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An Overview of IoT Hardware Development Platforms

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ABSTRACT: Internet of Things (IoT) as an emerging technological innovation bringing a paradigm shift in our professional and personal life. The substantial growth of IoT devices leads to rapid economic growth, prosperity, and social benefits resulting in cost savings, value creation, and productivity improvements. Because of rising demand for IoT devices, Espressif Systems, Arduino, Raspberry Pi, Particle, Samsung, Intel, Adafruit and many other companies, have developed several hardware platforms. This IoT hardware provides several capabilities, features, and opportunities for researchers and hobbyists. In this regard, we have studied, analysed, and compared different IoT hardware platforms used for domestic as well as commercial purposes.

Keywords: Adafruit, Arduino, ESP8266, Intel, Particle, Raspberry Pi, Samsung.

Abbreviations: BLE, Bluetooth low energy; DAC, Digital to analog converter; DIY, Do it yourself; FPU, Floating-point unit; IDE, Integrated development environment; IoT, Internet of Things; PWM Pulse width modulation; RPi, Raspberry Pi; SoC, System on chip; Trusted execution environment (TEE); USB, Universal serial bus; Wi-Fi, Wireless fidelity.

I. INTRODUCTION

The amalgamation of Internet, cloud computing, and machine-to-machine technologies can be seen as the ascending stage of IoT. IoT is an advanced automation and analytic system designed with interlinked data processing tools, computing devices, digital and mechanical units, objects, and environment to deliver a complete system for the products or services. It provides a unique encrypted identification to each device and smartly transfers data over a cloud network with M2M communication, i.e., machines to machine without human involvement. It achieves the goals and objectives of identifying, locating, tracking, monitoring, securing, and managing different things simultaneously using the internet [1]. As a connected environment, IoT adds customer value, loyalty, offers great prosperity, and rapideconomic growth.

Since the last decade or so, a lot of research have been carried out to make devices smart by introducing remote operating capabilities and extending the reach of the internet beyond computers and smartphones. Collecting data through various sensing devices, processing the data based upon some premise as defined by the user, and taking the necessary action with minimum human intervention lie at the very heart of IoT inventions. Many IoT inventions like smart homes, smart cars, smart cities, smart farming, smart grid, industrial automation, connected health, smart retail, wearables devices, etc., are at the advanced stage of implementations [2-10].

IoT is the kind of platform through which any kind of activity can be observed online. This platform connects different hardware, software, and the user for monitoring the physical activity as well as controlling other activities [11]. IoT appears to be a very powerful and completely scattered networking system made up of a massive amount of smart devices. In this research work, we have addressed IoT as the prime reinforcing element of an encouraging model for amalgamation and inclusion of various hardware technologies as communication, identification, verification, and integrating solutions using wireless technologies [12].

Nowadays the demand for smart devices is increasing rapidly and different types of IoT hardware and software are being developed. Each module has its communities, software development environment, hardware development platform, communication protocols, etc. For IoT prototyping, it is imperative to have a deep knowledge of diverse hardware platforms along with their potential as depicted in Fig. 1.

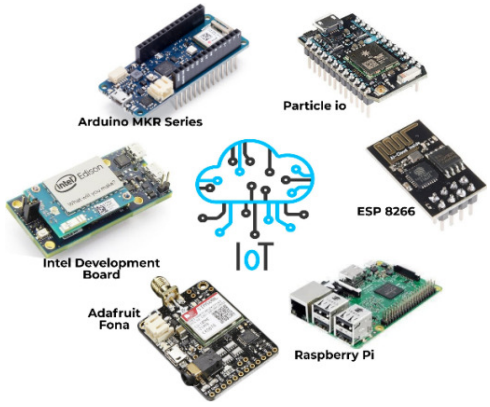


Fig. 1. Hardware Platforms for Internet of Things.

Keeping in view, we are giving an overview of different hardware development platforms for IoT based applications in this research work. This research paper is organized as follows: Section II will describe the hardware development platform for IoT. Commonly used IoT hardware platforms have been discussed

including ESP8266 Wi-Fi Module, Arduino development boards, Raspberry Pi, Particle (Photon and Electron), Samsung Artik, Intel IoT Development Boards, Adafruit, and a comparison model of these development modules. Section III will conclude the entire work and section IV will discuss future perspectives.

II. IoT HARDWARE DEVELOPMENT PLATFORMS

IoT platforms play a crucial role for fast establishment and deployment of IoT products. These platforms emerged as a major component in the development of IoT solutions and help IoT systems by providing built-in packages, development environment, and tools to aid businesses, developers, and users. IoT hardware platform is the amalgamation of embedded hardware, communication interface, and software development environment for a complete IoT solution. In this regard, we have studied and analysed different IoT hardware platforms offering diverse hardware capabilities, support, security, development infrastructure, and communities. Which are described in detail in the coming sections.

A. ESP8266 Wi-Fi Module

The ESP8266 is a system on chip (SoC) module with integrated TCP/IP protocol stack. It provides one of the most vigorous, highly integrated, and committed Wi-Fi interfaces for IoT applications. The ESP8266 module is a mini-board, which allows the pliability to control input-output pins along with the pseudo-code or programming language as depicted in Fig. 2.

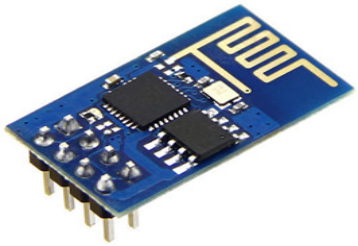


Fig. 2. ESP8266 Wi-Fi module [13-14].

It is a low cost, smaller in size, easy to use, and has a large and ever-growing community. A third-party manufacturer Ai-Thinker developed this module in Aug 2014 [13-14].

Table 1: ESP8266 Wi-Fi module features [13, 14].

Features	Capabilities
RAM/Cache Memory	32 KB
RAM (User Data)	80 KB
External QSPI flash	Up to 16 Mib support
Instruction RAM	32 Kb
GPIO pins	16
ADC	10 Bit
Communication Interface	I2C, I2S, SPI, UART
Power	3.3 to 3.6 V

Many projects can be developed for IoT using this module like smart cities, grids, industrial internet, smart cars, wearable devices, etc. ESP8266 features several protocols for IoT applications that enable the smart device to cautiously, securely, and logically access the data over the network via dedicated Wi-Fi connectivity. The technical blueprint of the ESP8266 Wi-Fi module is given in Table 1.

B. Arduino

Arduino is a company that offers open-source hardware as well as software to design the microprocessor and controller for the project and community-based service for manufacturing smart digital devices [15]. With a set of digital and analog input/output pins, the boards are rigged. Arduino offers various onboard features as in serial communication interfaces, Universal Serial Bus (USB), etc. C and C++ are the common languages used for programming the module. Many projects have been demonstrated with the help of sensors, actuators, etc., thus, making Arduino a perfect development board.

Some of the Arduino boards available in the market are Arduino Uno, Arduino Due, Arduino Mega, Arduino Leonardo, Arduino MKR Series IoT Boards, etc. A comparison of the features of Arduino boards in terms of the type of processors, memory, digital and analog input-output pins, communication interface, and operating voltage is given in Table 2.

Table 2: Comparison of Arduino boards.

Arduino	Uno	Due	Mega	Leonardo
Processor	8-bit	32-bit	8-bit	8-bit
Clock (MHz)	16	84	16	16
Flash SRAM (KB)	32, 2	512, 96	256, 8	32, 2.5
Digital Pins (PWM)	14(6)	54(12)	54(15)	20(7)
Communication Interface	SPI, UART, I2C	UART, SPI, CAN, I2C	UART, SPI, I2C	TWI, SPI, USB (CDC)
Analog I/O	6/0	12/2	16/0	12/0
Voltage	5 V	3.3 V	5 V	5 V

Arduino Uno. Arduino Uno board is based upon the ATmega328 microcontroller unit. It has a total of 14 input/output pins, out of which 6 of them are used as an analog input, another 6 are used by the PWM (Pulse Width Modulation) output [16]. There is a reset button available on the board, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a power jack, a USB port, and an ICSP header is also available on the Arduino UNO board as shown in Fig. 3.

Fig. 3. Arduino Uno Board [16].

Arduino Due. It is a microcontroller development board based on the AT91SAM3X8E SAM3X8E-32 BIT 32-bit ARM Cortex-M3 with a clock speed of 84MHz [17-18]. This module has a total of 54 digital I/O pins, out of which 12 pins are used as PWM outputs, 16 analog inputs, 4 UARTs, 2 DAC (Digital to Analog Converter), 2 CAN, 2 TWI, SPI header, a JTAG header, a power jack, an USB OTG capable connection, and a reset button. This Arduino board is mostly used in powerful, large Arduino based projects and shown in Fig. 4.

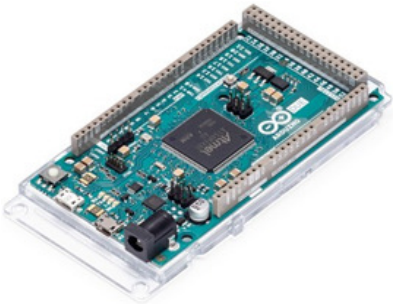


Fig. 4. Arduino Due Board [17-18].

Arduino Mega. Arduino Mega is an open-source microcontroller board based on the ATmega 2560 MU with a clock speed of 16 MHz. It is an 8-bit board with 54 digital I/O pins and out of which 16 pins are analog inputs. It has 15 PWM output pins, 4 UARTs, an ICSP header, a power jack, a USB capable connection, and a Reset switch as shown in Fig. 5 [19]. This board is compatible with most shields designed for the Arduino Uno.

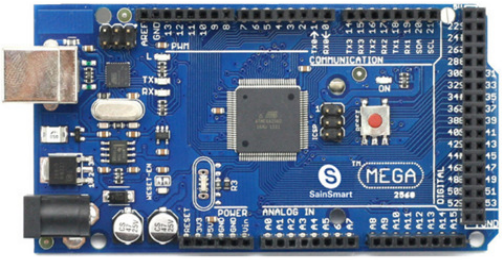


Fig. 5. Arduino Mega2560 Board [19].

Arduino Leonardo. Arduino Leonardo is the first development board manufactured by the Arduino company, this board is very simple to use and cost effective [20]. It is based upon ATmega32u4, an 8-bit AVR microcontroller family member offering a clock speed of 16 MHz. Only one microcontroller is used in this board with the USB. On this development board, there are 20 digital I/O pins. Out of which 12 are used as analogue input pins and 7 pins as PWM outputs. It has SPI, a micro USB (CDC) port connection, a power jack, and a Reset switch interface as depicted in Fig. 6.

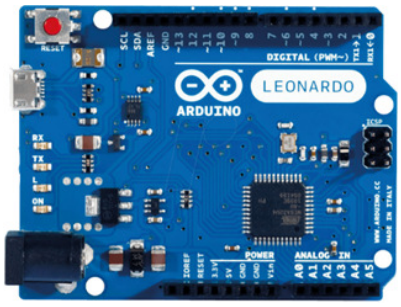


Fig. 6. Arduino Leonardo Board [20].

Arduino MKR Series IoT Boards. Arduino MKR series development boards are designed for in-built network connectivity to reduce the cost and time for IoT hardware products development. These are integrated with SAMD21 Cortex-M0+ 32-bit low power ARM microcontroller processing unit. The MKR series IoT boards have a similar number of I/Os pins across each module. Each module has a total of 22 digital I/O pins out of which, 12pins are used as PWM outputs. They also have 7 analog inputs pins with 1 analog output. Some of the commonly used modules are MKR 1000 with Wi-Fi, GSM 1400, WAN 1300 with LoRa, and Fox 1200 development boards and shown in Fig. 7 [21-22].
MKR series have been designed to provide a hands-on and cost-effective solution for IoT enthusiasts. It is suitable for those who want to add Wi-Fi, GSM, Lo-Ra WAN, or SigFox connectivity into its product with or without having previous knowledge in networking. These modules also have various built-in features such as RTC, LiPo battery charging circuit, MKR ENV Shield, MKR Term Shield, etc.

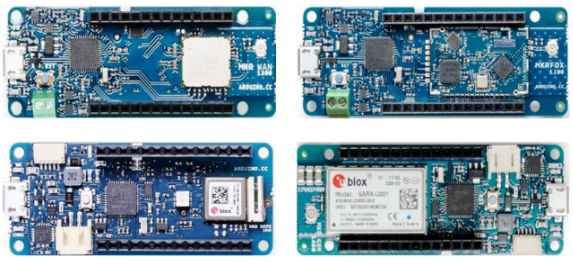


Fig. 7. MKR 1000, WAN 1300, GSM 1400, and Fox 1200 development boards [21, 22].

Hence forth, this has enhanced MKR series board capabilities to realize IoT products shortly and quickly. A table of comparison between Arduino and MKR series development boards is shown in Table 3.

Table 3: A comparison between Arduino and MKR Series Development Boards.

Specifications	Arduino	MKR Series
Microcontroller	ATmega328P	SAMD21 ARM Cortex-M0+
Speed	16 MHz	48 MHz
Digital I/O Pins	14	22
Wireless Connectivity	No	WiFi, GSM, Lo-Ra, SigFox
Supported Battery	No	Li-Po single cell, 3.7V, 700mAh min.
Shield Compatibility	Yes	Speciality shields or use MKR2UNO
PWM Pins	6	12
UART/SPI/I2C	No	1
Analog I/O Pins	6	8
Flash /SRAM	32 KB	256 KB/32 KB

C. Raspberry PI

The "Raspberry Pi" is the series of development boards manufactured by the "Raspberry Pi Foundation". A "United Kingdom" charity, focusing and aiming to educate people with embedded hardware and software programming for creating awareness and access to computer education [23-26]. The Raspberry Pi has commonly employed in small-scale IoT industries, educational projects, and robotics.
Nowadays, it is gaining popularity and becoming famous among researchers and hobbyists due to its minimum cost in the market as well as portability. The Pi does not have any added peripherals with them. A diagram of Raspberry Pi has been given in Fig. 8.

Fig. 8. Raspberry Pi Board [23, 24].

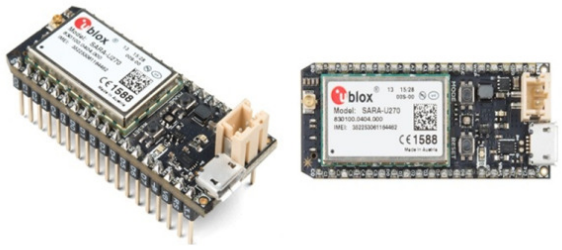
There are many types of models of Pi available in the market. A comparison of different models of Raspberry Pi has given in terms of their release date, instruction set bits, SoC, floating-point unit (FPU), memory, SD RAM, and the number of USB ports as shown in Table 4.

Raspberry Pi is used in the field of home automation that helps us in the security system of the home and for controlling the home appliances like T.V, Refrigerator, Airconditioner, etc. It is also used in the field of industrial automation for automation of mechanical components that are very helpful for safety purposes. In 2020, the pandemic of COVID-19 is spread on the world level. Therefore, during this time the demand for Raspberry Pi is very high because, with the help of the Pi, many low-cost smart devices are manufactured by which we can fight against this Novel Coronavirus.

D. Particle

Particle is an IoT hardware platform that offers embedded hardware, communication interfaces, cloud network services, and application builder tools for IoT services. The data can be accessed by IFTTT and use it for action and trigger purposes to send an email and receive commands through the user easily. It has an integrated development environment (IDE), software development tools, and various development modules for different IoT products. It has different types of communication modules such as Boron/Electron GSM with 2G/3G enabled, Xenon with mesh only, and Photon/ Argon with Wi-Fi [27]. It offers various services like design and development support, application builder tools, device cloud services, device-to-cloud encryption and security services, standard remote firmware updates, remote diagnostics, fully managed connectivity, role-based Access Controls, etc. Particle Photon device is shown in Fig. 9.

Particle is open source and can be integrated into other products. It has a powerful STM32F205RGY6 ARM Cortex M3 processor offering a clock speed of 120MHz with a Broadcom BCM43362 Wi-Fi chip. This module is called P-zero or PØ Wi-Fi module because of its tiny size. Which lets us connect to the Internet through Wi-Fi. It has 6 Analog I/O ports with 2 ports for Rx and Tx, one DAC, and 8 digital I/O ports with inbuilt LED at D7 port. Particle Photon has a 1 MB Flash memory with 128 KB RAM, onboard RGB status LED, FreeRTOS (Real-time operating system), and open-source design [28, 29].



(a) (b)

Fig. 9. Particle Photon device (a) Perspective view and (b) Front view [28-29]

E. Samsung's Artik

Samsung's Artik is one of the platforms which is integrated for IoT and contributes the quickest way to impart assured connectivity, resourceful IoT devices and services. The Artik brings together all the hardware, software, cloud services, and security on a unique development board. It is always ready to interact with any device with the third-party application, devices or services [30, 31].

With the help of Samsung Artik modules, cloud API, and other smart tools, new or latest IoT projects and their solutions can be imported in the market. This helps them to grow their business. It is one of the top platforms, which can make the device smarter. Samsung Artik is designed by all kinds of devices from miniature devices to entire homes as well as large factories can publicize with everyone. The smart component Artik can only be feasible for the preceding prosperity of smartphones.

Table 4: A comparison of different models of Raspberry Pi (RPi).

Feature/ Module	Release Date	Instruction set- bit	SoC	FPU	CPU	Memory SDRAM	USB Port
RPi 1 A	Feb 2013	ARMv6Z 32-Bit	BCM2835	VFPv2	700MHz	256Mb	1
RPi 1 A+	Nov 2014	ARMv6Z 32-Bit	BCM2835	VFPv2	700MHz	256/512Mb	1
RPi 3A+	Nov 2018	ARMv8 64-Bit	BCM2837B0	VFPv4+NEON	1.4GHz	512Mb	1
RPi 1B	June 2012	ARMv6Z 32-Bit	BCM2835	VFPv2	700MHz	256/512Mb	2
RPi 1B+	July 2014	ARMv6Z 32-Bit	BCM2835	VFPv2	700MHz	512Mb	4
RPi 2B	Feb 2015	ARMv8-A 64/32 Bit	BCM2836	VFPv3+NEON	900MHz	1Gb	4
RPi 3B	Feb 2016	ARMv8-A 64/32 Bit	BCM2837	VFPv4+NEON	1.2GHz	1Gb	4
RPi 3B+	Mar 2018	ARMv8-A 64/32 Bit	BCM2837B0	VFPv4+NEON	1.4GHz	1Gb	4
RPi 4B	Jun 2019	ARMv8-A 64/32 Bit	BCM2711	VFPv4+NEON	1.5GHz	1,2,4 or 8 GB	2
RPi 0	Nov 2015	ARMv6Z 32-Bit	BCM2835	VFPv2	1GHz	512Mb	1m-USB
RPi 0 W	Feb 2017	ARMv6Z 32-Bit	BCM2835	VFPv2	1GHz	512Mb	1m-USB

Some of the family members of the SAMSUNG ARTIK named as ARTIK 05X, 020, 030, 530/530S/520, and ARTIK 710/710S are described in details as under.

Samsung ARTIK 05X. SAMSUNG ARTIK 05X IoT module is a Wi-Fi compatible module for the devices which needs compactness, connectivity, and security for its hardware. The ARTIK 05X module works on the Tizen RT platform, which provides support for Light Weight Machine to Machine protocols [32]. This platform contains an RTOS with in-built TCP/IP stack and this module has been shown in Fig. 10.

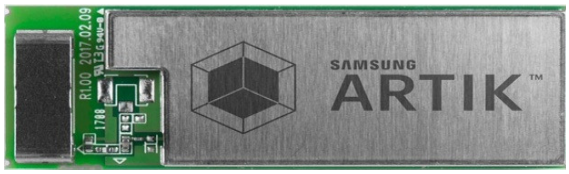


Fig. 10. Samsung ARTIK 05 module [30-31].

Samsung ARTIK 020. ARTIK Bluetooth / 802.15.1 is a Bluetooth IoT module with 32-bit ARM Cortex-M4 processor for low energy applications and is suitable for medium to short-range communication networks. The ARTIK 020 accommodates all the requisite elements aimed at novel BLE applications in smart healthcare, fitness, beacons, security, home entertainment, etc. It contains Bluetooth low energy radio and software stack. This module offers great flexibility in terms of hardware to interface different smart devices, sensors, actuators, and even capable to run host-end user applications as shown in Fig. 11.

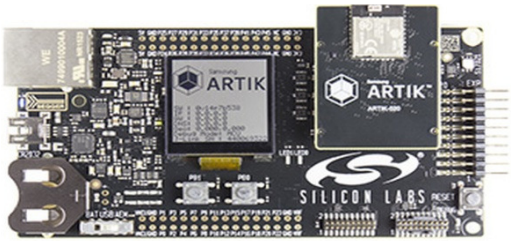


Fig. 11. Samsung ARTIK 020 [30, 31].

Samsung ARTIK 030. For wireless mesh solution, The ARTIK 030 networking module is a fully integrated and pre-certified IoT module. It contains an integration ZigBee module. It features a multiprotocol wireless SoC with a dedicated RF/antenna, energy-efficient, development environment, and software stack as given in Fig. 12. This module is most suitable for fast development of IoT applications.

Fig. 12. Samsung ARTIK 030 [30, 31].

Samsung ARTIK520 and ARTIK 530/530S. ARTIK520 development board includes a highly integrated system on modules with built-in Wi-Fi, ZigBee, and Bluetooth Low Energy Module. ARTIK520 utilizes a dual-core ARM Cortex A7 processor whereas ARTIK530 has a dual-core ARM Cortex A9 processor. Both modules have an extensive range of wireless communication protocols options. This includes WLAN standards 802.11a/b/g/n, Bluetooth Low Energy protocol 4.1, and LR-WPANs 802.15.4 for Zigbee. ARTIK module has a multimedia engine to handle audio and video processing. ARTIK 530/530s takes 520 combinations of power and multimedia, this adds more power while simultaneously reducing cost. ARTIK 530/530s uses a quad-core ARM Cortex A9 processor to handle data and multimedia processing. It also supports a rich UI/UX interface for display and camera requirements.

For end-to-end security, a hardware-based secure element is included. This module is shown in Fig. 13.

Samsung ARTIK 710/710S. This module has an octa-core ARM Cortex A53 processor boxed DRAM and flash memory, It provides support to a wide range of wireless communication like Gigabit Ethernet, fastest available Wi-Fi, BLE, and Zigbee module [32]. It also supports a rich user interface for display and camera requirements. A hardware-based securing element is included and works with the Trusted Execution Environment (TEE) and ARM TrustZone to protect against the threat from the surrounding environment, thus enhanced end-to-end security. The module has been shown in Fig. 14.

The Technical Specification of Samsung Artik is given in Table 5.

Fig. 13. Samsung ARTIK 530 module [30, 31].

Fig. 14. Samsung ARTIK 710S moodle [30, 31].

Table 5: A comparison of the Samsung Artik development boards.

Module/Features	ARTIK 05X	ARTIK 020	ARTIK 030	ARTIK 530/530S	ARTIK 710/710S
Processor	32-bit ARM Cortex R4	32-bit ARM Cortex M4	32-bit ARM Cortex M4	Quad-core ARM Cortex A9	Octa-core ARM CortexA53
DRAM	1280 KB	32 KB	32 KB	512 MB/1 GB DDR3	1GB DDR3
FLASH Memory	8 MB	256 KB	256 KB	4 GB	4 GB
Wireless Interface	Wi-Fi	Bluetooth	Zigbee/ Thread	Bluetooth 4.2	Bluetooth 4.0
Power	5-12 V	3.8 V	1.85-3.8 V	3.3 V	3.3 V
I/O Pins	68	50	25	107	110

F. Intel IoT development boards

Intel is one of the corporations, which manufactures different types of development boards designed for sudden mock-up of computing smart devices to immediately produce Internet of Things and computing devices. Intel manufactures development mock-upboards; these are individually designed for students, makers, researchers, and do it yourself (DIY) electronics addicts. Some of the popular IoT development boards manufactured by Intel are Intel Galileo Gen 2 development board, Intel Edison Breakout Board/kit, Intel Edison Board/Kit for Arduino, etc.

Intel Galileo Gen 2 development board. The development board is based on Intel Quark SoC X1000 32-bit processor operating at speeds up to 400MHz and shown in Fig. 15.

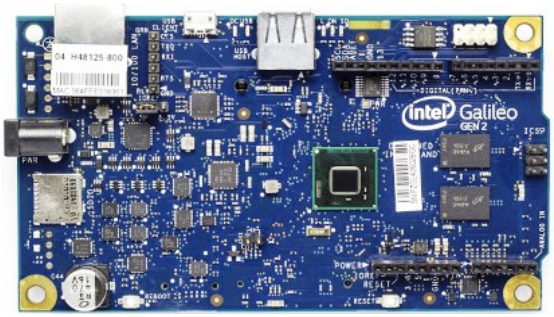


Fig. 15. Intel Galileo Gen 2 development board [35].

Its design is compatible with both hardware and software connected with Arduino shields designed for Uno R3. It has 20 digital I/O pins of which 6 can be used as PWM outputs and 6 as analog input pins. It has ICSP header, a JTAG header, USB 2.0 Host Port, micro-SD slot, PCI Express, UART port, and 2 reset buttons.

It supports shields that operate at 3.3 or 5V voltage and its operating voltage is 3.3V. The Galileo board software is compatible with Arduino IDE [33-34].

Intel Edison Breakout kit/board. The first IoT development platform is Intel Edison, which is cheap, already prepared-product and this product help every stage of the learner, entrepreneurs from pro-inventor to general electronics user and the association who are engaged with the Internet of Things. This Intel Edison equipment is a booming set of ingredients in its tiny shape and size. The performance and endurance of this tiny component are supportive which helps them meet a huge range of consumers. The particular sequence of tiny sizes, energy consumption, and upper-class efficiency supports inspirational imagination and facilitates expeditious contraption from precursor to construction for all the learners and entrepreneurs. The figure of Intel Edison Breakout Kit is given in Fig. 16.

Fig. 16. Intel Edison Breakout Kit [34].

Intel Edison Board/Kit for Arduino. The Intel Edison kit for Arduino is designed for both the hardware and software compatibility with Arduino shields. This Kit of Arduino contributes the pinout of Arduino 1.0 and it has ideal connectors i.e. a micro USB attached to a UART, type-A connector for USB hosting, SD cardholder and a DC power jack are available on the board as shown in Fig. 17. A comparison of various features offered by different modules of Intel IoT Development Boards have given in Table 6.

Table 6: Technical Specifications of Intel IoT Development Boards.

Features/ Module	Galileo Gen 2 Board	Edison `Breakout Board/Kit	Edison Board/kit for Arduino
Model	Intel Quark SoC*1000	Intel Quark SoC*500	Intel Quark SoC*Dual core
Power	7 to 15 V	7 to 15 V	7 to 15 V
ISA	32 Bit Intel Pentium	32 Bit Intel Quark	32 Bit Intel Quark
Speed	400 MHz	500MHz	500 MHz
DRAM	256 MB DDR3	1 GB	1 GB
Ports	4	4	2
I/O Pins	20	20	20

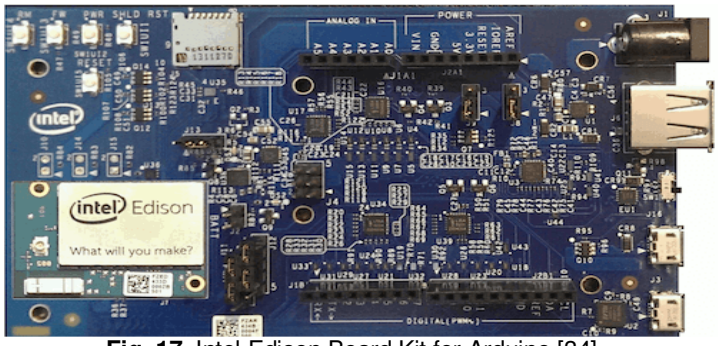
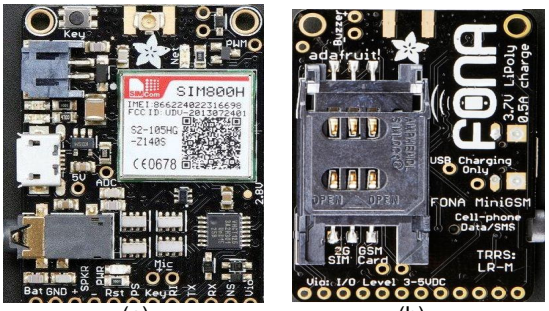


Fig. 17. Intel Edison Board Kit for Arduino [34].

G. Adafruit Range of IoT Development Boards

Adafruit was founded in 2005 by MIT engineer, Limor "Ladyada" Fried. Adafruit is the smart electronics device/component which is manufactured by the Adafruit industry. With the help of these development modules, many problems can be solved, projects can be completed, and communication systems can be improved. The dimension and weight of the module is quite small and handy for the customers. Two types of Adafruit IoT development boards are discussed here named as Adafruit FONA and Adafruit FEATHER M0 [36-37].

Adafruit FONA. It is an IoT development board of Adafruit which is named as Adafruit FONA. Adafruit FONA is a MiniGSM, all-in-one cellular board for IoT applications [38]. It uses the latest SIM800 and support band for global cellular connection.



(a) (b)

Fig. 18. Adafruit FONA module (a) front view and (b) back view [36, 37] .

This development board need a processor to run it such as an Arduino board. It contains a surprising amount of technology into its little size and has an onboard Lipo battery charging circuitry with MicroUSB. Using this module consumers can attach voice, text, SMS messages, make and receive calls using a headset or speaker, get GPRS data and coordinates to check or monitor objects, and FM radio broadcast. Adafruit FONA has been shown in Fig. 18.

Adafruit Feather M0. A new developed IoT board from Adafruit is Adafruit FEATHER M0, which is very less in weight as well as thin in dimension. The development board is based upon the ATSAMD21G18 ARM Cortex M0 processor offering a clock speed of 48 MHz and with an operating voltage of 3.3 V. This module is Arduino compatible with Wi-Fi w/ATWINC1500. This module has an inbuilt USB and battery charging features. The size of flash memory and RAM is 256 KB, and 32 KB, respectively. The ADAFRUIT FEATHER M0 module is shown in Fig. 19.

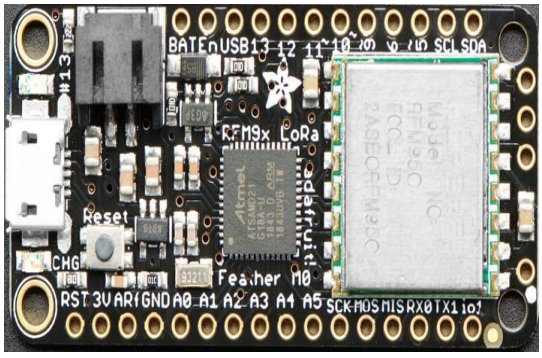


Fig. 19. Adafruit FEATHER M0 module [36, 37].

A comparison of features for Adafruit FONA and Adafruit FEATHER IoT development board are given in Table 7.

Comparison model of H/W development boards. A comparison of different IoT hardware development boards is given in Table 8. These modules have been compared based on their microcontroller-processing unit, frequency speed, amount of RAM, power requirement, USB ports, and general-purpose input-output pins they support, respectively.

III. CONCLUSION

In this research work, we have studied and analyzed IoT hardware development platforms. Different IoT hardware is compared in terms of their processing capabilities, communication protocols, the technology used, ports, analog and digital I/O pins, dimensions, battery power, memories, etc. These modules are designed to offer versatility and to meet specification requirements of customers. IoT reduces human effort and savesa lot of time, money, and resources. It delivers large amount of data in real-time and uses advanced analytics to uncover business insights, and opportunities. With the help of IoT, trustworthy relationships and interactions can be created in different fields like asset tracking and inventory control, location and shipping, individual tracking and conservation of energy, etc.

Table 7: Module specification of Adafruit IoT development board.

Features/ Module	Adafruit FONA	Adafruit FEATHER
Processor	Quad-band	ATSAMD21G18 ARM Cortex M0
Technology used	GSM	BROADCOM
Power	3 to 5 V	3.3 V
Battery	4.2 V	3.7 V
Flash, RAM	-	32 KB, 2 KB
Connector pins	3	20
Dimensions	1.75"x1.25"	2.0" x 0.9" x 0.28"

Table 8: Comparison of different IoT development boards

Modules	Processor	Clock Speed	Ram	Power (V)	USB Port	GPIO Pins
ESP8266	L106 32 BIT RISC	80 MHz	32 & 80 KB	3.3	No.	16
ARDUINO UNO	ATmega328P	16 MHz	2 KB	5	1	20
ARDUINO MEGA	ATmega2560	16 MHz	8 KB	5	1	54
ARDUINO MKR	SAMD21 Cortex-M0+	48 MHz	32 KB	3.7	1	22
RASPBERRY PI 3 A+	ARMv8 64-BiT	1.4GHz	512 MB	5	1	40
RASPBERRY PI 3 B	ARMv8-A 64/32 Bit	1.2 GHz	1 GB	5	4	40
RASPBERRY PI 3 B+	ARMv8-A64/32 Bit	1.4 GHz	1 GB	5	4	40
RASPBERRY PI 4 B	ARMv8-A64/32 Bit	1.5 GHz	1,2,4,8GB	5	2	40
PHOTON with Wi-Fi	STM32F205RGY6 ARM M3	120 MHz	128 KB	3.3	1	18
Samsung ARTIK 05X	32 bit ARM Cortex R4	320 MHz	1280 KB	5-12	1	68
ARTIK 530/530S/520	Quad core ARM Cortex A9	1.2 GHz	512 MB/ 1GB	3.3	4	107
ARTIK 710/710S	Octa core ARM Cortex A53	1.4 GHz	1 GB	3.3	4	117
Intel Galileo Gen 2	Intel Quark SoC*1000	400 MHz	256 MB	7-15	4	20
Intel EDISON Board	Intel Quark SoC*Dual core	500 MHz	1 GB	7-15	2	20
Adafruit FONA	Quad band	850/900/1800/1900MHz	-	3-5	-	-
FEATHER M0	ATSAMD21G18 ARM Cor.M0	8 MHz	32 KB	3.3	2	-

IV. FUTURE SCOPE

Despite, of the concern over privacy and security in the internet of things, IoT applications will see rapid growth and prosperity in the coming years. Eventually, IoT will have a bright future and lead to tremendous opportunities and benefits, thus helping in economic growth.

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