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APPLIED INTERNET OF THINGS ESSENTIALS (AIOTE)

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"The duty of helping one's self in the highest sense involves helping of one's neighbours"

– Samuel Smiles

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Thanks

MODULE 1 & 2

- **Background and Development**
- **Applications in Different Domains**
- **Internet of Things (IOT) Models, Prototyping, Architecture, and demonstration**
- **Hardware and Software Platforms**
- **Introduction to Industrial IOT (IIOT)**
- **Predictive Analytics**
- **Machine Learning**

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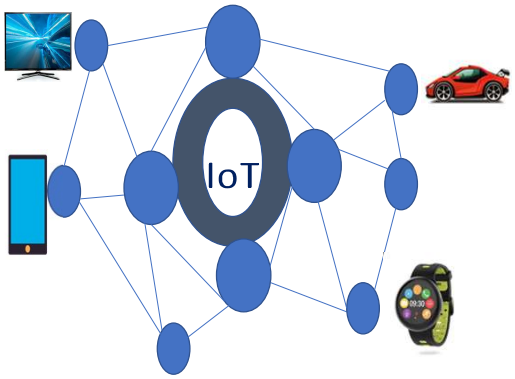
What is IoT?



- Internet of Things (IoT) is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure.
- IoT allows devices to automatically collect, exchange and store data and such objects create Systems that are Secure , Interoperable & Scalable.

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IoT Definitions

WIKIPEDIA
The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors and connectivity to enable it to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices. !

OXFORD
A proposed development of the Internet in which everyday objects have network connectivity, allowing them to send and receive data.

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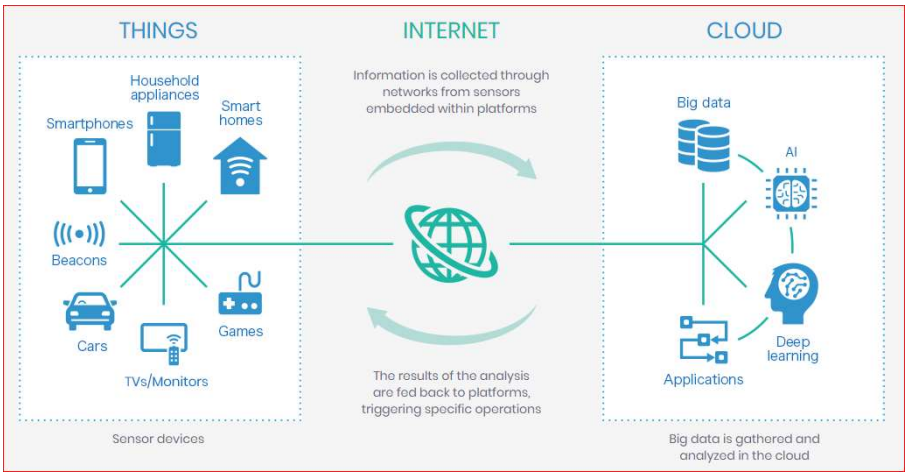
How IoT Works?



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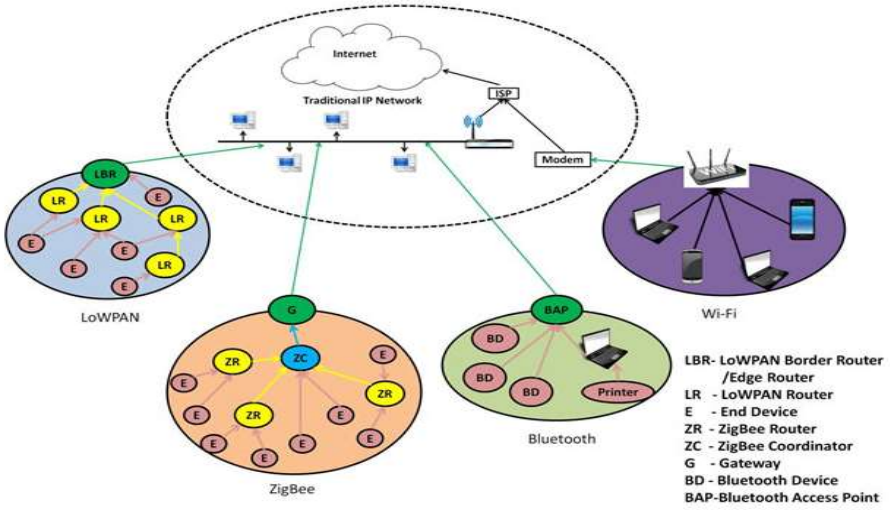
IoT Scenario



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IoT

- **IoT Provides**
  - Networking
  - Sensing
  - Big Data
  - Artificial Intelligence
- **IoT Allows**
  - Transparency
  - Control
  - Performance
- **IoT Applications**
  - Unique Flexibility
  - Unique Ability
  - Suitable In Any Environment
- **IoT Enhances**
  - Advanced Automation
  - Analytics System
  - Data Collection
  - Operations

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Business Overview of IOT

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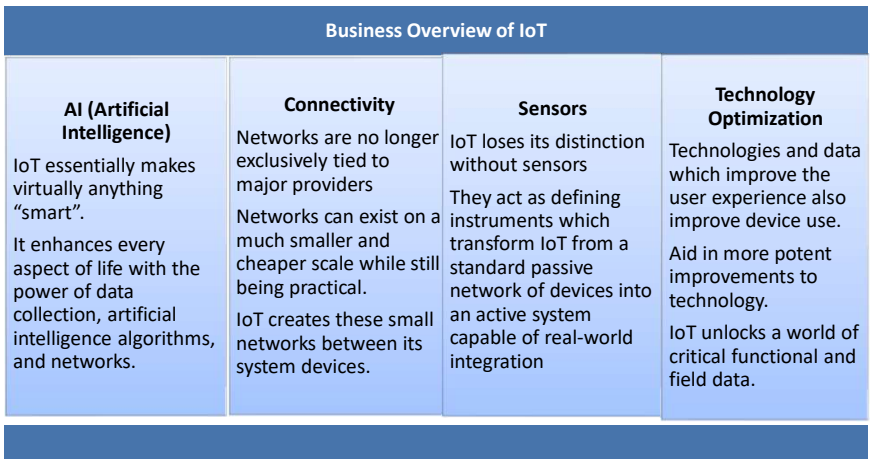
Business Overview of IoT



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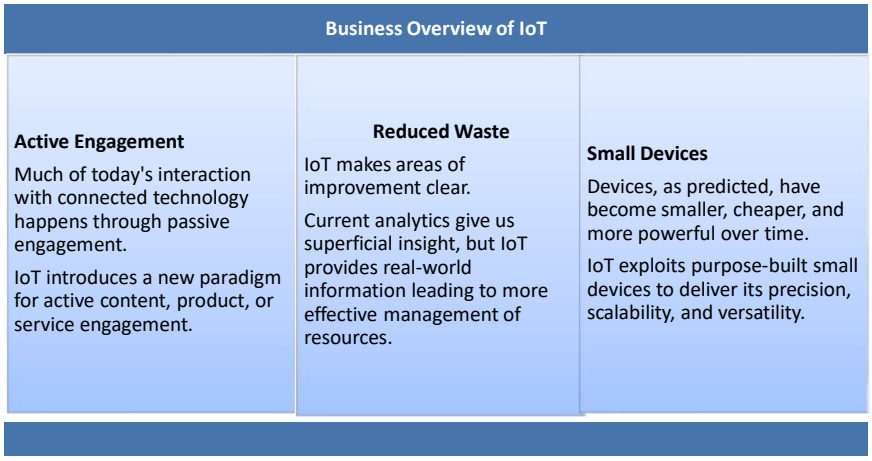
Business Overview of IoT (continue)



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IoT Architecture

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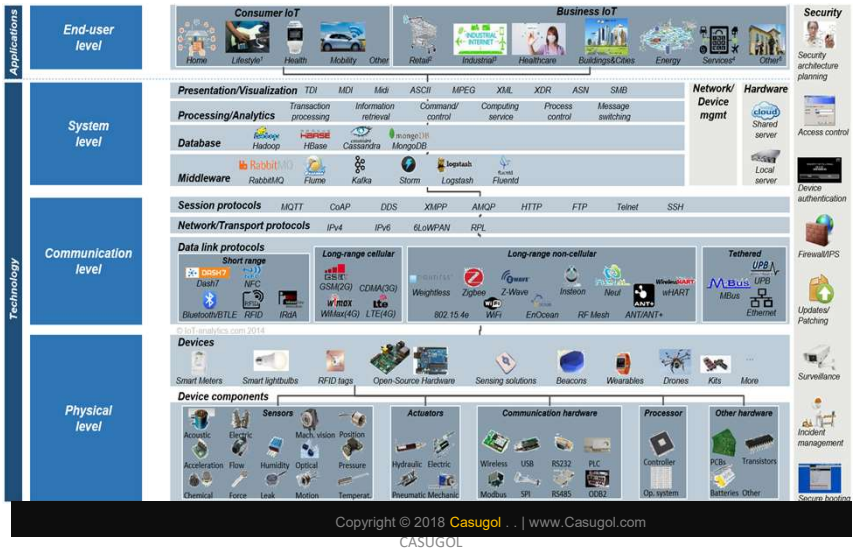
Technology Architecture



Physical/Sensor Layer

- Lowest Abstraction Layer
- Incorporated to measure physical quantities
- Interconnects the physical and digital world
- Collects and process the real time information

- Sensors collect data from the environment or object under measurement and turn it into useful data.
- This stage of the IoT is expanding rapidly, with robotic camera systems, water level detectors, home voice controllers, air quality sensor, smart baby monitoring devices, etc.
  All of these devices will collect user data, including sign-on times, level and hours of usage, location statistics, etc.
- As these devices produce an avalanche of data, it will be important to your organization to choose which data is useful to you and which can be ignored. Enterprises can expect a surge in data velocity, and with that surge, organizations will benefit from moving their data into the cloud.
- Some data should be processed immediately, i.e., time-sensitive data – threat detection, immediate crash statistics, abrupt shutdowns, etc. Otherwise, data that will undergo deep processing and analyzation should be pushed directly to the cloud, to avoid network clutter.

Gateway and Network Layer

- Robust and High performance network infrastructure
- Supports the communication requirements for latency, bandwidth or security
- Allows multiple organizations to share and use the same network independently

- Data collected from the sensors or actuators is very raw. This data has to be aggregated and converted into digital streams for further data processing.
- To carry out this data processing, it is imperative to use a data acquisition system (DAS or DAQ).
- Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer.
- Data acquisition systems typically convert analog waveforms into digital values for processing.
  The DAS connects to the sensor network, aggregates outputs, and performs the analog-to-digital conversion.
- The Internet gateway receives the aggregated and digitized data and routes it over Wi-Fi, wired LANs, or the Internet, to Stage 3 systems for further processing.

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Management Service Layer

- Capturing of periodic sensory data
- Data Analytics (Extracts relevant information from massive amount of raw data)
- Streaming Analytics (Process real time data)
- Ensures security and privacy of data.

- This layer is used for managing the IoT services. Management Service layer is responsible for Securing Analysis of IoT devices, Analysis of Information (Stream Analytics, Data Analytics), Device Management.
- Data management is required to extract the necessary information from the enormous amount of raw data collected by the sensor devices to yield a valuable result of all the data collected. This action is performed in this layer.
- Also, certain situation requires immediate response to the situation. This layer helps in doing that by abstracting data, extracting information and managing the data flow.
- This layer is also responsible for data mining, text mining, service analytics etc.

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Application Layer

- Provides a user interface for using IoT.
- Different applications for various sectors like Transportation, Healthcare, Agriculture, Supply chains, Government, Retail etc.

- This layer is responsible for delivering application specific services to the user.
- Once data has been aggregated, cleaned, and surveyed, the information can be fed to the server to be analyzed and applied to new products and services.

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Internet of Things (IOT) Models and Prototyping

OSI & TCP/IP Model

	OSI Model	TCP/IP Model	Function	PDU	Services/Protocols	Hardware Devices
Logical/Virtual /Software Layers	Application	Application	Responsible for providing user interface and network services to users	Data	Telnet, SSH, FTP, SMTP, HTTP, NFS, SNMP	NA
	Presentation		does the job of formatting the data to be presented to the application layer	Data	JPG, PNG, GIF, MPEG, ASCII, CSS, HTML	
	Session		helps to initiation, management, and termination of connections between applications.	Data	RPC, SQL, NFS	
Heart of Layers	Transport	Transport	ensures correct and transparent data transfer between end systems and is also responsible for recovery and flow control	Segment	TCP & UDP	
Hardware Layers	Network	Internet	The network layer, facilitates the switching and routing of data packets, connects different networks together	Packet	IP V4, IP V6, ICMP, Ipsec	Router, L3 Switch
	Datalink	Link Local / Network Access	provides peer-to-peer data transfer and acts as a link between two connected peers. It also offers services like flow control and frame synchronization	Frame	MAC, PPP, HDLC, Frame Relay	Bridge, Switch, NIC
	Physical		Responsible for transmitting and receiving raw bit streams and packets over a physical media	Bits	Ethernet, ISDN, USB, DSL	Wired Media

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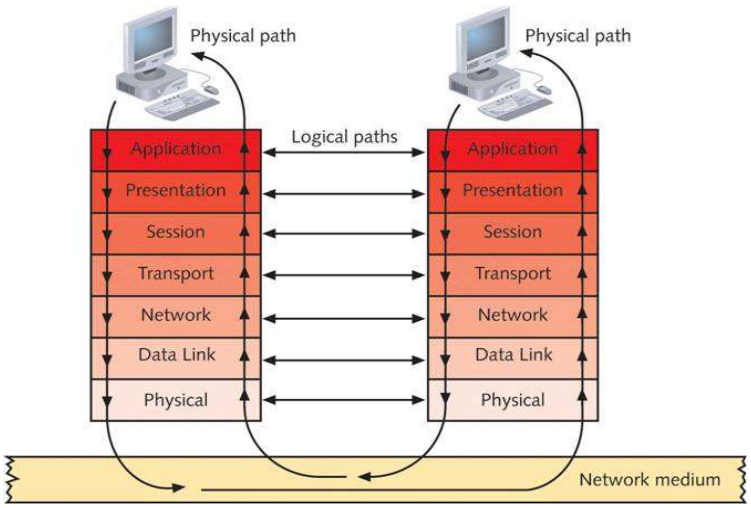
OSI Model Data Flow



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Protocols-Services-Applications

Internet Control Message Protocol	ICMP	TCP/UDP	7
File Transfer Protocol	FTP	UDP	20,21
Simple Mail Transfer Protocol	SMTP	TCP	25
Post Office Protocol	POP3	TCP	110
Telnet		TCP	23
Secure Shell	SSH	TCP	22
Domain Name System	DNS	TCP/UDP	53
Hyper Text Transfer Protocol	HTTP	TCP	80
Hyper Text Transfer Protocol Secure	HTTPS	TCP	443
Dynamic Host Configuration Protocol	DHCP	UDP	67,68
Simple Network Management Protocol	SNMP	UDP	161
Address Resolution Protocol	ARP	TCP/UDP	219
Reverse Address Resolution Protocol	RARP	TCP/UDP	219
Network Time Protocol	NTP	UDP	123
Trivial File Transfer Protocol	TFTP	UDP	69

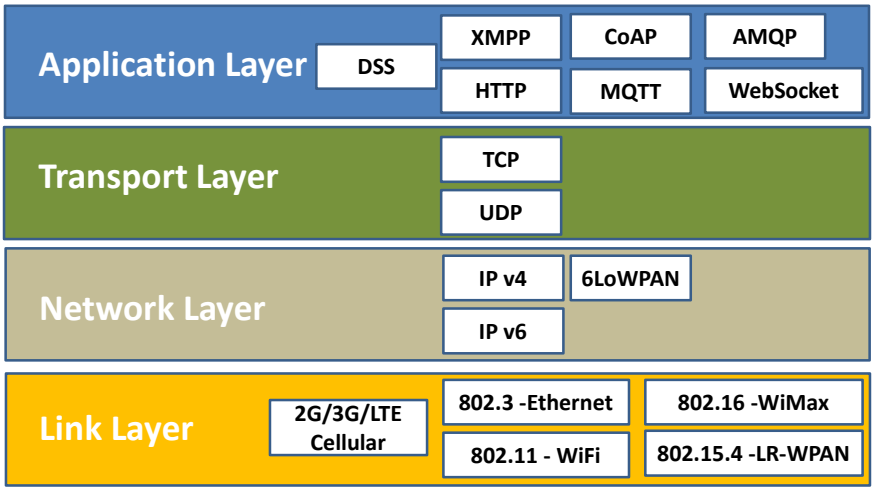
What is Port?

- Port is medium for communication between 2 computers. Every service on a host is identified by a unique 16-bit number called a port.
- TCP and UDP are two of the protocols that make up the TCP/IP protocol suite which is used universally to communicate on the Internet.
- Each of these has ports 0 through 65535 available ,so essentially there are more than 65,000 doors to lock.
- The first 1024 TCP ports are called the Well-Known Ports and are associated with standard services such as FTP, HTTP, SMTP or DNS.
- Ports 1025–65535 are free to be assigned and used randomly by any application.

IP Address followed by Port Number called as **Socket**.

For example, 192.168.1.10:80 is referred to as a socket.

IoT Protocols and Reference Model



Link Layer

802.3 Ethernet	802.11a –at 5 GHz 802.11b/g – at 2.4 Ghz 802.11n –at 2.4/5 Ghz 802.11ac –at 5 Ghz 802.11ad –at 60 Ghz Data rates – 1 Mb/s to 6.75 Gb/s	802.16 WiMax Mobile station – 100 Mb/s Fixed station – 1 Gb/s Data rates – 1.5 Mb/s to 1 Gb/s	802.15.4 – LR-WPAN For power constrained devices Data rates – 40 Kb/s to 250 Kb/s	2G/3G/4G – Mobile Communication 2G – GSM and CDMA 3G – UMTS and CDMA2000 4G – LTE Data rates – 9.6 Kb/s to 100 Mb/s
802.3 – Coaxial cable 802.3.i – Copper twisted-pair 802.3.j – Fiber optics Data rates – 10 Mb/s to 40 Gb/s				

Network Layer

IPv4	IPv6	6LoWPAN
1974 IETF 32 Bit Dotted Decimal 5 Classes Clear Text	1998 IETF 128 Bit Hexadecimal Decimal Uses SSL for Encryption	Low power devices with limited processing capabilities Transfer rate – 250 Kb/s Frequency – 2.4 Ghz Works with 802.15.4 link layer protocols

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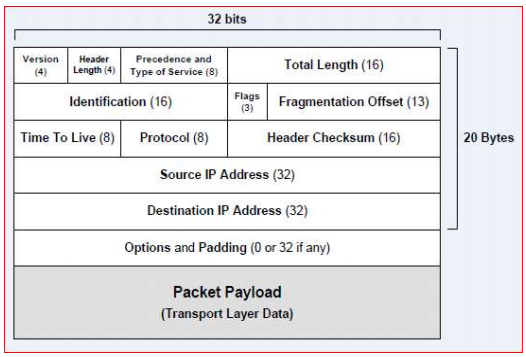
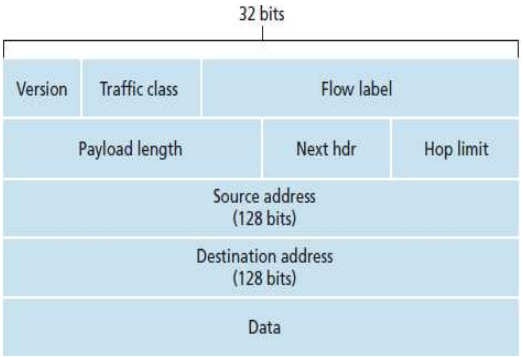
Network Layer

- **IP V4 Segment**



- **IP V6 Segment**



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IP v4 Classes

Class	First Octet Range	Valid Network Numbers	Default Subnet Mask	Max number of networks	Max number of hosts
A	**0**0000000 – 0 **0**1111111 – 127	1.0.0.0 – 126.0.0.0	8 bits, 255.0.0.0	$2^7 - 2$, 126	$2^{24} - 2$, 16777214
B	**10**000000 – 128 **10**111111 – 191	128.0.0.0 – 191.255.0.0	16 bits, 255.255.0.0	2^{14}, [1] 16384	$2^{16} - 2$, 65534
C	**110**00000 – 192 **110**11111 – 223	192.0.0.0 – 223.255.255.0	24 bits, 255.255.255.0	2^{21}, [2] 2097152	$2^8 - 2$, 254
D [3]	**1110**0000 – 224 **1110**1111 – 239	224.0.0.0 – 239.255.255.255	–	–	–
E [4]	**1111**0000 – 240 **1111**1111 – 255	240.0.0.0 – 255.255.255.255	–	–	–

Address Class	Reserved Address Space		Number of Networks
Class A	10.0.0.0 – 10.255.255.255	(10.0.0.0/8)	1 Class A network
Class B	172.16.0.0 – 172.31.255.255	(172.16.0.0/12)	16 Class B networks
Class C	192.168.0.0 – 192.168.255.255	(192.168.0.0/16)	256 Class C networks

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IP v6

- IPv6 uses 128 bits for IP addressing, as compared to the 32-bit in IPv4.
- IPv6 addresses are represented in eight 16-bit hexadecimal segments and are written in hexadecimal notation, with colons between each quartet.
- Ex: 10.1.1.1 in IPv4, is 0000:0000:0000:0000:0000:FFFF:0A01:0101 in IPv6.
- The number of possible addresses in IPv6 is 2^{128} – approximately 3.4 x 10^{38} addresses.
- Although IPv6 has many advanced features, the primary reason for the move to IPv6 is the depletion of IPv4 addresses. IPv6 provides greater flexibility in assigning addresses.
- IPv6 does not use nor send out broadcasts.
- IPv6 provides solutions to some other challenges and problems found in IPv4,eg: broadcast storm, address renumbering, network layer security (IP is vulnerable to attacks).
- Besides providing a larger address space, some other additional benefits of IPv6 are:
  - Simplified header
  - Autoconfiguration
  - Security with mandatory IPSec for all IPv6 devices
  - Mobility
  - Enhanced multicast support
  - Extension headers
  - Flow labels
  - Improved address allocation
  - Address aggregation

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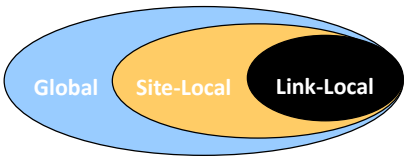
IP v6

- Addresses are assigned to interfaces
- No change from IPv4 Model
- Interface 'expected' to have multiple addresses
- Addresses have scope
  - Link Local
  - Site Local
  - Global
- Addresses have lifetime
- Valid and Preferred lifetime



- **Unicast**
  - Address of a single interface
  - Delivery to single interface
- **Multicast**
  - Address of a set of interfaces
  - Delivery to all interfaces in the set
- **Anycast**
  - Address of a set of interfaces
  - Delivery to a single interface in the set
- No more broadcast addresses

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IP Usage

Web Services

- IP family of protocols that can be used to provide services to a device
- Examples: SMS text, e-mail, file sharing, streaming audio, speech to text, social media …

IoT Services

- The availability of back-end services based on IP protocols Differentiating "IoT devices" from "connected devices":
- Examples: Storage, multiple devices/applications data usage, system analytics and potential for efficiency gain…

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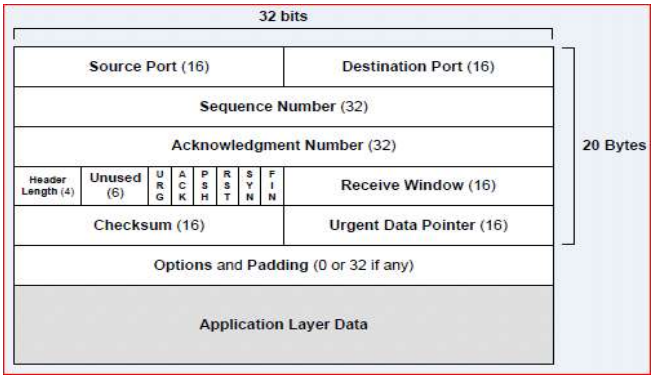
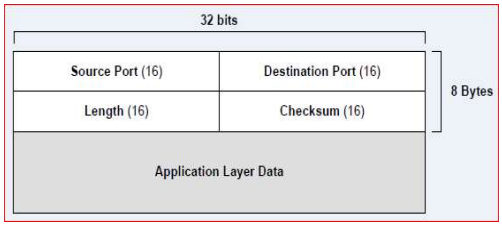
Transport Layer

TCP	UDP
• Reliable • Connection-oriented • Segment Retransmission • Flow control • Segment Sequencing • Acknowledge Segments	• Unreliable • Connectionless • No Retransmission • No Flow control • No Segment Sequencing • No Acknowledge Segments

TCP Segment Format

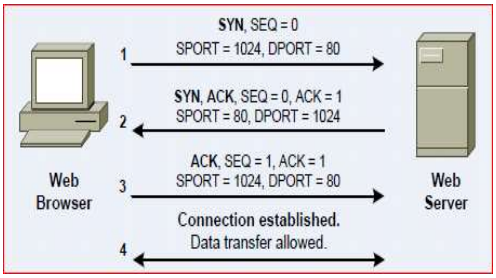


UDP Segment Format

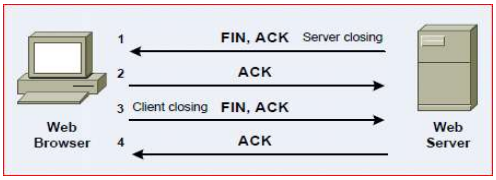


TCP Connection States

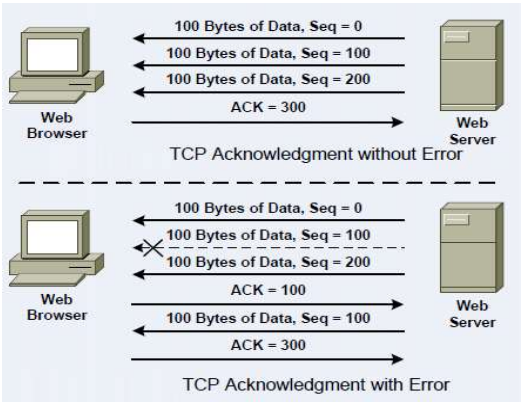
TCP Connection Establishment



TCP Connection Termination



TCP Acknowledgement & Error Recovery



Network Troubleshooting

Latency

- It is an expression of how much time it takes for a packet of data to get from one designated point to another

Bandwidth

- Bandwidth is defined as a range within a band of frequencies or wavelengths. Bandwidth is also defined as the amount of data that can be transmitted in a fixed amount of time

Throughput

- Throughput is a measure of how many units of information a system can process in a given amount of time

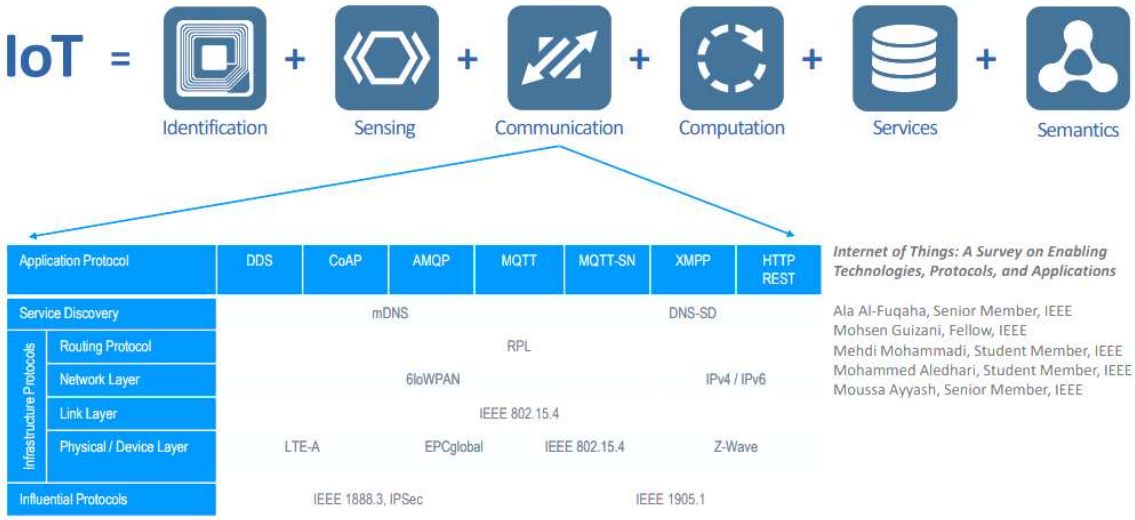
TTL (Time to Live)

- The time-to-live (TTL) is the number of hops that a packet is permitted to travel before being discarded by a router

- Ping
- Traceroute/Tracert
- Ipconfig/Ifconfig
- Netstat
- Nslookup
- Pathping (combination of Ping and Traceroute)
- Route print
- netsh.exe wlan show profiles

APPLICATION LAYER

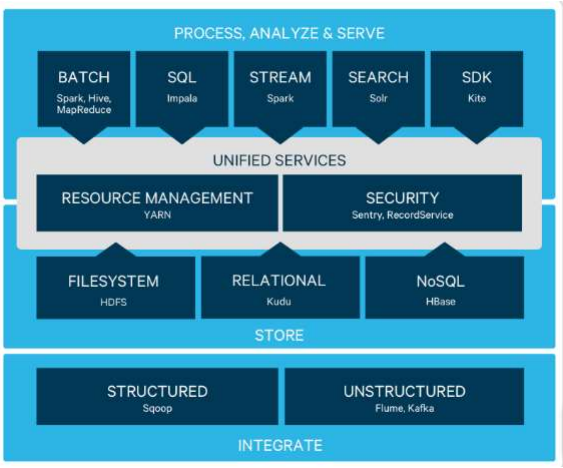
IoT Building Blocks



Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications

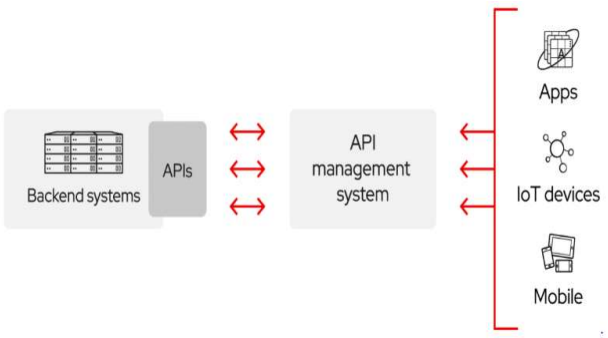
Ala Al-Fuqaha, Senior Member, IEEE
Mohsen Guizani, Fellow, IEEE
Mehdi Mohammadi, Student Member, IEEE
Mohammed Aledhari, Student Member, IEEE
Moussa Ayyash, Senior Member, IEEE

HADOOP



- Apache Hadoop is an open-source framework designed for distributed storage and processing of very large data sets across clusters of computers. Apache Hadoop consists of components including:
- Hadoop Distributed File System (HDFS), the bottom layer component for storage. HDFS breaks up files into chunks and distributes them across the nodes of the cluster.
- Yarn for job scheduling and cluster resource management.
- MapReduce for parallel processing.
- Common libraries needed by the other Hadoop subsystems.
- Key benefits of Hadoop
  - Speed, Scale, and Reliability
  - Machine Learning
  - Data Warehouse Optimization at Lower TCO
  - Event Stream Processing
  - Interactive Analytics
  - Data Integration

API (Application Programming Interface)



- API is the acronym for Application Programming Interface, which is a software intermediary that allows two applications to talk to each other.
- Each time you use an app like Facebook, send an instant message, or check the weather on your phone, you're using an API.
- When you use an application on your mobile phone, the application connects to the Internet and sends data to a server.
- The server then retrieves that data, interprets it, performs the necessary actions and sends it back to your phone.
- The application then interprets that data and presents you with the information you wanted in a readable way. This is what an API is - all of this happens via API.

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DDS

- **Data Distribution Service**

DDS The Proven Data Connectivity Standard for the IoT

Fast
- 100,000's update/sec

Scalable
- Load independent # apps

Managed with QoS

Reliable
- No single point of failure

Key Features

- Integrates components of system together
- Providing low-latency data connectivity
- Extreme reliability
- Scalable architecture

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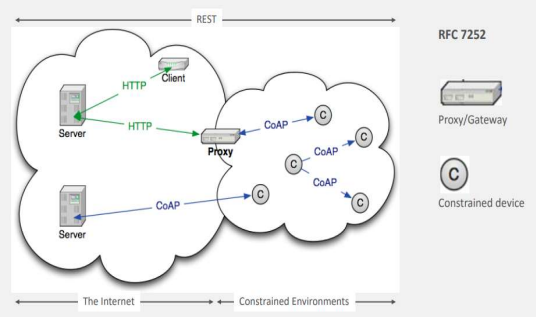
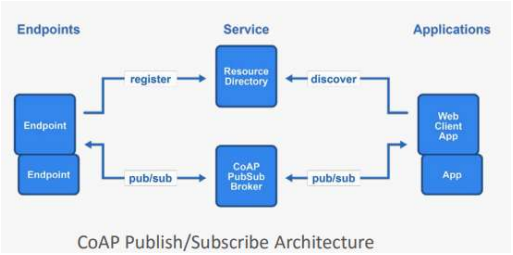
CoAP



Constrained Application Protocol

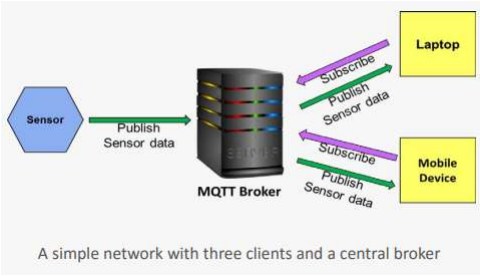
- CoAP runs on UDP and thus can be run on extremely resource constrained environments.
- It offers semantics parallel to HTTP for the most part.
- It is a good mechanism for local network communication, particularly when their is an ecosystem of other CoAP devices.

CoAP
Constrained Application Protocol



CoAP Publish/Subscribe Architecture

MQTT



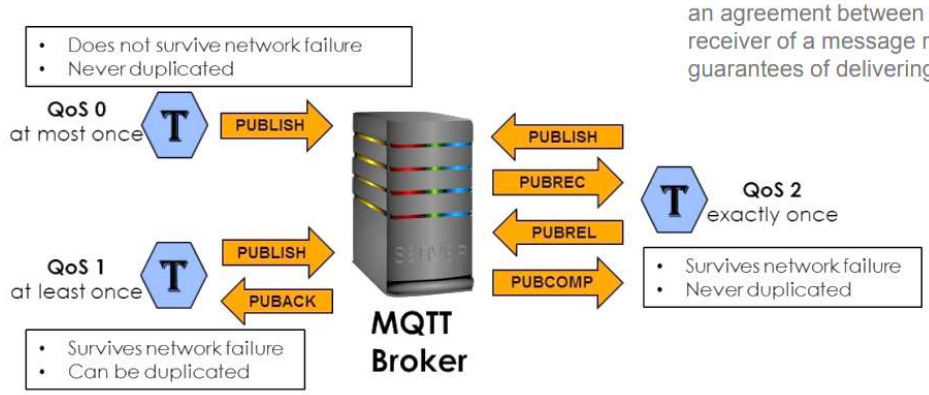
A simple network with three clients and a central broker

- **Message Queue Telemetry Transport**
- Apart from being light weight, MQTT offers publish/subscribe semantics (on the same socket) which makes it easier to program on the IoT device side.
- IoT cloud service providers like AWS IoT and Evrythng and others offer MQTT based device connectivity. It requires a message broker (server) for its functioning.
- This makes it a good option for remote/cloud communication, since the cloud server acts as the message broker between the IoT device and other app/services.
- This also makes it NOT a great option for local network communication between devices, because it requires the end-user to deploy an additional broker in her system.

MQTT QoS

There are 3 QoS levels in MQTT:

The Quality of Service (QoS) level is an agreement between sender and receiver of a message regarding the guarantees of delivering a message.



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AMQP

- **Advanced Message Queuing Protocol**
- Open standard for passing business messages between applications or organizations.
- It connects systems, feeds business processes with the information they need and reliably transmits onward the instructions that achieve their goals.

Key Features	Key Capabilities
• Security • Reliability • Interoperability • Standard • Open	• Organizations • Technologies • Time • Space

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XMPP

- **Extensible Messaging and Presence Protocol**
- XMPP was originally developed in the Jabber open-source community to provide an open, decentralized alternative to the closed instant messaging services at that time.

XMPP

Set Of Open Technologies	Key Advantages
• Instant messaging • Presence • Multi-party chat • Voice and video calls • Collaboration • Lightweight middleware • Content syndication • Generalized routing of XML data	• Open • Standard • Proven • Decentralized • Secure • Extensible • Flexible • Diverse

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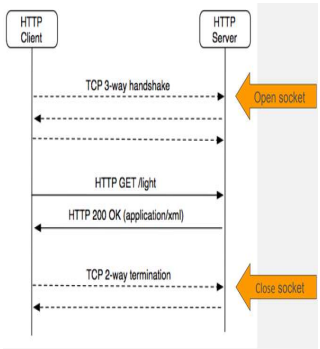
HTTP

- **Hyper Text Transfer Protocol**

HTTP Request : Client opens connection and sends a request message to HTTP server Server returns a response Client closes the connection HTTP is 'stateless'



Key Features
• Foundation of WWW • Request – response model • Stateless protocol • Uses URI (Universal Resource Indentifiers)

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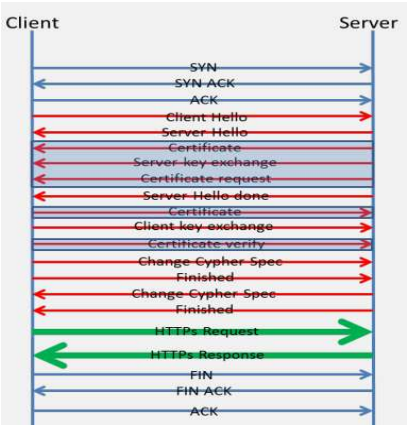
HTTPS



- Typical HTTPS showing the messages, not the number of packets
- Areas in blue are optional bidirectional SSL/TLS
- Connection is initiated by a client
- Client always has to poll the server, server cannot initiate connection: not efficient for an embedded device
- High overhead: Open/Send/Close for every message

WebSocket

- Web sockets are defined as a two-way communication between the servers and the clients.
- It mean both the parties communicate and exchange data at the same time.
- The key points of Web Sockets are **true concurrency** and **optimization of performance**, resulting in more responsive and rich web applications.

Key Features

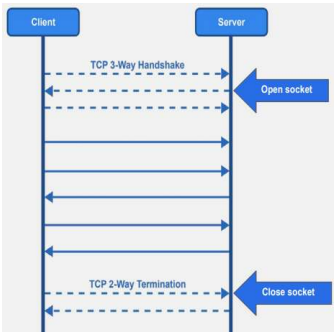
- Communication between web servers and clients
- Transforming to cross platform standard
- Web application can speed up
- Provides full duplex over a single TCP connection

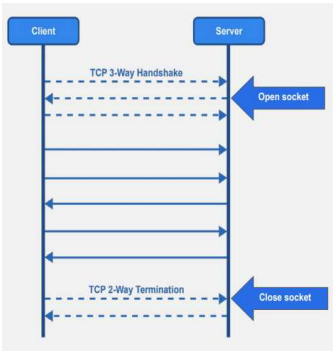
websocket.org

WebSocket

- WebSockets are a bi-directional, fullduplex, persistent connections from a client to a server. Once a WebSocket connection is established the connection stays open until the client or server decides to close this connection.

With this open connection, the client or server can send a message at any given time to the other. This makes web programming entirely event driven, not (just) user initiated. It is stateful.





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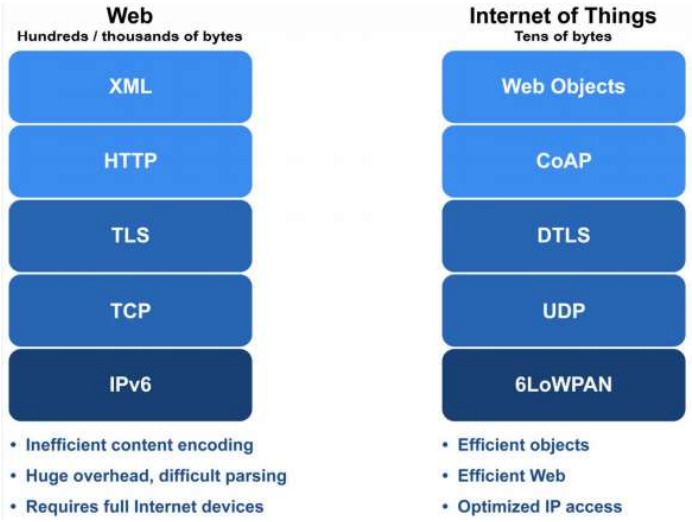
Web Versus Dedicated IoT



- Inefficient content encoding
- Huge overhead, difficult parsing
- Requires full Internet devices

- Efficient objects
- Efficient Web
- Optimized IP access

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Hardware and Software Platforms

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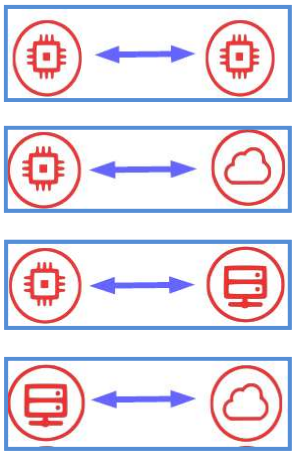
Architecture



- Device to Device
- Device to Cloud
- Device to Gateway
- Gateway to Cloud

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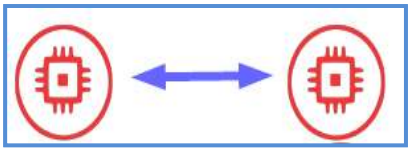
Device to Device



Features	Applications
• Peer to Peer • Mesh • Master/Slave • No traditional client-server model	• WiFi Direct, Bluetooth 4.0, LoRa, ZigBee • ShareIT, BitTorrent, Bitcoin

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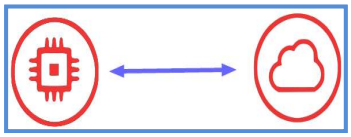
Device to Cloud



Features	Applications
• Client setup on device side • **Server/Broker on client side** • Internet connectivity on the device • Pub/Sub and Request/Response	• MQTT • CoAP

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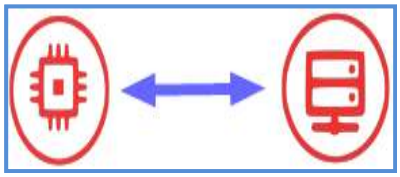
Device to Gateway



Features	Applications
• Client setup on device side • **Server/Broker on gateway side** • Internet connectivity on the gateway • Pub/Sub and Request/Response	• MQTT • CoAP*

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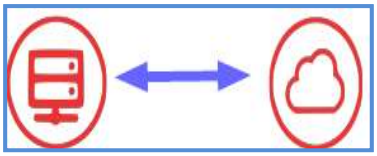
Gateway To Cloud



Features	Applications
• Pub/Sub and Request/Response • Local storage • Alert • Local and cloud id	• MQTT • CoAP • XMPP • AMQP • HTTP

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EMBEDDED DEVICE

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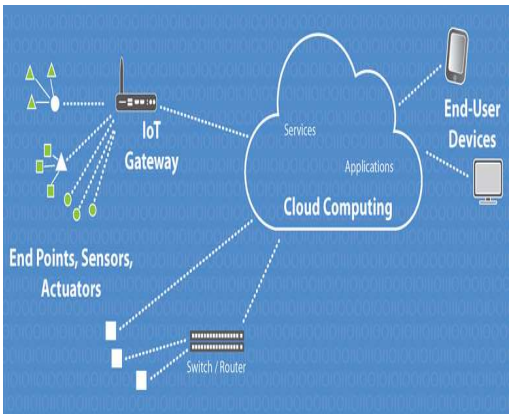
UART



- As a "universal" setup, we can configure UART to work with many different types of serial protocols.
- UART was adapted into single-chip units in the early 1970s, starting with Western Digital's WD1402A.
- In a UART communication scheme:
  - One chip's Tx (transmit) pin connects directly to the other's Rx (receive) pin and vice versa. Commonly, the transmission will take place at 3.3 or 5V. UART is a single-master, single-slave protocol, where one device is set up to communicate with only one partner.
  - Data travels to and from a UART in parallel to the controlling device (e.g., a CPU).
  - When sending on the Tx pin, the first UART translates this parallel information into serial and transmits it to the receiving counterpart.
  - The second UART receives this data on its Rx pin and transforms it back into parallel to communicate with its controlling device.

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Example UART

- Highly-integrated USB to UART bridge controller providing a simple solution for updating RS-232 designs to USB using a minimum components and PCB space. It provides USB connectivity to devices with a UART interface.
  - It uses a standard USB type A male and TTL 6pin connector
- This USB CP2102 Serial Converter is a small adapter for Arduino/Seeeduino board to accept firmware upgrades from a computer

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SPI

- **Serial Peripheral Interface** is another very simple serial protocol.
- A master sends a clock signal, and upon each clock pulse it shifts one bit out to the slave, and one bit in, coming from the slave.
- Signal names are therefore SCK for clock, **MOS**I for **Master Out Slave In**, and **MISO** for **Master In Slave Out**.
- By using **SS (Slave Select)** signals the master can control more than 1 slave on the bus.
- There are two ways to connect multiple slave devices to one master, one is mentioned above i.e. using slave select, and other is daisy chaining, it uses fewer hardware pins (select lines), but software gets complicated.

- **Advantages of using SPI**
  - Protocol is simple as there is no complicated slave addressing system like I2C.
  - It is the fastest protocol compared to UART and I2C.
  - No start and stop bits unlike UART which means data can be transmitted continuously without interruption
  - Separate MISO and MOSI lines which means data can be transmitted and received at the same time

- **Disadvantages of using SPI**
  - More Pin ports are occupied, practical limit to number of devices.
  - There is no flow control specified, and no acknowledgement mechanism confirms whether data is received unlike I2C
  - Uses four lines – MOSI, MISO, NCLK, NSS
  - No form of error check unlike in UART (using parity bit)
  - Only 1 master

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Example SPI

ENC28J60 OVERLAYS HAT for Raspberry Pi

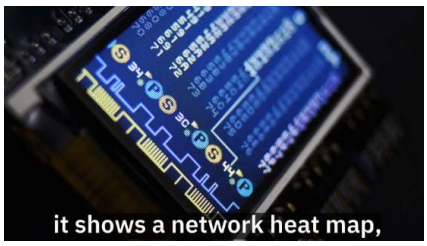
- This product by Seeed, The Pi zero ENC28J60 is a simple Network Adapter module for Pi zero and its very easy to assemble and configure.
- It allows your Raspberry Pi zero to access the network smoothly, and it is easy to do system updates and software installation operations.
- Microchip's ENC28J60 is a 28-pin, 10BASE-T stand alone Ethernet controller with a SPI interface.
- The SPI interface serves as a communication channel between the host controller and ENC28J60.

I2C

- **Inter-Integrated Circuit, pronounced "I squared C"** is also a synchronous protocol, and it's the first we see which has some "intelligence" in it; the other ones dumbly shifted bits in and out, and that was that.
- I2C uses only 2 wires, one for the clock (SCL) and one for the data (SDA). That means that master and slave send data over the same wire, again controlled by the master who creates the clock signal.
- I2C doesn't use separate Slave Selects to select a particular device, but has addressing.
- The first byte sent by the master holds a 7 bit address (so that you can use 127 devices on the bus) and a read/write bit, indicating whether the next byte(s) will also come from the master of should come from the slave.

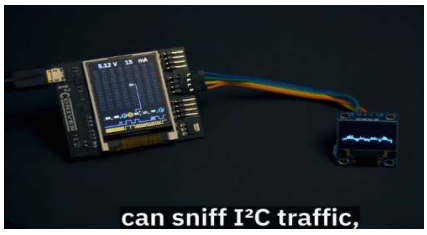
- **Advantages of using I2C**
  - Has a low pin/signal count even with numerous devices on the bus
  - Flexible, as it supports multi master and multi slave communication.
  - Simple as it only uses 2 bidirectional wires to establish communication among multiple devices.
  - Adaptable as it can adapt to the needs of various slave devices.
  - Support multiple masters.
- **Disadvantages of using I2C**
  - Slower speed as it requires pull-up resistors rather than push-pull resistors used by SPI. It also has an open-drain design = limited speed.
  - Requires more space as the resistors consume valuable PCB real estate.
  - May become complex as number of devices increases.

Example I2C



I2C Driver/Adapter-Easily Driver I2C Devices

- I²C Driver is an easy-to-use, open source tool for controlling I²C devices. It works with Windows, Mac, and Linux, and has a built-in color screen that shows a live “dashboard” of all the I²C activity.
- With the built in display shows a heatmap of all active network nodes, you are able to observe from an I²C network with multiple devices which ones are the most active.



Sniffing I2C Traffic

- When an I²C Driver is connected to an existing I²C bus, it “snoops” the traffic and displays it on the screen.
- This provides an excellent tool for debugging I²C issues, because you can listen in on the conversation as it happens.

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JTAG

- **The Joint Test Action Group (JTAG)** method of connection is the IEEE standard #1149, It is also known as “JTAG boundary scan”.
- Typically, JTAG is a feature found in relatively high pin count devices, but not in low pin count devices.
- I2C and SPI can be found in both high pin count devices like microcontrollers and in low pin count devices like A/D converters.
- JTAG is commonly used for the following applications:
  1) Board Assembly Test (verifies the connectivity of device pins to the PCB)
  2) Development Tool (in-circuit emulator)
  3) System Debug (provides a “back door” into the system)
  4) Testing internal device circuitry (not be discussed here)
- The idea was to define an interface that could be used to test hardware (micro controllers and connected peripherals after manufacturing). I.e. after development of the hardware and subsequent production of it.
- The devices used to do the boundary scan according to JTAG are called **JTAG probes**. They used to be connected to the parallel port of your machine, but these days are more often connected via USB and based on one of the FTDI chips.
- On a PCB the chip(s) and peripherals form a "daisy chain" connected to the TAP (test access port). So you can test the various components through one port. The instruction BYPASS is used to tell a device earlier on the chain to ignore your commands and pass them on. IDCODE is used to identify the device and a few basic characteristics.

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Example JTAG

The JTAG connector in the upper right provides hardware debug support for the ultra-low-power, Ambiq Micro Cortex-M4 Apollo microcontroller.

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Summary

Feature	UART	I2C	SPI
Complexity	Simple	Easy to chain many devices.	Complex as device increases
Speed	Slowest	Faster than UART	Fastest
Number of devices	Up to 2 devices	Up to 127 but may get complex as devices increases	Many, but there are practical limits and may get complicated
Number of wires	1	2	4
Duplex	Full Duplex	Half Duplex	Full Duplex
Number of masters and slaves	No multiple slaves and masters	Multiple slaves and masters	Only 1 master but can have multiple slaves.

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SOFTWARE AND CLOUD COMPONENTS

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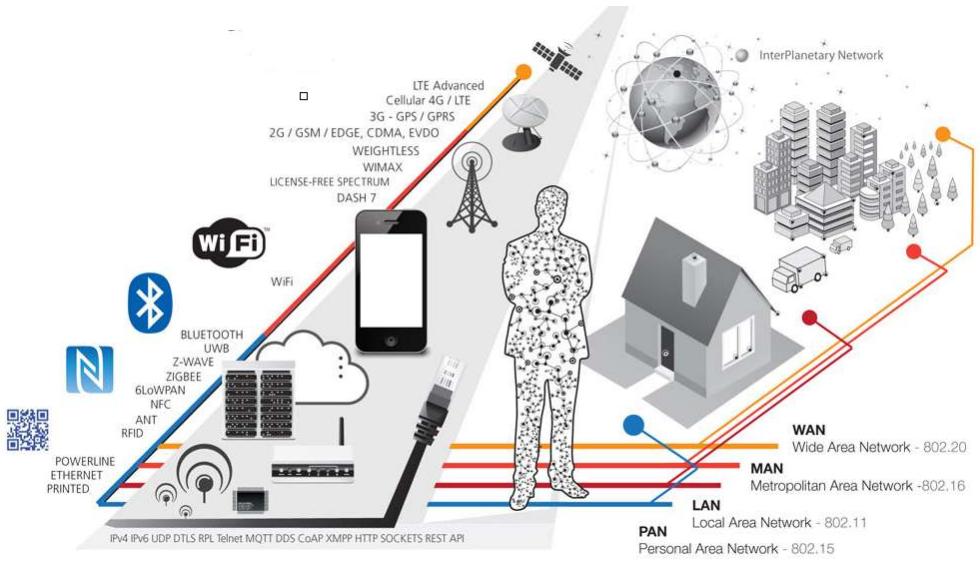
Radio Communication



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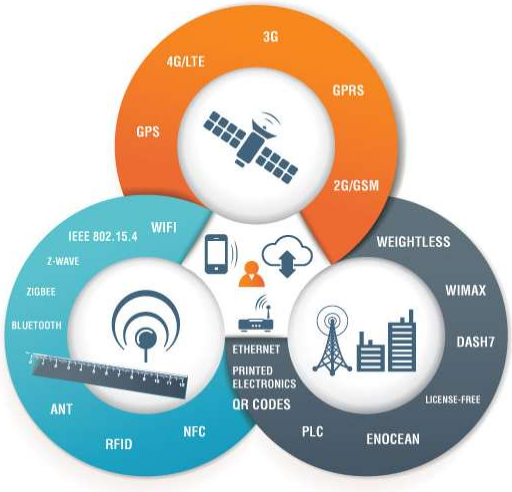
Radio Communication (continue)



- **There exists an almost bewildering choice of connectivity options for electronics engineers and application developers working on products and systems for the Internet of Things (IoT).**
- Depending on the application, factors such as range, data requirements, security and power demands and battery life will dictate the choice of one or some form of combination of technologies.

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WiFi

Standard	• Based on 802.11n • Most common usage in homes today
Frequencies	• 2.4GHz and 5GHz bands
Range	• Approximately 50m
Data Rates	• 600 Mbps maximum, • Latest 802.11-ac standard 500Mbps to 1Gbps

- Wi-Fi enabled computers send and receive data indoors and out.
- Its just as fast as cable modem connection.It refers to the IEEE 802.11 communications standard.
- It usually establishes a Local Area Network(LAN).
- It uses high frequency radio waves rather than wires to communicate and transmit data.
- An Access Point connects wired and wireless networks together and enables the sending and receiving of data between wireless clients and the wired network.
- The wireless SSID, also known as the 'Network Name', is the Service Set Identification controls access to a given wireless network.

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WiFi

Advantages:
- Frees network devices from cables
- Cheaper development for embedded system
- Reliable products
- Security
- High speed

Disadvantages:
- 802.11b/g use the 2.4 GHz spectrum, which is crowded with other devices (Bluetooth…)
- 802.11n doubles the radio spectrum/bandwidth (40 MHz)
- Power consumption
- Limited network range
- Security risks (configuration)

Applications of Wifi:
- Internet Access
- Hotspots
- City-wide Wi-Fi
- Campus-wide Wi-Fi
- Direct computer-to-computer communications
- Wireless ad hoc network

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WiFi Direct

- *Wi-Fi Direct*, initially called Wi-Fi P2P, is a Wi-Fi standard enabling devices to easily connect with each other without requiring a wireless access point.
- It is useful for everything from internet browsing to file transfer.
- Communicate with one or more devices simultaneously.
- Ability to connect devices even if they are from different manufacturers.
- It establish a peer- to-peer connection.
- It uses a number of standards to accomplish its functions:
  - Wifi Technology
  - Wifi Direct Device and Service Discovery
  - Wifi Protected Setup
  - WPA2

Advantages:
- Portable Wi-Fi® that goes with you anywhere.
- Use Wi-Fi Direct without an Internet connection.
- Wi-Fi Direct connections happen anywhere, anytime.
- Simple Secure Connections.

Disadvantages:
- It is new to android.
- It need to establish the connection with the other devices and as soon as you leave the group, you are not connected any more.
- It does not support the iPhones.

Applications of Wifi Direct :
- Game Controllers
- Remote Control Devices
- Utility Application
- Home Control Application

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Bluetooth

- An important short-range communications technology is of course Bluetooth, which has become very important in computing and many consumer product markets.
- It is expected to be key for wearable products in particular, again connecting to the IoT albeit probably via a smartphone in many cases. The new **Bluetooth Low-Energy (BLE**) or Bluetooth Smart, as it is now branded is a significant protocol for IoT applications.
- Importantly, while it offers similar range to Bluetooth it has been designed to offer significantly reduced power consumption.
- However, Smart/BLE is not really designed for file transfer and is more suitable for small chunks of data.
- It has a major advantage certainly in a more personal device context over many competing technologies given its widespread integration in smartphones and many other mobile devices.

- According to the Bluetooth SIG, more than 90 percent of Bluetooth-enabled smartphones, including iOS, Android and Windows based models, are expected to be 'Smart Ready' by 2018.
- Devices that employ Bluetooth Smart features incorporate the Bluetooth Core Specification Version 4.0 (or higher – the latest is version 4.2 announced in late 2014) with a combined basic-data-rate and low-energy core configuration for a RF transceiver, baseband and protocol stack.
- Importantly, version 4.2 via its Internet Protocol Support Profile will allow Bluetooth Smart sensors to access the Internet directly via 6LoWPAN connectivity
- This IP connectivity makes it possible to use existing IP infrastructure to manage Bluetooth Smart 'edge' devices.
  - ❑ **Standard:** Bluetooth 4.2 core specification
  - ❑ **Frequency:** 2.4GHz (ISM)
  - ❑ **Range:** 50-150m (Smart/BLE)
  - ❑ **Data Rates:** 1Mbps (Smart/BLE)

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Bluetooth

Advantages:

- It is cheap
- Easy to install
- It is wireless
- It is free to use if the device is installed with it.
- It makes connecting to different devices convenient

Disadvantages:

- It can be hacked into
- If installed on a cell phone it is prone to receiving cell phone viruses
- It only allows short range communication between devices
- It can only connect two devices at once
- It can lose connection in certain conditions

Applications of Bluetooth:

- Wireless networking between laptops and desktop computers, or desktops that are in a confined space and little bandwidth is needed.
- The transfer of files, images and MP3, between mobile phones.
- Bluetooth technology headsets for smart phones and cell phones.
- Data logging equipment that transmits data to a computer via Bluetooth technology.

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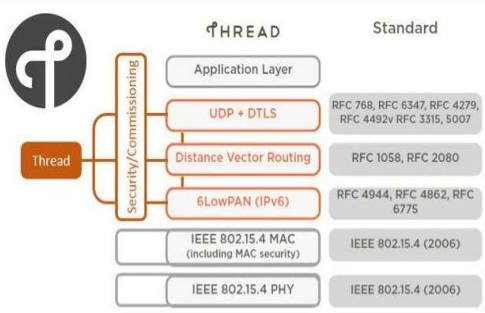
Thread



- ❑**Standard:** Thread, based on IEEE802.15.4 and 6LowPAN
- ❑**Frequency:** 2.4GHz (ISM)
- ❑**Range:** 100 meters
- ❑**Data Rates**: 250 kbps

- A very new IP-based IPv6 networking protocol aimed at the home automation environment is Thread. Based on 6LowPAN, and also like it, it is not an IoT applications protocol like Bluetooth or ZigBee.
- However, from an application point of view, it is primarily designed as a complement to WiFi as it recognises that while WiFi is good for many consumer devices that it has limitations for use in a home automation setup.
- Launched in mid-2014 by the Thread Group, the royalty-free protocol is based on various standards including IEEE802.15.4 (as the wireless air-interface protocol), IPv6 and 6LoWPAN, and offers a resilient IP-based solution for the IoT.
- Designed to work on existing IEEE802.15.4 wireless silicon from chip vendors such as Freescale and Silicon Labs, Thread supports a mesh network using IEEE802.15.4 radio transceivers and is capable of handling up to 250 nodes with high levels of authentication and encryption.
- A relatively simple software upgrade should allow users to run thread on existing IEEE802.15.4-enabled devices.

Zigbee

- ZigBee, like Bluetooth, has a large installed base of operation, although perhaps traditionally more in industrial settings.
- ZigBee PRO and ZigBee Remote Control (RF4CE), among other available ZigBee profiles, are based on the IEEE802.15.4 protocol.
- ZigBee/RF4CE has some significant advantages in complex systems offering low-power operation, high security, robustness and high scalability with high node counts and is well positioned to take advantage of wireless control and sensor networks in M2M and IoT applications.
- The latest version of ZigBee is the recently launched 3.0, which is essentially the unification of the various ZigBee wireless standards into a single standard.
  - ❑ **Standard:** ZigBee 3.0 based on IEEE802.15.4
  - ❑ **Frequency:** 2.4GHz
  - ❑ **Range:** 10-100m
  - ❑ **Data Rates:** 250kbps

Zigbee

Advantages:

- Wireless nodes that are capable of multi-year battery lives.
- Direct communication
- It is less complex than Bluetooth.
- Low-power consumption
- Wireless
- Mesh-networking

Disadvantages:

- Working on small distance with low speed
- Costly

Applications of Zigbee :

- Road map products-tracking
- Consumer electronics
- Personal and healthcare
- Commercial and residential control
- Industrial and government markets worldwide
- Home networking
- Industrial control and management

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Z-Wave

- Z-Wave is a low-power RF communications technology that is primarily designed for home automation for products such as lamp controllers and sensors among many others.
- Optimized for reliable and low-latency communication of small data packets with data rates up to 100kbit/s, it operates in the sub-1GHz band and is impervious to interference from WiFi and other wireless technologies in the 2.4-GHz range such as Bluetooth or ZigBee.
- It supports full mesh networks without the need for a coordinator node and is very scalable, enabling control of up to 232 devices.
  - **Standard:** Z-Wave Alliance ZAD12837 / ITU-T G.9959
  - **Frequency:** 900MHz (ISM)
  - **Range:** 30m
  - **Data Rates:** 9.6/40/100kbit/s

Advantages of Z-Wave :

- Reliable and secure communication
- Simple installation
- Low power consumption
- Remote or local control
- A number of available devices, interoperability
- Affordability

Applications of Z-Wave :

- Home Security
- Energy Saving
- Smart product and Application based on IoT

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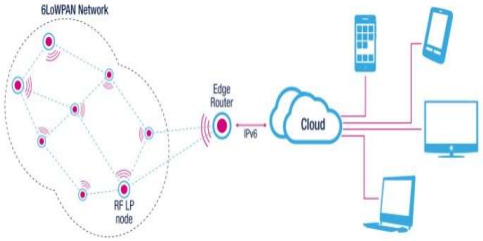
Comparison

Variable	Wi-Fi	Z-Wave	ZigBee	Thread	BLE
Year first launched in Market	1997	2003	2003	2015	2010
PHY/MAC Standard	IEEE 802.11.1	ITU-T G.9959	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.1
Frequency Band	2.4 GHz	900 MHz*	2.4 GHz	2.4 GHz	2.4 GHz
Nominal Range (0 dBm)	100 m	30 – 100 m	10 – 100 m	10 – 100 m	30 m
Maximum Data Rate	54 Mbit/s	40-100 kbit/s	250 kbit/s	250 kbit/s	1 Mbit/s
Topology	Star	Mesh	Mesh	Mesh	Scatternet
Power Usage	High	Low	Low	Low	Low
Alliance	Wi-Fi Alliance	Z-Wave Alliance	ZigBee Alliance	Thread Group	Bluetooth SIG

6LowPAN



- A key IP (Internet Protocol)-based technology is 6LowPAN (IPv6 Low-power wireless Personal Area Network).
- Rather than being an IoT application protocols technology like Bluetooth or ZigBee, 6LowPAN is a network protocol that defines encapsulation and header compression mechanisms.
- The standard has the freedom of frequency band and physical layer and can also be used across multiple communications platforms, including Ethernet, Wi-Fi, 802.15.4 and sub-1GHz ISM.
- Designed to send IPv6 packets over IEEE802.15.4-based networks and implementing open IP standards including TCP, UDP, HTTP, COAP, MQTT, and websockets.

❑ **Standard:** RFC6282
❑ **Frequency:** (adapted and used over a variety of other networking media including Bluetooth Smart (2.4GHz) or ZigBee or low-power RF (sub-1GHz)
❑ **Range:** N/A
❑ **Data Rates:** N/A

Applications of 6LowPAN :
- Equipment health monitoring
- Environment monitoring
- Security
- Home Automation
- Building automation

LoRaWAN

- LoRaWAN targets wide-area network (WAN) applications and is designed to provide low-power WANs with features specifically needed to support low-cost mobile secure bi-directional communication in IoT, M2M and smart city and industrial applications.
- Optimized for low-power consumption and supporting large networks with millions and millions of devices, data rates range from 0.3 kbps to 50 kbps.

- ❑ **Standard:** LoRaWAN
- ❑ **Frequency:** Various
- ❑ **Range**: 2-5km (urban environment), 15km (suburban environment)
- ❑ **Data Rates:** 0.3-50 kbps.

Geolocation
Enables GPS-free, low power tracking applications
Low cost
Reduces costs three ways: infrastructure investment, operating expenses and end-node sensors
Standardized
Improved global interoperability speeds adoption and roll out of LoRaWAN-based networks and IoT applications
Low power
Protocol designed specifically for low power consumption extending battery lifetime up to 20 years
Long range
Single base station provides deep penetration in dense urban/indoor regions, plus connects rural areas up to 30 miles away
Secure
Embedded end-to-end AES128 encryption
High capacity
Supports millions of messages per base station, ideal for public network operators serving many customers

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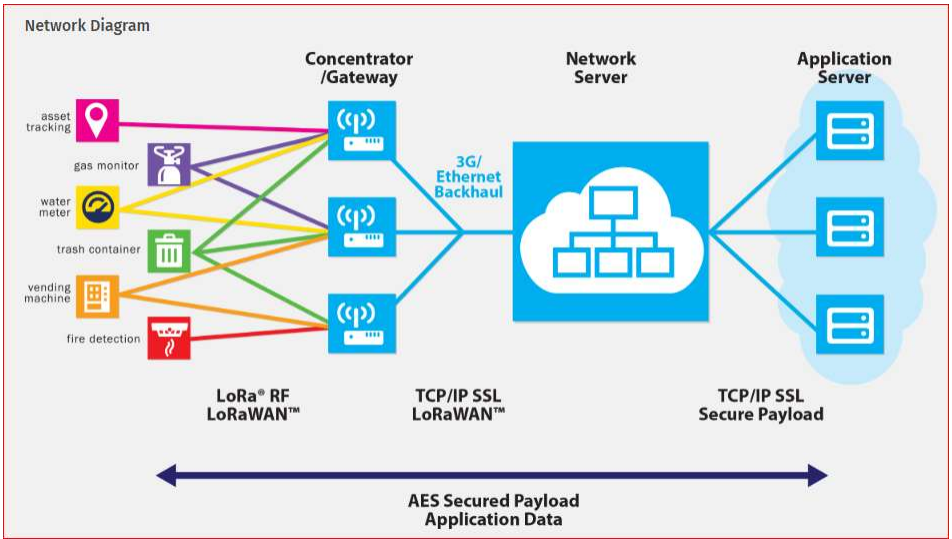
LoRaWAN Implementation



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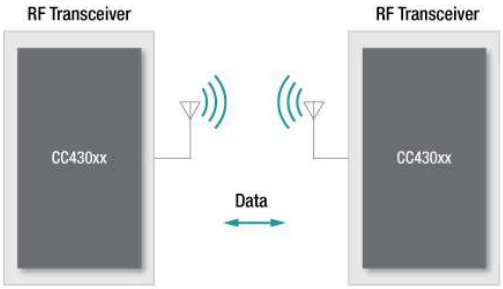
RF(Radio Frequency)



- Integrated circuits designed to transmit and/or receive radio signals.
- They have a radio transmitter and/or receiver.An umbrella term that includes many different pieces of hardware.
- It works on several different wireless protocols. Antennas are used to transmit and receive data.It uses either wireless serial or a specific protocol.
- The signals containing data or information are modulated.

Application of RF Module:

- Vehicle monitoring
- Remote control
- Telemetry
- Small-range wireless network
- Wireless meter reading
- Access control systems
- Wireless home security systems
- Industrial data acquisition system
- Radio tags reading.
- RF contactless smart cards

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Cellular

Standard	• GSM/GPRS/EDGE (2G) • UMTS/HSPA (3G), LTE (4G)
Frequencies	• 900/1800/1900/2100MHz
Range	• 35km max for GSM; 200km max for HSPA
Data Rates	• 35-170kps (GPRS), 120-384kbps (EDGE), • 384Kbps-2Mbps (UMTS), 600kbps-10Mbps (HSPA), 3-10Mbps (LTE)

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3G Technology

- 3G technology refer to third generation which was introduced in year 2000s.
- Data Transmission speed increased from 144kbps- 2Mbps.
- Typically called Smart Phones and features increased its bandwidth and data transfer rates to accommodate web-based applications and audio and video files.

Advantages of 3G:
Providing Faster Communication
Send/Receive Large Email Messages
High Speed Web / More Security
Video Conferencing / 3D Gaming
TV Streaming/ Mobile TV/ Phone Calls
Large Capacities and Broadband Capabilities

Disadvantages of 3G:
Expensive fees for 3G Licenses Services
It was challenge to build the infrastructure for 3G
High Bandwidth Requirement.
Expensive 3G Phones.

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4G Technology

- 4G technology refer to or short name of fourth Generation which was started from late 2000s.
- It is capable of providing 100Mbps — 1Gbps speed.One of the basic term used to describe 4G is MAGIC.
- MAGIC stands for Mobile Multimedia,Anytime Anywhere, Global Mobility Support, Integrated Wireless Solution, Customized Personal Services.
- Also known as Mobile Broadband Everywhere.

Advantages of 4G are same as of 3G.
Disadvantages of 4G:
- Battery uses is more
- Hard to implement
- Need complicated hardware
- Expensive equipment required to implement next generation network.

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3G vs 4G Comparison

3G vs 4G

Technology	3G	4G
Data Transfer Rate	3.1MB /sec	100MB/sec
Internet services	Broadband	Ultra Broadband
Mobile -TV Resolution	Low	High
Bandwidth	5 - 20 MHz	100+ MHz
Frequency	1.6 - 2 GHZ	2 - 8 GHz
Network Architecture	Wide Area Network	Hybrid Network
Signal Quality	Good	Best
Communication Type	Circuit Switching	Packet Switching

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Near Field Communication

- **NFC,**is the acronym for Near Field Communication.
- It is a short-range high frequency wireless communication technology that enables the exchange of data between devices.
- It enables two electronic devices, one of which is usually a portable device such as a smartphone, to establish communication by bringing them within 4 cm (1.6 in) of each other..

Advantages:
- Wide Research and Availability.
- Can be use in various situations.
- Very easy to used.
- Value added services.
- Compatible with existing RFID infrastructure.

Disadvantages:
- Only works in short ranges
- Low data transfer rate
- Can be costly for merchant companies to initially adopt the technology

Applications of NFC:
- Your phone is your t*ravel card.*
- Share data and files between devices.
- Get information by touching *smart posters.*
- Your phone is your *credit/debit card.*

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What is IIOT?

- Industries hold the biggest shares in the world's economy, so even a few seconds of downtime or a longer breakdown in one of these industries can cost millions.
- Industries attempt to diminish these possibilities by scheduling maintenance for their manufacturing plants. But what if the machine breaks down before maintenance? Or what if the maintenance was performed too early for a machine which was at that time extremely efficient? In both cases, the cost of maintenance is huge and non-recoverable.
- Manufacturers started wondering if it would be possible to accurately predict need, and so schedule these maintenance jobs.
- We can term this as predictive maintenance, and yes, this became possible with IIoT.

The Industrial IoT Consortium lists these 15 possible uses of IIoT: https://www.iiconsortium.org/

- Smart factory warehousing applications
- Predictive and remote maintenance.
- Freight, goods and transportation monitoring.
- Connected logistics.
- Smart metering and smart grid.
- Smart city applications.
- Smart farming and livestock monitoring.
- Industrial security systems
- Energy consumption optimization
- Industrial heating, ventilation and air conditioning
- Manufacturing equipment monitoring.
- Asset tracking and smart logistics.
- Ozone, gas and temperature monitoring in industrial environments.
- Safety and health (conditions) monitoring of workers.
- Asset performance management

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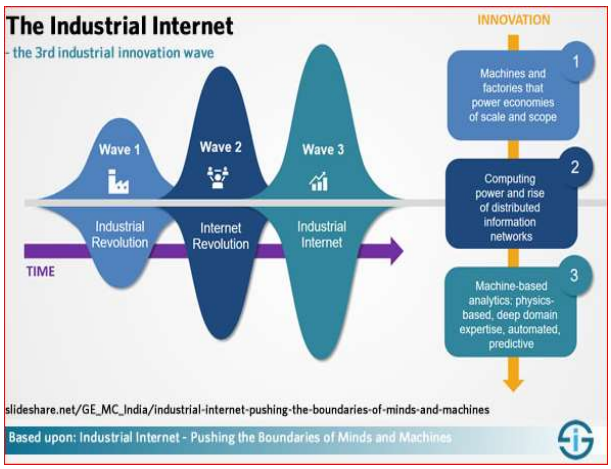
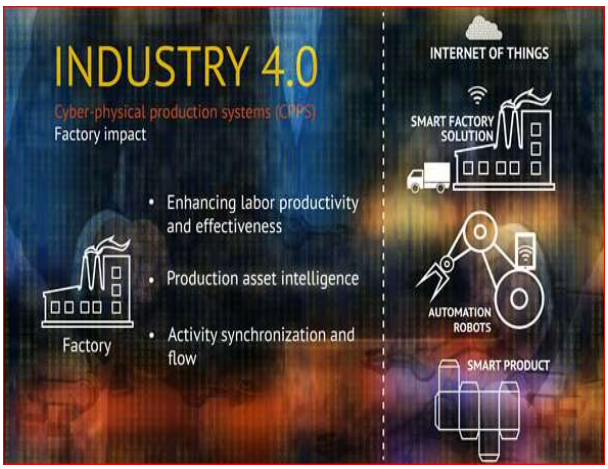
What is IIOT?





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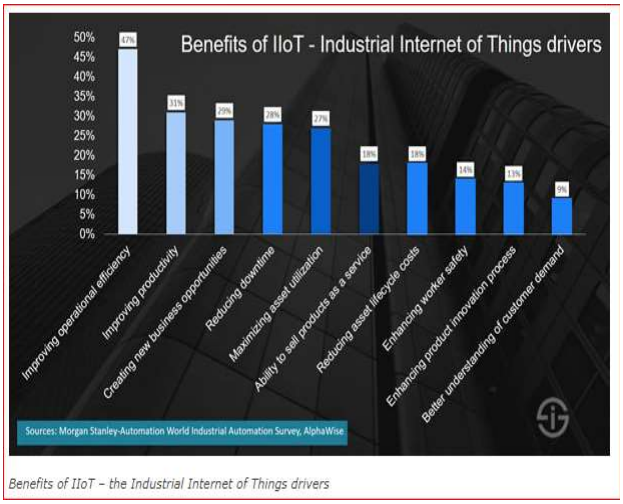
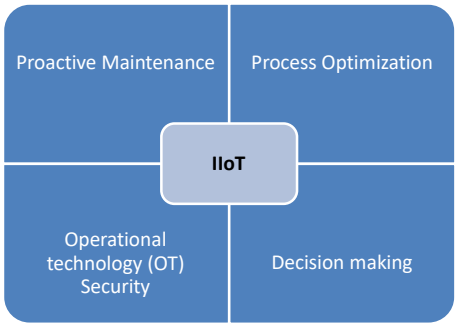
Industries Are Benefiting from IIOT



Benefits of IIoT – the Industrial Internet of Things drivers

- With the help of highly calibrated sensors, big data analytics, cheaper connectivity and the development in machine learning, industries have started to implement predictive maintenance, much of it supported by IIoT.
- This allows the optimum time for maintenance procedures to be predicted then scheduled, so lowering the cost of maintenance, which in turn helps the industry to become more efficient and deliver faster.



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IIOT Security Challenges

Security

- With various devices being connected together by default within IIoT, they are prone to cyber attacks and potential security malfunctioning.
- As with all internet technologies, security must be discussed and meticulously designed.

Interoperability

- With various devices and sensors needing to be connected, interoperability will also become a challenge.
- To have them all successfully connected can be extremely tough, as standards for each device vary and connection protocols will also differ from device to device.

Lack of Standardization

Money

People

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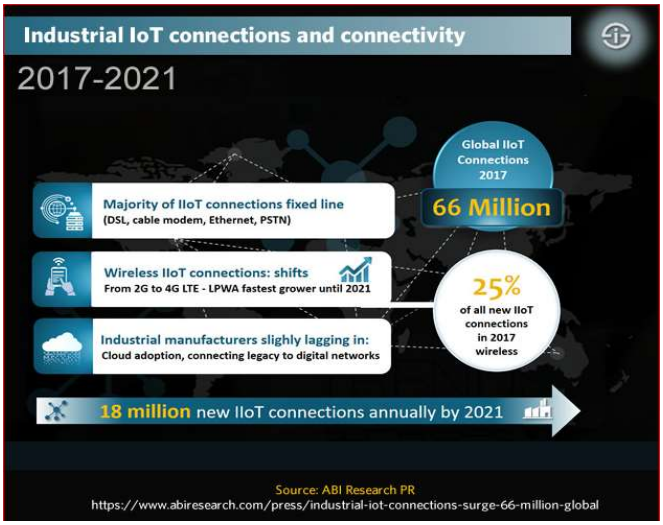
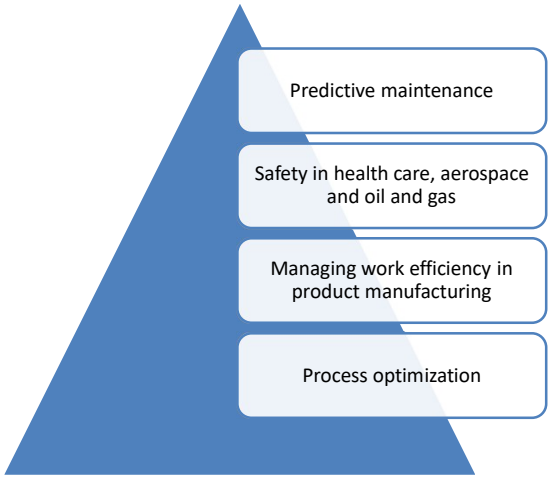
What is the future of IIoT?





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Predictive Analytics

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Predictive Analytics

- Predictive analytics uses historical data to predict future events. Typically, historical data is used to build a mathematical model that captures important trends.
- Predictive model is then used on current data to predict what will happen next, or to suggest actions to take for optimal outcomes.
- Predictive analytics brings together advanced analytics capabilities spanning ad-hoc statistical analysis, predictive modeling, data mining, text analytics, optimization, real-time scoring and machine learning.
- These tools help organizations discover patterns in data and go beyond knowing what has happened to anticipating what is likely to happen next.
- Predictive analytics has received a lot of attention in recent years due to advances in supporting technology, particularly in the areas of big data and machine learning.

Why Predictive Analytics?

- Rise of Big Data
- Increasing Competition
- Cutting-Edge Technologies for Big Data and Machine Learning

Predictive Analytics Benefits

- Enable A Smarter Operations
- Reduce Expenses
- Increase Profitably

Predictive Analytics Process

- **Define Project** – Define the project outcomes, deliverable, scope of the effort, business objectives, identify the data sets that are going to be used.
- **Data Collection** – Data mining for predictive analytics prepares data from multiple sources for analysis. This provides a complete view of customer interactions.
- **Data Analysis** – Data Analysis is the process of inspecting, cleaning and modelling data with the objective of discovering useful information, arriving at conclusion
- **Statistics** – Statistical Analysis enables to validate the assumptions, hypothesis and test them using standard statistical models.
- **Modelling** – Predictive modelling provides the ability to automatically create accurate predictive models about future. There are also options to choose the best solution with multi-modal evaluation.
- **Deployment** – Predictive model deployment provides the option to deploy the analytical results into everyday decision making process to get results, reports and output by automating the decisions based on the modelling.
- **Model Monitoring** – Models are managed and monitored to review the model performance to ensure that it is providing the results expected.

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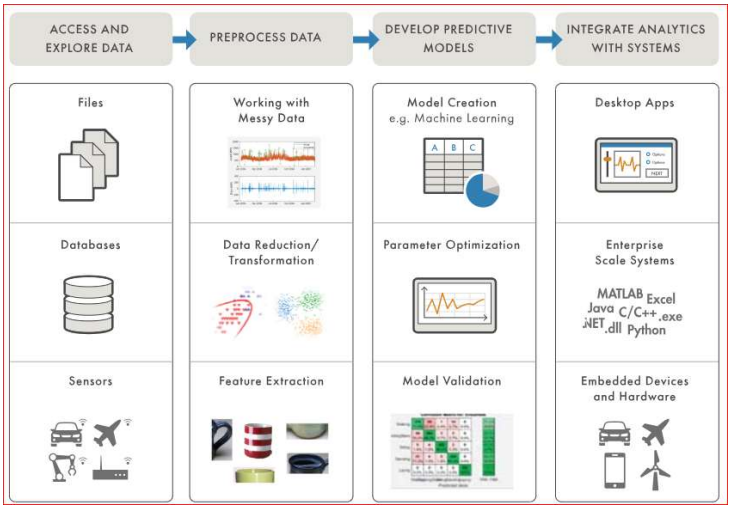
Predictive Analytics Workflow



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Predictive Analytics Examples

- Companies developing driver assistance technology and new autonomous vehicles use predictive analytics to analyze sensor data from connected vehicles and to build driver assistance algorithms.
- To improve aircraft up-time and reduce maintenance costs, an engine manufacturer created a real-time analytics application to predict subsystem performance for oil, fuel, liftoff, mechanical health, and controls.
- Sophisticated forecasting apps use models that monitor plant availability, historical trends, seasonality, and weather.
- Financial institutions use machine learning techniques and quantitative tools to predict credit risk.
- A plastic and thin film producer saves 50,000 Euros monthly using a health monitoring and predictive maintenance application that reduces downtime and minimizes waste.
- An asthma management device records and analyzes patients' breathing sounds and provides instant feedback via a smart phone app to help patients manage asthma and COPD.

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Predictive Analytics vs. Prescriptive Analytics

- Organizations that have successfully implemented predictive analytics see prescriptive analytics as the next frontier.
- **Predictive analytics** creates an estimate of what will happen next; **prescriptive analytics** tells you how to react in the best way possible given the prediction.
- Prescriptive analytics is a branch of data analytics that uses predictive models to suggest actions to take for optimal outcomes.
- Prescriptive analytics relies on optimization and rules-based techniques for decision making. Forecasting the load on the electric grid over the next 24 hours is an example of predictive analytics, whereas deciding how to operate power plants based on this forecast represents prescriptive analytics.

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Machine Learning

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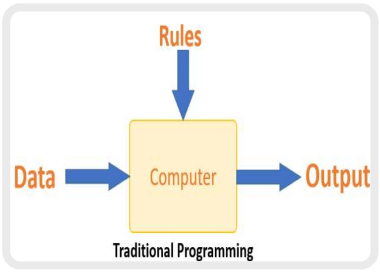
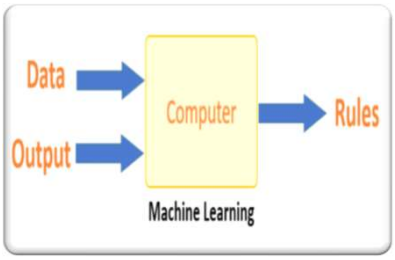
Machine Learning

- Machine Learning (ML) helps in making machines acquire human-like behavior, while retaining their original capabilities.
- Machine can singularly learn from the data (i.e., example) to produce accurate results.
- Machine learning combines data with statistical tools to predict an output. This output is then used by corporate to makes actionable insights.
- The machine receives data as input, use an algorithm to formulate answers.
- ML is also used for a variety of task like fraud detection, predictive maintenance, portfolio optimization, automatize task and so on





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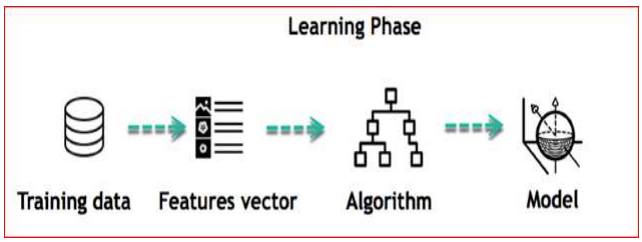
Learning Phase

- The core objective of machine learning is the **learning** and **inference.**
- First of all, the machine learns through the discovery of patterns.
- One crucial part of the data scientist is to choose carefully which data to provide to the machine. The list of attributes used to solve a problem is called a feature vector.
- The machine uses some fancy algorithms to simplify the reality and transform this discovery into a model. Therefore, the learning stage is used to describe the data and summarize it into a model.



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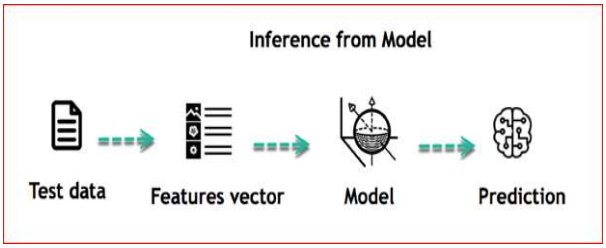
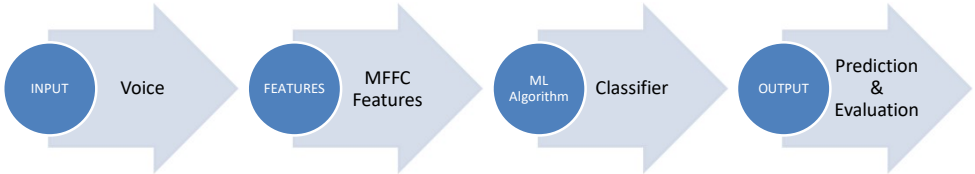
Inference

- When the model is built, it is possible to test how powerful it is on never-seen-before data.
- The new data are transformed into a features vector, go through the model and give a prediction. This is all the beautiful part of machine learning.
- There is no need to update the rules or train again the model. You can use the model previously trained to make inference on new data.
- The life of Machine Learning programs is straightforward and can be summarized in the following points:
    - Define a question
    - Collect data
    - Visualize data
    - Train algorithm
    - Test the Algorithm
    - Collect feedback
    - Refine the algorithm
    - Loop 4-7 until the results are satisfying
    - Use the model to make a prediction



ML : Problem-solving Approaches

- **Data preparation:** Input data is usually pre-processed, and then fed into the next module for further processing.
- **Feature extraction:** Features are quantitative variables which best represent the input data. Several algorithms for feature extraction are available in research literature, specific to different domains.
- **Classifier:** A typical task of ML is classification. It goes through the data instances and classifies them into one or another class after building the classifier model using training data.
- **Prediction and Evaluation:** A classifier predicts the class label of a given instance on an unknown sample. The prediction performance is measured for correctness, using performance metrics such as accuracy.



- ***Audio data is described using very well known mel-frequency cepstral coefficient (MFCC) features***

Machine Learning Applications and Tools

Tools For Building Machine Learning Applications

Tool	Functionality/Remarks
Weka	GUI based interface with implemented algorithms
R	A rich package with inbuilt algorithms
Python	A computational package with many rich libraries
Orange	GUI interface (similar to Weka)
RapidMiner	GUI interface (similar to Weka)
MATLAB	The richest computational package, but commercial
Octave	An open source alternative to MATLAB

Applications Of Machine Learning

- Speech processing.
- Music information retrieval
- Computer vision
- Video processing Sentiment.
- Recommender systems
- Anomaly detection
- Document
- Cognitive radio
- Robotics

MODULE 3

- **Introduction to Raspberry Pi 3**
- **Introduction to Python**
- **Introduction to GPIO and Programming GPIO's with Python**

MODULE 4

- **Understanding Raspberry Pi 4**
- **Introduction to Python**
- **Introduction to GPIO and Programming GPIO's with Python**
- **Interfacing Sensors with Pi**
- **Interfacing Actuators with Pi using Serial Communication**
- **Installation of (LAMP) Linux, Apache, MySQL, and PHP Web Server on Raspberry Pi 4**

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Introduction to Raspberry Pi 4

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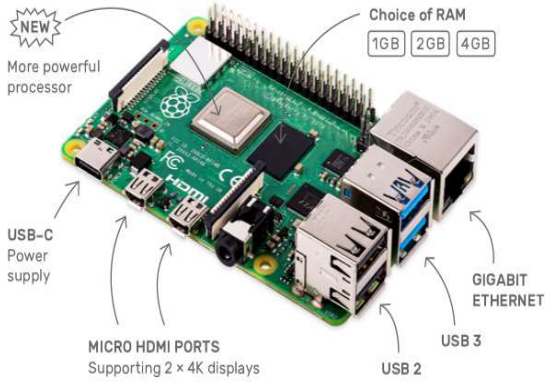
Introduction to Raspberry Pi 4



Raspberry Pi

- Microprocessor
- Runs on Linux/Windows
- More software oriented programming
- Full Networking System
- Installed by default on the Raspberry Pi:
  - C & C++
  - Java
  - Scratch
  - Ruby
- The Raspberry Pi Foundation recommends Python

Why Raspberry Pi?

- Low cost, credit-card sized computer
- Capable of doing everything you'd expect a desktop computer to do
- Raspbian is the Foundation's official Operating System

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Raspberry Pi 4

Hardware

- Quad core 64-bit ARM-Cortex A72 running at 1.5GHz
- 1, 2 and 4 Gigabyte LPDDR4 RAM options
- H.265 (HEVC) hardware decode (up to 4Kp60)
- H.264 hardware decode (up to 1080p60)
- VideoCore VI 3D Graphics
- Supports dual HDMI display output up to 4Kp60

Software

- ARMv8 Instruction Set
- Mature Linux software stack
- Actively developed and maintained
  - Recent Linux kernel support
  - Many drivers upstreamed
  - Stable and well supported userland
  - Availability of GPU functions using standard APIs

Interfaces

- 802.11 b/g/n/ac Wireless LAN
- Bluetooth 5.0 with BLE
- 1x SD Card
- 2x micro-HDMI ports supporting dual displays up to 4Kp60 resolution
- 2x USB2 ports
- 2x USB3 ports
- 1x Gigabit Ethernet port (supports PoE with add-on PoE HAT)
- 1x Raspberry Pi camera port (2-lane MIPI CSI)
- 1x Raspberry Pi display port (2-lane MIPI DSI)
- 28x user GPIO supporting various interface options:
  - Up to 6x UART
  - Up to 6x I2C
  - Up to 5x SPI
  - 1x SDIO interface
  - 1x DPI (Parallel RGB Display)
  - 1x PCM
  - Up to 2x PWM channels
  - Up to 3x GPCLK outputs

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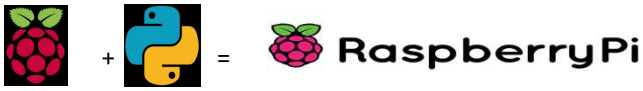
Raspberry Pi Origin

- Raspberry + Python = Raspberry Pi



- Broadcom + University Of Cambridge = Raspberry Pi Foundation
- Alternatives of Raspberry Pi
  - ❑ Banana Pi
  - ❑ Orange Pi
  - ❑ Jeagal Bones

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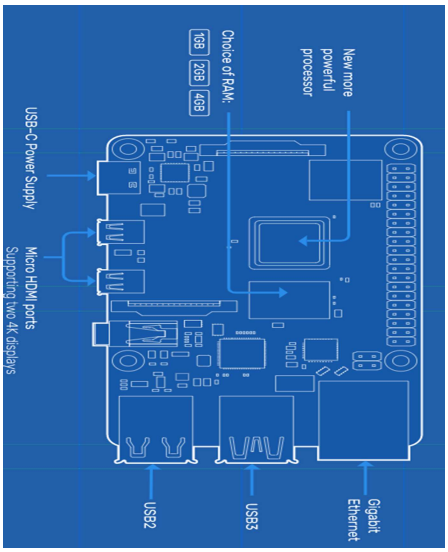
Technical Specification Raspberry Pi 4



- Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- 1GB, 2GB or 4GB LPDDR4-3200 SDRAM (depending on model)
- 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE
- Gigabit Ethernet
- 2 USB 3.0 ports; 2 USB 2.0 ports.
- Raspberry Pi standard 40 pin GPIO header (fully backwards compatible with previous boards)
- 2 × micro-HDMI ports (up to 4kp60 supported)
- 2-lane MIPI DSI display port
- 2-lane MIPI CSI camera port
- 4-pole stereo audio and composite video port
- H.265 (4kp60 decode), H264 (1080p60 decode, 1080p30 encode)
- OpenGL ES 3.0 graphics
- Micro-SD card slot for loading operating system and data storage
- 5V DC via USB-C connector (minimum 3A*)
- 5V DC via GPIO header (minimum 3A*)
- Power over Ethernet (PoE) enabled (requires separate PoE HAT)
- Operating temperature: 0 – 50 degrees C ambient

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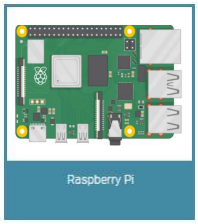
What You Will Need


Raspberry Pi


Monitor or TV


HDMI cable


USB keyboard


USB mouse


Power supply


8GB SD card

LET'S START LAB

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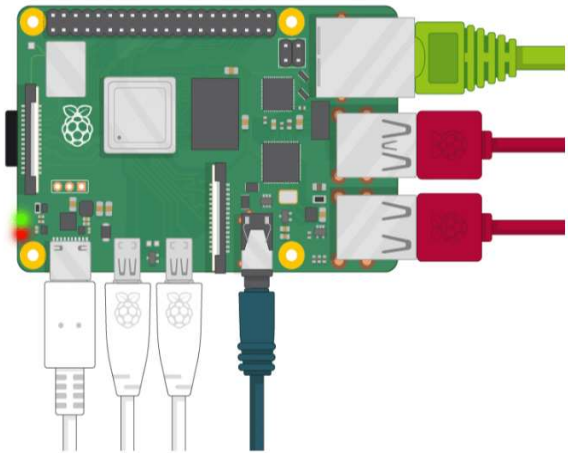
Booting Up Pi for the First Time



- Insert the microSD card into the microSD card slot of the Pi.
- Connect the Pi to the HDMI monitor.
- If you are connecting the VGA monitor, connect it using the HDMI to VGA converter.
- Connect the USB mouse and the USB keyboard.
- Connect the Pi to a power supply using the micro USB power cable.
- Make sure the power is switched off at this point.
- Check all the connections once and then switch on the power supply of the Pi.

Introduction to Python

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Python

- Python was first designed by Guido van Rossum and appeared the first time in 1991 publicly.
- Interpreted high-level programming language and was created on an ideology that pays particular focus on code readability.
- Provides a platform for explicit programming on both small and large scales
- Exhibits a dynamic type system and automatic memory management
- Supports multiple programming paradigms like imperative, functional and procedural.
- Equipped with an extensive and comprehensive standard library
- Unique feature of Python is being an Object-oriented (OOP) program is the one which is based on data instead of logic or objects instead of actions
- The Python interpreter can be run in two ways:
  - As an interactive shell to execute individual commands, or as a command-line program to execute standalone scripts.
  - The integrated development environment (IDE) bundled with Python and the Raspberry Pi is called IDLE

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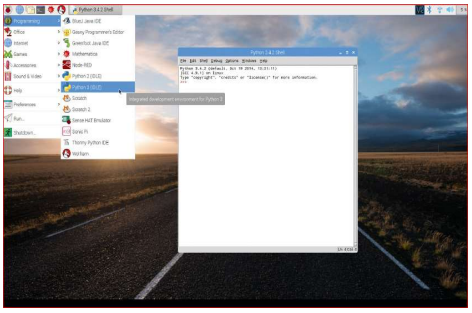
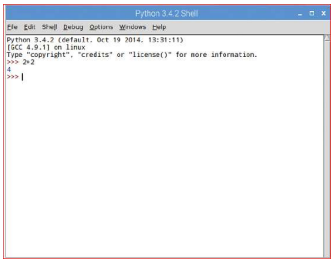
Start Python in Raspberry Pi



```
>>> print("Hello everyone!")
Hello everyone!
>>>
```



Python IDE Colour Coding

Colour	Use for	Examples
Black	Data & variables	`23.6 area`
Green	Strings	`"Hello World"`
Purple	Functions	`len() print()`
Orange	Commands	`if for else`
Blue	User functions	`get_area()`
Dark red	Comments	`#Remember VAT`
Light red	Error messages	`SyntaxError:`

Python

Advantages of Python

- Extensive Support Libraries
- A powerful and fast programming language.
- Clear, readable, and easy to understand syntax.
- Dynamic type programming language.
- Python Runs immediately.
- The python community always provides support to Python users.
- Modular and portable programming language.
- Less coding is required.
- Open source language.
- Easy to maintain.

Disadvantages of Python

- Design restrictions.
- Underdeveloped database access layers.
- Weak in mobile computing and browsers.
- Speed limitations.

Introduction to GPIO and Programming GPIO's with Python

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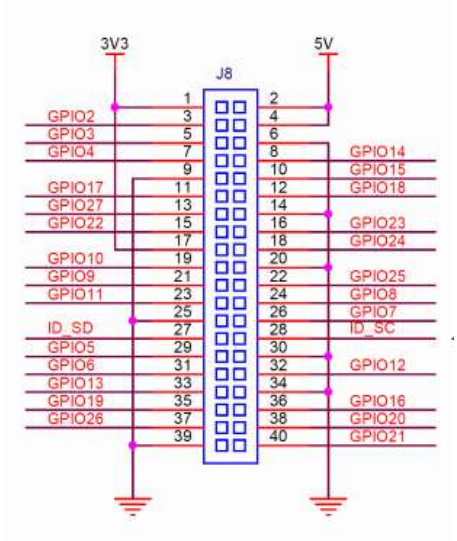
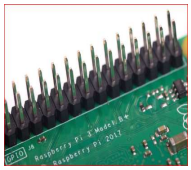
GPIO



- **General Purpose Input Output**
  - One of the keys to the success of the Raspberry Pi is a design that offers GPIO interfaces.
  - In the PC era, people had to attach their home-brewed hardware through the PC's printer parallel interface or work with the more cumbersome RS-232 interface.
  - With the Pi, you have access to serial data, a clock, I2C, serial peripheral interface (SPI), pulse width modulation (PWM), and general I/O signaling.
  - This arrangement is far more capable and opens a world of options to the Pi user.



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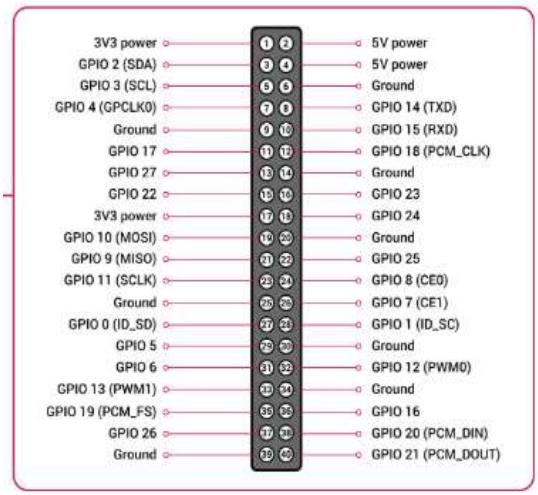
GPIO Pin Numbering



- An IoT device has a hardware component that provides an interface for external devices to read digital data or to get electricity.
- This is called **GPIO** or **General Purpose Input Output**.
- This hardware component is basically a series of pins that can be connected to external devices.
- These GPIO pins can be controlled by a program.
- For example, based on some conditions, we can turn on a GPIO pin which provides 5V electricity and any device which is connected to this pin will turn on.
- This program can listen to a message sent from the internet and control this pin.
- Hence the IoT, Building such an IoT device from scratch can be tough since it has a lot of components to work with.
- There are pre-built devices that you can purchase and they are extremely cheap.
- These devices come with GPIO hardware and means to connect to the internet.

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Interfacing with Sensors, and Actuators using Raspberry Pi 4

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Sensors

1.
- Sense or track real time data

2.
- Converts gathered information into digital codes

3.
- Like nervous system continuously collects streams of data to be further processed.

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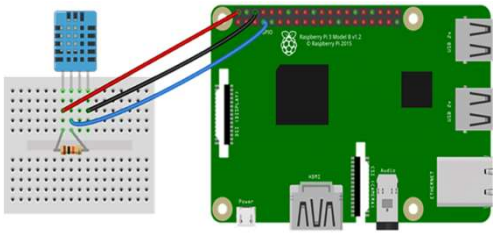
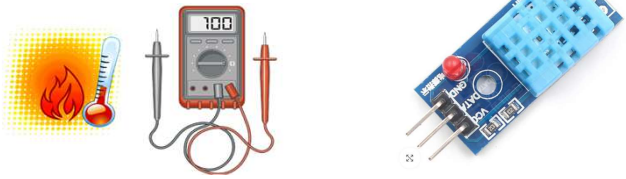
Temperature & Humidity Sensor (DHT11)





- A temperature sensor measures the hotness or coolness of an object.
- The sensor's working base is the voltage that's read across the diode.
- The temperature rises whenever the voltage increases.

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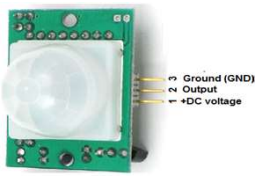
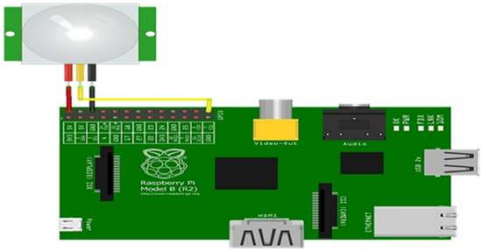
PIR / Motion Sensor





- PIR sensors allow you to sense motion, almost always used to detect whether a human has moved in or out of the sensors range.
- They are often referred to as PIR, "Passive Infrared" Sensors.

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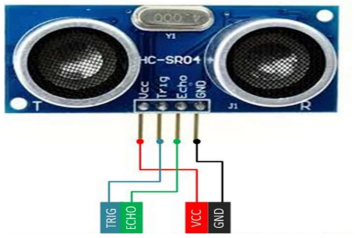
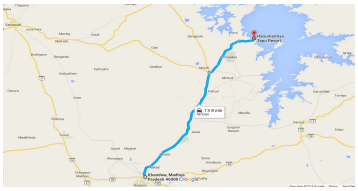
Ultrasonic Sensor





An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves.
It measures distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back.

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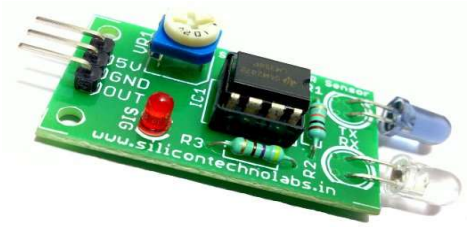
Infrared Sensor



- An infrared sensor is used to sense certain characteristics of its surroundings by emitting or detecting infrared radiation.

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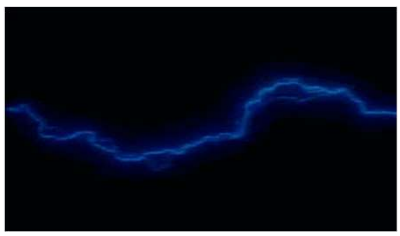
Current Sensor



- A current sensor is a device that detects and converts current to an easily measured output voltage, which is proportional to the current through the measured path.
- Current sensing means developing a voltage signal which is representative of the current flowing at the particular place of interest in the circuit.

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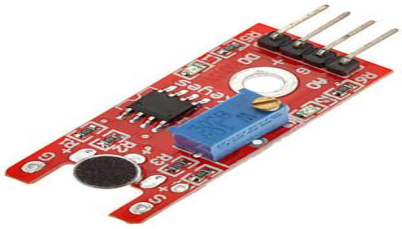
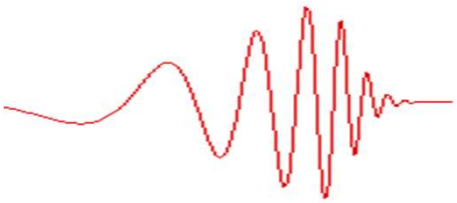
Sound Sensor





- Sound Sensor can detect the sound intensity of the environment.
- When you make a sound, the diaphragm vibrates and thus the attached coil moves in the magnetic field, producing current.
- The sound sensor is able to measure noise levels in decibels (dB) at frequencies around 3-6kHz where the human ear is most sensitive.

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Actuators

1.
- Produces actions or real time effects

2.
- Uses Energy to make any action happen in real time

3.
- Converts Electrical Output to Physical Output

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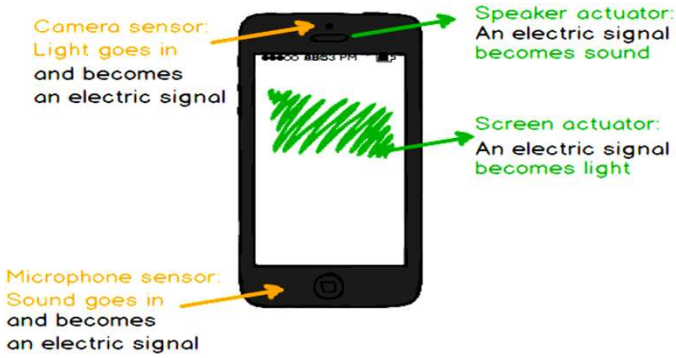
Sensors Vs Actuators



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Hydraulic Actuators

- Depends on hydraulic power and a cylinder or fluid monitor to act on some mechanical process.
- This mechanical motion gives an output in terms of linear, rotary or oscillatory motion

E.g. : Hydraulic Machine

- Similar to hydraulic actuators only they use compressed gas instead of liquid.
- Pneumatic actuators enable large forces to be produced from relatively small pressure changes.
- Pneumatic actuators convert compressed air into rotary or linear motion.

E.g. diaphragm cylinders, telescoping cylinders and through-rod cylinders.

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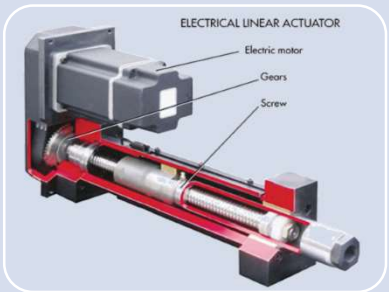
Electric Actuators



Are powered by motors that convert electrical energy into mechanical torque.

E.g. Electric Motor

Mechanical actuators convert rotary motion to linear motion.

E.g. Screw jacks and rack & pinion

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Installation of (LAMP) Linux, Apache, MySQL, and PHP Web Server on Raspberry Pi 4

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What is Web Server?

- A *web server* is a computer that serves content by using standard Internet protocols.
- Web servers are called HTTP servers because they use the Hypertext Transfer Protocol (HTTP) as their base network protocol. Many other protocols are involved in delivering web content, of course, including Internet Protocol (IP), Transmission Control Protocol (TCP), and Address Resolution Protocol (ARP).
- Any device that can (a) connect to a local area network or the Internet, and (b) has a web browser or web-aware application installed makes use of these standard protocols. The content that is served by a web server consists of the following media types at the very least:
  - **Web Pages:** Text that is formatted with hyperlinks, pointers to other content on the same page, the same website, or a different website (representative file types: .htm, .html, .php, .aspx).
  - **Image Images:** These can be static or animated pictures of the bitmap or vector variety (representative file types: .gif, .jpg, .png, .svg).
  - **Image Audio:** These can be background clips or full songs (representative file types: .mp3, .wav, .m4a).
  - **Image Movies:** Video segments of any length, displayed in either standard or high definition (representative file types: .mov, .mp4).
  - **Image Interactions:** These can be games, tutorials, simulations, and so forth (representative file types: .swf, .xap).

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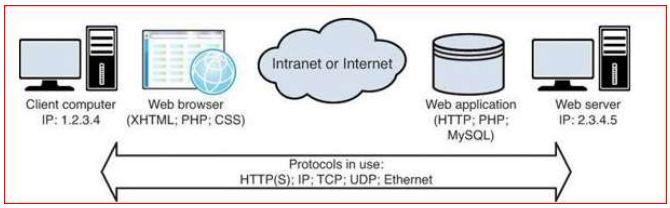
What Is the Stack?

- In web development terminology, a protocol stack is a suite of related networking protocols and technologies that fit together like finger in glove to accomplish particular kinds of work.
- Many years ago, when websites were simply static collections of manually created HTML web pages.
- Nowadays, any web developer or designer needs dynamically generated web pages that pull data from a database such as MySQL, Oracle, or Microsoft SQL Server. These dynamic websites are called data-driven web applications
  - **Linux:** This is the base operating system for the web server.
  - **Apache:** This is the world-standard open source HTTP server software.
  - **MySQL:** This is the world-standard semi-open source Structured Query Language (SQL) relational database management system (RDBMS).
  - **PHP:** This is the world-standard open source web development programming language. Incidentally, PHP is a strange acronym that stands for Hypertext Pre Processor.



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MODULE 5

- **Socket Programming (TCP & UDP)**
- **HTTP IoT Protocol (Python with Flask)**
- **Introduction to MQTT IoT Protocol**
- **Mosquito IoT Broker and Gateway**

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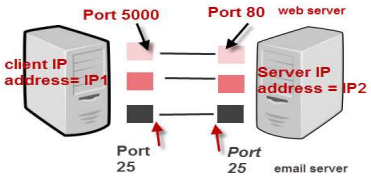
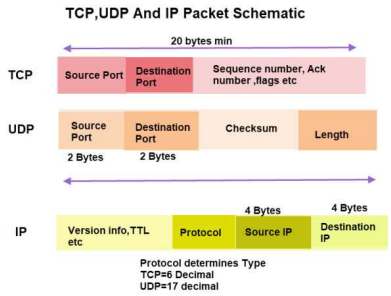
Socket Programming (TCP & UDP)



IP Address + Port number = Socket

TCP/IP Ports And Sockets

- On a TCP/IP network every device must have an IP address.
- The **IP address identifies the device** e.g. computer.
- However an IP address alone is not sufficient for running network applications, as a computer can run **multiple applications** and/or **services**.
- Just as the IP address identifies the computer, The network **port** identifies the **application**
- ***The use of ports allow computers/devices to run multiple services/applications.*** **or service** running on the computer.



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HTTP IoT Protocol (Python with Flask)

- Pip install Flask
- Create a Flask named folder
- Create app.py file in created folder
- Create Html Templates

- Flask is called a micro framework because it does not require particular tools or libraries.
- It has no database abstraction layer, form validation, or any other components where pre-existing third-party libraries provide common functions.
- However, Flask supports extensions that can add application features as if they were implemented in Flask itself.
- Flask has been identified as one of a series of microdevelopment frameworks.
- Flask can be thought of as a "lightweight" web server with limited but reasonable functionality as compared to the much larger and capable Apache web server
- http://flask.pocoo.org/

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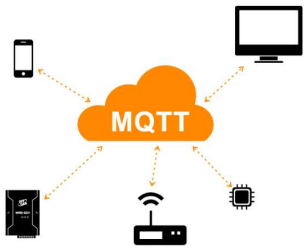
MQTT IoT Protocol



- MQTT is one of the most commonly used protocols in IoT projects. It stands for Message Queuing Telemetry Transport.
- In addition, it is designed as a lightweight messaging protocol that uses publish/subscribe operations to exchange data between clients and the server. Furthermore, its small size, low power usage, minimized data packets and ease of implementation make the protocol ideal of the "machine-to-machine" or "Internet of Things" world.

Why MQTT?

- MQTT has unique features you can hardly find in other protocols, like:
- It's a lightweight protocol. So, it's easy to implement in software and fast in data transmission.
- It's based on a messaging technique. Of course, you know how fast your messenger/WhatsApp message delivery is. Likewise, the MQTT protocol.
- Minimized data packets. Hence, low network usage.
- Low power usage. As a result, it saves the connected device's battery.
- It's real time! That's is specifically what makes it perfect for IoT applications.

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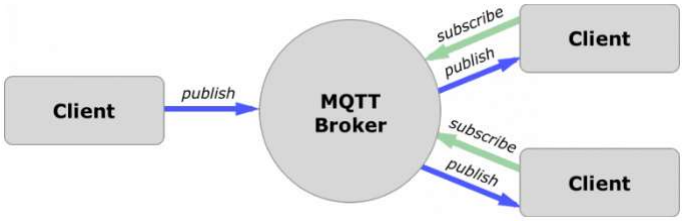
How MQTT Works?



- Like any other internet protocol, MQTT is based on clients and a server. Likewise, the server is the guy who is responsible for handling the client's requests of receiving or sending data between each other.
- MQTT server is called a broker and the clients are simply the connected devices.
  So:
- When a device (a client) wants to send data to the broker, we call this operation a "publish".
- When a device (a client) wants to receive data from the broker, we call this operation a "subscribe".
- In addition, These clients are publishing and subscribing to topics. So, the broker here is the one that handles the publishing/subscribing actions to the target topics.

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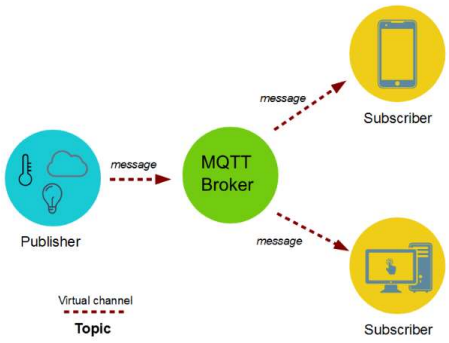
MQTT Components



- That takes us to the MQTT components, which are 5 as follows:
- Broker, which is the server that handles the data transmission between the clients.
- A topic, which is the place a device want to put or retrieve a message to/from.
- The message, which is the data that a device receives "when subscribing" from a topic or send "when publishing" to a topic.
- Publish, is the process a device does to send its message to the broker.
- Subscribe, where a device does to retrieve a message from the broker.

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Why not HTTP

- HTTP is slower, more overhead and power consuming protocol than MQTT.
- Slower: because it uses bigger data packets to communicate with the server.
- Overhead: HTTP request opens and closes the connection at each request, while MQTT stays online to make the channel always open between the broker “server” and clients.
- Power consuming: since it takes a longer time and more data packets, therefore it uses much power.

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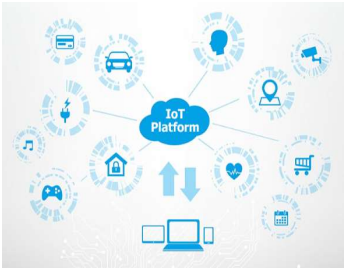
Mosquitto Broker

- Mosquitto is an open source message broker that implements the MQTT protocol.
- It’s lightweight and suitable for use on all devices from a low power single board like Arduino, ESP32 to full computers and servers.
- But rather than using the Mosquitto on a local PC, you will need to use a cloud-based server that implements the Mosquitto broker.
- That’s necessary to make your IoT projects controllable over the internet



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MODULE 6 & 7

- **Raspberry Pi 4 as a Smart Home Automation Hub**
- **Connecting Raspberry Pi 4 to Cloud Platforms (PubNub / AWS / BlueMix) and Data Exchange**
- **Raspberry Pi as a Video Streaming Server (LAN / Remote Network)**
- **Mobile Application using MIT App Inventor**

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Raspberry Pi 4 as a Smart Home Automation Hub

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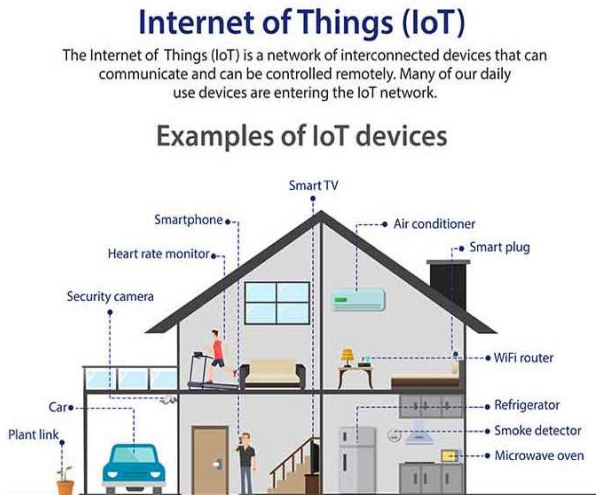
Smart Home Automation Hub with IoT



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Connecting Raspberry Pi 4 to Cloud Platforms

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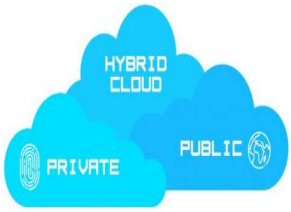
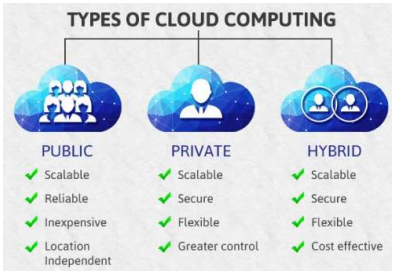
IoT Cloud Platform Characteristics





- *Cloud computing , or on-demand computing, is a term used for using remote servers typically hosted on a public network like the Internet to store, process and manage data.*

Types of Cloud Computing

Private Cloud

- Private clouds are solely owned and operated by an organization for a limited group of users.

Public Cloud

- Public clouds are owned and operated by organizations that want to offer access over public network to various computing resources.

Hybrid Cloud

- Hybrid Cloud utilizes features from both private and public Cloud computing. It may choose to host some features and functions in-premises for privacy reasons while getting some additional features from a publicly hosted Cloud.

Community Cloud

- A community cloud is shared between organizations with a common goal or that fit into a specific community (professional community, geographic community, etc.).

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Cloud Computing Offerings Example

Software-as-a-Service (SaaS)

- In this type of offering, applications are hosted on servers accessible over a public network.

Platform-as-a-Service (PaaS)

- This type of offering provides the customer with a platform to develop, run, and manage applications without getting involved in the complexity of developing the entire development stack from scratch.

Infrastructure-as-a-Service (IaaS)

- This type of offering is best suited for startup companies that need all computing resources (network, data processing, storage) but don't want to invest in setting up their own data center. It offers better flexibility and scalability.

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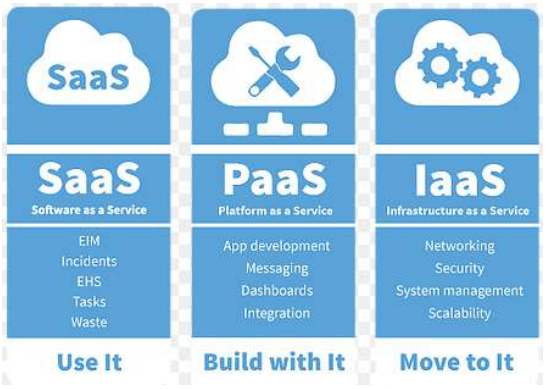
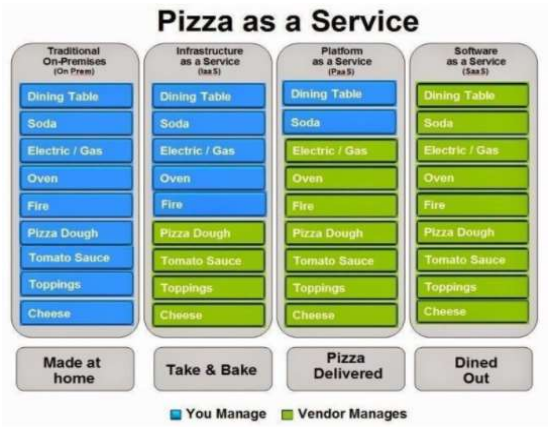
Cloud Computing Offerings Example





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Cloud Computing

Uses of Cloud Computing

- Create new apps and services as well as store, back up and recover data
- Host websites and blogs
- Stream audio and video
- Deliver on demand software services
- Analyse data for patterns
- Make predictions

Benefits of Cloud Computing

- Environment-friendly
- Better Data Security
- Work From Anywhere
- Reduced Expenditure Costs
- Updates And Maintenance
- Easy Disaster Recovery Solutions
- Scalability

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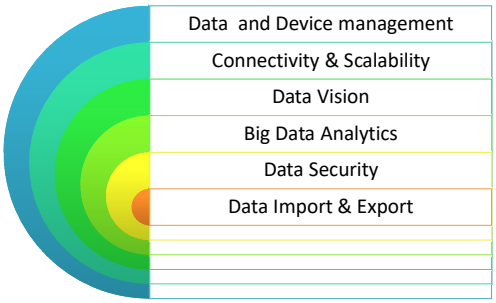
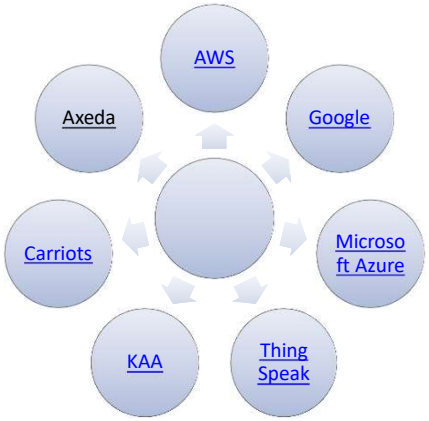
IoT Cloud Platform Characteristics





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Interfacing with Web Cameras using Raspberry Pi 4

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Connect Webcam to Raspberry Pi

- Locally/Remotely accessing webcams is a fairly common activity that many people perform routinely
- Raspberry PI persists in its pride stage due to its relevance in performing image processing applications.
- Real time image processing schemes can be developed using a Raspberry Pi, as it supports the webcam interface, and there by we can process the algorithms for detection, recognition, segmentation, surveillance etc.

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Raspberry Pi as a Video Streaming Server

- With its tiny dimensions and HDMI connection, the Raspberry Pi is ideally suited to become a great media server.
- It's amazingly easy to set up a Raspberry Pi to stream the latest movies and TV shows.

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Mobile Application using MIT App Inventor

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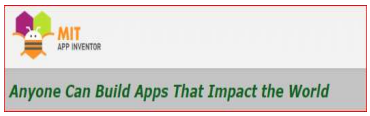
MIT App Inventor

- MIT App Inventor is an intuitive, visual programming environment that allows everyone, even children to build fully functional apps for smartphones and tablets.
- Blocks-based tool facilitates the creation of complex, high-impact apps in significantly less time than traditional programming environments.
- The MIT App Inventor project seeks to democratize software development by empowering all people, especially young people, to move from technology consumption to technology creation.
- A small team of CSAIL staff and students, led by Professor Hal Abelson, forms the nucleus of an international movement of inventors.
- In addition to leading educational outreach around MIT App Inventor and conducting research on its impacts, this core team maintains the free online app development environment that serves more than 6 million registered users.
- Blocks-based coding programs inspire intellectual and creative empowerment.
- MIT App Inventor goes beyond this to provide real empowerment for kids to make a difference a way to achieve social impact of immeasurable value to their communities.
- In fact, App Inventors in school and outside of traditional educational settings have come together and done just that
- http://appinventor.mit.edu



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MODULE 8

- **Use of Node-Red Interface**
- **Use of Various GPIO Nodes**
- **Use of the MQTT node, Email Node, SMS node**

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Use of Node-Red Interface

- Node-RED is a visual tool for wiring the Internet of Things developed by IBM Emerging Technology and the open source community. Using Node-RED, developers wire up input, output and processing nodes to create flows to process data, control things, or send alerts.
- It works by allowing you to wire up web services or custom “nodes” to each other, or to things, to do things like:
  - Send an email on a rainy weather forecast.
  - Push sensor data to services like Twitter.
  - Perform complex analysis on data with ease.
- Node-RED is a visual tool for non-programmers to work with the Internet of Things, it can be used to build application fasters and reduce the “go to market” time for IoT products.
- Node-RED can be used to easily interface hardware devices, APIs, and other online services together in new and interesting ways.
- Node-RED is an open source IoT tool and has been implemented by the IBM Emerging Technology organization. It is written in JavaScript and works on the NodeJS platform.
- Node-RED’s dashboard nodes provide a comprehensive set of UI components for building basic dashboards suitable for the Internet of Things (IoT) – offering graphs, gauges, basic text as well as sliders and inputs.
- However, there will always be situations when you need something custom.
- The template node is the solution and in this tutorial we’ll show you a quick example of using it to create your own UI widget

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Email Node

- **Nodemailer** is a module for Node.js applications to allow easy as cake email sending.
- The project got started back in 2010 when there was no sane option to send email messages, today it is the solution most Node.js users turn to by default.

Nodemailer features

- A single module with zero dependencies – code is easily auditable, as there are no dark corners
- Heavy focus on security, no-one likes RCE vulnerabilities
- Unicode support to use any characters, including emoji 💪
- Windows support – you can install it with npm on Windows just like any other module, there are no compiled dependencies. Use it hassle free from Azure or from your Windows box
- Use HTML content, as well as plain text alternative
- Add Attachments to messages
- Embedded image attachments for HTML content – your design does not get blocked
- Secure email delivery using TLS/STARTTLS
- Different transport methods in addition to the built-in SMTP support
- Sign messages with DKIM
- Custom Plugin support for manipulating messages
- Sane OAuth2 authentication
- Proxies for SMTP connections
- ES6 code – no more unintentional memory leaks, due to hoisted var's
- Autogenerated email test accounts from Ethereal.email

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