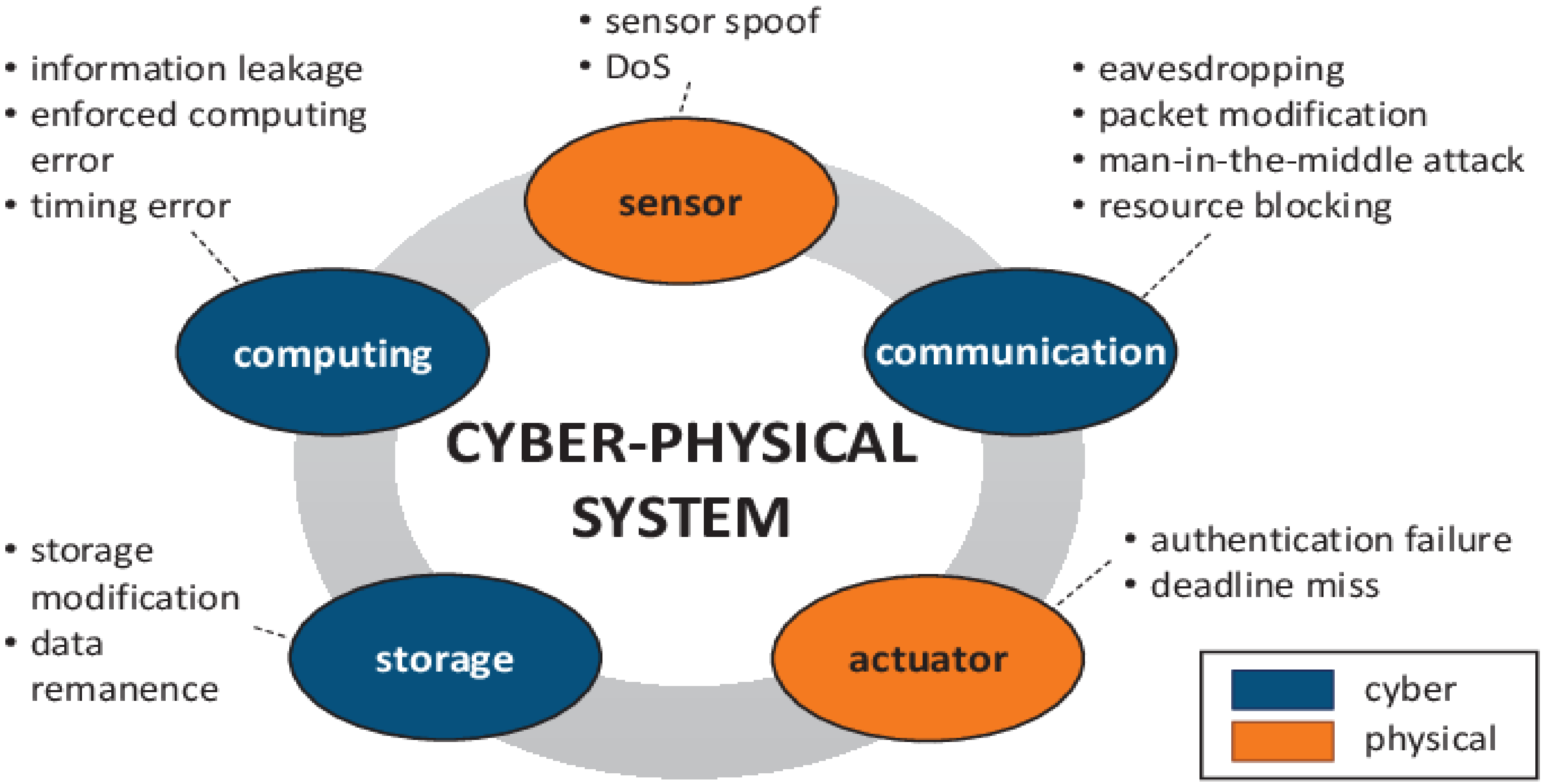
Cyber Physical Systems

UNIT 6

Cyber Physical Systems

- A cyberphysical system is a computer system in which a mechanism is controlled or monitored by computer-based algorithms
- **Cyber-Physical Systems** (CPS) are integrations of computation, networking, and **physical** processes. Embedded computers and networks monitor and control the **physical** processes, with feedback loops where **physical** processes affect computations and vice versa.
- **Cyber-Physical System** (CPS), a new generation of digital **system**, mainly focuses on complex interdependencies and integration between **cyberspace** and **physical** world. A CPS is composed of highly-integrated computation, communication, control, and **physical** elements.

Cyber Physical Systems



Internet of things

- The Internet of Things (**IoT**) refers to a system of interrelated, internet-connected objects that are able to collect and transfer data over a wireless network without human intervention. The personal or business possibilities are endless.
- In short, the Internet of Things refers to the rapidly growing network of connected objects that are able to collect and exchange data using embedded sensors. Thermostats, cars, lights, refrigerators, and more appliances can all be connected to the **IoT.**
- An **IoT** system consists of sensors/devices which “talk” to the cloud through some kind of connectivity. Once the data gets to the cloud, software processes it and then might decide to perform an action, such as sending an alert or automatically adjusting the sensors/devices without the need for the user.
- The **IoT** provides a platform that creates opportunities for people to connect these devices and control them with big data technology, which in return will promote efficiency in performance, economic benefits and minimize the need for human involvement. It's the most **important** development of the 21st century.

IOT

- The Internet of Things (IOT) is a worldwide network of intercommunicating devices. It integrates the ubiquitous communications, pervasive computing, and ambient intelligence. IOT is a vision where “things”, especially everyday objects, such as all home appliances, furniture, clothes, vehicles, roads and smart materials, etc. are readable, recognizable, locatable, addressable and/or controllable via the Internet.

History of IoT

The concept of the Internet of Things first became popular in 1999, through the Auto-ID Center at MIT and related market-analysis publications.

Radio-frequency identification (RFID) was seen as a prerequisite for the IoT at that point. If all objects and people in daily life were equipped with identifiers, computers could manage and inventory them. Besides using RFID, the tagging of things may be achieved through such technologies as near field communication, barcodes, QR codes, bluetooth, and digital watermarking.

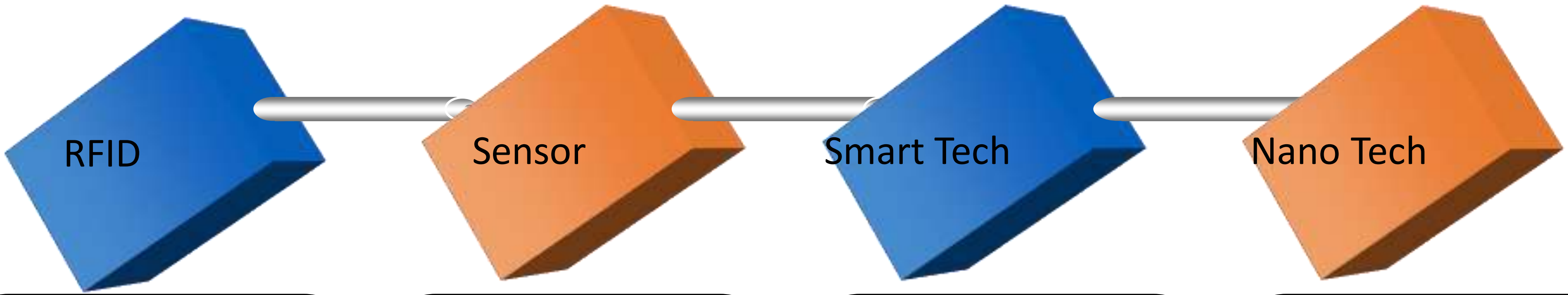
How IoT Works?

Internet of Things is not the result of a single novel technology; instead, several complementary technical developments provide capabilities that taken together help to bridge the gap between the virtual and physical world.

These capabilities include:

- ***Communication and cooperation***
- ***Addressability***
- ***Identification***
- ***Sensing***
- ***Actuation***
- ***Embedded information processing***
- ***Localization***
- ***User interfaces***

How IoT Works?



To identify and track the data of things

To collect and process the data to detect the changes in the physical status of things

To enhance the power of the network by devolving processing capabilities to different part of the network.

To make the smaller and smaller things have the ability to connect and interact.

Cloud Computing

- Simply put, **cloud computing** is the delivery of **computing** services—including servers, storage, databases, networking, software, analytics, and intelligence—over the Internet (“the **cloud**”) to offer faster innovation, flexible resources, and economies of scale.
- **Cloud computing** is the on-demand availability of **computer** system resources, especially data storage (**cloud** storage) and **computing** power, without direct active management by the user. The term is generally used to describe data centers available to many users over the Internet.
- A **simple** definition of **cloud computing** involves delivering different types of services over the Internet. ... You can access it from just about any computer that has internet access. For businesses, **cloud computing** means improved collaboration and productivity, as well as significant cost reductions.

Important applications of IOT

- **Wearables.**
- **Virtual glasses, fitness bands to monitor for example calorie expenditure and heart beats, or GPS tracking belts, are just some examples of wearable devices that we have been using for some time now**. Companies such as Google, Apple, Samsung and others have developed and introduced the Internet of Things and the application thereof into our daily lives.
- These are small and energy efficient devices, which are equipped with sensors, with the necessary hardware for measurements and readings, and with software to collect and organize data and information about users.

Health.

- The use of wearables or sensors connected to patients, allows doctors to monitor a patient's condition outside the hospital and in real-time. Through continuously monitoring certain metrics and automatic alerts on their vital signs, **the Internet of Things helps to improve the care for patients and the prevention of lethal events in high-risk patients.**
- Another use is the integration of IoT technology into hospital beds, giving way to smart beds, equipped with special sensors to observe vital signs, blood pressure, oximeter and body temperature, among others.


TELEHEALTH
SMART PILLS
IoT for Healthcare
INTERNET OF HEALTH THINGS
TRACKING HARDWARE PERFORMANCE
REAL TIME HEALTH SYSTEMS

Agriculture

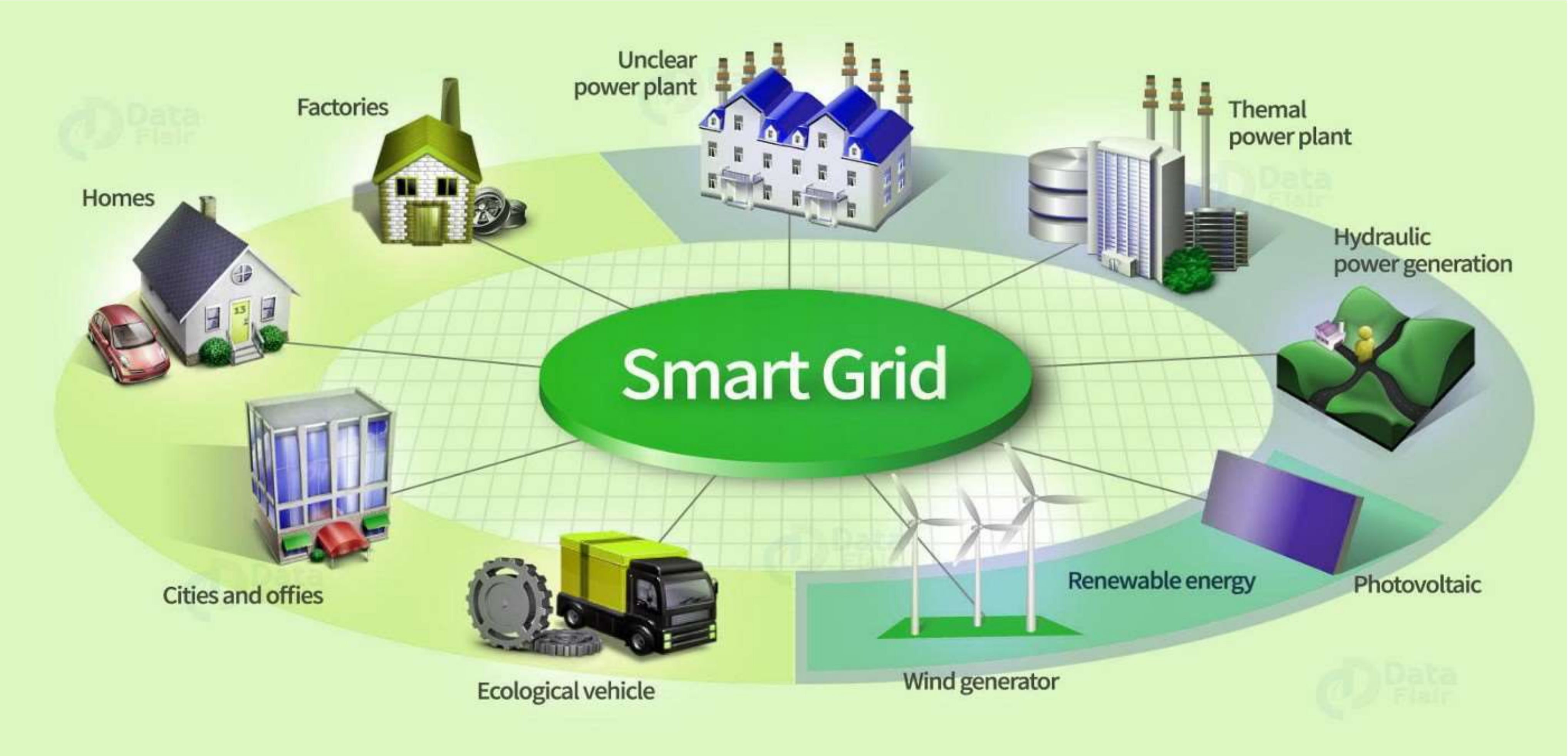
- Smart farms are a fact. The quality of soil is crucial to produce good crops, and the Internet of Things offers farmers the possibility to access detailed knowledge and valuable information of their soil condition.
- **Through the implementation of IoT sensors, a significant amount of data can be obtained on the state and stages of the soil.** Information such as soil moisture, level of acidity, the presence of certain nutrients, temperature and many other chemical characteristics, helps farmers control irrigation, make water use more efficient, specify the best times to start sowing, and even discover the presence of diseases in plants and soil.

IOT in
Agriculture
DreamzTech Solutions
Diagnosis of
Diseases
Variable rate
of Fertility
Auto
Spreading
Water
Stress
Crop yield
Analysis
Field
Monitoring
Soil
Erosion
Smart Data
Wednesday:
Hi: 90°F
Lo: 72°F
Thursday:
83°F
So far today:
Hi: 88°F Lo: 71°F
Rain: 0"
Gust: 6mph S
Heat Index: 89°F
Humidity: 72%
Dew Point: 73°F

Smart grid and energy saving

- The progressive use of intelligent energy meters, or meters equipped with sensors, and the installation of sensors in different strategic points that go from the production plants to the different distribution points, allows better monitoring and control of the electrical network.
- IoT can be used in customer side in smart meters to measure different types of parameters, intelligent power consumption, interoperability between different networks, charging and discharging of electric vehicles, manage energy efficiency and power demand.
- By establishing a bidirectional communication between the service provider company and the end user, information of enormous value can be obtained for the detection of faults, decision making and repair thereof.
- It also allows offering valuable information to the end user about their consumption patterns and about the best ways to reduce or adjust their energy expenditure.

Smart Grid

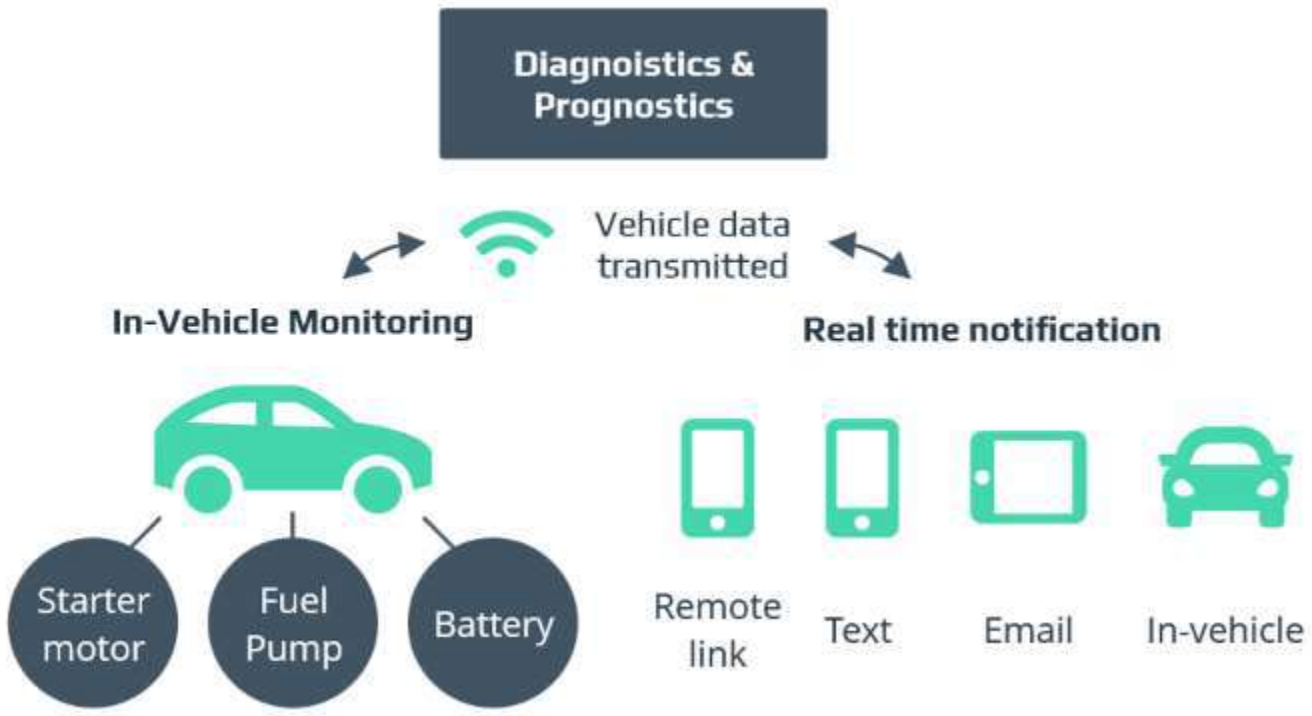


Unclear
power plant
Factories
Themal
power plant
Homes
Hydraulic
power generation
Smart Grid
Renewable energy
Photovoltaic
Cities and offies
Ecological vehicle
Wind generator

IOT in automobiles

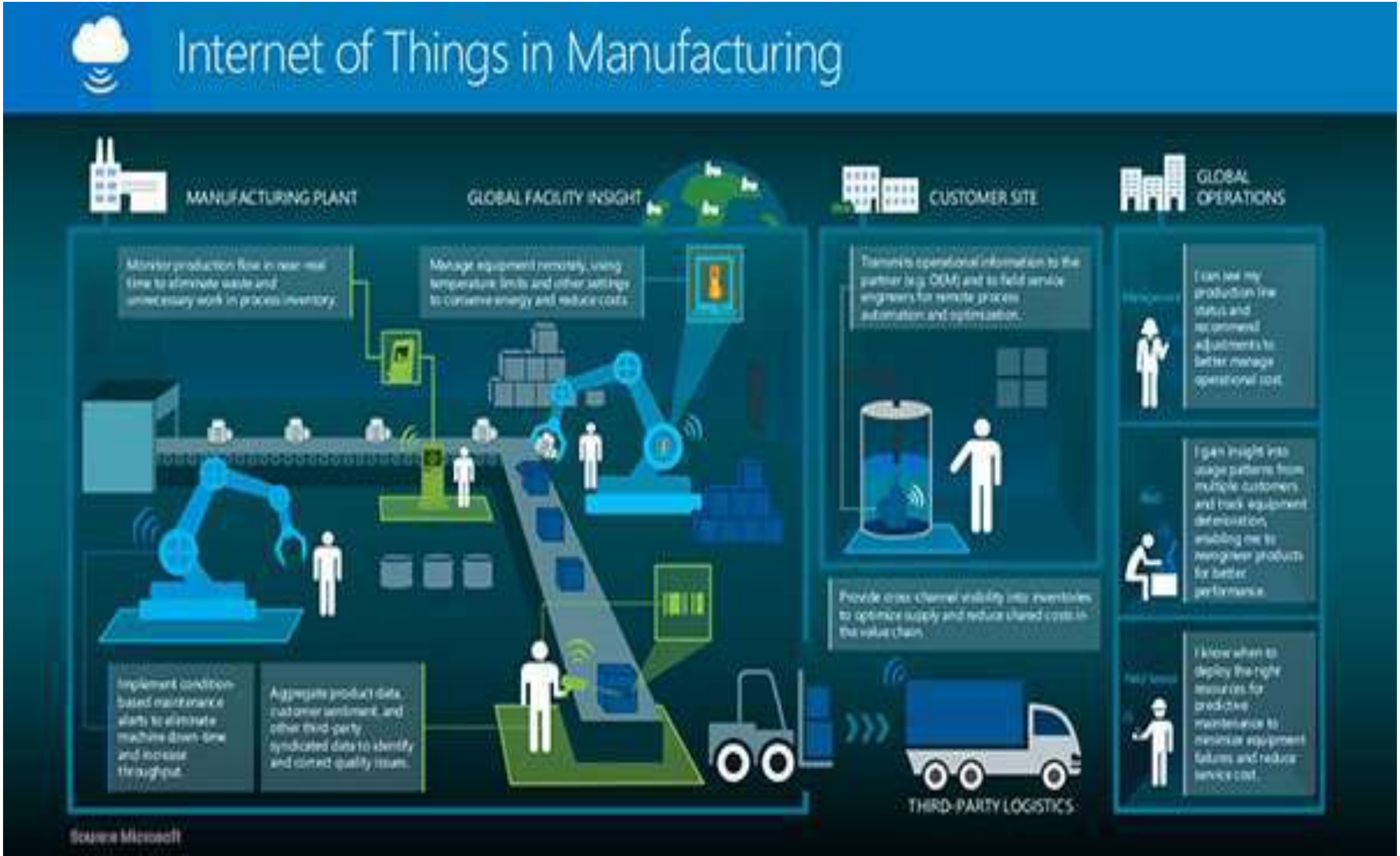
- **IoT** infused semi-autonomous cars take on-spot decisions while partly controlling the vehicle operations to avoid accidents and reduce the load from the driver. Along with different proximity sensors and cameras, cars are integrated with **IoT** systems to reduce human error and make driving more comfortable and safe.

IOT in automobiles



Manufacturing

- Industrial Internet of Things (IIoT) is a way to digital transformation in **manufacturing**. Industrial **IoT** employs a network of sensors to collect critical **production** data and uses cloud software to turn this data into valuable insights about the efficiency of the **manufacturing** operations.


Internet of Things in Manufacturing
MANUFACTURING PLANT
GLOBAL FACILITY INSIGHT
CUSTOMER SITE
GLOBAL OPERATIONS
Monitor production flow in near-real time to eliminate waste and unnecessary work in process inventory.
Manage equipment remotely, using temperature limits and other settings to conserve energy and reduce costs.
Transmits operational information to the partner (e.g. OEM) and to field service engineers for remote process automation and optimization.
I can see my production line status and recommend adjustments to better manage operational cost.
I gain insight into usage patterns from multiple customers and track equipment deterioration, enabling me to reengineer products for better performance.
Provide cross channel visibility into inventories to optimize supply and reduce shared costs in the value chain.
I know when to deploy the right resources for predictive maintenance to minimize equipment failures and reduce service cost.
Implement condition-based maintenance alerts to eliminate machine down time and increase throughput.
Aggregate product data, customer sentiment, and other third-party syndicated data to identify and correct quality issues.
THIRD-PARTY LOGISTICS
Source Microsoft

Quick Quiz (Poll 1)

- Point out the correct statement regarding Cloud computing:

a) A client can request access to a cloud service from any location
b) A cloud has multiple application instances and directs requests to an instance based on conditions
c) Computers can be partitioned into a set of virtual machines with each machine being assigned a workload
d) All of the mentioned

Quick Quiz (Poll 2)

- PWM stands for:

  a) None of the above
  b) Pulse Width Mode
  c) Pulse With Modulation
  d) Pulse Width Modulation