Survey on IOT Enabling Technologies, Applications and Implementation Challenges

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Abstract

The main aim of this paper is to discuss the Internet of things in detail and comparision on protocols, technologies, applications and its issues. IoT concept is the integration of different technologies. Advancements in RFID, smart sensors, communication technologies, and Internet protocols enhance this Technology. Main challenge is in deploying smart sensor to deliver a class of applications without any human participation. Advancements in Internet, smart phone and M2M technologies constitute the first phase of IoT. In future probably IoT will be one of the hub between various technologies facilitating smart decision making. In this paper we discuss IoT architecture, protocols and applications and related issues with comparison of several survey papers. Our main aim to provide a framework to researcher and application developer that how different protocols works, some key issues of IoT and the relation between IoT and other technologies including big data analytics and cloud computing.

Keywords: *- Internet of things (IoT), IoT gateway, M2M*

INTRODUCTION

In recent time, IOT is getting more attention due to the advancements in Wireless Sensor networks. The idea behind is due to variety of entities such as RFID, NFC, Sensors, actuators, smart phones, etc. which can interact with each other by having a distinct address[1]. The IoT enables standalone objects to share information and to synchronize pronouncements. The IoT transforms them smart by manipulating its underlying technologies such as omnipresent and pervasive computing, embedded devices, communication technologies, sensor networks, protocols and applications. When, IoT was introduced, Radio frequency (RFID) seemed to be necessary for it. Similar to RFID, Near Field communications (NFC), Machine to Machine (M2M) and vehicular to vehicular communications (V2V), can be used to implement the modern idea of IoT. IoT influence domestic aspects, such as assisted living, smart homes, smart cars, etc. IoT has remarkable advancements in manufacturing and service industry such as better services, more production and superior quality. Global adaption of above mentioned technologies does appear comfortable but involves several issues.. The major issues that complicates IoT are security, standardization issues, addressing problems and scalability problems etc. This paper enables the reader to have basic idea of IoT, its technologies and applications and the major issues that IoT is facing which needed to resolve for near future. NASSCOM states that, the global market size of IOT is expected to touch USD 3 trillion by 2020. In this landscape, startups are playing the biggest role in enabling IOT services in the consumer as well as the industrial segment.

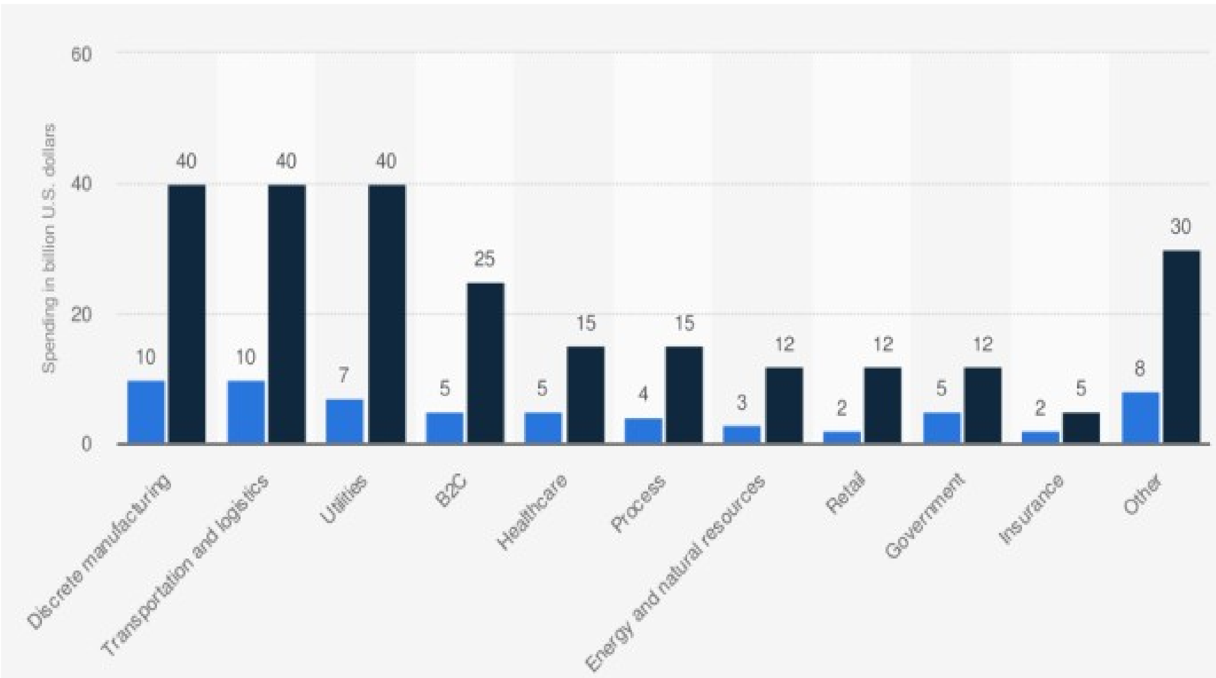

Figure 1. Spending on IOT worldwide by vertical in 2015 and 2020.

PREDICTIONS ABOUT INTERNET OF THINGS

- The International Data Corporation (IDC) estimates that, by 2025 upwards of 42 billion will be connected, generating 79.4 zettabytes of data.

- In the recent Schneider Electric Global IoT Survey of more than 2,500 business, decision-makers indicated that they believe IoT makes business sense.

- 63 % of surveyed organizations plan to leverage IoT to better analyze customer behavior and improve service levels.

- 41% of respondents anticipate that cybersecurity threats will be a critical challenge.

- IoT can help the 195 countries that pledged their commitment to the COP21 agreement meet their objectives.

- IoT enabled SAC can turn cumbersome spreadsheets into a powerful, Web-based, user-friendly platform, thus encouraging greater adoption throughout the apparel and footware industry.

- As per the market analysts at McKinsey, 40% to 60% of the total values lies on our ability to achieve interoperability between different IoT systems.

- According to Hubspot report, sponsored by Par Stream, out of 86% of business stakeholders who claim that data is integral to their IoT project, only 8% are able to capture and analyze IoT data in a consistent manner.

- Based on this report by Hubspot, it is apparent that 44% of IoT stakeholders face difficulty in capturing data and 30% confirms that their analytics capabilities are not strong and flexible.

Figure 2. No. of connected devices globally.

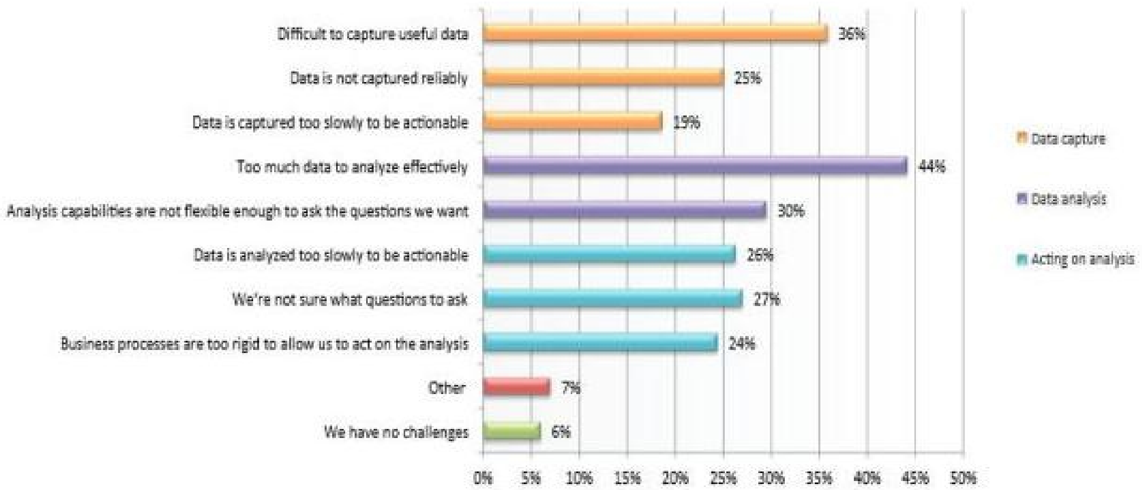

Figure 3. Challenges faced in collecting and analyzing the data in IOT projects.

INTRICATE TECHNOLOGIES

Various technologies are involves implementing the idea of IOT. In this paper we will focus on these

- Short-range wireless
- Medium-range wireless
- Long-range wireless
- Long Range wired

Short-range wireless

1. Bluetooth mesh networking

Bluetooth Mesh is a computer mesh networking standard based on Bluetooth

Low Energy that allows for many-to-many communication over Bluetooth radio[29]. The Bluetooth Mesh specifications were defined in the Mesh Profile and Mesh Model specifications by the Bluetooth Special Interest Group (Bluetooth SIG). Bluetooth Mesh was conceived in 2014 and adopted on July 13, 2017.

2. Light-Fidelity (Li-Fi)

Li-Fi is a light communication system that is capable of transmitting data at high speeds over the visible light, ultraviolet, and infrared spectrums. In its present state, only LED lamps can be used for the transmission of visible light.

3. Near-field communication (NFC)

Near-field communication (NFC) is a set of communication protocols for communication between two electronic devices over a distance of 4 cm or less[1]. NFC offers a low-speed connection with simple setup that can be used to bootstrap more-capable wireless connections.

***4.* Radio-frequency identification (RFID)**

Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. An RFID tag consists of a tiny radio transponder; a radio receiver and transmitter. When triggered by an electromagnetic interrogation pulse from a nearby RFID reader device, the tag transmits digital data, usually an identifying inventory number, back to the reader. This number can be used to inventory goods.

5. Wi-Fi

Wi-Fi uses multiple parts of the IEEE 802 protocol family, and is designed to interwork seamlessly with its wired sibling Ethernet. Compatible devices can network through wireless access points to each other as well as to wired devices and the Internet. The different versions of Wi-Fi are specified by various IEEE 802.11 protocol standards, with the different radio technologies determining radio bands, and the maximum ranges, and speeds that may be achieved. Wi-Fi most commonly uses the 2.4 gigahertz (120 mm) UHF and 5 gigahertz (60 mm) SHF ISM radio bands; these bands are subdivided into multiple channels. Channels can be shared between networks but only one transmitter can locally transmit on a channel at any moment in time.

***6.* ZigBee**

ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection[7]. Hence, ZigBee is a low-power, low data rate, and close proximity (i.e., personal area) wireless ad hoc network.

MEDIUM-RANGE WIRELESS

1. LTE-Advanced

LTE Advanced is a mobile communication standard and a major enhancement of the Long Term Evolution (LTE) standard. It was formally submitted as a candidate 4G to ITU-T in late 2009 as meeting the requirements of the IMT-Advanced standard, and was standardized by the 3rd Generation Partnership Project (3GPP) in March 2011 as 3GPP Release 10.

2. 5G

5G is the fifth generation of wireless communications technologies supporting cellular data networks. Large-scale adoption began in 2019 and today virtually every telecommunication service provider in the developed world is upgrading its infrastructure to offer 5G functionality. 5G communication requires the use of communications devices (mostly mobile phones) designed to support the technology.

The frequency spectrum of 5G is divided into millimeter waves, mid-band, and low-band. Low-band uses a similar frequency range as the predecessor, 4G. 5G millimeter wave is the fastest, with actual speeds often being 1–2 Gbit/s down. Frequencies are above 24 GHz, reaching up to 72 GHz, which is above the extremely high frequency band's lower boundary. The reach is short, so more cells are required. Millimeter waves have difficulty traversing many walls and windows, so indoor coverage is limited.

LONG-RANGE WIRELESS

1. Low-power wide-area networking (LPWAN)

A low-power wide-area network (LPWAN) or low-power wide-area (LPWA) network or low-power network (LPN) is a type of wireless telecommunication wide area network designed to allow long-range communications at a low bit rate among things (connected objects), such as sensors operated on a battery. The low power, low bit rate and intended use distinguish this type of network from a wireless WAN that is designed to connect users or businesses, and carry more data, using more power.

The LPWAN data rate ranges from 0.3 kbit/s to 50 kbit/s per channel. A LPWAN may be used to create a private wireless sensor network, but may also be a service or infrastructure offered by a third party, allowing the owners of sensors to deploy them in the field without investing in gateway technology.

2. Very small aperture terminal (VSAT)

A very small aperture terminal (VSAT) is a two-way satellite ground station with a dish antenna that is smaller than 3.8 meters. The majority of VSAT antennas range from 75 cm to 1.2 m. Data rates, in most cases, range from 4 kbit/s up to 16 Mbit/s. VSATs access satellites in geosynchronous orbit or geostationary orbit to relay data from small remote Earth stations (terminals) to other terminals (in mesh topology) or master Earth station "hubs" (in star topology).VSATs are used to transmit narrowband data (e.g., point-of-sale transactions using credit cards, polling or RFID data, or SCADA), or broadband data (for the provision of satellite Internet access to remote locations, VoIP or video). VSATs are also used for transportable, on-the-move (utilising phased array antennas) or mobile maritime communications.

LONG-RANGE WIRED

1. Ethernet

Ethernet is a family of computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN).It was commercially introduced in 1980 and first standardized in 1983 as IEEE 802.3. Ethernet has since retained a good deal of backward compatibility and has been refined to support higher bit rates, a greater number of nodes, and longer link distances[29]. Over time, Ethernet has largely replaced competing wired LAN technologies such as Token Ring, FDDI and ARCNET. The original 10BASE5 Ethernet uses coaxial cable as a shared medium, while the newer Ethernet variants use twisted pair and fiber optic links in conjunction with switches. Over the course of its history, Ethernet data transfer rates have been increased from the original 2.94 megabits per second (Mbit/s) to the latest 400 gigabits per second (Gbit/s). The Ethernet standards comprise several wiring and signaling variants of the OSI physical layer in use with Ethernet.

2 .Power-line communication (PLC)

Power-line communication (PLC) carries data on a conductor that is also used simultaneously for AC electric power transmission or electric power distribution to consumers. It is also known as power-line carrier, power-line digital subscriber line (PDSL), mains communication, power-line telecommunications (PLT), or power-line networking (PLN).

A wide range of power-line communication technologies are needed for different applications, ranging from home automation to Internet access which is often called broadband over power lines (BPL). Most PLC technologies limit themselves to one type of wires (such as premises wiring within a single building), but some can cross between two levels (for example, both the distribution network and premises wiring). Typically transformers prevent propagating the signal, which requires multiple technologies to form very large networks. Various data rates and frequencies are used in different situations.

Technology	Frequency	Data Rate	Range	Power Usage	Cost
2G/3G	Cellular Bands	10 Mbps	Several Miles	High	High
Bluetooth/BLE	2.4Ghz	1, 2, 3 Mbps	~300 feet	Low	Low
802.15.4	subGhz, 2.4GHz	40, 250 kbps	> 100 square miles	Low	Low
LoRa	subGhz	< 50 kbps	1-3 miles	Low	Medium
LTE Cat 0/1	Cellular Bands	1-10 Mbps	Several Miles	Medium	High
NB-IoT	Cellular Bands	0.1-1 Mbps	Several Miles	Medium	High
SigFox	subGhz	< 1 kbps	Several Miles	Low	Medium
Weightless	subGhz	0.1-24 Mbps	Several Miles	Low	Low
Wi-Fi	subGhz, 2.4Ghz, 5Ghz	0.1-54 Mbps	< 300 feet	Medium	Low
WirelessHART	2.4Ghz	250 kbps	~300 feet	Medium	Medium
ZigBee	2.4Ghz	250 kbps	~300 feet	Low	Medium
Z-Wave	subGhz	40 kbps	~100 feet	Low	Medium

Figure 4. Comparision of IOT enabling technologies.

APPLICATIONS

IoT is expected to add a value of 10-15 Trillion Dollars in the Global GDP. From everyday uses to large scale industry applications, IoT is expanding at an interesting speed. When coupled with Artificial Intelligence, it can bring in more value to the Global GDP.

a. Consumer applications
b. Commercial applications
c. Industrial applications
d. Infrastructure applications
e. Militrary applications

A. CONSUMER APPLICATIONS

1. Smart home

The concept of Home Automation aims to bring the control of operating your every day home electrical appliances to the tip of your finger, thus giving user affordable lighting solutions, better energy conservation with optimum use of energy.

Most of the IoT based Home Automation systems available today work on three widely used wireless communication protocols : Wi-Fi, ZigBee and Z-Wave. The ZigBee and the Z-Wave controllers are assigned a network ID which is distributed over other sensors in the network. The communication amongst devices take place in a mesh topology where there is no fixed path for the signals transmitted from the controller to the sensors and vice versa[29]. Depending on the availability of the shortest path the signal from the controller will travel to the target sensors either directly or through signal hops. If any intermediate sensor in the pathway is busy or occupied the signal will trace another path within the mesh network to reach the final destination. Note that sensors with different Network IDs cannot communicate with each other over common channel.

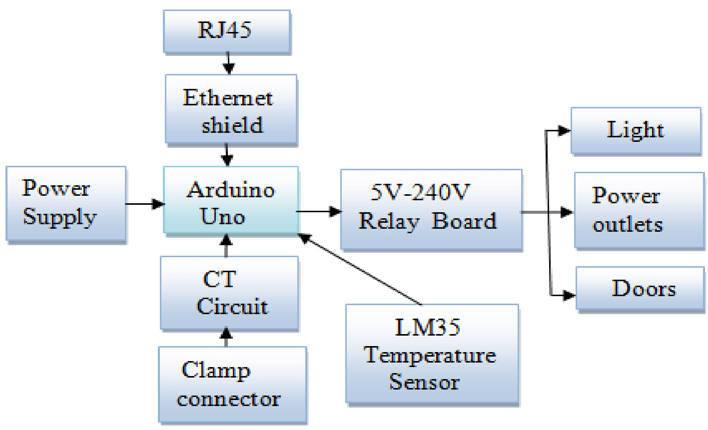

Figure 5. Home automation system Architecture.

Elder care

Smart home is to provide assistance for those with disabilities and elderly individuals. These home systems use assistive technology to accommodate an owner's specific disabilities. Voice control can assist users with sight and mobility limitations while alert systems can be connected directly to cochlear implants worn by hearing-impaired users. They can also be equipped with additional safety features. These features can include sensors that monitor for medical emergencies such as falls or seizures. Smart home technology applied in this way can provide users with more freedom and a higher quality of life. By 2019, it is estimated that the EIoT will account for 9.1 billion devices

B. CONSUMER APPLICATIONS

1. *Medical and healthcare*

IoT devices can be used to enable remote health monitoring and emergency notification systems. These health monitoring devices can range from blood pressure and heart rate monitors to advanced devices capable of monitoring specialized implants, such as pacemakers, Fitbit electronic wristbands, or advanced hearing aids. Some hospitals have begun implementing "smart beds" that can detect when they are occupied and when a patient is attempting to get up[29]. It can also adjust itself to ensure appropriate pressure and support is applied to the patient without the manual interaction of nurses. A 2015 Goldman Sachs report indicated that healthcare IoT devices "can save the United States more than $300 billion in annual healthcare expenditures by increasing revenue and decreasing cost."Moreover, the use of mobile devices to support medical follow-up led to the creation of 'm-health', used analyzed health statistics."

2. *Transportation*

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3. V2X communications

Vehicular communication systems are computer networks in which vehicles and roadside units are the communicating nodes, providing each other with information, such as safety warnings and traffic information. They can be effective in avoiding accidents and traffic congestion[29]. Both types of nodes are dedicated short-range communications (DSRC) devices. DSRC works in 5.9 GHz band with bandwidth of 75 MHz and approximate range of 300 m. Vehicular communications is usually developed as a part of intelligent transportation systems (ITS).

4. Building and home automation

Building automation is the automatic centralized control of a building's heating, ventilation and air conditioning, lighting and other systems through a building management system or building automation system (BAS). The objectives of building automation are improved occupant comfort, efficient operation of building systems, reduction in energy consumption and operating costs, and improved life cycle of utilities. A BAS should reduce building energy and maintenance costs compared to a non-controlled building. Most commercial, institutional, and industrial buildings built after 2000 include a BAS. Many older buildings have been retrofitted with a new BAS, typically financed through energy and insurance savings, and other savings associated with pre-emptive maintenance and fault detection.

C. INDUSTRIAL APPLICATIONS

1. Manufacturing

The IoT can realize the seamless integration of various manufacturing devices equipped with sensing, identification, processing, communication, actuation, and networking capabilities. Based on such a highly integrated smart cyber-physical space, it opens the door to create whole new business and market opportunities for manufacturing. Network control and management of manufacturing equipment, asset and situation management, or manufacturing process control bring the IoT within the realm of industrial applications and smart manufacturing as well[29]. The IoT intelligent systems enable rapid manufacturing of new products, dynamic response to product demands, and real-time optimization of manufacturing production and supply chain networks, by networking machinery, sensors and control systems together. Digital control systems to automate process controls, operator tools and service information systems to optimize plant safety and security are within the purview of the IIoT.But it also extends itself to asset management via predictive maintenance, statistical evaluation, and measurements to maximize reliability. Industrial management systems can also be integrated with smart grids, enabling real-time energy optimization. Measurements, automated controls, plant optimization, health and safety management, and other functions are provided by a large number of networked sensors.

2. *Agriculture*

There are numerous IoT applications in farming such as collecting data on temperature, rainfall, humidity, wind speed, pest infestation, and soil content. This data can be used to automate farming techniques, take informed decisions to improve quality and quantity, minimize risk and waste, and reduce effort required to manage crops. For example, farmers can now monitor soil temperature and moisture from afar, and even apply IoT-acquired data to precision fertilization programs. In August 2018, Toyota Tsusho began a partnership with Microsoft to create fish farming tools using the Microsoft Azure application suite for IoT technologies related to water management. Developed in part by researchers from Kindai University, the water pump mechanisms use artificial intelligence to count the number of fish on a conveyor belt, analyze the number of fish, and deduce the effectiveness of water flow from the data the fish provide[29]. The specific computer programs used in the process fall under the Azure Machine Learning and the Azure IoT Hub platforms

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D. INFRASTRUCTURE APPLICATIONS

1. *Energy management*

Significant numbers of energy-consuming devices already integrate Internet connectivity, which can allow them to communicate with utilities to balance power generation and energy usage and optimize energy consumption as a whole. These devices allow for remote control by users, or central management via a cloud-based interface, and enable functions like scheduling. The smart grid is a utility-side IoT application; systems gather and act on energy and power-related information to improve the efficiency of the production and distribution of electricity[29].Using advanced metering infrastructure (AMI) Internet-connected devices, electric utilities not only collect data from end-users, but also manage distribution automation devices like transformers.

2. *Environmental monitoring*

Environmental monitoring applications of the IoT typically use sensors to assist in environmental protection by monitoring air or water quality, atmospheric or soil conditions, and can even include areas like monitoring the movements of wildlife and their habitats. Development of resource-constrained devices connected to the Internet also means that other applications like earthquake or tsunami early-warning systems can also be used by emergency services to provide more effective aid. IoT devices in this application typically span a large geographic area and can also be mobile. It has been argued that the standardization IoT brings to wireless sensing will revolutionize this area

3. *Living Lab*

Living Lab which integrates and combines research and innovation process, establishing within a public-private-people-partnership. There are currently 320 Living Labs that use the IoT to collaborate and share knowledge between stakeholders to co-create innovative and technological products. For companies to implement and develop IoT services for smart cities, they need to have incentives. The governments play key roles in smart cities projects as changes in policies will help cities to implement the IoT which provides effectiveness, efficiency, and accuracy of the resources that are being used. For instance, the government provides tax incentives and cheap rent, improves public transports, and offers an environment where start-up companies, creative industries, and multinationals may co-create..

E. INFRASTRUCTURE APPLICATIONS

1. *Internet of Battlefield Things (IoBT)*

The Internet of Battlefield Things (IoBT) is a project initiated and executed by the U.S. Army Research Laboratory (ARL) that focuses on the basic science related to IoT that enhance the capabilities of Army soldiers. In 2017, ARL launched the Internet of Battlefield Things Collaborative Research Alliance (IoBT-CRA), establishing a working collaboration between industry, university, and Army researchers to advance the theoretical foundations of IoT technologies and their applications to Army operations.

The Internet of Battlefield Things Collaborative Research Alliance (IoBT-CRA), also known as the Internet of Battlefield Things Research on Evolving Intelligent Goal-driven Networks (IoBT REIGN), is a collaborative research alliance between government, industry and university researchers for the purposes of developing a fundamental understanding of a dynamic, goal-driven Internet of Military Things (IoMT) known as the Internet of Battlefield Things (IoBT). It was first established by the U.S.

2. *Ocean of Things*

The Defense Advanced Research Projects Agency (DARPA) is an agency of the United States Department of Defense responsible for the development of emerging technologies for use by the military. The Ocean of Things project is a DARPA-led program designed to establish an Internet of Things across large ocean areas for the purposes of collecting, monitoring, and analyzing environmental and vessel activity data. The project entails the deployment of about 50,000 floats that house a passive sensor suite that autonomously detect and track military and commercial vessels as part of a cloud-based network.

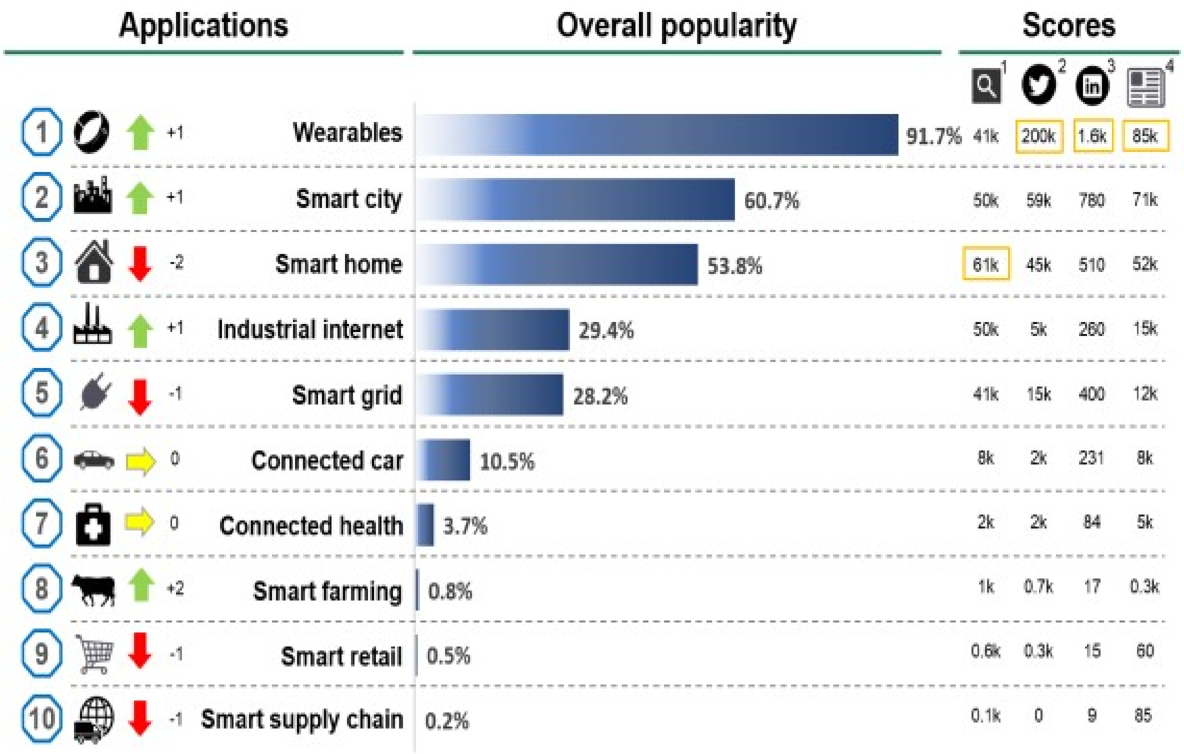
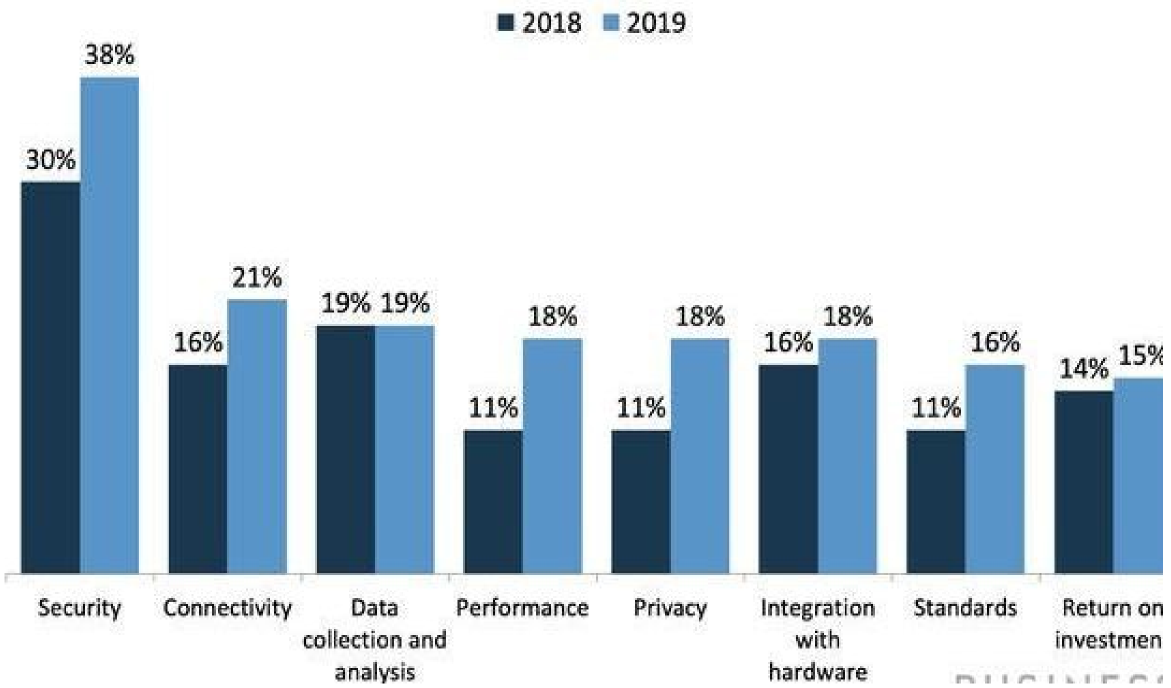


Figure 6. Top IOT applications ranking.

CHALLENGES



CONCLUSION

World has been changed completely due to Internet and Internet based application development. Interaction in all scenario becomes seems impossible without it. IoT has potential to broaden its horizon by enabling communication between smart objects. IoT will changed everything drastically if implemented successfully, But still there are various issues which need thorough research to improve the quality of life.

In this Paper, we have discussed various technologies with its specification that can result in making IoT a reality. In next section, we presented some handsome application of IoT and its comfort in life. Finally, some important issues that needed to be resolved have been discussed before wide acceptance of this technology. We finally conclude the need for new "smart" autonomic management, data aggregation, and protocol adaptation services to accomplish better integration among IoT service

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