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Internet Of Things Challenges And Obstacles - A Comparative Study

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Abstract

Internet of Things (IoT) is that the field that connects things along and to the net, material possession them exchange knowledge, communicate with one another and act with the human. Recently, it's been wide accustomed transcend the machine to machine (M2M) communication and covers sort of protocols and applications that facilitates people's approach of living. However, several challenges still hinder its advances, particularly security and power problems. during this paper, a comparative study for IoT architectures, platforms and applications is given with a case study maybe the most IoT ideas and levels of abstraction. Then, a Strengths – Weaknesses – Opportunities – Threats (SWOT) analysis is given to assess the current and also the way forward for IoT.

Keywords—IoT, Protocol, Communication, Application, Hardware, Smart; design, SWOT, Platform.

I. INTRODUCTION

Internet of Things (IoT) is one in all the foremost promising analysis topics in engineering and business. IoT is believed to revolutionize the approach individuals board the close to future by connecting traditional objects with one another distantly and establishing communication channels between them. As a result, not solely that abundant data would be nonheritable regarding several objects and processes that weren't to be nonheritable before with identical ease, however additionally rigorously designed systems would wear down these objects and also the data nonheritable from them mechanically. This leads to unexampled automation that will build industries' performance higher and everyday lives abundant easier. additionally, several applications would be attainable that weren't applicable before, like sensible homes, sensible cities and implantable devices in physical structure. per Cisco's net of Things cluster (IOTG), the number of connected devices is anticipated to succeed in fifty billion by 2020 [1].

IoT is that the evolution of machine to machine (M2M) communication. M2M is that the

technology that permits physical objects or machines to attach to the net. This helps the machines communicate and share data with none human interference. while not M2M technology, the net of things can ne'er become a reality; because it is not possible to form a standard network of communication between all physical entities.

M2M has joined in several fields to facilitate the human life, as shown in Fig. 1. In spite of the various edges and facilities IoT offers, there are still tons of challenges that require best solutions so as for IoT to unfold in everyday lives. Therefore, several analyses are being conducted to beat these challenges and solve IoT issues, and there are opportunities for far more analysis within the future. However, up until currently, little or no analysis work is completed to match the IoT totally different completely different} platforms in terms of their performance within the different IoT system levels. Therefore, during this study, the most focus was given to the comparison between the various IoT platforms to suggest best solutions for the various IoT applications.

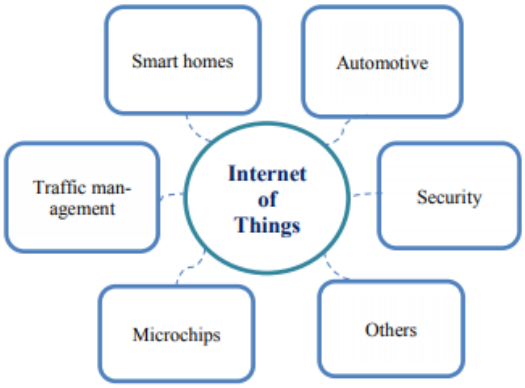

Fig. 1. *IoT connects machines together from various fields.*

The paper is organized as follows: Section II discusses the design of IoT and also the completely different abstraction layers that represent it. Then, section III presents a case study that illustrates however IoT abstraction layers operate and act with one another. After that, section IV discusses IoT package and hardware platforms giving examples for every platform, followed by section V that presents a comparative study to pick the most effective hardware and communication protocol for every mentioned IoT application. Finally, section VI presents a Strengths – Weaknesses – Opportunities – Threats (SWOT) analysis that evaluates the IoT current and future business and analysis practicableness.

II. IOT DESIGN

IoT platforms have several levels of abstraction. It starts from the appliance layer, that is that the main layer for the users, wherever they'll management devices and receive knowledge on their sensible devices, then the communication layer, wherever knowledge are transferred between the assorted sensors, mechanism and their native gateways similarly as between international gateways mistreatment completely different protocols, and eventually the physical layer, that has sensors, actuators and controllers and their interaction with the entrance. Figure two describes IoT design.

There are 2 design perspectives: issue centrical design and net centrical design. In issue centrical design, the user is within the center wherever all devices are contacting, and also the knowledge is saved domestically on the user's device [2]. On the opposite hand, in net centrical design, devices are connected to the cloud wherever all the information are keep and managed. The user accesses the information on the cloud from an online application that's connected to the net. the overall trend is to use the net centrical design, nonetheless it'd not be the most effective architecture; as in some cases human actions should be taken. the subsequent subsections detail the degree of abstraction of IoT.

A. IoT Application Layer

Internet of things' application layer holds the responsibility for providing services and defines the set of messages' protocols that are passing at this level. There should be some processing setting for analyzing the information fetched from the devices (sensors, controllers…. etc.) and creating this knowledge usable [3]. Thus, this usability may be through direct applications with simple graphical computer program (GUI) for individual users, like mobile applications for easy IoT applications, or for enormous comes that host international users, clouds may be

accustomed analyze, delineated and store the information, and websites may be used as an interface [4].

The application layer is also concerned with providing a virtual service layer that is responsible for data transport, security, and service discovery and device management on a high level of abstraction, independent of communication technologies in the lower layers. This ensures the right connectivity between devices and various IoT applications to realize horizontally – on the same level – integrated IoT for specific applications. This virtual service layer provides information collected from objects and the performance of the actuators. For instance, while data from a temperature sensor for home automation are provided, it should also describe if it is the indoor temperature of a room, or a fridge… etc. [3]. IoT potential allows it to customize any kind of applications. Here are some main examples for IoT applications with a brief customization discussion about each:

1. *Smart homes:* they are homing whose gadgets and devices are manipulated using a single application platform, such as a mobile phone application. Yet, most IoT smart home systems are more concerned with economic feasibility and friendly user interfaces rather than high performance [5].
2. *Automotive:* the new trend in automotive industry is directed towards self-driving auto-adjusting machines that can be controlled remotely. For example, BMW's vision is to fabricate a motor cycle with a self-balancing system that uses signals to adjust the motor cycle position. IoT of automotive devices requires fast responsivity, high level of security, durability and reliability [6].
3. *Traffic management:* as the number of vehicles is dramatically increasing every day, the road congestion increases in all world cities. A new traffic management smart automated system is required to not only solve this issue, but also help save lives in addition to reducing road crimes. IoT in traffic management senses the level of crowdedness, suspicious movements and emergency cases. It then controls traffic signals and gives the most suitable commands; thus, it requires high level of security and reliability [7].
4. *Security:* tracking and regulating stockings in businesses is commonly used through normal means of big cameras and under human supervision. It will be very helpful if a smart small system that uses IoT concepts is utilized in security applications. This will increase the performance, reduce many efforts and economically make it more feasible. IoT in security domain requires fast response, highly secured communication, economic feasibility and reliability [8].

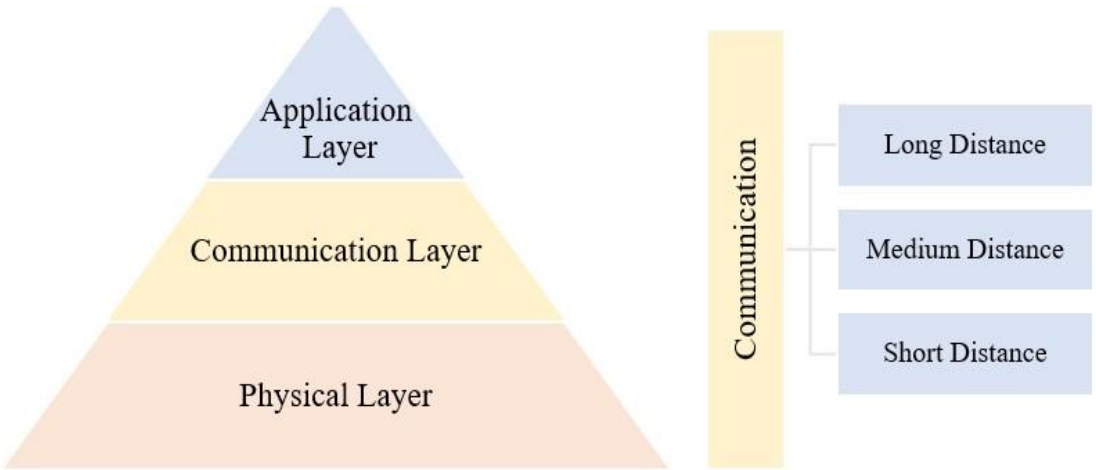

Fig. 2. *IoT Architecture.*

5. *Microchips:* the applications of microchips are very broad; as they are being used in lots of fields like biological needs, energy harvesting tools for providing self-maintaining applications, and standard day to day items. IoT requirements in this domain differ according to the application needs, but one thing is common, which is the small size of the whole system [6].

IoT application layer is a very wide topic that gets shaped in many forms at many different scales. Some companies manufacture tools to help people develop their applications [9], e.g., some tools to develop mobile application in a simple way [10, 11] and connectivity tools to connect between IoT devices and gateways (like programmable cellular connectivity ships to IoT projects) [12]. The importance of such products is unleashing the potential to unify the communication technologies and protocols for wider IoT range of applications, giving the possibility to form huge webs of devices connected to and controlling each other, which is one of the biggest challenges facing IoT.

B. IoT Communication Layer B. IoT Communication Layer

The communication layer is taken into account because the backbone of the IoT systems. it's the most channel between the appliance layer and completely different operative activities within the IoT system. the complete physical system is loaded with amounts of knowledge and knowledge that require to be shared with different nodes. Therefore, it's required to line up an acceptable association network among these nodes through a communication protocol [13]. The communication might be wire-connected or wireless supported the protocol outlined by the designer. per the space, communication protocols are divided into 3 main categories:

a. Short distance communication: In native areas, various knowledge protocols are capable of managing the information flow between native nodes, like Wi-Fi, that may be a wireless networking technology that produces use of radio frequencies to send and receive knowledge, and RFID, that is usually utilized in business applications to watch offer chains particularly in producing and retail industries.
b. Medium distance communication: Connecting multiple gateways needs communication protocols for medium distance [14]. local area network may be a model as a result of it manages connections between the connected gateways through put in wired systems.
c. Long distance communication: The existence of active support of satellite networks offers vast communication ranges. Also, suppling the mobile phones with Fifth Generation (5G) communication protocol enhances the communication speed over a really long distance. Since billion of devices round the world communicate along, IoT will simply unfold everywhere the globe.

Building a decent IoT system needs the following:

- Connect a really sizable number of native gateways in an exceedingly heterogeneous setting through multi-modal technologies and completely different light-weight protocols like 5G.
- Use low power systems the maximum amount as attainable.
- speedily manages the traffic flow of knowledge and modify Realtime call actions.
- Maintain a secure association for data. x Have unlimited addressing capability.

Some of the most communication protocols are mentioned below.

1. local area network (Medium): Ethernet may be a wired communication protocol wide used for laptop networking. it absolutely was 1st introduced to the market in 1980, and its use got internationally standardized in 1983 as IEEE 802.3 [15]. Physically, it uses homocentric cables, twisted pairs or optical fibers, with networking speeds starting from ten Mbits/s up to a hundred Gbits/s, and also the speed is anticipated to rise even up to four hundred

Gbits/s by 2018 [16]. local {area network|LAN} is sometimes utilized in native area network (LAN), additionally to metropolitan space network (MAN) and wide space network (WAN) [17]. In OSI model, local area network is enclosed within the circuit layer.

Due to its support for prime speed communications, local area network is good for applications with vast amounts of knowledge and people requiring high speed. additionally, it's convenient for prime information measure applications. what is more, {ethernet|local ara network|LAN} cables are ideal to move knowledge to terribly so much destinations. However, local area network additionally suffers from disadvantages relative to different communication protocols. for example, local area network may be a wired protocol, that makes it inconvenient for wireless applications. Being a wired protocol not solely needs direct physical association between nodes, however additionally it makes the association prone to physical harm.

2. Bluetooth (Short): Bluetooth may be a wireless communication protocol wide used these days to attach devices along. it absolutely was initial introduced in 1989 by Nick Rydbeck and Johan Ullman [18]. It uses magnetic force (EM) waves with frequencies travel primarily between two.4 gigacycle per second and a couple of.485 gigacycle per second [19]. it's supported a master-slave configuration within which communication is established between a master and up to seven slaves most [20]. the most recent version is Bluetooth five, that supports higher Bluetooth speed connections (2 Mbits/s) and additional vary (more than three hundred m). Bluetooth five additionally contains options that support IoT, like coded communication and forwarded error correction [21, 22]. There square measure several benefits for Bluetooth that produces it appropriate for IoT use. initial of all, it's a wireless protocol, and therefore it supports wireless applications like wearable devices. Secondly, Bluetooth may be a low power protocol, that is additionally ideal for IoT. On the opposite hand, Bluetooth limits the quantity of slave devices connected to a master device (7 devices maximum). additionally, power transmission limits the most distance at that a affiliation may be established, that creates an exchange between power consumption and furthest distance for communication.
3. Wi-Fi (Short): Wi-Fi is a simple and cheap communication protocol that connects electronic devices to the web employing a wireless router [23]. This router receives the signal and sends the data to the web exploitation LAN. it's used primarily as a replacement for the high-speed cables in native areas. additionally, Wi-Fi is that the extremely adopted communication protocol got IoT. the most recent version of Wi-Fi these days is 802.11ac, that has super high speeds starting from 433 Mbps up to gigabytes per second, and providing wide ranges of information measure (80 megahertz and one hundred sixty MHz) [24]. The vary of Wi-Fi reaches a hundred meters [25].

3) ZigBee (Short): ZigBee may be a communication technology for knowledge transfer in wireless networks. It offers low power affiliation. additionally, it's designed for multi-channel management systems, alarm systems and lighting management. what is more, ZigBee is additional economical than Wi-Fi and Bluetooth; because it consumes less power. Moreover, it ensures that networks stay operable in conditions of regularly dynamic qualities between communication nodes. On the opposite hand, ZigBee features a low bit transfer rate that solely reaches many kilobits per second; the most bit rate transfer for ZigBee is 250 Kbit/s [22, 26]. ZigBee is usually used for applications that need low knowledge transfer rate and low power consumption. sadly, ZigBee isn't wide acknowledged like Wi-Fi and Bluetooth; because it is commonly

embedded within systems; and it's not visible.

4. Radio Frequency Identification Tags (RFID) (Short): oftenest identification sensors play a crucial role in transmittal and receiving knowledge. A RFID tag carries knowledge and sends them in radio waves to a RFID reader that reads them. It doesn't need shut communication between the tag and therefore the reader; instead, it will establish itself from a distance with none human issue. There square measure 2 common RFID configurations: close to and much. the previous configuration uses a RFID reader that features a coil through that electrical energy passes and therefore generates flux. The tag should have a smaller coil that generates potential thanks to the changes within the flux. it's then including a capacitance to power up a tag chip. Meanwhile, the latter configuration features a reader and a tag with dipole within which EM waves propagate [13].
5. Fifth Generation (5G) (Long): 5G is that the most up-to-date knowledge protocol utilized in good phones and expected to be over a brand-new generation. it's expected to introduce a brand-new era of connectivity; because it can provide speeds of over a hundred megabits per second, a new knowledge information measure and fewer delay thanks to inherent computing intelligence that handles knowledge terribly expeditiously [27]. So, it'll connect billions of devices within the quickest, most reliable and best ways that. As a result, 5G is predicted to require IoT to a brand-new revolutionary level and extend its use additional and additional [28].
6. Satellites Networks: Satellites have an excellent role behind the expansion of IoT. they allow the event of consumer centric services that provides smart expertise to the user. they provide IoT with large benefits that can't be offered by wireless fidelity deployments, Bluetooth or terrestrial GSM (Global System for Mobile Communications) networks like Coverage. Satellite networks serve to hide a large vary, thus IoT is predicted to embrace billions of devices round the world even in remote locations. As a result; exploitation active support of satellite networks, like the L-band services provided by Thuraya, can make sure the final success of IoT growth [29].
7. IoT Physical Layer The physical layer is that the most careful level of abstraction in IoT. It primarily consists of sensors that acquire data for the system and actuators that do actions in response to directions from the system. To imagine however they each, actuators and sensors, act along in a very system, a sensible home is thought of for instance. The actuators here square measure accustomed lock and unlock doors, switch on/off the lights and alert users of any warnings or management the temperature of a space or the complete house. The sensors square measure accustomed send feedback to the controller of every tiny system of these systems mentioned on top of. for instance, they send feedback regarding the condition of the rooms and whether or not their square measure any individuals within the rooms or not, and consequently, the controller sends its signals to the actuators to show off unessential operating devices like the lights, the air conditioner… etc. during this section, sensors, actuators and controllers square measure mentioned well.

a. Sensors: A device may be a small device that measures a selected physical amount. All IoT systems rely on the existence of 1 or additional sensors. they're terribly essential all told aspects of life; as they're thought of feedback to the management that provides its signal to the mechanism to achieve a desired goal. There square measure differing types of sensors, as well as phone-based, medical, environmental, and chemical sensors. all of them have light-weight weights and single functions, additionally to being cheap and miniaturized devices, however affected to

the battery capability and therefore the easy readying.

There square measure differing types of good phone sensors like accelerometers that sense the motion of a portable, gyroscopes that discover the orientation of the portable, GPS (Global Positioning System) sensors that discover the position of the mobile, light-weight sensors, proximity sensors, magnetometers, cameras and microphones. Accelerometers may be mechanical, exploitation springs, cantilever beams and seismic plenty, capacitive, exploitation electrical phenomenon plates that amendment the capability with their movement, or electricity, that generate electrical signals once squeezed.

On the opposite aspect, medical sensors square measure important for aid applications. they'll monitor terribly vital parameters that ease the patient's identification and supply fast feedback to the doctor while not the urge to travel to the hospital. These parameters contain rate, blood heat and glucose levels. Recently, there has been a brand new promising IoT device, referred to as observation patch, that's put to sleep the skin to watch a particular health parameter sporadically [13]. Neural sensors are getting usually utilized in our lives. they create it simple to infer the brain state and train it for higher focus or, in alternative words, neurofeedback. This technology is named graph (Electroencephalography). The communication of neurons electronically creates field of force. This field of force is measured in terms of frequency and characterized into alpha, beta, gamma and delta waves [13].

Due to the terribly speedy changes within the atmosphere, environmental sensors square {measure} accustomed measure temperature, humidity, pressure and air and pollution. Chemical sensors, on the opposite hand, discover each chemical and organic chemistry substances. New technologies like e-nose and e-tongue are wide accustomed live the quantity of some chemicals that indicate the standard odor and style, severally [13].

b. Actuators: AN mechanism may be a device that converts AN electrical signal into a mechanical signal or the other helpful sort of energy. Some examples embody speakers, heaters, cooling components and displays. they'll be electrical, hydraulic or gas actuators counting on their theory of operation. for instance, hydraulic actuators use mechanics to facilitate motion, whereas gas actuators build use of the compressed gas to get pressure distinction [13].
c. Controllers: The controller is that the device that receives the sensors' signals, processes them and makes computations on them, so sends instruction signals to the actuators. sometimes on top of things systems, these instruction signals square measure supported the distinction between the sensors' readings and therefore the desired values of the physical quantities, and therefore these instruction signals square measure sent to the actuators so as to line the system back to the required physical quantities' values [13].

III.IOT: A CASE STUDY

To understand however all IoT layers work along, a sensible traffic system is taken into account as a case study for IoT, wherever a camera will monitor the road and records knowledge for congestion, accidents, and climatic conditions. The camera communicates the standing to an entrance that mixes it with alternative cameras' knowledge to make AN intelligent broad traffic system. This intelligent traffic system is connected to alternative broad transportation systems that get knowledge from their own intelligent devices, making an outsized intelligent system of systems. By analyzing the tip to finish knowledge across this network, it is often worked out however the directions ought to be. for instance, if the city's intelligent traffic system detects nice congestion thanks to AN accident, that insight is often sent to the broad installation that, in turn, analyzes the accidents' impact on alternative town systems.

Recognizing the impact of the accident just about AN flying field and town faculties, it may inform these systems so they'll alter flights and schools' schedules. Besides, the traffic digital system will send directions to guide drivers round the accident. The physical layer (the camera) interacts with the native system in a very network or a entrance (the camera system) and communicates on the web with alternative systems (the transportation system), then {the knowledge the info the information} get analyzed on the cloud data center to send the simplest directions to the users in their cars, faculties and air planes [30].

IV. IOT HARDWARE AND CODE PLATFORMS

Owing to build a whole IoT system, a designer ought to select the right hardware and code platform that's appropriate to his specifications. There square measure necessary parameters that monitor our alternative for the best platform for any IoT system. once coping with large data-flows, the hardware platform is principally involved with 2 process tasks, either higher cognitive process management or processing. a strong software system is additionally required so as to drive the hardware platform and facilitate develop the required applications with wonderful performance. consequent half is bothered with the necessary properties of the hardware platform. Another half highlights the key parameters to settle on the correct software system. The last half presents knowledge centers that square measure to be used once coping with massive knowledge.

A. Hardware Platform The factors that outline the hardware platform for IoT applications square measure [31]:

a. Reduction of used transistors: this can mirror on the die size, packaging and cost. The progress created on semiconductor unit space decreases the price, however outpouring power dominates on the general chip.
b. Time-to-market: it's the most issue that guides the look to the correct platform. The market needs a generic resolution to use its demands, thus time may be a terribly vital issue to settle on what kind of platform is required, which could be in most cases a chic one.
c. Nonrecurring Engineering (NRE) costs: it's the price of the event method for the IoT platform, either code or hardware. This doesn't solely imply property in reliable systems, however additionally the flexibility to develop the platform in less time the maximum amount as attainable.

Based on the previous factors, the designer is capable of selecting the right platform out of the following:

1. Application-Specific microcircuit (ASIC): ASIC may be a well-established method designed, because the name suggests, for a particular application. The invented ASIC chips provide terribly best performance with the bottom range of transistors, and most significantly, the smallest amount power consumption. additionally, the technology is extremely low cost once mass created. However, ASIC isn't typically used, as a result of it consumes time and resources to develop. In brief, it's giant time-to-market, that makes the business ask for alternative quicker generic solutions.
2. Field Programmable Gate Array (FPGA): FPGAs give an additional generic answer that's needed in business. they need less time-to-market and NRE prices to develop their product. However, they consume rather more power than ASIC chips, that is one amongst the foremost difficult problems in IoT. additionally, they're terribly high-ticket, so that they are utilized in applications with minimum range of units required [31, 32]. One of the foremost spectacular solutions is to merge the options of ASIC and FPGA along. The merging makes use of the benefits of each ASIC and FPGA. one amongst the vital options is that it consumes lower power than FPGAs additionally to lowering the time-to-market [32].
3. Microprocessors: Microprocessors are used as a platform for building IoT devices. Some chips have the microchip at the side

of alternative blocks like RAMs and completely different alternative modules. during this technique, the complete system is constructed on the chip with all its peripherals. The system acts as an entryway for the native devices to the net. this needs that the chip should support many protocols to facilitate the communication between native devices and sensors with the microcontroller (Bluetooth, ZigBee) furthermore as causation and receiving knowledge from the cloud (Wi-Fi, Ethernet). There are many systems used commercially for this purpose. Arduino family (Uno, Yun) are supported ATmega32U4 processor with its peripherals to try and do the entire functions. alternative chips are used like Raspberry Pi, that uses Broadcom BCM283 (5~7) SoC. These platforms are generic and might be used for many applications. As a result, hardware overheads are put in. This will increase the facility consumption for the system. Therefore, additional improvement is needed to save lots of the battery for the longest time.

Package Platforms In order for the hardware to perform well, operational systems ought to be put in. operational systems organize the usage of hardware. For IoT applications, low power and tiny hardware overhead operational systems ought to be used.

The package platform is important to acknowledge the received knowledge, establish the required manipulation for the required action by the user and transmit with efficiency the new knowledge to the proper node.

There are multiple of business operational systems like IBM Watson platform furthermore as open supply platforms like UNIX system, RIOT ...etc. selecting the proper software system may be a crucial move in order to build the optimal IoT system for the desired application. In this section, the key parameters to choose the suitable operating system (OS) are investigated as follows.

a. *IoT heterogeneous hardware support:* A lot of IoT systems usually work on different types of hardware from 16-bit microcontrollers to FPGAs based on the implemented hardware. Therefore, the operating system shall be compatible with the implanted hardware platform in order to achieve excellent performance [34].

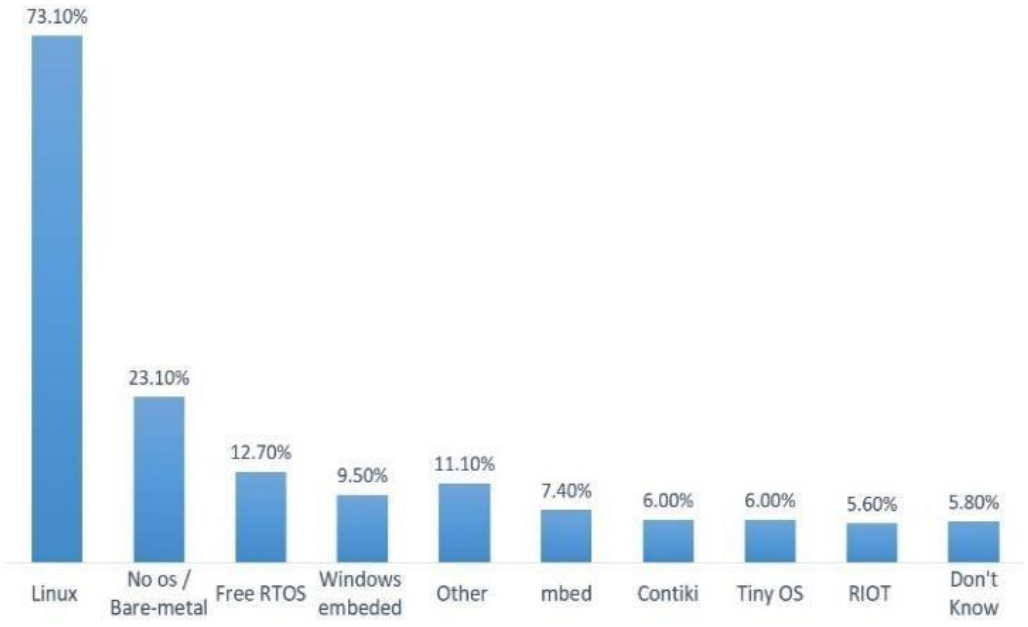

Fig. 3 *Market share for different operating systems [33].*

b. *Real-time operating systems:* One of the most important factors that guide most of IoT designs is that whether the operating system supports predictability or not.

Predictability allows the system to be in an alert position based on earlier received data. This helps the software take actions rapidly, especially in situations like fires and accidents on the road. In turn, this is great evidence on how predictability reflects the degree of smartness of IoT systems, that is in high want for development. [33].

Table 1. *Comparison Between Different Open -Source Operating Systems [33].*

	Contiki	RIOT	FreeRTOS	TinyOS	Uclinux	Mbed
Architecture	Monolithic	microkernel RTOS	microkernel RTOS	Monolithic	Monolithic	Monolithic
Scheduler	Cooperative	Preemptive, tickless	Preemptive, optional tickless	Cooperative	Preemptive	Preemptive
Programming model	Event-driven, protothreads	Multi-threading	Multi-threading	Event-driven	Multi-threading	Event-driven, single-thread
Targeted device class(1)	Class 0,1	Class 1,2	Class 1,2	Class 0	> class 2	Class 1,2
Supported MCU families or vendors	AVR®, MSO430™, ARM®, Cortex-M®, PIC32,6502	AVR®, MSO430™, ARM®, Cortex-M®, x86	AVR®, MSO430™, ARM®,x86, 8052, Renesas	AVR®, MSO430™, px27ax	ARM7™, ARM®, Cortex-M®	ARM®, Cortex-M®
Programming languages	C	C,C++	C	nesC	C	C,C++
License	BSD	LGPLv2	Modified GPL	BSD	GPLv2	Apache license 2.0

(1) Target device class definition
a. Class 0 << 10kB data size and << 100kB code size,
b. Class 1 ~10kB data size and ~100kB code size, and
c. Class 2 ~50kB data size and ~250kB code size

c. Developer friendly: IoT evolves apace, which needs a simple platform to use new solutions and add sensible options to the specified applications. so as to own low time-to-market, it's needed to choose what in operation systems are spare for developing the specified IoT system. engaged on a developer friendly platform is very needed for corporations so as to not be delayed for the market, that has its drawbacks.
d. Memory: The software shall have low size so as to suit within the internal reminiscences of microcontrollers. On the opposite hand, additional memory is required to meet the dimensions of the software [33].
e. Security: Security may be an important issue that ought to be thought-about altogether the layers of IoT. so as to attain a decent level of security, the software ought to support cryptography engines, secure boot functions and usage of wireless authentication protocols.
f. Accommodation for low power: Despite the actual fact that the hardware platform takes power problems into consideration, in operation systems that enable power management capabilities gain a lot of focus from IoT designers. Power management feature helps increase the battery life, particularly for end-nodes. as an example, the software package will operate solely with the desired space of the hardware for straightforward functions as long as there's no necessity to perform continual calculations, that is that the case in most times. specializing in such a factor will

increase the dependability of IoT merchandise.

g. Support needed for communication and network: IoT needs differing types of protocols in little, medium and huge signals. The software package has got to powerfully support such integration to perform operations on IoT systems.

The graph in Figure three offers the share of usage of in operation systems by developers. However, the usage of various IoT software package tools isn't sensible for IoT systems as a result of it makes communication a lot of advanced. this suggests the importance of getting a generic resolution and customary ground for IoT in operation systems.

One of the in-operation systems that are designed particularly for IoT is RIOT. The sensible software tries to avoid wasting the foremost doable power and space for the sensible device. RIOT is associate degree open supply software which needs little RAM and store in addition [34]. The design of RIOT is microkernel primarily based, wherever the user application will address totally different layers within the software. one among the necessary blessings of RIOTOS is that it supports C/C++ programming languages, permitting big selection of programmers to form the most effective use of the OS to serve the specified application with low power as long because it will handle heterogeneous hardware comes. RIOT-OS facilitates the communication with the sensors and actuators; because it supports totally different communication protocols. moreover, RIOT supports multi-threading, increasing correspondence. several IoT applications need period operations; that's why RIOT-OS enforces regular kernel periods to divide the tasks and work on all of them in real time. This guarantees a promising future for RIOT-OS within the IoT business, particularly that it needs bit of memory and power. additionally, its programmability permits it to serve a large vary of applications. On the opposite hand, it would not be straightforward to port RIOT to developer boards and totally different microprocessors.

The most used software today in IoT platforms is UNIX. UNIX is associate degree open supply software that permits developers to change it to convey the most effective response. It supports C/C++ programming languages furthermore as multi thread technology. it's currently the foremost established and used software package platform in IoT styles. However, it needs comparatively massive memory (RAM and ROM) to control. The hardware overhead in memory furthermore because a lot of needed power to control aren't ideal for real-time operation and so hinder UNIX implementation in numerous IoT devices. Table I [33] offers a comparison between totally different open supply software package tools employed in IoT systems. RIOT-OS shows nice excellence for IoT platforms. The comparison includes the various architectures and schedulers furthermore because the memory sizes and also the supported programming languages.

Some other business software package tools are used for IoT comes like IBM Watson and Amazon net Services (AWS). IBM Watson is one among the leading software package tools for IoT devices. it had been free in 2014 and changed at that time to incorporate increased reality, psychological feature capabilities and a lot of capabilities to unfold the software to several devices and developers. However, developers found many difficulties to develop the software to try and do the desired functions [35]. AWS is one among the most effective playacting in operation systems in IoT fields; because it has its own cloud service furthermore as an easy interface.

Knowledge Centers the main worth of IoT lies within the knowledge analysis and process. The larger the info, the larger the computers storing this knowledge should be. In early Nineteen Nineties, direct server storage quickly became unmanageable; as storage demand enhanced, and there was no thanks to pull capability across multiple servers.

Hence, knowledge centers emerged once UNIX operating system servers replaced mainframes for running most business applications in their high-end server environments. an information

center may be a technical facility that homes associate degree organization's IT operations and instrumentality. The potency, optimization, dependability and security are the foremost crucial factors in any knowledge center, as a result of it's the network of all systems and knowledge. knowledge centers could vary in line with their primary perform. they need technical areas and subsystems like physical security systems, network and IT systems, power resources, environmental management and performance and operational management [36].

A software package outlined knowledge center (SDDC) may be a knowledge storage facility during which infrastructure parts of the info center are virtualized and delivered as a service. Virtualization is that the main rule of the SDDC. There are 3 styles of virtualization: network virtualization, storage virtualization and server virtualization. Network virtualization connects network resources by cacophonous the information measure into many freelance channels that may be appointed to a selected server or device within the same time. Storage virtualization turns physical storage from multiple network memory devices into one storage device managed by a central console. Server virtualization is regarding providing server resources that contain the identity of individual physical servers, processors and in operation systems, from server users. The new approach is to spare users from managing difficult server-resource details [37].

V. RECOMMENDATIONS FOR EVERY IOT APPLICATION

In this section, the antecedently mentioned 5 main IoT application examples are being investigated, and also the best tools from every IoT layer fitting every domain are suggested [38], [39].

a. Smart homes: physically, we have a tendency to advocate mistreatment either ASIC chips for production or Arduino microprocessors for comparatively low production and simple programmable installation; since each are technically and economically possible in these applications. As for the communication layer, Wi-Fi appears to be the most effective resolution, principally as a result of Wi-Fi is already obtainable in most homes, that makes it associate degree obtainable resource as a communication protocol and simple to be utilized by residents. additionally, its wireless nature, most high speed, simplicity and low price build it ideal to be employed in sensible homes.

b. Automotive: for a reliable optimally-performing hardware, ASIC chips represent the most effective choice. the amount of dependability depends on the standard of the fabrication method and also the used materials. Besides, the amount of security is often made-to-order through the used rule. On the communication level, Bluetooth is best suggested for automotive IoT thanks to its high speed and low power.

c. Traffic management: thanks to the distinction in practicality between the devices needed during this domain, ASIC isn't a decent choice and can be terribly expensive. the pliability and programmability of FPGAs are terribly desired during this domain. FPGAs give an additional economical resolution, whereas a high level of security and responsibility is nonheritable through the used software package. On the communication level, satellite networks offer the most effective performance thanks to their long vary that covers cities and their direct property to the web and different communication protocols for determinative location like GPS.

Table II: *IoT Layers' Elements Recommendation For Each Domain Summary*

IoT Domains	Hardware Layer Recommendations	Communication Layer Recommendations
Smart homes	ASIC, Arduino	Wi-Fi
Automotive	ASIC	Bluetooth
Traffic management	FPGAs, Arduino	Satellite Networks
Security	Arduino	Wi-Fi
Microchips	ASIC	Bluetooth, ZigBee

d. Security: for production and optimum performance, ASIC could be a smart possibility. However, since the sphere of security is dynamic and new algorithms are developed a day, programmability within the used controllers is important. Thus, microprocessors, like Arduino, are the most effective possibility during this domain. For the communication level, high speed and secure communication protocols are needed, therefore Wi-Fi is best suggested.
e. Microchips: considering the size of the devices during this domain and wherever there to be used, like within the human bodies within the biological application, then the sole possibility for controllers in such serious applications is ASIC, which provides the foremost attainable improvement of size and performance. Bluetooth and ZigBee are the foremost economical communication protocol in such applications, thanks to their low power, responsibility and straightforward property to sensible devices like sensible phones and laptops.

Table II summarizes the most effective choices for IoT domains within the hardware and communication layers.

VI. SWOT ANALYSIS

Along with the numerous advantages and potentials of IoT, there are still several challenges and difficulties facing its development and market. Therefore, a SWOT analysis is bestowed during this section.

A. IoT Strengths

IoT has been invoking all fields. It facilitates the automation of varied processes that create life easier and quicker. The market is currently open and prepared for sensible IoT devices that are being introduced to the purchasers. cost additionally plays a job in spreading the technology. a budget fabrication price creates a good edge for the merchandise to be obtainable in several markets. These devices are used anyplace and anytime; as all the information are sent and keep via the web. The automation allowed U.S. to try to not possible tasks in dangerous or far off wherever humans cannot reach [40]. The communication between the machines decreases human interference, preventing several errors. However, period observation permits direction the method with an in-depth log of the taken actions, that helps up the styles and also the architectures of IoT devices.

B. IoT Weaknesses

IoT weaknesses are principally generated from the massive scale the online of the items covers. For such sophisticated systems, having a transparent methodology to urge identifiers for everything globally is tough [41]. IoT communication protocols don't seem to be well secured primarily for the sake of size reduction and low power consumption. thanks to the distinction in communication protocols, compatibility between several of them is tough, and this issue might cause failure in IoT systems if not treated well. the massive quantity of changed knowledge between objects needs knowledge assortment and storage, that is tough considering the number of objects within the net and the way knowledge are to be optimally organized [42]. little failures within the system are tough to be copied and debugged, and that they are terribly threatening to the systems. the massive quantity of communication traffic within the system will increase the noise significance, and a careful investigation in these problems is required for adequate immunity from the noise.

C. IoT Opportunities

There are voluminous factors that facilitate the IoT technology improvement. 1st of all, IoT could be a large field that pulls large investments; as a result of it's concerned in everyday activities. Secondly, like all new field, it attracts the researchers; because it opens new fields for additional applications. additionally, IoT may gain advantage from new analysis works relating to batteries and investments on them; as several applications today ought to be supercharged while not battery [43], [44]. Finally, the new trend to manufacture self-

maintained devices and energy harvesters directs additional investments to the IoT technology.

D. IoT Threats

As virtually every device around is to be reworked into a wise device, the number of devices accessing the web can increase tremendously. this can cause addressing issues and enormous knowledge traffic; as all the devices are going to be connected to the web at the same time, causing vital data to the cloud. Security may well be a good threat; as a result of hackers is also able to reach this data. encoding and security should have nice considerations particularly for governmental data. Power is also one amongst the most important threats for IoT [45], [46]; as devices should be reliable for a protracted amount of your time. victimization current batteries with high power consumption makes the device fail when short time, decreasing its period in several applications. IoT devices might not be appropriate to figure below extreme conditions, that are required for several applications. moreover, coping with sensible devices may well be too advanced of individuals World Health Organization are to seek out great issue in victimization this new technology. As a result, future business is going to be hindered till customers have enough awareness concerning these products [47]. Table III summarizes the SWOT analysis points [48].

Table III. *SWOT Analysis for IoT*

Strengths	**Weaknesses**
Automation that makes life much easier. Very big market: it communicates with big industries. Inexpensive: usage of cheap sensors. A hot area of research: a lot of problems is not solved yet. All data are reserved on the cloud. Easy usage for customers. Complete hard tasks in deep and remote areas. Rapid and smart monitoring. Rapid data sharing. Rapid decision making. Documentation of real analysis over large time zones. Higher efficiency at less time. Decreases human interference.	A clear methodology for getting unique identifiers for objects at a global scale is difficult. Difficulties with security issues in IoT communication protocols. Less compatibility; as there are different protocols and a need for some standard communication. Data collection issues; as there will be a higher need for data storage to keep up with the increasing amount of data. Difficulties to debug small failures within the system could cause huge consequences. Difficulties to achieve immunity to noise and filter data.
Opportunities	**Threats**
Tendency to invest massively in the field. Opportunities for new applications. Opportunities for new researchers. Tendency to harvest energy from the surroundings. IoT could benefit from new research regarding batteries and invest on it. Get involved of everyday activities.	Addressing to numerous nodes. Low public awareness might hinder near future IoT business. Hacking on IoT communication protocols. Not being accepted by the society. Not to meet user expectations. National security concerns.

Health care application improvements. Smart Infrastructure improvement. Tendency to construct longer lifetime devices. IoT could be miniaturized and integrated as wearable devices. Being eco-friendlier technology. Many applications nowadays need to be powered with no battery.	Tendencies to use nowadays regular batteries and the need to recharge or replace old batteries, which are the weak point to miniaturize devices. Questions regarding working well under irregular conditions such as: extreme high temperature. High updating costs. IoT could replace numerous human jobs, causing deployment. People would not be able to keep up rapidly with IoT changes.

VII. CONCLUSIONS

IoT has voluminous potentials and opportunities within the close to future. several devices all round the world are expected to terribly presently be part of the massive network of things and devices. large markets are expected to be open for sensors, actuators, hardware controllers, communication protocols and software package applications. additionally, life quality of individuals is anticipated to rise, and work and industries are expected to possess abundant higher performance, helped with the automation and also the great amount of knowledge IoT presents. during this study, a comparative study was allotted to focus on the strengths and weaknesses of the various IoT platforms and suggest optimum solutions for various IoT applications.

Although IoT has several advantages and potentials, voluminous difficulties still hinder its advances and challenge its market like power and security problems and public awareness. Thus, it's an awfully hot space of analysis. withal, several expectations are in favor of IoT. So, IoT is anticipated to relinquish far more prosperity within the terribly close to future.

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