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Internet of Things: A Survey of IoT Applications based on their desirable device characteristics

Abstract: This paper provides an overview of the Internet of Things (IoT) with emphasis on the device characteristics of IoT hardware .It also identifies the desirable device characteristics for the variousIoT applications.From the vast number of IoT development boards available in the market, it is very difficult to select the ideal development kit for IoT app developers to test their ideas and take advantage of full potential of IoT. This paper is giving an outsight into the selection of the IoT development kits based on their device IoT characteristics. Compared to other survey papers in the field, the objective of this paper is to provide a summary of the most relevant IoT device characteristics and identify the application areas for such characteristics.

Introduction

One way to view the IoT is as a vast network, with of low-power interconnected things linking up each element. The things inIoT can range from edge objects, namely smart or wearable devices which are battery powered with sensors and wireless connectivity, through aggregation nodes, namely hubs, routers and gateways for data aggregation, up to information processing servers in the Cloud to handle the data pushed by edge objects[1].IoT is a giant signal chainof objects with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities.physical attributes and virtual personalities use intelligent interface and integrated into the cloud network. IoT is the inter networking of physical devices, animals, vehicles, buildings and other items embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. The fast growth of IoT is due to the availability ofthe latest developments in RFID, smart sensors, communication technologies and Internet protocols.Basically, this is the idea of fundamentally interfacing any gadget to the Internet .This incorporates everything from cellphones, earphones, heart monitoring implants, biochip transponders on farm animals, cameras streaming live feeds of wild animals in coastal waters,lights, vehicles, commodities, wearable gadgets etc. and just about whatever else anybody can consider. The concept of things in IoT also appliesto parts of machines, for industries like chemical, mining etc to name a few. One of the biggestparadigms behind this trend is the Internet of Things (IoT) which makes a world permeated withembedded smart devices, often called “smart objects”, inter-connected through the Internet.Internet of Things is a technological revolution which is totally a dynamic in nature. It has beenconverging multiple technologies like Communication, Backbone, Hardware, Protocols, Software, Data Brokers / Cloud Platforms and Machine Learning. Advances in IoT creates new dimension of services that improves the quality of lifeof consumers and productivity of enterprises. From the consumer point of view, the IoT has thepotential applications such as deliver solutions that dramatically improve energy efficiency, emergency aids, asset tracking,health, education, connected cars, smart homes, smart retails and many other aspects of daily life.For enterprises, IoT can underpin solutions that improve decision-making and productivity inmanufacturing, cost effective business, agriculture and other sectors.The development of the IoT has been primarily driven by needs of large corporations that stand to benefit greatly from the foresight and predictability afforded by the ability to follow all objects through the commodity chains in which they are embedded. The ability to code and track objects has allowed companies to become more efficient, speed up processes, reduce error, prevent theft, and incorporate complex and flexible organizational systems through IoT [2]. The IoT is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology. They are going tag the each object for identifying, automating, monitoring and controlling.

The Internet of Things was initially inspired by members of the RFID community, who referred to the possibility of discovering information about a tagged object by browsing an internet address or database entry that corresponds to a particular RFID or Near Field Communication technologies[3].The key technologies of IoT are RFID, the sensor technology, Nano technology and intelligence embedded technology. Among them, RFID is the foundation and networking core of the construction of Internet of Things . The Internet of Things (IoT) enabled users to bring physical objects into the sphere of cyber world. This was made possible by different tagging technologies like NFC, RFID and 2D barcode which allowed physical objects to be identified and referred over the internet . IoT, which is integrated with Sensor Technology and Radio Frequency Technology, is the ubiquitous network based on the omnipresent hardware resources of Internet, is the Internet contents objects together. It is also a new wave of IT industry since the application of computing fields, communication network and global roaming technology had been applied. It involves in addition to sophisticated technologies of computer and communication network outside, still including many new supporting technologies of Internet of Things, such as collecting Information Technology, Remote Communication Technology, Remote Information Transmission Technology, Sea Measures Information Intelligence Analyzes and Controlling Technology etc.Radio Frequency Identification (RFID) Radio Frequency Identification (RFID) is a system that transmits the identity of an object or person wirelessly using radio waves in the form of a serial number . First use of RFID device was happened in 2nd world war in Brittan and it is used for Identify of Friend or Foe in 1948. The main components of RFID are tag, reader, antenna, access controller, software and server. It is more reliable, efficient, secured, inexpensive and accurate. RFID has an extensive range of wireless applications such as distribution, tracing, patient monitoring, military apps etc. Internet Protocol (IP) Internet Protocol (IP) is the primary network protocol used on the Internet, developed in 1970s. IP is the principal communications protocol in the Internet protocol suite for relaying datagrams across network boundaries. The two versions of Internet Protocol (IP) are in use: IPv4 and IPv6. Each version defines an IP address differently. Because of its prevalence, the generic term IP address typically still refers to the addresses defined by IPv4. There are five classes of available IP ranges in IPv4: Class A, Class B, Class C, Class D and Class E, while only A, B, and C are commonly used. The actual protocol provides for 4.3 billion IPv4 addresses while the IPv6 will significantly augment the availability to 85,000 trillion addresses . IPv6 is the 21st century Internet Protocol. Barcode is just a different way of encoding numbers and letters by using combination of bars and spaces of varying width. Behind Bars serves its original intent to be descriptive but is not critical. In The Bar Code Book, Palmer (1995) acknowledges that there are alternative methods of data entry techniques. Quick Response (QR) Codes the trademark for a type of matrix barcode first designed for the automotive industry in Japan. Bar codes are optical machine-readable labels attached to items that record information related to the item. Recently, the QR Code system has become popular outside the automotive industry due to its fast readability and greater storage capacity compared to standard. There are 3 types of barcodes of Alpha Numeric, Numeric and 2 Dimensional. Barcodes are designed to be machine readable. Usually they are read by laser scanners, they can also be read using a cameras. Wireless Fidelity (Wi-Fi) Wireless Fidelity (Wi-Fi) is a networking technology that allows computers and other devices to communicate over a wireless signal. Vic Hayes has been named as father of Wireless Fidelity. The precursor to Wi-Fi was invented in 1991 by NCR Corporation in Nieuwege in the Netherland. The first wireless products were brought on the market under the name WaveLAN with speeds of 1 Mbps to 2 Mbps. Today, there are nearly pervasive Wi-Fi that delivers the high speed Wireless Local Area Network (WLAN) connectivity to millions of offices, homes, and public locations such as hotels, cafes, and airports. The integration of Wi-Fi into notebooks, handhelds and Consumer Electronics (CE) devices has accelerated the adoption of Wi-Fi to the point where it is nearly a default in these devices . Technology contains any type of WLAN product support any of the IEEE 802.11 together with dual-band, 802.11a, 802.11b, 802.11g and 802.11n. Nowadays entire cities are becoming Wi-Fi corridors through wireless APs. Bluetooth Bluetooth wireless technology is an inexpensive, short-range radio technology that eliminates the need for proprietary cabling between devices such as notebook PCs, handheld PCs, PDAs, cameras, and printers and effective range of 10 - 100 meters. And generally communicate at less than 1 Mbps and Bluetooth uses specifi- cation of IEEE 802.15.1 standard. At first in 1994 Ericson Mobile Communication company started project named “Bluetooth”. It is used for creation of Personal Area Networks (PAN). A set of Bluetooth devices sharing a common channel for communication is called Piconet. This Piconet is capable of 2 - 8 devices at a time for data sharing, and that data may be text, picture, video and sound. The Bluetooth Special Interest Group comprises more than 1000 companies with Intel, Cisco, HP, Aruba, Intel, Ericson, IBM, Motorola and Toshiba. ZigBee is one of the protocols developed for enhancing the features of wireless sensor networks. ZigBeetechnology is created by the ZigBee Alliance which is founded in the year 2001. Characteristics of ZigBee are low cost, low data rate, relatively short transmission range, scalability, reliability, flexible protocol design. It is a low power wireless network protocol based on the IEEE 802.15.4 standard ZigBee has range of around 100 meters and a bandwidth of 250 kbps and the topologies that it works are star, cluster tree and mesh. It is widely used in home automation, digital agriculture, industrial controls, medical monitoring &power systems. Near Filed Communication (NFC) Near Field Communication (NFC) is a set of short-range wireless technology at 13.56 MHz, typically requiring a distance of 4 cm. NFC technology makes life easier and more convenient for consumers around the world by making it simpler to make transactions, exchange digital content, and connect electronic devices with a touch. Allows intuitive initialization of wireless networks and NFC is complementary to Bluetooth and 802.11 with their long distance capabilities at a distance circa up to 10 cm. It also works in dirty environment, does not require line of sight, easy and simple connection method. It is first developed by Philips and Sony companies. Data exchange rate now days approximately 424 kbps. Power consumption during data reading in NFC is under 15ma. 4.9. Actuators An actuator is something that converts energy into motion, which means actuators drive motions into mechanical systems. It takes hydraulic fluid, electric current or some other source of power. Actuators can create a linear motion, rotary motion or oscillatory motion. Cover short distances, typically up to 30 feet and generally communicate at less than 1 Mbps. Actuators typically are used in manufacturing or industrial applications. There are three types of actuators are (1) Electrical: ac and dc motors, stepper motors, solenoids (2) Hydraulic: use hydraulic fluid to actuate motion (3) Pneumatic: use compressed air to actuate motion. All these three types of actuators are very much in use today. Among these, electric actuators are the most commonly used type. Hydraulic and pneumatic systems allow for increased force and torque from smaller motor. A WSN is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations .Formed by hundreds or thousands of motes that communicate with each other and pass data along from one to another. A wireless sensor network is an important element in IoT paradigm. Sensor nodes may not have global ID because of the large amount of overhead and large number of sensors. WSN based on IoT has received remarkable attention in many areas, such as military, homeland security, healthcare, precision agriculture monitoring, manufacturing, habitat monitoring, forest fire and flood detection and so on. Sensors mounted to a patient's body are monitoring the responses to the medication, so that doctors can measure the effects of the medicines.Artificial Intelligence (AI) Artificial Intelligence refers to electronic environments that are sensitive and responsive to the presence of people. In an ambient intelligence world, devices work in concert to support people in carrying out their everyday life activities in easy, natural way using Information and Intelligence that is hidden in the network connected devices. It is characterized by the following systems of characteristics (1) Embedded: Many Net-worked devices are integrated in to the environment (2) Context Aware: These devices can recognize you and your situational context (3) Personalized: They can be tailored to your needs (4) Adaptive: They can change in response to you (5) Anticipatory: They can anticipate your desires without conscious mediation

Hardware Requirements of Iot Applications

The hardware unit of IoT can be classified as Sensors/actuators , Power management module, and Communication units.First one is the sensing module which consists of the different types of sensors like Accelerometers, Magnetometers, Pressure Sensors , Humidity Sensors ,Temperature Sensors, Image Sensors etc[4].They monitor "things," or real-world objects, including industrial equipment, home appliances, buildings, cars, warehouse inventory items, and people (in the case of wearable devices).Secondly there is Power management module comprising of five major components, energy source(s),energy harvesting module ,power delivery module and power management controller.These components will be using various hardware devices like ultra-capacitors ,microbatteries, Li-Ion battery ,AAA/AA Batteries etc.The final one, Communication Module consists of Signal Processing Unit ,Wifi , ZigBee ,Bluetooth LE, Radio Transceiver ,Duplexer etc.Off the shelf IoT hardware platforms like Arduino, Raspberry Pi etccan help jump start the process of rapid prototyping and refinement, because most of the modules mentioned above are readily available in them and require less investment than designing and fabricating custom printed circuit boards (PCBs) at each iteration of the design. As part of this process, there is a need to consider the hardware requirements for a specific IoT application, and evaluate and refine the prototype of IoT devices that you build against these requirements.In the context of IoT, device is an overloaded term that describes hardware that has been designed or adapted for a particular purpose. It is used to refer to individual hardware components including sensors and actuators, as well as to off-the-shelf boards like Raspberry Pi, and also to custom prototype and production units that are built from a number of constituent devices. In this paper, some of the widely available off-the-shelf hardware options are reviewed along with their device characteristics.In the next section the various IoT applications are discussed along with the device characteristics suitable for each of them, which will be useful for prototyping and developing an IoT project.

IoT device characteristics

We can define the IoT by simply describing all the characteristics of hardware devices involved in it[5][6].New devices and device platforms are continually being released as the IoT landscape matures. It is necessary to understand the key characteristics that are common across most IoT devices to compare and evaluate new devices as they become available.Information that is collected by Sensing module of the IoT system goes through five phases of IoT lifecycle: Firstly, acquisition phase, where devices or sensors collect information from the physical environment around them. Secondly, analytics phase which in cooperate some sort of intelligence to process the data collected from smart connected devices and can use themto generate insights that can help businesses, customers and partners; thirdly, communicate phase, where the data and events generated are sent through the network to the desired destination; fourthly, aggregate phase, where data collected are aggregated by devices itself and where, upon further sophisticated analytics the aggregated data can be used to generate basic patterns, control and optimize processes .The last phase is act phase, where suitable actions are performed based on the information created. The IoT is a complex system involving all the phases mentioned above and each phase involves devices with a number of characteristics. Its characteristics vary from one domain to another. Some of the general and key characteristics identified in this research paper to characterize IoT devices in terms of these high-level capabilities are as follows.

- Intelligence
- Data acquisition and control
- Data processing and storage
- Connectivity
- Dynamic Nature
- Scalability
- Heterogeneity
- Power management
- Peripherals - diverse IoT applications require differing assortment of Timers, Display controller, UARTs, CAN, and other serial interfaces.
- Analog Interface
- DSP Capability - some IoT applications (e.g., biomedical devices, scientific instruments) require DSP capability for analysis and manipulation of signal.
- Security - security is of vital importance for IoT, some microcontrollers provide hardware support for security.
- Cost - microcontrollers for IoT can be cheap because of simplicity or have premium cost for additional features.

Data acquisition is the process of measuring real-world conditions,which is mostly in the form of analog signals and converting these measurements into digital form. Some of the off-the-shelf IoT kits have built-in analog-to-digital converters whereas others have to interface such units in them.Sensors are the input components that measure physical variables and convert them to electrical signals (voltages). Sensors are the troops of the "internet of things," the on-the-ground pieces of hardware doing the critical work of monitoring processes, taking measurements and collecting data. They are often one of the first things people think of when picturing IoT.The decreasing price of these tiny devices is helping keep IoT deployment costs low and enabling a myriad of use cases. But not every sensor is made the same and every IoT installation requires a specific type of sensor. Choice of sensors can be made from thousands of types of off-the-shelf sensors to measure a range of variables, including temperature, humidity, pressure, smoke, gas, light, sound, vibration, air-flow, water-flow, speed, acceleration, proximity, GPS position, altitude, or force, and the list goes on. But sensors don't just measure ambient conditions; proprioceptive sensors monitor the internal state of the device, and sensors like buttons, sliders, or a touchscreen can be used for interacting directly with the device, providing a Human-Machine Interface. For each individual type of sensor, like a temperature sensor, you'll have dozens of alternative component choices from a range of manufacturers, each with slightly different specifications in terms of accuracy and precision, and each designed for specific applications and operating conditions, such as for use underwater or to withstand extremes of heat and cold if they are used for applications like industry.An important characteristic of sensor components is their resolution. The resolution of a sensor represents the smallest amount of change that the sensor can reliably read and is related to the size of the numeric value that is used to represent raw sensor readings. For example, an analog temperature sensor with 10 bits of resolution represents a temperature reading using a numeric value between 0 and 1023. Bits are binary, so 10 bits provides two to the power of 10, or 1024 possible values in total. However, in practice, sensors are affected by electrical noise which reduces the actual resolution.In a sensor node, the amount of data to be sent over the wireless link should be relatively small. As such, ZigBee provides an optimal mesh networking solution; Bluetooth Smart is an excellent choice for standards-based, power-sensitive point-to-point configurations, and proprietary sub-GHz solutions provide maximum flexibility for network size, bandwidth and data payloads in star or point-to-point configurations.

IoT devices require data processing and storage capabilities to perform basic handling, transformation, and analysis of the data that they capture[7]. IoT devices can process data directly, or they can transmit this data to other devices, gateway devices, or cloud services or apps for aggregation and analysis.Edge analytics involves performing data analysis at the edges of a network rather than in a centralized location. Data can be analyzed in near real-time on the devices themselves, or on a nearby gateway device (like a router) that the IoT devices are immediately connected to, rather than devices transmitting large volumes of data upstream to a cloud server or data center for further analysis. Processing data at the edge provides an opportunity to aggregate and filter the data as it is collected, with only the most salient data selected to be sent upstream. Ultimately, edge analytics reduces the upstream processing and storage requirements as well as relieves the load on the network.The processing power and storage that is used by an IoT application will depend on how much processing occurs on the device itself as opposed to how much processing is performed by the services or apps that consume the data. The amount of memory that is available and the specifications of the processor, including the clock speed and number of cores, determine the rate at which data can be processed by the device. The capacity of the non-volatile flash memory, which is used to persist data until it can be transmitted upstream, determines how much data can be stored on the device. Devices performing edge analytics will require substantially more processing capabilities than devices that perform only basic data processing like validating, normalizing, scaling, or converting readings, such as converting raw temperature readings into Celsius.

Network connectivity is one of the defining characteristics of any IoT device. Devices communicate with other devices locally, and publish data to services and apps in the cloud. Some devices communicate wirelessly, by using 802.11 (wifi), Bluetooth, RFID, cellular networks, or Low Power wide area network (LPWAN) technologies like LoRa, SigFox or NB-IoT. Wired communication is suited to stationary devices, which are installed in smart buildings, home automation, and industrial control applications, where they can be connected with Ethernet or retrofitted with Ethernet over power. Serial communication is also a form of wired connectivity between devices, using standard protocols like Universal Asynchronous Receiver Transmitter (UART), or the Controller Area Network (CAN) protocol, which has its origins in the automotive industry.

Applications like monitoring of energy consumption, Tracking, Smart Parking ,Inventory management etc. are mostly handling scalar type of data whereas applications like Smart surveillance, patient health real-time monitoring ,assisted driving is mainly dealing with analog type of data.[8] Most IoT devices rely on analog sensors to at least some extent to collect the data that's used for the device's operation. In most cases, these analog sensors are integrated with an analog-to-digital converter (ADC), which translates the raw data from the sensors into digital form which is then aggregated and analyzed, and offered for interpretation. MCUs with on-chip, low to high resolution ADC at low to moderate sampling rate are available. DACs may be available, in some cases D-A conversion can be done through PWM. Analog comparator is also available as a basic analog interface. Some IoT applications involving biomedical devices, scientific instruments etc. require DSP (Digital Signal Processing) capability for analysis and manipulation of signal. Security is of vital importance for IoT, and some of the microcontrollers provide hardware support for security. Cost is another device characteristic which changes with the various type of applications. Microcontrollers for IoT can be cheap because of simplicity or have premium cost for additional features.

IoT Applications

Inventory management and Monitoring

The connectivity and real-time analytics inherent in IoT could be the game changer for retailers' inventory woes[9].With digital shelves, a sensor can be added that understands the level of inventory on the shelf, reading smart tags on the products. Another sensor could read passing foot traffic to determine whether the product placement is attracting enough passers-by.With digital shelving, if inventory is low in a store yet, at the same time, these items are being shipped back, you can reroute the units to go directly where demand is high. Typically, inventory is shipped back to distribution, then processed and resent to stores in need. By cutting out the middleman and rerouting shipments, retailers avoid the extra time and costs associated with processing returns — and can get the product to customers faster. Robotic carts, guided by sensors and video cameras, are intended to let shoppers summon them using their smartphones and then dispatch them back to the storage area when they are finished. Employees can then concentrate on filling shelves or working at checkout, rather than rounding up carts throughout the store and in the parking lot — or further. Connected to an inventory management system, robo-carts could determine highly accurate real-time inventory as customers move them around the store. This would ensure an accurate, up-to-the-minute view of what shelves need restocking and what products are selling fast — or which are being returned. Incorporating real-time analytics and process orchestration allows supply chain and merchandising processes to respond in real time and determine whether they need to apply a discount to items they want to get rid of. Tackling the inventory challenge requires investment, but it can be attained quickly via real-time connectivity and sophisticated orchestration across different systems, including ERP, store inventory management, warehouse management and other inventory masters such as the inventory systems of suppliers.

Energy consumption monitoring

If it is known how much energy your home is using and when it's using it, you can better respond to that usage and take control of costs[10]. Before smart home systems, energy monitoring mostly meant scanning your electricity bill each month and then telling your family to shut off the lights. New technology makes the process much easier.There are several ways you can monitor (and then respond to) your home's electricity usage. Some methods let you monitor only the appliance you have connected to the monitoring device, while other systems take a whole-house approach. TED Pro Home Energy Monitoring System energy monitoring systems worth checking uses your home's existing power lines to monitor energy usage in real-time. It can actually tackle up to 32 individual circuits, as well as individual rooms. That way, you can keep tabs on devices that are energy hogs and unplug them accordingly.The TED Pro electricity monitor uses measuring devices that clamp onto the main conductors inside your breaker panel. The devices then send the data that's measured over your home's powerlines. No extra wiring is needed! That data is collected in a receiving unit, which you can plug into any outlet around the house. Inside, the receiving unit has the company's Footprints software, which can store and track up to 10 years' worth of energy data. Homeowners can keep tabs on that information via any web-enabled device (such as a smartphone). You can even opt to receive customized alerts via text or email messages. Other features include colored LEDs to alert users to different parameters, as well as the option to turn loads on and off based on the cost of electricity, use, and more.The DigiXBee Smart Meter plugs into any outlet to make it into a smart outlet and lets you monitor and measure whatever is plugged into that outlet, and even control those devices as needed. The DigiXBee Smart Meter connects to your ZigBee network. And if you're looking to monitor multiple devices, you can do that, by adding in one of the company's ConnectPort X gateways. That combination allows you to have multiple DigiXBee Smart Meters scattered throughout the house, creating one whole-house energy management solution

Smart Home

Smart homes filled with connected products are loaded with possibilities to make our lives easier, more convenient, and more comfortable[11].Imagine that you're driving home on a hot summer day. But rather than turn the air conditioner on when you get home and wait for your house to cool, you simply use your smartphone when you leave your office to tell your smart thermostat to lower the temperature. BI Intelligence, Business Insider's premium research service, expects the number of smart home devices shipped will grow from 83 million in 2015 to 193 million in 2020. This includes all smart appliances (washers, dryers, refrigerators, etc.), smart home safety and security systems (sensors, monitors, cameras, and alarm systems), and smart home energy equipment, like smart thermostats and smart lighting.

Assisted Driving

The transportation industry is associated with high maintenance costs, disasters, accidents, injuries and loss of life[12].With the right implementation of IoT technology, we can mitigate risks, prevent damage and reduce costs. The deployment of smart, connected sensors, combined with machine-learning-powered analytics tools, can enable us to gather information, make predictions and reach decisions that will make our roads safer. IoT sensors and smart cement (cement equipped with sensors) can monitor the structural status of roads and bridges under dynamic conditions and alert us about deficiencies before they turn into catastrophes.

Smart Parking

Small Parking IoT models has been developed where a camera is used to click minute-by-minute photos of parking lots, which are then analyzed by a computer[13]. Using an object detection algorithm, the free spaces are found and communicated to the user.A truly smart parking system should not only be aware of the occupancy status of each space, but also be able to guide the user to it. All of this should happen without human intervention. A smart solution would account for many issues.Each space should be tracked by the system. Multiple types of sensors can be used for this, but the sensors' accuracy cannot be compromised. False positives must be minimal. As the number of sensors increases, cost will be drastically reduced. When the status of the sensors changes, a gateway device will be notified.The issues to be tackled here are battery life, sensor positioning and the communication channel. As there will be a large number of sensors, wiring them for energy is out of the question. As a result, these sensors must be battery powered with power management algorithms. The sensors' enclosure will have to take positioning into account. If installed in the open, the sensors need to be protected from heat, dust, rain, bugs and other natural phenomena. If they're installed on the parking lot floor, the sensors must be able to take the weight of cars without malfunctioning or breaking down. In order to keep the number of gateway devices to a minimum, the servers must communicate on a technology with a long reach, like radio frequency, or they must work on a mesh protocol so the status change will reach the gateway by hopping.

eHealth

The internet of things has numerous applications in healthcare, from remote monitoring to smart sensors and medical device integration[14]. It has the potential to not only keep patients safe and healthy, but to improve how physicians deliver care as well. Healthcare IoT can also boost patient engagement and satisfaction by allowing patients to spend more time interacting with their doctors. But healthcare IoT isn't without its obstacles. The number of connected devices and the tremendous amount of data they collect can be a challenge for hospital IT to manage. There is also the question of how to keep all of that data secure, especially if it is being exchanged with other devices.

Logistics

Capacity estimation and sensing with IOT for logistics solutions help in the staffers in getting the stacking and loading operations done quickly without any error[15]. Operating inside the inventory in a warehouse can be cumbersome with frequent to and fro trips between the stacking shelf and containers. In-house visibility for the containers is as crucial for the staffers as in-transit visibility. It also helps in avoiding the theft or loss of freight scenarios where the staffers can get clueless about the needed shipment at the time of loading. An efficient route optimization scheme for the carriers can result in the elimination of 175 grams of carbon emission produced by every extra mile traveled by it. Think about the impact that can be made by an IOT enabled route optimization system which can save thousands of miles to be traveled by the carrier.The IoT applications in logistics has to focus on 1) Seamless interoperability for exchanging sensor information in heterogeneous environments 2) Establishment of trust and ownership of data and overcoming privacy issues in the IoT-powered supply chain 3)Clear focus on reference architecture for the IoT 4) Change in business mindset to embrace the full potential of the Internet of Thing

Industrial Control

The Industrial Internet of Things (IIoT) describes the Internet of Things (IoT) as it is used across several industries such as manufacturing, logistics, oil and gas, transportation, energy/utilities, mining and metals, aviation and other industrial sectors[16].The industrial IoT market is estimated to reach $123.89 Billion by 2021.Just like the Internet of Things in general, the Industrial IoT covers many use cases, industries and applications. Initially focusing on the optimization of operational efficiency and rationalization/automation/maintenance, with an important role for the convergence of IT and OT, the Industrial Internet of Things opens plenty of opportunities in moving towards an on demand service model, new ways of servicing customers and the creation of new revenue models, often in unexpected ways. While the business outcomes and partnerships with key stakeholders and others are obviously essential, security is at least as much from connectivity to devices and connected applications. Security by design and embedded security is a must. And as in all transformational projects, involve security early on. It's about the data which you turn into insights, action and automation in your Industrial Internet of Things project and the need to use analytics in order to turn data into these insights, also for data you already might have. Remember DIKW, in IIoT too. Industrial Internet of Things with a focus on several aspects whereby intelligent machines, advanced analytics and people at work were three key elements.

Tracking(Security & Emergencies)

IoT enabled approach that can provide emergency communication and location tracking services in a remote car that meets an unfortunate accident or any other emergency situation[17]. Immediately after an accident or an emergency, the system either starts automatically or may be triggered manually. Depending upon type of emergency (police and security, fire and rescue, medical, or civil) it initiates communication and shares critical information e.g. location information, a set of relevant images taken from prefixed angles etc. with appropriate server/authority. Provision of interactive real-time multimedia communication, real-time location tracking etc. have also been integrated to the proposed system to monitor the exact condition in real-time basis. The device goes in cars and transmits information about accidents to emergency services. The emergency responders get the exact time and location of the accident, the vehicle registration number, and the severity of the accident. Thus emergency responders can find accidents more quickly and easily, and better prepare for the situation.The IoT device goes in cars and transmits information about accidents to emergency services. The emergency responders get the exact time and location of the accident, the vehicle registration number, and the severity of the accident. Thus emergency responders can find accidents more quickly and easily, and better prepare for the situation.Usingwireless platform, such devices sends information over mobile networks to cloud software which then distributes the data to emergency responders.

Smart Agriculture

The Internet of Things (IoT) is transforming the agriculture industry and enabling farmers to contend with the enormous challenges they face[18].IoT applications platforms are available which is useful in monitoring the field data as well as controlling the field operations which provides the flexibility. Later technologies in this field includes smart GPS based remote controlled robot to perform tasks like; weeding, spraying, moisture sensing, bird and animal scaring, keeping vigilance, etc. Secondly, it includes smart irrigation with smart control based on real time field data. Thirdly, smart warehouse management which includes; temperature maintenance, humidity maintenance and theft detection in the warehouse. Controlling of all these operations will be through any remote smart device or computer connected to Internet and the operations will be performed by interfacing sensors, Wi-Fi or ZigBee modules, camera and actuators with micro-controller and various IoT development kits.IoT also finds vast applications in animal farming. It controls growing conditions of the offspring in animal farms to make sure its survival and health. IoT can also be used to study ventilation and air quality in farms and detection of harmful gases from excrements.Location and identification of animals grazing in open pastures or location in big stables can be done with IoT Tracking devices. Another important application of IoT in agriculture isHydroponics, that is to control the exact conditions of plants grown in water to get the highest efficiency crops.

After the identification of the various IoT device characteristics and their scope in the various IoT applications, it has been listed in the below table Table 1.1.

IoT Applications	Desirable Device Characteristics
Smart Home	M2M and M2H Connectivity,Intelligence in edge devices,low cost data acquisitions
Smart surveillance	Intelligence, Analog Interface,connectivity
Smart Parking	Low cost data acquisition, High Connectivity to users.
Inventory management and Monitoring	Scalar Data Input, Intelligence,Real Time Data Transfer
Energy consumption monitoring	Low cost monitoring devices,M2H connectivity
Assisted Driving	Power Management, M2H Connectivity
e-healthCare	M2M and M2H Connectivity, High Data Acquisition Rate,Intelligence, High Resolution Sensors, DSP, ADC
Tracking(Security & Emergencies)	High Resolution Sensors and High Connectivity
Smart Environment	Power Management
Smart Water	Power Management
Industrial Control	High Resolution Sensors,IoT devices to withstand very high and very low working temperatures,Security,Intelligence
Logistics	Low cost monitoring devices,M2H connectivity
Smart Agriculture	Power Management,ADC
Smart Animal Farming	Power Management, ADC

Table 1.1 Desirable IoT Device Characteristics of Various Applications

IoT Development Platforms

While starting with the development of IoT application 1)Choose your hardware platform 2) Develop the application software, including any back-end and networking support 3) Create the integrated UI 4) Develop the APIs, beacons, web sockets, and procedure calls that enable the high-level communications that occur between devices 5) Establish security, data storage, and analytics measures. The range of embedded devices is vast—from small prototypes people develop for fun, to mass-produced technology—and there's hardware to suit every project. Usually, these small computers are referred to as boards, or chips, and they come with a wide range of price points and processing capabilities.Hardware components can include low-power boards; single-board processors; field-programmable gate arrays (FPGA); and shields, which are smaller boards that plug into main boards to extend functionality by abstracting specific functions (e.g., GPS, light and heat sensors, or interactive displays).MSP430FR5994 LaunchPadHas a Built in ADC and so without any additional interfaces can be used in applications having analog input like Smart Home,AssistedDriving,Smart Environment etc. Because of its SD card interface, it finds its applications, requiring high data logging .FlyportPRO also has a large number of GPIOs out of which 10 are analog inputs.Flyport has a good number of connectivity options like WIFI,Ethernet and GPRS which makes it suitable for applications involving high quality Machine-to-Machine as well as Machine-to-Human interaction.FlyportPRO is a system-on-module available in several pincompatible versions: Wi-Fi, GPR Sand EthernetFlyportPROand the IDEpro speed up the development of Your projects. FlyportPRO is very compact and certified to be used on professional applications.Working temperature of FlyportPRO i.e. -20°C..+85°C also makes it suitable for Industrial applications.FlyportPRO has a serial bootloader onboard (but if you are free to use MPLAB and Microchip tools).It is available in 3 versions.

- FlyportPRO Wi-Fi 802.11G
- FlyportPRO GPRS v2 Quadband
- FlyportPRO Ethernet

8051 development board helps to develop basic level applications. Such as Data acquisition systems, automatic light intensity control system, industrial temperature control systems etc.The Electron is a tiny development kit for creating cellular-connected electronics projects and products. It comes with a SIM card (Nano 4FF) and an affordable data plan for low-bandwidth things. It is also available for more than 100 countries worldwide. It also comes with Particle's development tools and cloud platform for managing and interacting with your new connected hardware. With its onboard cellular antenna, this diminutive board will offer a huge range of deployment options and alleviate the hassle of using a custom cellular breakout board with your micro controller projects. They're offering two versions, with either 2G or 3G connectivity.
FiPy can be used for veriety of applications like monitoring, managing or a controlling application, and it offers five types of connectivity options Sigfox ,WiFi, BLE, cellular LTE-CAT M1/NB1and LoRa.It's various applications include Industrial Wireless Control , Surveillence, Wearable Electronics, Wi-Fi Location-aware Devices and Wi-Fi Position System Beacons Smart Homes. Raspberry Pi® is an ARM based credit card sized SBC(Single Board Computer) created by Raspberry Pi Foundation. Raspberry Pi runs Debian based GNU/Linux operating system Raspbian and ports of many other OSes exist for this SBC.It doesn't hve any wireless connectivity.It has to be interfaced. BeagleBone is one of the most popular choices out there. The BeagleBone Black Industrial takes it a step further by adding industrial temperature capabilities, meaning temperature rating from -40 to +85 degrees Celsius, this board perfect for rugged applications that operate in extreme environments.Project to development for innovators, with laptop like performance and next level expandability.Great for use in robotics applications or where systems control is an integral part of the design. QualcommDragonBoard 410C features Qualcomm Snapdragon 410 Processor and is compliant with 96Boards specification.DragonBoard410C providing an open platform targeted at software developers, the maker community, higher education, and embedded OEMs. The various device characteristics of some of the popular Iot development boards have been listed in Table 1.2.

Hardware	Data acquisition and control	SoC, Data processing and storage	Connectivity	Power/Temperature	Cost	Security	DSP Capability
MSP430FR5994 LaunchPad	68 gpio	256KB of FRAM and 8KB of SRAM	integrated peripherals for communication	3.3-V and 5-V power	Approximately 1000	No	yes
FlyportPRO	▪ up to 32 GPIO ▪ up to 10 Analog inputs (10 bit ADC onboard	PIC 24FJ256GB206,96Kbyte RAM - 64Kbit EEPROM onboard,16Mbit FLASH onboard- 256 Kbyte program memory	WIFI,Ethernet, GPRS	20°C..+85°C	High	No	No
8051	32 GPIO	4 KB on chip program memory.128	Can be interfaced with Ethernet		Low	No	Yes

		bytes on chip data memory(RAM).	module.				
Particle Electron	12 Analog in2 Analog out 30 Digital - 15 PWM	STM32F205 120Mhz ARM Cortex M3 processor 1 Mb flash,128 kB RAM	USB,WiFi.	3.9VDC to 12VDC. -20 to +60	Approximately 3000Rs	Built-in security	No
FiPy	• Up to 22 GPIO pins	Espressif ESP32 SoCTensilica L106 32-bit micro controller. SPI flash of 512KB	WiFi, BLE, cellular LTE-CAT M1/NB1, LoRa and Sigfox	3.3V – 5.5V Min -40 Max 125	Approximately 3000Rs	Security ID Tags	No
Raspberry Pi 3 Model B	40 I/O pins, including 29 Digital	ARM Cortex A53	Wifi, Ethernet, Bluetooth	+5.1V micro USB supply -70°C to 75°C	>3000	Can be implemented	simple DSP operations.
BeagleBone Black	65 Digital - 8 PWM 7 Analog in	AM335X ARM Cortex A8	Ethernet, USB ports allow external wifi / Bluetooth adaptors	-40 to +85 degrees Celsius	>2000	yes	yes
Qualcomm DragonBoard 410c	12 Digital	ARM Cortex A53. 1GB RAM, with 4.84GB internal storage available to the user out of the 8GB eMMC flash.	Wifi, Bluetooth, GPS	-30 to 40 degree celcius 6.5 and 18V	Rs 5000-6000	Yes	Yes

Table 1.2 Device Characteristics of Various IoT development boards

Conclusions

IoT has been gradually bringing a sea of technological changes in our daily lives, which in turn helps to making our life simpler and more comfortable, though various technologies and applications. There is innumerable usefulness of IoT applications into all the domains including medical, manufacturing, industrial, transportation, education, governance, mining, habitat etc. Though IoT has abundant benefits, there are some flaws in the IoT governance and implementation level. The key objective of the survey was to identify the device characteristics desirable for each of the IoT applications and also a study of few of the most popular and new IoT development boards with respect to their device characteristics and identifying their most suitable application domain. Some other observations in the literature are that (1) IoT development kit with more built-in features like wireless connectivity with lesser cost should be the goal of researchers.2) Since there are so many vendors in the IoT industry a standard protocol which is simple, lightweight, loosely-coupled, scalable and flexibleis much awaited from the research community.

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