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A Comprehensive Review: Internet of Things (IOT)

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Abstract: *"Internet of things"– is a subject of great interest for many in today's world. IoT is the future that scholars and researchers anticipate and work for. IoT tries to bring everything under one umbrella with cross disciplinary collaboration. The unification of everything in the world, making use of a common infrastructure that can, not only provide the users with the control but also helps them understand the state of it is the zenith of IoT. Keeping this in mind, this study addresses various IoT concepts through professional discussion with experts, systematic review of scholarly research papers and online databases. This research paper consists of definitions, evolution, IoT hardware, software, cloud services, and tools for analysing data sets. The prime objective is to provide thumbnail information about the Internet of Things and technologies used in day to day life.*

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I. Introduction

The Internet of Things (IoT) is a framework in which all things have a representation and a presence in the Internet [1]. It is the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data. IOT broadly refers to the extension of network connectivity and computing capability to objects, devices, sensors, and items not ordinarily considered to be computers. As the father of IoT, Kevin Ashton once said, "Information is a great way to reduce waste and increase efficiency, and that's really what Internet of Things provides". These "smart objects" require minimal human arbitration to generate, exchange, and consume data; they often feature connectivity to remote data collection, analysis, and management capabilities. The fields of application for IoT technologies are as numerous as they are diverse, as IoT solutions are increasingly extending to virtually all areas of everyday. The most prominent areas of application include, e.g., in smart industry, development of intelligent production systems and connected production sites, in the smart home or building area, intelligent thermostats and security systems are receiving a lot of attention, while smart energy applications focus on smart electricity, gas and water meters. Solutions for smart transport include, e.g., vehicle fleet tracking and mobile ticketing [2], while in the smart health area, topics such as patients' surveillance and chronic disease management are being addressed[3].

II. Definitions

The term Internet of Things was first attributed by Kevin Ashton (the father of IoT) [4]. No unique definition for Internet of Things is available that is accepted by the community of users. All the definitions have these two in common. First, the internet is about the data created by people and second, is the data created by things. The best definition of Internet of Things is: "The network of everyday physical objects which surround us and that are increasingly being embedded with technology to enable those objects to collect and transmit data about their use and surroundings." IoT is the integrated part of future internet and could be represented as a dynamic global network infrastructure with self configuring capabilities based on a standard and interoperable communication protocol where physical and virtual things have identities, physical attributes and virtual personality and use intelligent interface and are coherently integrated into the information network [5, 6].

In IoT, things are expected to become active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data information sensed about the environment, while reacting autonomously to the real or physical world events and influencing it by running processes that trigger actions and create services with or without direct human intervention. Consolidation of services facilitates interactions with these smart things over the internet taking into account security and privacy issues [7-13].

III. Evolution

The following information is accessed from URL [14]:
1999: The term Internet of Things is coined by Kevin Ashton, Executive Director of the Auto-ID Center in Massachute Institute of Technology (MIT)
1999: Neil Gershenfeld first time spoken about IoT principles in his book titled "When Things Start to Think"
1999: MIT Auto-ID Lab, originally founded by Kevin Ashton, David Brock and Sanjay Sarma in this year. They helped to develop the Electronic Product Code
2000: LG announced its first Internet of refrigerator plans
2002: The Ambient Orb created by David Rose and others in a spin-off from the MIT Media Lab is released into wild with NY Times Magazine naming it as one of the Ideas of Year
(2003-2004): RFID is deployed on a massive scale by the US Department of Defense in their Savi program and Wal-Mart in the commercial world
2005: The UN's International Telecommunications Union (ITU) published its first report on the Internet of Things topic
2008: Recognition by the EU and the First European IoT conference is held
2008: A group of companies launched the IPSO Alliance to promote the use of IP in networks of "Smart Objects" and to enable the Internet of Things
2008: The FCC voted 5-0 to approve opening the use of the 'white space' spectrum
(2008-2009): The IoT was born according to Cisco's Business Solutions Group
2008: US National Intelligence Council listed the IoT as one of the 6 "Disruptive Civil Technologies" with potential impacts on US interests out to 2025
2010: Chinese Premier Wen Jiabao calls the IoT a key industry for China and has plans to make major investments in Internet of Things
2011: IPv6 public launch-The new protocol allows for 340, 282, 366, 920, 938, 463, 463, 374, 607, 431,768, 211, 456 (2^{128}) addresses.

IV. IoT hardware platform

The Internet of Things – IoT, can be looked as a highly dynamic and radically distributed networked system. In other words, it is a system composed of a very large number of smart objects which are identifiable, able to communicate and to interact, either among themselves, building networks of interconnected objects, or with end-users or other entities in the network [1]. Today, we can find different IoT hardware platforms available for us to use and collaborate with a variety of sensors that help us collect and store raw data and also perform several operations on them. Below is a list of IoT platforms one can think of implementing as an underlying hardware for their IoT project:

1. Raspberry Pi

Raspberry Pi is a small, powerful, cheap, hackable and education-oriented computer board introduced in 2012 (Fig. 1). It operates in the same way as a standard PC, requiring a keyboard for command entry, a display unit and a power supply. This credit card-sized computer with many performances and affordable for 25-35$ is perfect platform for interfacing with many devices. The vast majority of the system's components – its central and graphics processing units, audio and communications hardware along with 256 MB (Model A) – 512 MB (Model B) memory chip are built onto single component. The Raspberry Pi board shown in Fig. 1 and Fig. 2 contains essential (processor, graphics chip, program memory - RAM) and other optional devices (various interfaces and connectors for peripherals). The processor of Raspberry Pi is a 32 bit, 700 MHz System on a Chip, which is built on the ARM11 architecture and can be overclocked for more power [15]. SD Flash memory serves as a hard drive to Raspberry Pi's processor. The unit is powered via the micro USB connector while internet connectivity may be via an Ethernet/LAN cable or via an USB dongle (Wi-Fi connectivity) [16, 17].

Figure 1: Raspberry Pi

The Raspberry Pi, like any other computer, uses an operating system. The Linux option called Raspbian is a great match for Raspberry Pi because it's free and open source, keeping the price of the platform low, and making it more hackable.

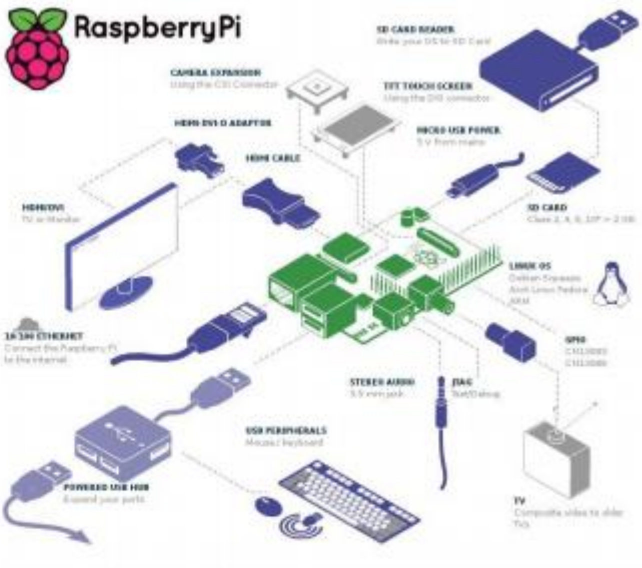


Figure 2: Raspbian

2. Arduino

The Arduino is open-source, which means hardware is reasonably priced and development software is free. The Duemilanove board features an Atmel ATmega328 microcontroller operating at 5 V with 2 Kb of RAM, 32 Kb of flash memory for storing programs and 1 Kb of EEPROM for storing parameters. The clock speed is 16 MHz, which translates to about executing about 300,000 lines of C source code per second [18]. The board has 14 digital I/O pins and 6 analog input pins. There is a USB connector for talking to the host computer and a DC power jack for connecting an external 6-20 V power source, for example a 9 V battery, when running a program while not connected to the host computer. Headers are provided for interfacing to the I/O pins using 22 g solid wire or header connectors [19].

Figure 3: Arduino Uno board with Atmega microcontroller

3. Beaglebone Black

The next-generation offering from BeagleBoard.org – BeagleBone Black – helps hobbyists, engineers and students alike transform ideas into usable products – for only $45! BeagleBone Black is a ready-to-use, 1-GHz Linux™ computer that offers a truly open hardware and software development platform. BeagleBone Black provides 1-GHz performance – 150 percent higher performance than ARM11™ for more advanced user interfaces and computation power. High-speed peripheral interfaces like USB, Ethernet and HDMI on the credit-card-size BeagleBone Black mean that practically any peripheral device can be connected to these fast, portable, low-power computers. Enhanced user interfaces to connect with devices such as a keyboard, a mouse and an HD LCD display are a snap to deploy. a variety of plug-in boards – called "capes" – can be deployed almost immediately by simply plugging one or more capes into one of the board's expansion headers. As many as four capes can be stacked on top of each other for even greater capabilities.

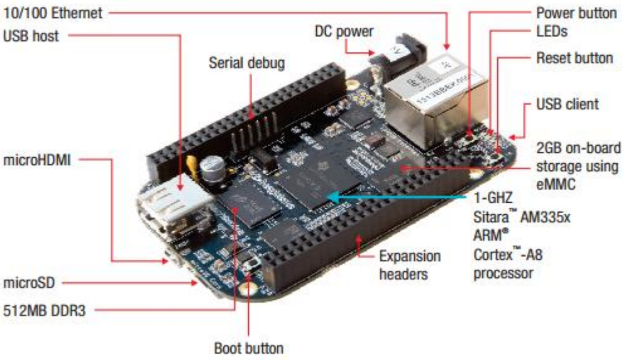


Figure 4: Beaglebone Black

4. Particle.io (photon and electron)

Particle.io (formerly known as Spark Core) Photon and Electron is a Wi-Fi enabled IOT hardware platform. It was built using powerful STM32 ARM Cortex M3 and Broadcom Wi-Fi chip. The striking feature of this Particle product is a website cloud platform that allows user to send and receive data seamlessly from anywhere rather than only accessing data from your local network.

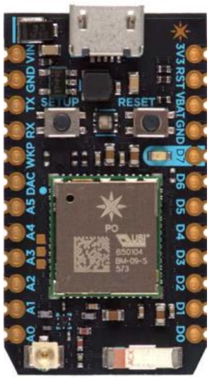


Figure 5: Particle.io

5. Intel Edison

Intel Edison is a tiny processor. Its x86 architecture brings lot of benefits to the embedded controller, which becomes in all respects a custom, low cost, low power and easy to use PC. Fig. 6 shows a block diagram resuming the key features of this custom hardware platform. Following are more details about the PCB:

- Board outline: 132 mm x 72 mm;
- complies with DIN-RAIL mounting;
- 8 layers;
- FR-4 glass epoxy

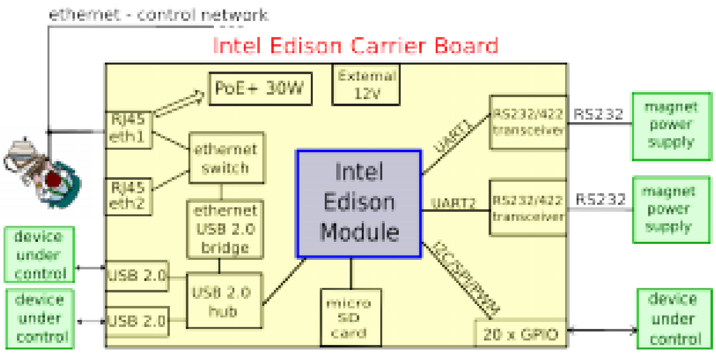


Figure 6: Intel Edison

6. Netduino

Netduino is an open source electronics prototyping platform build around STMicro STM32F4 controller and runs in .NET Micro Framework. A special version of this Netduino Ethernet and Wi-Fi certainly gives an edge for IOT developers and enthusiasts. Ethernet board equipped with inbuilt Ethernet connectivity and Wi-Fi connectivity for the Wi-Fi board. Other features such as UART, I2C, SPI and SD card connectivity adds flavour to it.

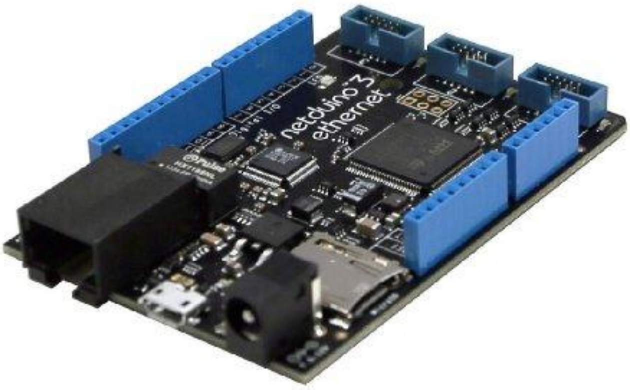


Figure 7: Netduino

7. Tessel 2

The following are the features of Tessel 2:

- A 580MHz WiFi router system on chip (Mediatek MT7620n) running linux (OpenWRT)
- 64 MB of DDR2 RAM
- 32 MB of flash storage
- 2 High-speed USB 2.0 ports
- a micro USB port
- A 10/100 Ethernet port (RJ-45 jack)
- A 48MHz ARM Cortex M0 microcontroller (Atmel SAMD21)
- Two module ports that are much more capable than their predecessors
- a button and a bunch of LEDs

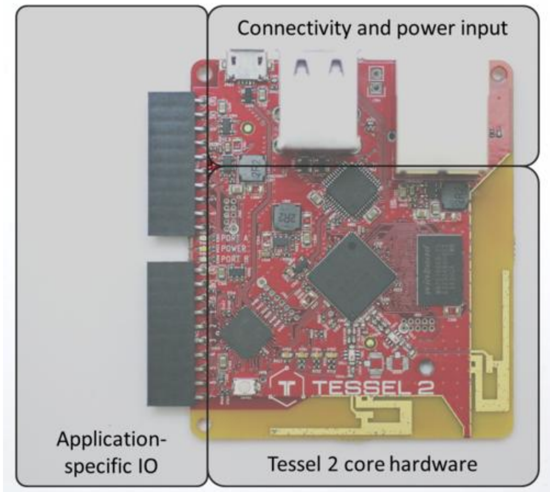


Figure 8: Tessel Hardware.

V. IoT Architecture

IoT architecture has five layers. They are listed as follows:

1. Perception Layer

It is also called device layer. It composed of physical objects and sensor devices [20]. It is responsible for gathering physical object features such as humidity, motion, temperature, location, and acceleration. It is done by varieties of sensors like RFID, 2D barcode, and another sensor type. The collected data is transmitted from perception layer to network layer. The main purpose of perception layer is transforming gathered data to digital signals

2. Network Layer

The network layer may be called as "transport layer." The medium of data transition may be wired or wireless and the using technology can be Wi-Fi, 3G, Zig-Bee, Z-Wave, etc [21]. The basic task of this layer is transportation. It transports data from the network layer to the middleware layer

3. Middleware Layer

This layer also termed as "Processing Layer". Middleware layer is responsible for storing, analyzing, and processing the information of objects that received from the network layer and linked to the database [22]. It can make computations and take decisions depending on the results signals

4. Application Layer

This layer offered inclusive management of application that relies on the objects information that processed in the middleware layer [23]. The implemented application of IoT may be transportation, logistics, smart health, smart home, smart city, etc.

5. Business Layer

Business layer likes a manager of IoT. The management includes applications, relevant system model, and services. Technology success relies on technology priority as well as innovation of business model. The purpose of this layer is to determine the future actions and business strategies signals [24].

VI. Tools and techniques for analyzing data

There are several techniques and tools for solving many IoT data management challenges like Big data, cloud computing, semantic sensor web, data fusion techniques, and middleware.

1. Big Data Analytics and Tools

There are many techniques or methodologies that can solve IoT data processing and analytics [25] issues in many concepts; Fig.9 shows the Apache Hadoop ecosystem.

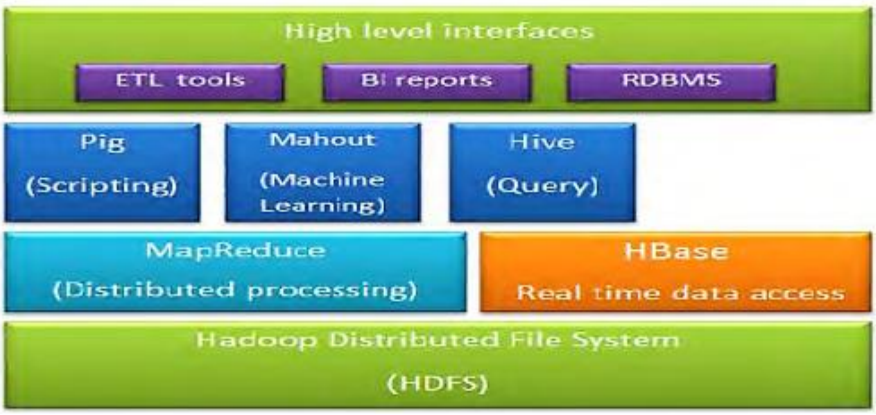


Figure 9: Apache Hadoop ecosystem.

1.1 Hadoop: Hadoop is an open source mission that managed by the Apache Software Foundation. Big data can be collected and handled by Hadoop. Hadoop is proposed to parallelize data processing through computing nodes to hurry computations and hide latency. There are two main components for Hadoop: Hadoop Distributed File System (HDFS) and Map Reduce engine. HDFS stores enormous data constantly set and reproduce it to the user application at high bandwidth. MapReduce is a framework that is used for processing massive data sets in a distributed fashion through numerous machines [26] [27] [28].

1.2 Map Reduce: MapReduce was constructed as a broad programming paradigm. Some of the original employments offered all the key needs of parallel execution, fault tolerance, load balancing, and data manipulation. The Map Reduce named with this name because it includes two abilities from existing functional computer languages: map and reduce. The MapReduce framework gathers all sets with the common key from all records and joins them together. Therefore, it acquires forming one group for each one of the different produced keys. MapReduce is one of the new technologies, but it is just an algorithm, a technique for how to fit all the data. To acquire the best from MapReduce, we need more than just an algorithm. We need a collection of products and technologies created to manage the challenges of Big data.

1.3 HBase: HBase is a database model inside the Hadoop framework that looks like the original system of Big Table. The HBase has a column that operates as the key and is the only index that can be used to get back the rows. The data in HBase is also saved as (key, value) sets, where the subject in the non-key columns can be represented by the values [29].

1.4 Hive: The already deployed tools for data warehousing are not able to be suitable especially in the situation wherever, data is accessible everywhere; they are costly and often privately-operated. Such as the notion like MapReduce is there, it requests for the ability to write job procedures. Map Reduce jobs are difficult to track the characteristics of reusable code as some jobs are business particular some of the time. Hive may be thought as the necessary portion of Hadoop system and views at the top that principally is the organization for the data

warehouse [30]. Hive cannot treat with applications and transactions of the real time those are achieved online. The motivation behind it is a complicated technique [31].
1.5 Pig: The Pig implementation designed within the Hadoop framework to offer additional database as functionality. A table in Pig is a group of tuples, and every field is a value or a set of tuples. So, this framework permits for nested tables, which is a great notion. Pig also provides a scripting language called PigLatin that offers all the common concepts of SQL, such as projections, joins, sorting, and grouping. PigLatin differs from SQL as scripts are procedural and are simple for programmers to be understood. The PigLatin language offers a higher extraction level to the MapReduce framework, as a query in PigLatin may be converted into a sequence of MapReduce tasks [32].
1.6 Mahout: Mahout is mainly built on an Apache open-source library which able to be scaled and managed for the massive volume of data. These segments rely on three significant machine learning missions that Mahout presently operates.
• Collaborative filtering
• Clustering
• Categorization/Classification [33].

1.7 NoSQL: It is an abbreviation to not only SQL, and the most usual notion for non-relational databases. These databases are appealed to operate better than SQL databases. Various types of NoSQL databases, which are keyvalue pair document, column-oriented, and graph databases, that permit programmers to display the data suitable to the structure of their used applications. Because of the growth of the Internet usability and the accessibility of low-cost storage, a massive quantity of structured, semi-structured and unstructured data are acquired and saved for different types of applications. This data is usually denoted to as Big data. Google, Facebook, Amazon, and several other enterprises use NoSQL databases.

2. Cloud Computing

Google's cloud computing is the most used cloud computing. Data storage technology is the Google File System (GFS). Data management technology is the BigTable, in addition to the Map-Reduce that discussed in the previous section as a programming model, used in cloud computing.

2.1 GFS: GFS is a distributed file system established by Google Inc. GFS is enhanced for Google's main data storage and usage requirements that can produce massive quantities of data that requires recalling. GFS has many purposes, such as performance, scalability, reliability, and availability of the distributed file system manipulated by application workloads and technological environment of Google [34].

2.2 BigTable: A Big Table development is initiated in 2004 and is now used by a much of Google applications, such as MapReduce [35]. It is often used for producing and altering data stored in BigTable, Google Reader, Google Maps, Google Book Search, Google Earth, Blogger.com, Google Code hosting, Orkut, YouTube, and Gmail. Google's motivation for evolving its specific database contains scalability, and better control of performance features. BigTable is augmented for data read processes, by distributed data storage management model, which is based on column storage to enhance data retrieving effectiveness. The main components of BigTable are a row, column, record tablet, and timestamp. Amongst them, there cord tablet is a link to the set of row [36].

3. Semantic Sensor Web

The quantity of existing sensors will be enormous, and the gathered data will be intensive. If we have the ability to put the collections of data into a homogeneous and heterogeneous form, then the interoperability problems of understanding the data will rely on the semantic technologies to process the data [37]. There are many aspects of semantic sensor Web as:

3.1Ontology: Ontology is the core of any semantic technology as semantic sensor Web. It is a tool for knowledge allocations and usage. Semantic Ontologies can be divided into some formats as OWL and RDF.
- OWL: OWL stands for Web Ontology Language. It defines discrete data substitution format. The great benefit of this ontology format is that there is no limitation to represent constraints as domain or range constraints.
- RDF: RDF is an abbreviation for description research framework. It is a research description language. This language determines the way that resources can interconnect with each other and perform interpretations.

3.2Data Fusion: It is a multidisciplinary extent that includes numerous fields, and it is difficult to launch a clear and precise classification. The developed methods and techniques can be divided as said by the following principles:

- According to the associations between the input data sources. These associations can be described as: (a) complementary, (b) redundant, or (c) cooperative data.
- According to the input/output data types and their nature. - According to an abstraction level of the employed data: (a) raw measurement, (b) signals, and (c) characteristics or decisions.
- According to the different data fusion levels stated by the JDL [37].
- According to the architecture type: (a) centralized, (b) decentralized, or (c) distributed.

4. Middleware

Middleware is integration between applications and services operating on heterogeneous computing and communication devices [38]. Many middlewares are listed below:
- Message- Oriented Middleware (MOM/ MQ/ JMS/ ESB)
- Transaction Middleware (TPM/ Tuxedo)
- Peer- to- Peer Middleware (JXTA)
- Mobile Computing Middleware (OSA/ Parlay/ JAIN/ OMA)
- Grid Middleware (PVM/ MPI/ Schedulers)
- RFID Edge Middleware (OATSystems, Sybase, Oracle, Tibco, SeeBeyond, IBM, SAP, Connectera, GlobeRanger, Manhattan Associates)
- Real- time CORBA Middleware (Real- time CORBA)
- Process- Oriented Middleware (WebMethods, SeeBeyond, Tibco, IBM, SAP, Oracle)

Some IoT middleware proposals are listed:

4.1 UBIWARE: It is an agent-based middleware that characterizes each source as a software agent. An agent is responsible for supervising the state of the source, and supporting the interoperation of the source with other elements. The core notions of UBIWARE are to permit automatic discovery, orchestration, choreography, invocation and execution of different Business Intelligence services.

4.2 Hydra: The Hydra middleware involves of a service-oriented architecture. It depends on Web services to support the resource discovery, description, and access that relies on XML and Web protocols. Hydra network uses a proxy to connect the restricted devices to it. The two principle tasks achieved by Hydra developers are (i) integrating non-Hydra devices and (ii) connecting Hydra-enabled devices to a network.

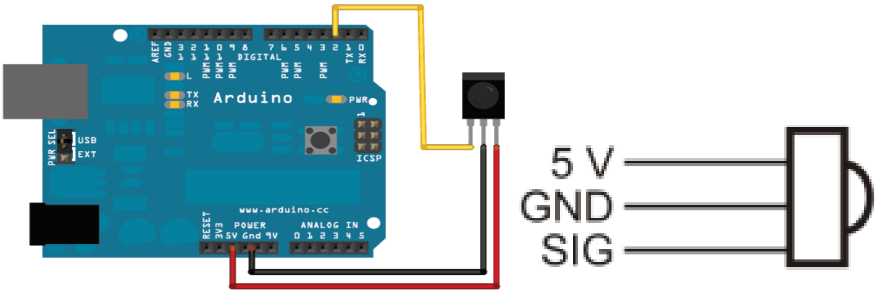
4.3 Link Smart Middleware: The Link Smart middleware deployed in the Hydra project permits the integration of heterogeneous physical devices into applications via a Web service interface for directing any physical device irrespective of its network technology, such as Bluetooth, RF, ZigBee, RFID, and Wi-Fi. Link Smart relies on a semantic model-driven architecture and permits the use of devices as services both by embedding services in devices and by proxy services for devices. The semantic description of devices relies on ontologies using OWL, OWL-s and SAWSDL.

4.4 Open IoT: The Open IoT project offers an open-source middleware platform. It allows the development of IoT applications rendering to a utility cloud computing delivery model. Open IoT role is to recognize the idea of on request access to IoT services obtained over clouds of Internet-connected objects, the called sensing as a service, offering a "cloud-of-things" [38].

VII. Sensors with applications as examples

IR Sensor: Arduino/Genuino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your UNO without worring too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

An infrared sensor is an electronic instrument which is used to sense certain characteristics of its surroundings by either emitting and/or detecting infrared radiation. Infrared sensors are also capable of measuring the heat being emitted by an object and detecting motion.



CODE

```
int ledpin=13;
int sw=4;
void setup() {
  // put your setup code here, to run once:
pinMode(ledpin,OUTPUT);
pinMode(sw,INPUT);
Serial.begin(9600);
}

void loop() {
  // put your main code here, to run repeatedly:
int val=digitalRead(sw);
if(val==0)
{
    digitalWrite(ledpin,LOW);
    Serial.println("No one is at the door");
}

if(val==1)
{
  digitalWrite(ledpin,HIGH);
  Serial.println("open door: visitor is at door");
}
}
```

RESULT

(In Serial Monitor)
No one is at the door
No one is at the door
open door: visitor is at door
No one is at the door

APPLICATION

- The IR sensor installed at the door informs the owner on arrival of a guest like in Shopping Malls.
- The same can be implemented for attendance monitoring system.

VIII. Conclusion

Internet of Things (IoT) is a trending topic in this technologically advancing world. Evidently so, as it has established its roots not only in the field of information technology but also in various other fields such as medical, telecommunication, agriculture, so on so forth. IoT has evolved remarkably over a very short period of time (as seen in the evolution section). The existing systems can be internetworked with the various hardware platforms available in the market. The functionality of the platform varies but the essence more or less will remain the same keeping in mind, the five layers of the IoT architecture. IoT made its presence notable in various departments be it science and technology, business, agriculture, or government because of the tools and techniques utilized to extract a meaning out of the raw data collected.

In conclusion, Internet of Things announced its arrival by doing extremely well in a variety of streams across the globe. This is just the beginning and one can predict more in the coming years. One may say that it will be much more than “things”.

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