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Scope of IoT: Performance and Hardware Analysis Between Raspberry Pi-3 And Arduino Uno

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Abstract— We are living in a modern and advanced era of computers where human effort is being minimized by the use of modern technologies. One of the aspects to achieve this is by bringing the daily household items or devices over the internet and let them communicate with each other autonomously. In this contribution we have used Raspberry Pi 3 and Arduino to analyze different parameters like RAM, Processor, OS (Operating Systems), GPIO (General Purpose Input Output) pins, Cost, Power & energy consumption and adaptability to cloud computing.

Keywords— IoT, Raspberry Pi-3, Gartner, IDC, HomeOS, Arduino, Resbian, NOOBS, Nest

I. INTRODUCTION

With the advent of Computer and Internet technologies, Human started to find the sophisticated ways to sooth themselves with the aid of modern technologies. For this purpose he started to propose the concepts and ideas where human input can be reduced at its epitome level. These theoretical assumptions came into being existence when Nest Inc. invented the Nest Learning Thermostat [1] in 2011 as its First product. This thermostat has the capability to learn the behavior of human against its daily usage of Air cooling units Like AC and Fans etc. Upon these heuristics this thermostat gets able to controls the central cooling units without the input of human [2]. This invention laid the foundation of Internet of Things (IoT). On the other hand, Google started to realize and analyzed the future of such kind of invention. The importance of IoT gets promoted when Google purchased Nest Labs for**$3.2** Billion on January 2014[3], which is double the investment Google made on YouTube in 2006. From above mentioned statistics no one can deny from that "**It is the Age of Internet of Things (IoT)**". The major investments of Google in Last 10 years have been highlighted from the following pictorial representation:

It is quite evident from above graph that Google is looking towards another paradigm shift and making its efforts to capture the market in huge volume. Now, what Apple is doing is much appreciable, Apple along launching of IOS 8 last year, it also introduces the home kit [4], upon this platform the developers will be able to write applications which have the capability to control home appliances like Bulb, Switches, TV etc.

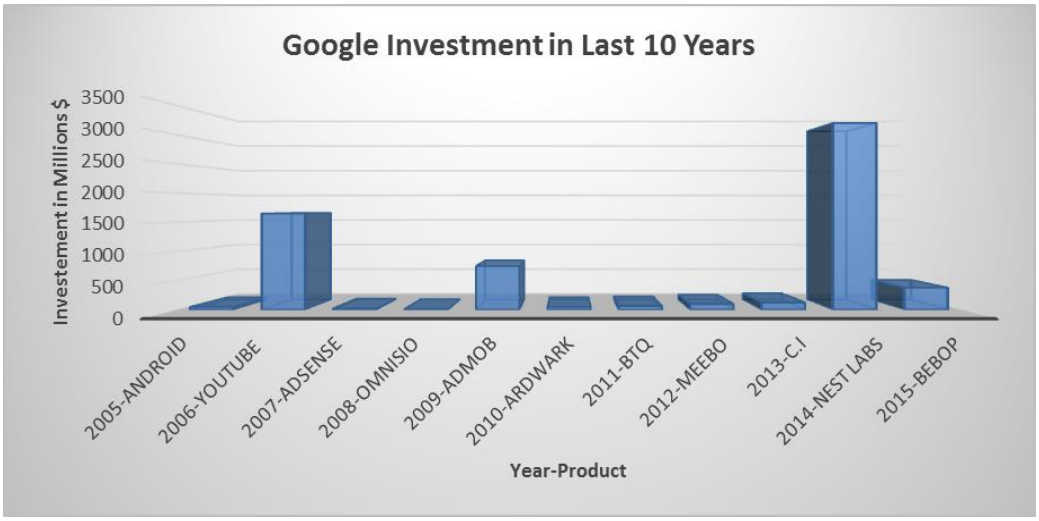

Fig 1 Google investment in last 10 years

This paper has been divided into two parts, in first part we have focused on how IoT (Internet of Things) will lead Market volume in next few decades, while in second part we have addressed how to bring this idea into the reality by taking two hardware into the account i.e. Raspberry Pi 3 and Arduino.

II. Literature Review

A. Gartner

Gartner is world's famous market analysis company, which investigates the common trends in the IT market by analysing the previous data. Gartner also helps the people to make decision on choosing the particular technology. World's leading business and market expert are associated with it. The experts collect the data and perform analysis on it and forecast what will be the future of this product or technology. Gartner also evaluated the behaviour of Google and predicted the future of IoT by keeping the investments of Google, Inc. into the account. These statistical and analytical data was further verified by Gartner, Inc. which forecasts that in 2016 Google and its partner organizations will connects 6.4 billion devices to the internet. Which is 30 % of the devices which became online in 2015 [5]. Gartner further predicted if the rate of increase of devices over the internet will remain the same, then this figure could reach to 20.8 billion. This means on the average 5.5 million devices will be online every day. According to the Gartner analysis, the trend of devices connected to internet since 2014 to date is shown in the following table.

Table 1: Trend of devices connected to internet since 2014

Category	**2014**	**2015**	**2016**	**2020**
Public users	2277	3023	4024	13509
Companies	1530	1880	2368	7288
Grand total	3807	4902	6392	20797

B. Microsoft (HomeOS)

So far we have analyzed what Google Inc. is doing in this emerging field and what steps they have taken till now. But things are not confined to Google only. It has also invoked the other big IT market bulls and bears to put their boats in the stream of IoT. So far so good, Microsoft has also joined the heads to make contribution in this. Since Google purchased all the labs from Nest, Inc. The question that arises in one's mind is that in which areas of IoT Microsoft may focus on? The answer is Microsoft has started to work in the opposite direction of hardware, because if the things will be online then these would be done through hardware and sensors which does require an Operating System (OS), while both Microsoft and Apple has the specialty in building and writing the sophisticated algorithm for operating system. By keeping the above scenario, Microsoft is working on HomeOS [6] operating system for home automation since 2010. Microsoft has also signed an agreement with the Insteon, Inc. Insteon is more deviated towards making the hardware chips, like motion sensor, infrared sensors, temperature sensors etc. Microsoft will help to let these modules operate through HomeOS. Microsoft has set its path in the IoT and opened the doors for future of IoT.

Despite the entire above, one must argue that, is there any need of Operating system for performing such activities of IoT? Before going towards whether an operating system will help us or it is just a formality to remain in the research of IoT. One should know the purpose of Operating system, if we delve into the deep analysis of operating system then it is obvious that these state of art work of IoT will only be best carried through a well robust operating system. As operating system is a bridge between hardware and end-user, irrespective of personification of end-user there is a high variability lies on the other side of bridge (Operating System) i.e. hardware. The motivation for building an efficient operating system is that we have to encounter with different hardware circuitries and on each day we have to face a new enhanced technology. If we limit ourselves to IoT then we can replace the word hardware with home appliances (such as Door Locks, Lights, Switches, TV, and Media etc.). Peoples are moving towards advanced house hold appliances each day. Our operating system should have the capability to make compatibility with such new hardware.

HomeOS has addressed the issues which may arise after new hardware is connected into the family of home appliances. HomeOS has managed the above issues in two ways:

1. How operating system will react if the new hardware is attached with the operating system, will our HomeOS discover this new appliance or not?
2. To operate new hardware, there arises the need of application development and we must have to provide ease/flexibility for developers to write application software that is independent of low level detail of the home utilities.

After realizing the requirement of a vigorous Operating system, Microsoft proposed a high level architecture to cope up the above issues. It divided the architecture into four layers and each layer is dependent on one another. Each layer is briefly described below in the order from machine architecture to user application end:

1) Device Connectivity Layer:

This layer has the responsibility to discover new devices over the internet. This layer also get the information of device semantics and passes this information to above layers. This meta-data of device specification is then utilized by the Developers to write the APIs for application. Hence, this layer has taken the major concern of those two issues which were recently described above.

2) Device Functionality Layer:

This layer is also termed as Device-Specific Layer. This layer has focused on the limitations in networking, where there is no universal protocol which could be compatible with all devices. Microsoft thought that if we write a driver per protocol then it will work for one or small number of devices, but it may cause problems if the number of devices for each protocol is increased. Therefore, they proposed more conventional way that is to write the drivers for each device. This will confine the devices to a single protocol. Hence, devices would be operate from single software.

3) Management Layer

One of the main and important layers in HomeOS is the management layer which does not bother what happens at lower layers. Firstly, it provides a central control to add or remove users and their access control policies, applications and devices. Secondly, an error free access control of devices through applications is provided so that each application does not require separate mechanism to handle the connected devices. Thirdly, it provides a simple and user friendly interfaces so that user can easily configure the required policies (such as time based access and security policy etc.).

4) Application layer

This is the place where developer written code works. Main purpose of this layer is to determine which applications are compatible with connected devices. In this context, a manifest file is required from applications. This file contains the services an application requires from HomeOS. Based on the services required user can download the best compatible application from HomeStore (The app store for HomeOS specific apps).

C. Apple (HomeKit)

Many IT companies have already set their goals in IoT. They know how to pop out the best innovations out of it. Apple was thinking too, although they cannot get as much appreciation in controlling the smart home and their appliances as Nest Inc. Google Inc. and Microsoft had. Apple was looking towards another paradigm shift in IoT. Apple started working on the development of the applications that would control all the smart home devices. These will be available in the iOS.

Apple has launched the flavor of HomeKit [4] with the release of iOS 8 on October, 2014. The application has the capability to control the smart home with ease and secured way. Apple also introduced the new way of interaction with the devices which are present in the data base. The application has the compatibility with voice. Devices are triggered by aiding the voice to the application which uses 'Siri' for their operations. If you are at night and you have decided to go bed then you just command the 'Siri' through voice by well-known phrase "Good Night". Siri understands the command and puts all the lights and shades off.

A well-known Consumer Electronics Association established a group in May, 2014. The purpose of this group is to make a standard template markup languages and software through which smart and mutual corresponding devices could remain in contact with each other. Apple has especially focused in HomeKit that users could not get frustrated about storing the new manufacturer device in their own data base that run iOS. Apple has provided the following features in the development of such application:

1. You can add commands and controls for more than one homes, Rooms and regions in their data base.
2. User can Add, Search or remove the appliances that are going to control by HomeKit applications.
3. HomeKit application can learn the behavior or we can ourselves define the behavior of certain devices that how frequently we use that at a particular time.
4. Multiple users can get the authorized access which can be further managed by an administrator (User).
5. Siri is used for controlling the devices like bulb, shades, door locks and thermostats through voice.

D. International Data Corporation (IDC)

IDC is one of the leading global providers of market intelligence for information technology, telecommunications and consumer technology markets. With a large team of professional analysts, IDC offers global, regional and local expertise on technology and industry opportunities and trends in over 110 countries. The following graph shows the revenue growth in the field of IoT since 2013 [7].

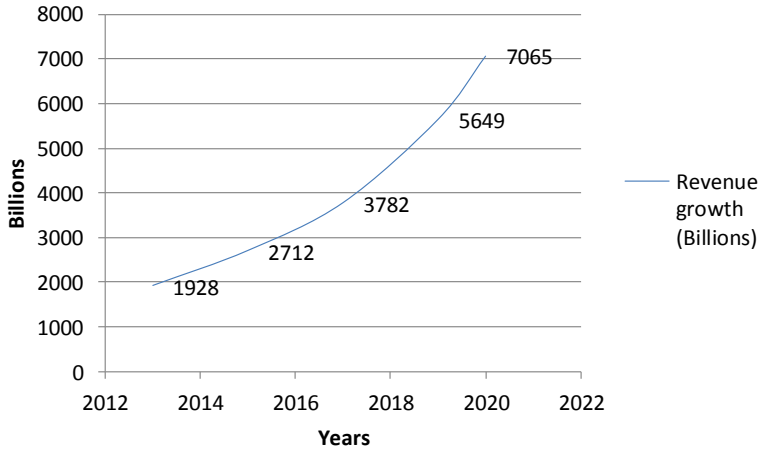

Fig 2 Revenue growth in the field of IoT

A model is presented in [8] to show the communication of real world. This model is implemented using the concept of IoT. For this purpose a small computer board based device Raspberry pi is used. This device smartly controls all the devices connected to it over the Wi-Fi.

III. IMPLEMENTATION

After viewing the bright future of Internet of Things (IoT), everyone should curious about how this advance stage of technology could be achieved? There are numerous single board devices are available in market through which this state of the art work could be carry out. We will introduce few of them here. The detailed description of these devices are listed below:

A. Raspberry Pi-3 Model B

Raspberry pi [9] is the credit size low cost as well as low power computing device. Motivation for building such a tiny computer with HDMI out is to build the skills in the young generation in somewhat more interesting way. Some students (6 in numbers) of University of Cambridge, United Kingdom analyzed the data of student enrollment of past few years in two parameter, one was number of student applying in computer science technology and the second parameter was computer skills. They evaluated the data and further concluded that number of applicants (students) for Computer Science are decreasing every year due to lack of skills in Computer Technology. By keeping this problem for the background of motivation, theses six students decided to build a small computer device which can do the physical computation. Physical computation means to make the personal computer capable for being interact with the real world hardware such as sensors, web servers, robots, locks and much more. For this physical computation, Raspberry has provided the GPIO (General Purpose Input Output) pins. These pins are like those standard input output pins which were dedicated in your personal computer for standard devices like Mouse and Keyboard etc. This GPIO module has made Raspberry different from other computer devices. This inspiration of raspberry Pi is more than enough to drive the Internet of Things (IoT) concept into the reality.

Raspberry is a microprocessor; therefore it requires an operating system to deal with it. Raspberry is the open source hardware and it has the compatibility with most well-known operating systems like Windows 10, Linux, UNIX and many others. But for the sake of convenience, raspberry has launched two its own operating system which are Linux based i.e. Raspbian and NOOBS. Here we have described the steps to how we can get and install Raspbian to Raspberry Pi-3. The pictorial representation of these steps is as follows:

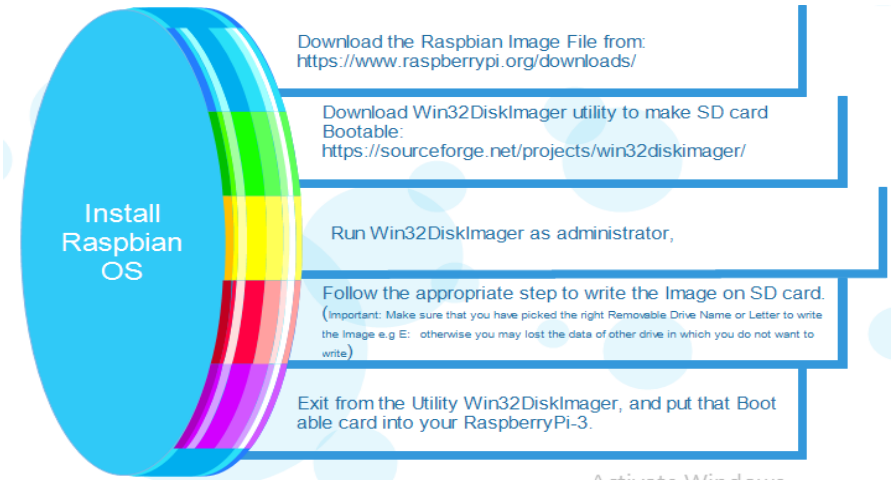

Fig 3 Installations steps of Raspbian OS

Why there comes a need to operate this single board through operating system? Why we cannot plug and play with this board like microcontrollers? The answer to this question is very simple, Raspbian has built-in different IDEs (Integrated Development Environments) Like Python, Mathematica, and Java etc., in which we can write code for versatile Integrated Circuits. These IDEs requires interpreters to generate the machine code for particular ICs.

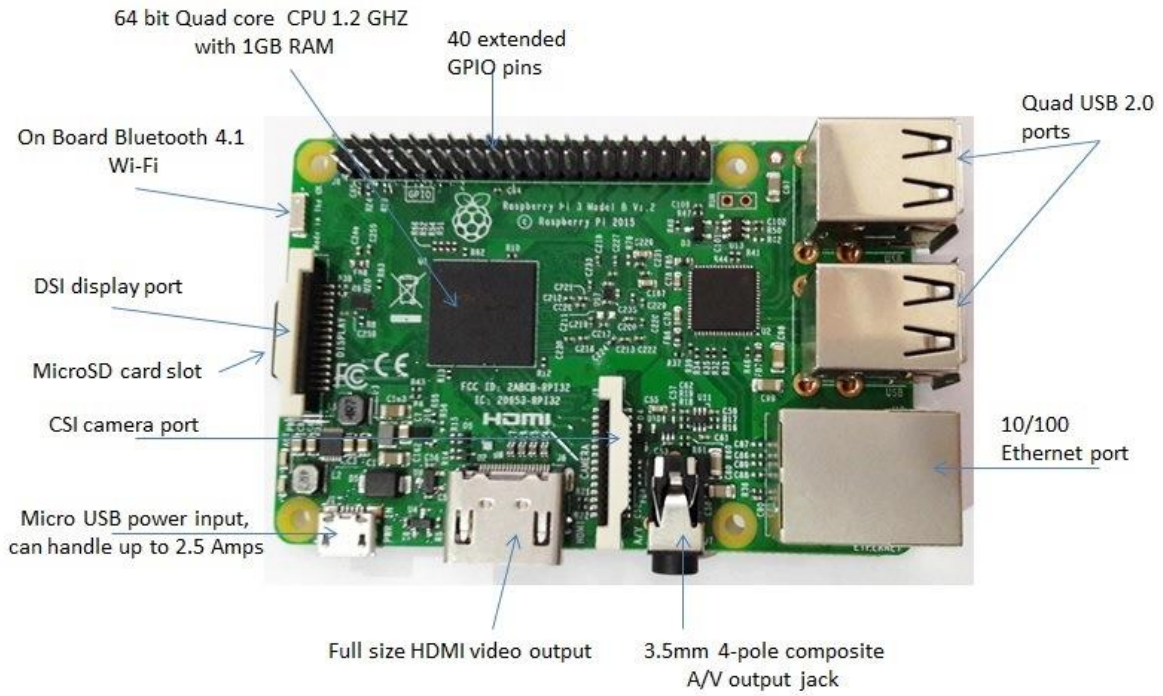

Fig 4 Raspberry Pi 3 board configuration

B. Arduino Uno

The drive for the evolution of Arduino [10] is much similar as that explained in the Raspberry. The aim of both devices is to make the better interaction of lay man of electronics with the complex circuits. The idea behind that even a novice could get the practical knowledge of electronics analysis at its ease. The name of this microcontroller (Not microprocessor) **Arduino** had been laid on the king named **King Arduin** who reign over the Italy (1002 AD).

Arduino Uno was invented in 2005 by some students of IDII (Interactive Design Institute, Ivrea). The foundation of Arduino was developed under the supervision of Banzi, who was Software architect by profession. He later on joined the IDII as associate professor. He has very sound knowledge regarding human computer interaction design. During his teaching time at this institute, there was a single board for doing electronics experiments, at which students can interact with electronics through computer. This board was termed as BASIC stamp. There were many issues with this board. These issues led the Banzi to invent somewhat more convenient microcontroller i.e. Arduino. The stamp board was coded in BASIC programming [10]. It has very less computing power and its cost was too much.

Arduino is also a credit size low cost and low power physical computing device. It has a flash RAM to which coded is loaded for operating the hardware like sensors, motors etc. Arduino is available in 8, 16 and 32 bit architecture. It also have the GPIO pins like Raspberry Pi-3. But one advantage that Arduino has over the Raspberry regarding GPIO pins is that Arduino also have the analog pins for input, which does not present in raspberry. As Arduino is very cheap, therefore it is also called the "**One Dollar Computer"**.

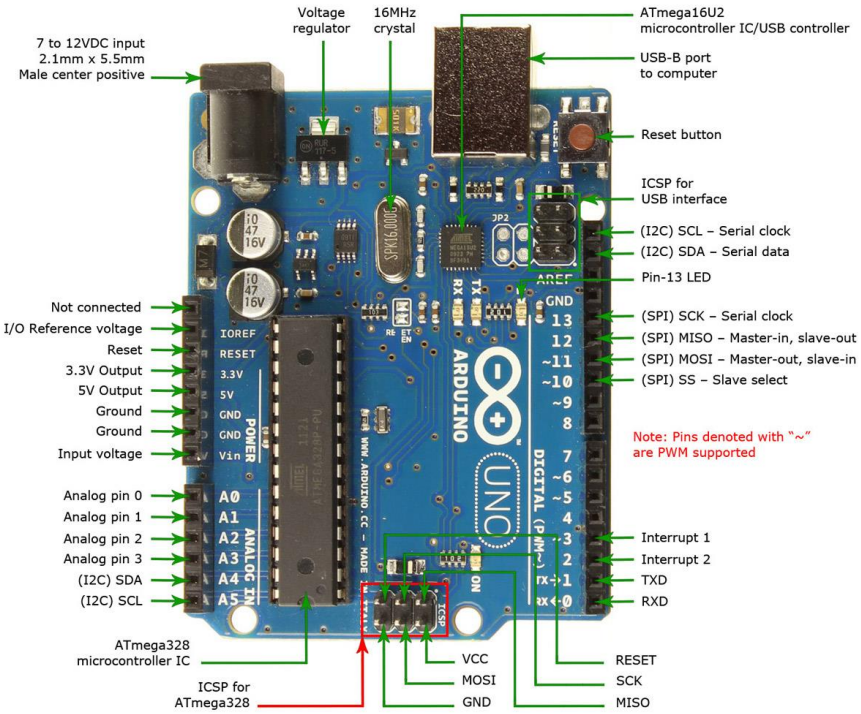

Fig 5 Arduino Uno board configuration

Unlike Raspberry, Arduino does not require any operating system for performing its operation. It does not require any interpreter or firmware. Arduino is coded in Arduino IDE software which can run on different Operating Systems like Mac, Windows and Linux. The code is written in Arduino IDE which is then compiled in machine or byte code, which further burned for hardware that is attached with Arduino board. Installation guide for this software over the windows platform is as follows in the diagram below:

Fig 6 Installations steps of Arduino IDE

IV. TRADE-OFF BETWEEN RASPBERRY PI-3 & ARDUINO UNO

One major confusion that could arise in reader's mind, which board must we purchase for performing our electronics experiments? The answer of this question depends upon to which type of project you are dealing with. If you are doing the electronics project that do not require much processing power like controlling motors, LEDs, robotics and sensors etc., then Arduino Uno will best fit to your requirements. But if the project in which you are interested requires much physical computations and Graphics like Web servers, Games, Media Centre, industrial/ Home automation, wireless access point, environmental sensing and monitoring, Robotics, Security monitoring and cloud servers etc., you should switch towards Raspberry Pi 3.

Table 2 Performance and hardware features comparison

Features	**Raspberry Pi 3**	**Arduino Uno**
Processor	Broadcom BCM2387	ATmega328
RAM	1GB DDR2	2KB
Clock Speed	1.2 GHz	16 MHz
Register Size	32 bit	8,16,32 bit
Ethernet	Yes	No
No. of USB Interfaces	4	1
GPIO Connectors	40	14
Input Voltage	3.3 V, 5 V	7-12 V
Ground Pins	Yes	Yes
GPU	Yes	N/A
HDMI	Yes (rev 1.3 & 1.4)	N/A
Bluetooth	Yes	N/A
Wifi	Yes	N/A
Camera Connectors	15-pin CSI-2	N/A
Display Connectors	15 way DSI	N/A
SD Card Slot	Yes (Booting)	N/A
EPROM	N/A	Yes
Analog Input Pins	N/A	Yes
DC Current per I/O Pin	2mA-16mA	40 mA
Power Consumption	700 mW	175 mW
Operating System	Linux, Windows IOT, others.	N/A
Interpreter for Coding	Yes	N/A
Firmware	Yes	N/A

V. CONCLUSION

Evolving trend towards IoT and recent investments have shown that the future of Information Technology will mostly be based on IoT infrastructure. In this research a detailed scope of IoT is elaborated along with features comparison between two small board devices [9][10]. In this context, Raspberry pi3, Arduino Uno and other tiny single board computers can play an effective role in IoT research. Both of the above mentioned devices have their own pros and cons. It is deeply analysed and shown in the above table that Raspberry Pi3 is far more dynamic, user friendly and adaptable to latest technologies.

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