THE INTERNET OF THINGS: LIMITLESS OPPORTUNITIES FOR BUSINESS AND SOCIETY

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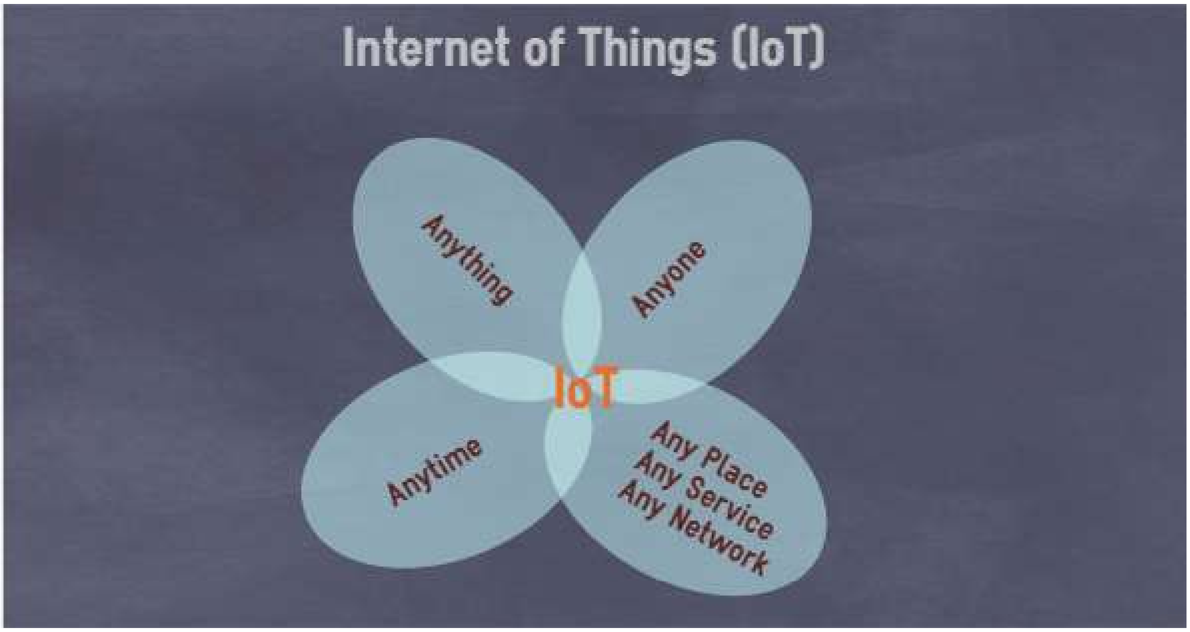
The World Wide Web created a connection from computers to networks. The next evolution that followed connected people to the Internet and to other people. The Internet of Things (IoT) is emerging as the third wave in the development of the Internet. IoT interconnects devices, people, environments, virtual objects, and machines. IoT is expected to revolutionize and change the way all businesses, governments, and consumers interact with the physical world. In the exploding world of IoT, there is much to learn and an overwhelming amount of research to be done. The objective of this paper is to go beyond the hype and explore basic issues related to IoT technology, including its promises as well as its pitfalls. This study discusses potential strategic benefits of this technology as well as its risks and limitations. It highlights its evolving technologies and trends and their impact on the world of tomorrow. Also, it reviews IoT's potential economic impact and explores many factors that may contribute to its successful adoption and deployment. Finally, this study explores IoT's potential application in various industries.

INTRODUCTION

A. IoT DEFINED

The "Internet of things" (IoT) is the concept of connecting any device with an on-and- off switch to the Internet and or to each other. The term refers to devices that collect and transmit data via the Internet. This includes everything from cellphones, wearable devices, industrial equipment such as car engines to jet engines or a drill of an oil rig, washing machines, coffee makers and anything else that we can think of. The concept is based on a general rule that "Anything that can be connected will be connected" (Figure-1). IoT could be considered as a giant network of connected people or "things". The connections is between things-things, people things, or people-people (Morgan, 2014).

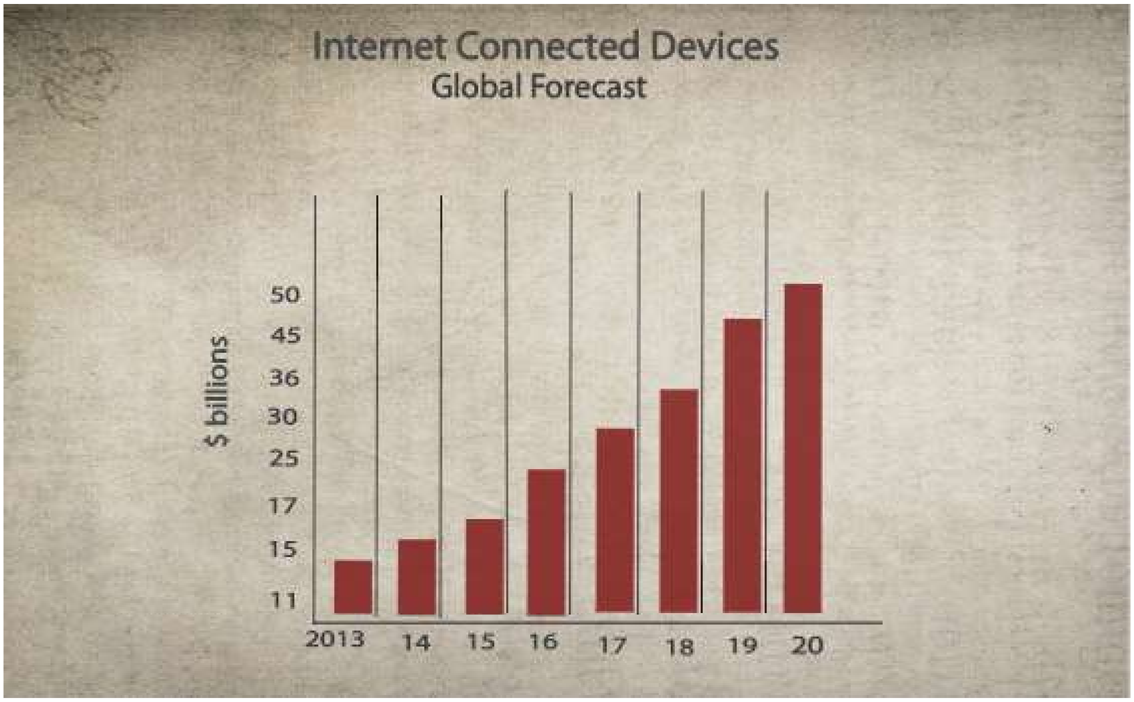
FIGURE 1



B. THE EVOLUTION OF TECHNOLOGIES

Radio Frequency Identification (RFID) technology is an e-tagging technology that can be used to provide electronic identity to any object. It was first used in the Second World War to identify friendly aircrafts. The desire to cut supply chain costs has made RFID technology one of the most discussed retail technologies in early 2,000. For a nominal price, a RFID tag is attached to the product in the initial stages of manufacturing that follows the product down the supply chain all the way to a retail setting, and finally into the hands of the consumer. There, it can again be scanned while in a box or crate, saving a bor. In a retail setting, the tag can serve as the price tag. Consumers can count on the tag for warranty information after purchase. Mandates from powerhouses such as Wal-Mart, Target Corp., and the US Department of Defense that require suppliers to begin using RFID technology is expanding this technology into supply chain operations (Attaran, 2007).

FIGURE 2



The second wave in the development of the Internet is labeled the Internet of people (IoP). It uses a PC, tablet or smartphone and run an application that connects to a remote server to get something done. Browsing the web, sending email, shopping online and watching videos are common examples of the Internet of People.

Extreme market competition and a dynamic business environment have forced companies to adopt state-of-the-art practices to optimize both the cost and operational efficiency of their information technology platform. IoT has emerged as a differentiating factor in business competition in the past few years (2012 and beyond). The technology will bring the next evolution in digital technology. The Internet of Things (IoT) is not new. The term "Internet of Things" was coined by Kevin Ashton, cofounder and executive director of the Auto-ID Center at MIT in 1999 (Rouse and Wigmore, 2016). Among the earliest object with IoT is ATM machines dated back to 1974.

The Internet of Things is very different from the Internet of people. IoT enabled devices can sense for themselves and use analytics and business intelligence to respond faster and better than a human. The reactions and adjustments will happen without any human intervention, and often without any human awareness. IoT has evolved from the convergence of four technologies: wireless, micro-electromechanical systems, microservices, and the Internet. The convergence has helped tear down the walls between operational and information technology.

According to some estimates, in the next 20 years, IoT will add $10-$15 trillion to global GDP. According to Cisco estimate, devices connected to the Internet were 11 billion in 2013, 15 billion in 2014, 25 billion in 2016 and will be over 50 billion connected devices by 2020-that is up to seven connected Things for every person on planet Earth. (Economist, 2014) (Figure-2). Yet, according to another study conducted by marketsandmarkets, the IoT market size is estimated to grow from $157.05 billion in 2016 to $ 661.74 billion by 2021, at a compound annual growth rate of 33.3% from 2016 to 2021 (Mukherjee, 2016).

TABLE 1
IoT SPENDING IN DIFFERENT INDUSTRIES

Industry	IoT Spending
Logistics	• Will invest $1.9 trillion in 10 years
Smart Cities	• Will reach $1.56 trillion investment by 2020
Retailers	• Will spend $2.5 billion by 2020
Auto Industry	• 250,000 vehicles will be connected to the Internet by 2020
Wearable Device Market	• Fitbit and Apple watches sold $10 million devices in 2015
Healthcare	• The value of improved health of chronic disease patients through remote monitoring could be as much as $1.1 trillion per year in 2025

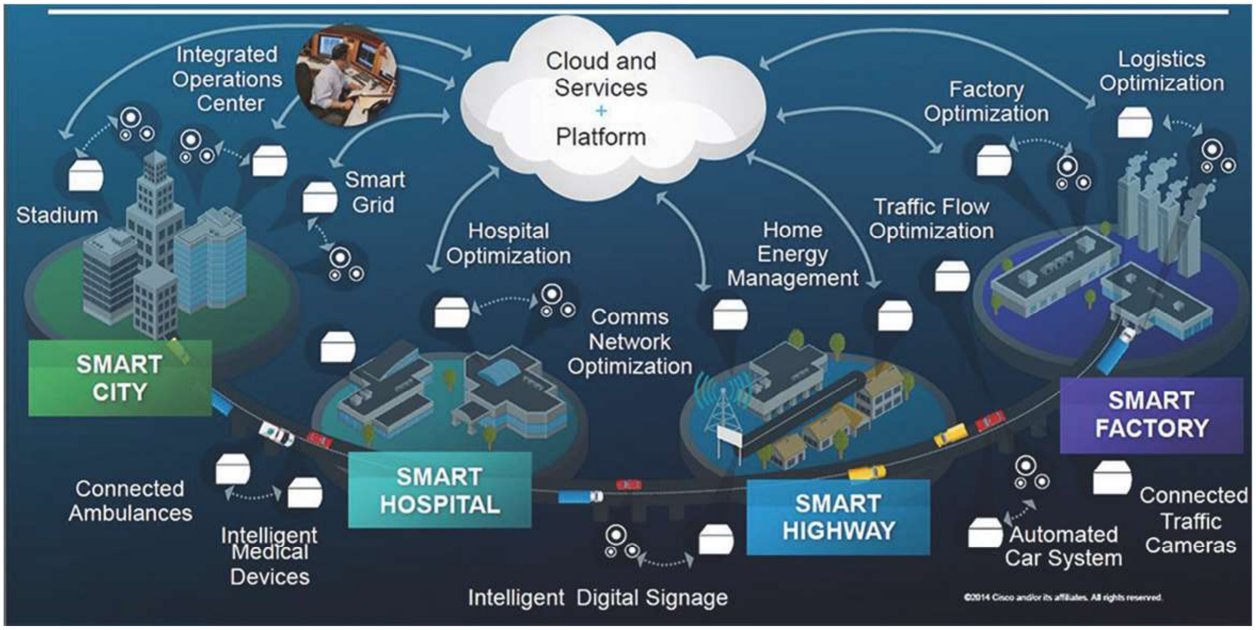
Nearly six trillion dollars will be spent on IoT solutions over the next five years. IoT has the potential to impact the way we work and the way we live. The widespread adoption of the IoT will take time, but the time line is advancing. According to another recent estimate, up to 28 billion devices will be connected to the Internet with two thirds of them being other “devices” – sensors, terminals, household appliances, thermostats, televisions, automobiles, production machinery, urban infrastructure and many other “things”, which traditionally have not been Internet enabled (Banafa, 2016).

IoT allows for virtually endless opportunities and connections to take place. Powering the IoT revolution can drastically impact the world we live in and fight our world’s biggest challenges.
With IoT there are limitless opportunities for business and society. As Table -1 shows, more and more industries and consumers are using IoT technology to reduce cost and optimize operational efficiency

(Libelium, 2016). All of these applications are creating a "perfect storm" for the IoT. From Figure-3, we can clearly see that IoT influences every aspect of our lives. IoT technology is maturing and continues to see tremendous innovation. There are several reasons for the tremendous growth of the concept, which include:

- Broadband Internet is becoming more widely available
- The cost of connecting to the Internet is decreasing. The cost of bandwidth has also declined precipitously, by a factor of nearly 40X over the past 10 years.
- The cloud – whether public, private or hybrid – has revolutionized IT infrastructure
- Advances in wireless networking technology and greater standardization of communications protocols make it possible to collect data from these sensors almost anywhere at any time
- Sensor prices have dropped to an average of 60 cents from $1.30 in the past 10 years.
- Processing costs have declined by nearly 60X over the past 10 years. This enables more devices to be capable of knowing what to do with all the new data they are generating or receiving.
- Ever-smaller silicon chips for this purpose are gaining new capabilities

FIGURE 3
USE OF IoT IN EVERYDAY APPLICATIONS



Source: Cisco

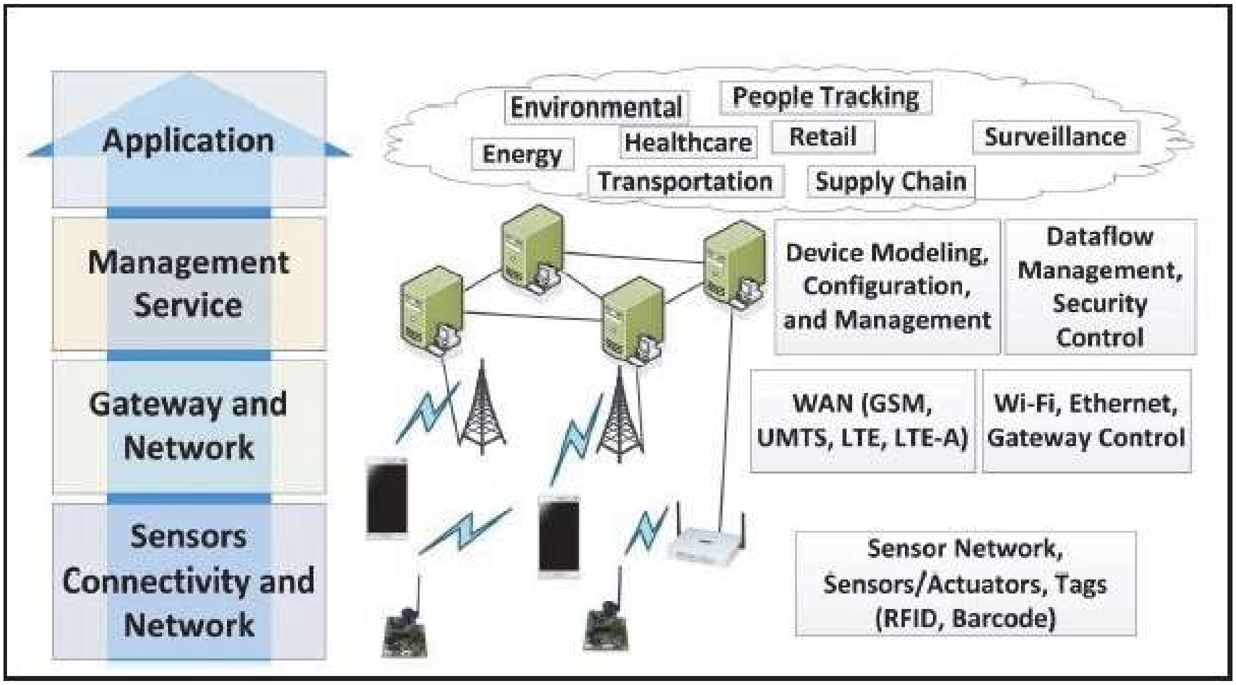
- More devices are being created with Wi-Fi capabilities and sensors built into them
- Technology costs are going down as more companies move to the cloud
- Smartphone penetration is sky-rocketing
- Massive increases in storage and computing power (via cloud computing) make number crunching possible at a larger scale and at a declining cost.
- The technology for capturing and analyzing "Big Data" is widely available at an ever lower price points.

C. IoT ARCHITECTURE LAYERS

As shown on Figure 4, there are four major layers of IoT architecture. Features of each of these architectural layers are discussed below (Opentechdiary, 2015):

1. **Sensor, Connectivity and Network Layer -** This layer is at the very bottom of IoT architecture and has sensors, RFID tags and connectivity network which collects information. The RFID tags or barcode reader and sensors are wireless devices and are essential part of an IoT system and are responsible for collecting raw data. They form the essential "things" of an IoT system. Sensors are active in nature and are collecting and processing real-time information. This layer also has the network connectivity, like WAN, PAN etc., which is responsible for communicating the raw data to the next layers.

FIGURE 4
IoT ARCHITECTURE LAYERS



Source: Opentechdiary, 2015

2. **Gateway and Network Layer –** This layer is consist of the gateway which is comprised of embedded OS, Signal Processors, Micro-Controllers, and the Gateway Networks which are LAN(Local Area Network), WAN(Wide Area Network), etc. The responsibility of Gateways are routing the data coming from the sensor, connectivity and network layer and pass it to the next layer which is the Management Service Layer. This layer must have a large storage capacity to store the enormous amount of data collected by the sensors, RFID tags etc. Also, this layer needs to have a consistently trusted performance in terms of public, private and hybrid networks.

3. **Management Service Layer –** This layer is responsible for data mining, text mining, service analytics analysis of IoT devices, analysis of information (stream analytics, data analytics) and device management. Data management is required to extract the necessary information from the enormous amount of raw data collected by the sensor devices to yield a valuable result. This layer also helps in certain situations requiring immediate response.

4. **Application Layer –** This layer is responsible for effective utilization of the data collected by tags and sensors. Smart buildings, precision farming, e-health and e-government are examples of various applications for IoT.

D. EVOLVING TECHNOLOGIES AND TRENDS

Today IoT enabled devices have become broader, deeper, and cheaper. Readers and sensors are using less power, growing more intelligent, operating faster and at longer distances and able to handle interference. This means better systems performance, greater capability to use sensors and tags with more data, and easier integration into existing systems without reprogramming. Sensors and tags are rapidly becoming cheaper by the day.

There has been a tremendous growth in applications software in recent years. Some innovative companies are working with academic and industry leaders and using hardware and software to develop powerful integrated IoT solutions. In cooperation with university research labs, these companies are developing the IT processes and applications to improve the efficiency of IoT application in different industries. Microsoft, and other software companies, are creating platforms upon which enterprises and consultants can create IoT enabled software and applications optimized for different devices.

Data scientists, IT managers and manufacturers are experimenting with how to use related IT technologies like Edge Computing and Smart Data devices to bring in more revenue, and improve decision-making processes. Smart data is digital information that is formatted and can be acted upon at the collection point. It is directly related to the data that smart sensors embedded in physical objects produce. The data entry point is intelligent enough to make some types of decisions on incoming data immediately, without requiring processing power from a centralized system. Smart data analytics programming (also called streaming analytics) monitors data at the source, captures events that are exceptions, assesses them, makes a decision and shares the output -- all within a specific window of time consisting of seconds or fractions of a second.

Another related technology that is also growing fast is Edge Computing or Fog Computing. Championed by Cisco, IBM, and Dell client data is processed at the periphery of the network, as close to the originating source as possible. To enable quicker response, intelligence is pushed from the cloud to the edge, localizing certain kinds of analysis and decision-making. The sheer number of networked devices in the (IoT), growth of mobile computing, and the decreasing cost of computer components all are driving forces behind the move toward Edge Computing architecture. Since transmitting massive amounts of raw data over a network puts tremendous load on network resources, it is much more efficient to process data near its source and send only the data that has value over the network to a remote data center. Time sensitive data will be processed in an edge computing architecture at the point of origin or sent to an intermediary server located in close geographical proximity to the client. Less time sensitive data is sent to the cloud for historical analysis or long-term storage. Edge Computing offers several advantages such as improving time to action, reducing response time down to milliseconds, while also conserving network resources (Rouse and Mixon, 2016). For example, edge computing plays a crucial role in real-time operating systems for Akamai Technologies Inc. in Cambridge, Massachusetts. The company collects the data at an aggregation point close to the user and transmits in real time only the data points that require immediate attention. Less time sensitive data from a sensor is sent to a centralized data warehouse (the cloud) for historical analysis or long-term storage (TechTarget, 2016).

IoT is in its infancy, but the use cases will grow exponentially over the next few years as more and more devices become connected, opening new opportunities for innovation with smart products. In the past few years, many technologies like Augmented Reality (AR), Industrial IoT (IIoT), Edge computing, and Low Power Wide-Area (LPWA) were introduced that will shape the next stages in IoT development (Table 2). AR enables IoT data in the form of text, graphs, images, and videos be visualized using smart phone, tablet, or smart glasses. Today most AR applications serve consumer markets. In the near future, the technology will be used in enterprise markets when AR technologies are paired with IoT and other application data.

TABLE 2
IoT TECHNOLOGIES AND TRENDS

Trends	Description
Augmented Reality (AR)	♦ IoT data in the form of text, graphs, images, and videos are superimposed onto a live image of the physical world ♦ Can be visualized using smart phone, tablet or smart glasses
Industrial IoT (IIoT)	♦ Labeled the next industrial revolution or industry 4.0 ♦ Industrial machines and associated processes become smarter increasing levels of utilization and provide greater flexibility for meeting customers' expectations
Low-Power Wide-Area (LPWA)	♦ Suitable for applications that have batteries, require low costs for connectivity hardware and services, and seek wide area connection ♦ Suitable for asset tracking, agriculture, and environmental monitoring
Edge Computing	♦ Represents a shift in architecture in which intelligence is pushed from the cloud to the edge – at the periphery of the networks, as close to the originating source as possible.
Analytics Automation	♦ Analytic Automation is automation of many of the manual activities. It uses a platform that can easily grab new data, make adjustments to analytics models an real time and automate prescriptive analytics
IoT Marketplaces	• Suppliers are offering IoT marketplaces that provide enterprises with a portfolio of hardware, software and services to assemble an IoT solution • Pre-integrated components, offered in marketplaces, are nearly plug-and-play and enable fast time-to-market
IoT Data Exchange	♦ Exploring the opportunities and challenges when enterprises exposing and sharing their IoT data with external parties ♦ Example is online transportation access industry where vehicle location data is shared by Uber, Lyft, Arro, and others
Enterprise Outsourcing	♦ Outsourcing of IoT activities, including building, running, and managing a suite of connected things to an outside vendor

IoT technology is driving force for the next industrial revolution, called Industry 4.0. In Industry 4.0, industrial processes and the associated machines become smarter and more modular providing greater flexibility for meeting customer demand. The resulting systems can monitor, collect, exchange, analyze, and instantly act on information to intelligently change their behavior or their environment. Low-Power Wide-Area (LPWA) technologies are suitable for application segments that only have batteries or energy capture for power, require low costs for connectivity hardware and services, and seek the simplicity of a wide area connection. All of these factors lower the total cost of ownership of IoT solutions and make the technology affordable for markets of asset tracking, agriculture, and environmental monitoring. Table 2 summarizes some of these innovation options set to change the IoT landscape that were introduced over the past year (ABI Research, 2016).

OBSTACLES TO RAPID ADOPTION

The Internet of Things has enormous promise. There are also numerous challenges in applying IoT technology in a way that would allow for its significant and rapid growth. IoT provides many opportunities but also many challenges with many billions of devices being connected. As devices become more connected, security and privacy become the primary concern among consumers and businesses. The major challenges include technological maturity, global standardization, government regulations, and cost, as summarized in Table 3 and described below:

1. **Technical** – Technology standard is non-consistent and still remains fragmented on most areas. Technical and boundary limitation still exist in some areas of technology. Capturing the full potential of IoT applications will require innovation in technologies and business models, as well as investment in new capabilities and talent. Among the technical problems of implementation are imperfect read-rates, unproven systems, and conflicting problems with assembling low-cost sensors. Further, growing interconnections among companies and links with consumer devices will create challenges to the integrity of corporate networks. Finally, companies often lack in-house expertise to implement IoT technology. Hiring outside experts can be difficult and expensive.

2. **Security -** IoT is a wireless technology and poses some potential security concerns to users regarding the compromise of data during wireless transmission, storage of data, and security of storage sites. Security remains a primary concern for businesses contemplating IoT adoption. What can we do to make sure that people personal information stays secure? The technology also opens up companies all over the world to more security threats. IoT enabled devices are vulnerable to hackings, and the fear is that they can be used to harm people. IoT devices that aren't properly secured can be easily accessible to the outside world and create a wealth of opportunities for hackers. Therefore, it's important to ensure that devices have some type of mechanism to recognize a hack. The following personal data could be at risk: location data, registration details (name, DoB, address, etc.), banking details, sensitive personal health information, contact details, viewing habits, life and health risks, habits and consumption, etc. According to the 2016 Data Threat Report, the protection of sensitive data ranked as the top concern (at 36% of those polled) among enterprises. Cyber-attacks are also a growing threat around the globe. Currently there is no government regulation around the IoT and there is also no organized effort by manufacturers to make these devices more secure (Meola, 2016). It is the responsibility of companies to embed methods of protecting critical information into technology architectures, business-model-innovation processes, and interactions with customers. Some of the security issues have been addressed by IoT vendors by employing a variety querying protocols, jamming and other techniques.

TABLE 3
IoT IMPLEMENTATION CHALLENGES

Levels	Challenges
Technical	♦ Imperfect read-rates ♦ Unproven systems ♦ Problems with assembling low-cost sensors ♦ Integrity of corporate networks ♦ Shortage of appropriate software and middleware ♦ Lack of in-house expertise to implement IoT ♦ Requires innovation in technologies and business models ♦ Requires investment in new capabilities and talent
Data Security	♦ Concern regarding the compromise of data ♦ Uncertainty around security of data storage ♦ Insufficient security for user data and their protection ♦ Physical security of storage site ♦ Concern about Cyber-Attacks and Cybercrime
Big Data	♦ Storing, tracking, analyzing and making sense of the vast amount of data that will be generated by IoT devices pose a great challenge
Privacy Issues & Government Regulations	♦ Privacy concerns and potential for legislation ♦ Lack of global standards - uncertainty around standards ♦ Intellectual property rights
Testing IoT Applications	♦ IoT applications must be subjected to stringent testing requirement
Human Elements	♦ The human elements have been labeled as the biggest threat to the reliability, resilience and security of IoT system

3. **Privacy Issues and Government Regulations –** The use of IoT could have profound social implications. Without safeguards in place, IoT technology has the potential to compromise consumer privacy and threaten civil liberties. Consumer groups have expressed concern over the privacy invasion that might result with widespread application of IOT enables devices. There are a few recent examples of filed complaints for violation of privacy and consumer protection laws against IoT enabled devices. On December 6, 2016, a group of consumer watchdogs have filed a complaint with the Federal Trade Commission over the My Friend Cayla doll and the i-Que robot both made by Genesis Toys. The doll and the robot are internet-connected toys that children can talk and interact with. The complaint claims the toys subject young children to ongoing surveillance, unfairly and deceptively collect, use, and disclose audio files of children's voices. That violates privacy and consumer protection laws. Furthermore, they claim that children’s recorded conversations are also uploaded to Nuance, a voice technology company that uses the recordings to improve the products it sells to military, government and law enforcement agencies (Criss, 2016).

4. **Big Data –** Data is flooding in at a rate never seen before-doubling every 18 months. The International Data Corporation report predicted that there could be an increase of digital data by 40 times from 2012 to 2020. Public customer data, proprietary, purchased sources, and new data gathered from IoT enabled devices are generating what is broadly known as "Big Data." The amount of data that IoT devices might report back to a cloud server could easily overwhelm a relational database. Companies offering IoT enabled devices need to be prepared to store, track, analyze, and make sense of the vast amounts of data that will be generated. The real value that IoT creates is at the intersection of gathering data and leveraging it. Big Data demand large scale computing and storage infrastructures for processing and data explorations. Cloud infrastructures are used for back-end computing and for the development of analytics for both scientific and business computing. Cloud-based applications are also used to interpret and transmit the data coming from all these sensors. However, it is anticipated that IoT's billions of connected objects will generate data volume far in excess of what can easily be processed and analyzed in the cloud, due to issues like limited bandwidth, network latency, etc.

5. **Challenges of Testing IoT Applications -** IoT doesn't function without applications to interpret and transmit the data coming from all these sensors. Vulnerability of network connections and the potential for misuse require IoT applications to be subjected to more stringent testing requirements. An important feature of IoT devices is the capability to immediately respond to the stimuli they are subjected to. This ability also demands testing for safety, reliability and adaptability. The safety of autonomous devices is a significant requirement that presents another challenge for the technology.

6. **Human Elements –** Human elements have been labeled as the biggest threats to the reliability, resilience, and security of any system. IoT developers should take into account that when Iot devices go rogue, they have the potential to do real harm. Software developers need to work harder than ever to ensure that their products are safe and secure before making IoT applications available for distribution.

POTENTIAL ECONOMIC IMPACT

Data scientists, business analysts, IT managers, marketing professionals and manufacturers are also experimenting with how to use IoT enabled devices to bring in more revenue, improve decision-making processes and spot problems before equipment fails. McKinsey & Company estimated a potential economic impact—including consumer surplus—of as much as $11.1 trillion per year in 2025 for IoT applications in different settings. The findings also reveals that the value of this impact, including consumer surplus, would be equivalent to about 11 percent of the world economy in 2025. The size of economic impact depends on a number of factors, including the declining costs of technology, and the level of acceptance by consumers and workers. McKinsey & Company estimated that factories are likely to have the greatest potential impact from IoT usage. The next-largest setting in terms of potential impact would be cities, retail environments, vehicles, and homes (Dobbs, et al. 2105).

IoT has the potential to optimize the performance of systems and processes, save time for people and businesses, and improve quality of life. The technology provides us with two distinct opportunities:

1. Transform business processes
   - Predictive maintenance
   - Better asset utilization
   - Higher productivity

2. Enable new business models
    - Remote monitoring, e.g. Telemedicine, Smart Home, Drones
    - Enables anything-as-a-service

As reported by Business Insider, the top adaptors of IoT solutions are businesses. IoT has the potential to lower operating costs and increase productivity. The technology also enables businesses to expand to new markets or develop new product offerings. The second largest adopters of IoT solutions are government. IoT solutions can increase productivity, decrease costs, and improving citizens' quality of life. Finally, consumers will be the third largest adopters where they invest a significant amount of money and purchase a great number of IoT enabled devices (Meola, 2016).

Bain & Company, a global management consulting firm, estimates that by 2020, annual revenues could exceed $450 billion for the IoT vendors selling the hardware, software and comprehensive solutions. In 2016, the company surveyed more than 170 IoT executives and analytics solutions vendors and found that businesses are optimistic about both the cost reduction and new revenue opportunities provided by the IoT. The survey identified improving service quality, workers productivity, and asset productivity as top reasons given for why businesses are adopting IoT solutions (Bosche, et al, 2016). The survey findings are summarized below:

- Improving quality of service product
- Improving productivity of workforce
- Increasing reliability of operations
- Increasing asset productivity
- Reducing costs of materials or waste
- Accessing new customer
- Increasing customer satisfaction
- Faster time to market, lower development costs
- Reducing risk of theft or other loss

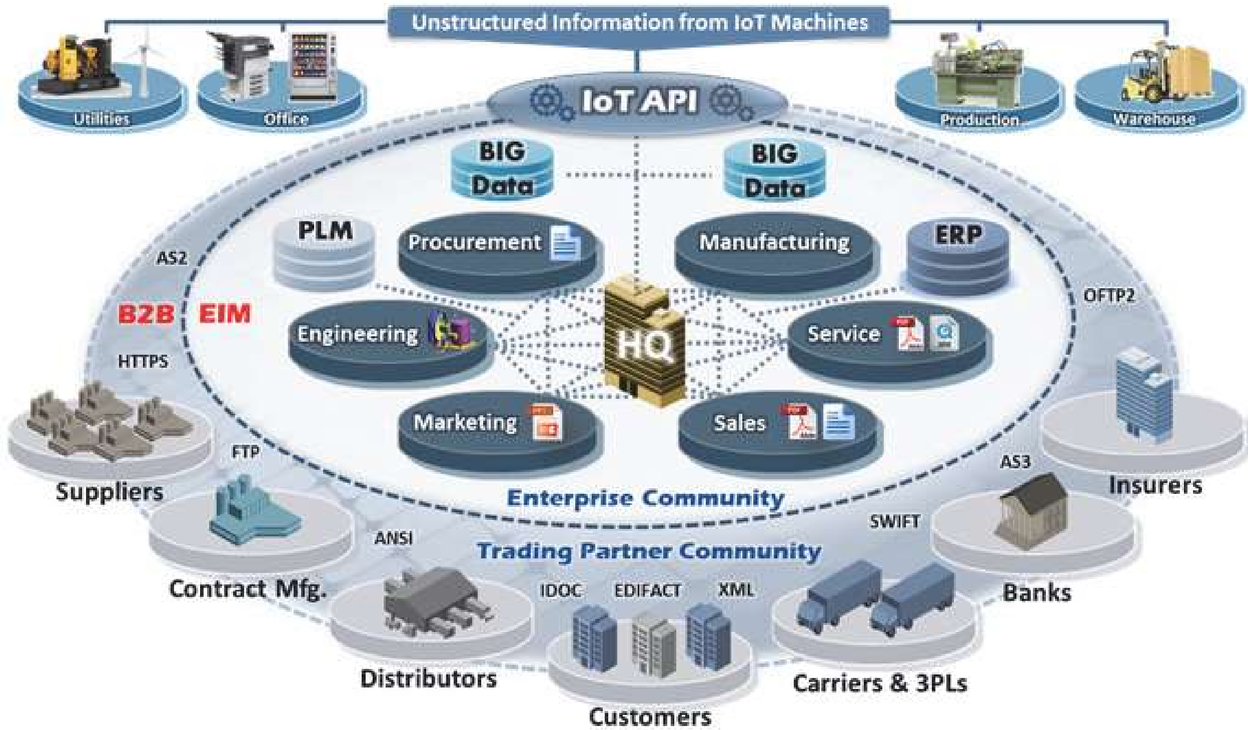
In 2015, McKinsey & Company analyzed more than 150 cases using IoT. Data security and privacy were the main concerns of all the organizations who participated in this research. Furthermore, the study revealed that in most organizations taking advantage of IoT requires leaders to truly embrace data-driven decision making. The findings also revealed the following (Dobbs, et al. 2105):

1. Business-to-business (B2B) applications can create more value than pure consumer applications. B2B uses can generate nearly 70 percent of potential value enabled by IoT.

2. Over the next 10 years, they estimated higher potential value for IoT in advanced economies because of higher value per use. However, nearly 40 percent of value could be generated in developing economies.

3. Interoperability between IoT systems is critically important in capturing the maximum value.

FIGURE 5
IMPACT OF IoT ON BUSINESS WORLD



4. Customers will capture most of the benefits. The users of IoT (businesses, other organizations, and consumers) could capture 90 percent of the value that IoT applications generate.

5. To realize the full potential from IoT applications, technology will need to continue to evolve, providing lower costs and more robust data analytics.

6. A dynamic industry is evolving around IoT technology. Both existing and new players have opportunities.

7. Currently, most IoT data are not used for optimization and prediction, which provide the greatest value

Common Uses of IoT

The breadth and impact of IoT continue to expand as the technology gains acceptance and functionality, making it a fast growing IT solution in a variety of industries. IoT emerges as a rapidly evolving technology that more and more industries are willing to adopt in order to improve their efficiency. Figure 5 highlights the impact of IoT on the business world.

There are three major sectors of the economy that will use IoT solutions: businesses, government and consumers. Businesses will be the top adopter of IoT solutions because it has the potential to lower operating costs, increase productivity, expand to new markets, and develop new product offerings. Governments will be the second-largest adopters and consumers will be the group least transformed by IoT (Meola, 2016)

Manufacturers, oil and gas companies, and other businesses have already begun to see the initial payoff from IoT technologies in their operations. Practical applications of IoT technology can be found in many industries today, including precision agriculture, building management, healthcare, and energy and transportation, as summarized in Table 4 and described below:

Healthcare Industry – The applications of IoT in the healthcare industry is limitless. The concept is referred to as the Internet of Medical Things or "LoMT". It is the collection of medical devices equipped with Wi-Fi and applications connected to healthcare IT systems through online computer networks. Information gathered by IoT is stored and analyzed in the cloud (Rouse, and DelVecchio, 2015). As hospitals struggle to lower operating costs and remain competitive, IoT has the potential to reduce costs and improve a patient's journey through a medical facility. The idea of telemedicine or the ability of a doctor with a webcam to diagnose patient's problems without an office visit is becoming popular. This is very useful when patients live in remote areas or when they need specialized care. Examples of how IoMT can help healthcare industry improve efficiency and reduce costs are summarized in Table-4.

Precision Agriculture – IoT concepts are used in farm management to ensure that crops and soil receive exactly what they need for optimum health and productivity. Specialized equipment, software devices, and sensors are used to ensure profitability, sustainability, and protection of the environment. Sensors installed in the field measure the moisture content and temperature of the soil and surrounding air. Images from satellites are processed and information from sensors and other data are integrated to yield guidance for immediate and future decisions. Decisions such as which fields to water, when, or where to plant a particular crop are optimized (Rouse and Wigmore, 2016).

Retail Industry – Amazon Go, a 1800-square-foot convenience store located in Seattle, allows shoppers to grab the items they want and leave. Shoppers start by scanning an app as they enter the Amazon Go shop. They shop as normal, and the computer vision and sensors included in every item identify the items in their cart and charge them to their Amazon account when they walk out the door. The store has no registers, no self-checkout, and no lines (Garun, 2016).

Transportation – The idea of driverless cars is not new. The first prototype was designed by Leonardo da Vinci around 1478. His car was designed as a self-propelled robot powered by springs, had a programmable steering, and the ability to run pre-set courses. Many companies are designing driverless cars including Audi, BMW, Ford, Google, General Motors, Volkswagen, and Volvo. The autonomous vehicle is designed to navigate without human intervention, travel between predetermined destinations over roads that have not been adapted for its use. Nevada, became the first jurisdiction in the world to allow driverless cars on public roadways in 2011 (Rouse, 2011). Sensors installed in individual vehicles are used to save maintenance costs by predicting when maintenance is needed. Mobike, a Chinese company created by a former Uber employee started a bike rental program in Shanghai. The rental program not only allows customers to pick up a bike for just 15 cents per half hour from a location nearest to them, but also allows them to drop the bike off anywhere in the city. Similar to Uber, to get started on Mobike, one would download the Mobik's app on your cell phone. You would be prompted to create an account and sign in. Next a GPS will locate your current position and scan to see if there are any bikes in the area. After you pick the bike, the app will calculate the distance of the bike from your current location and give you details such as the number of bikes at that point and the time needed for you to travel to get to the bike. The advantages of this new rental system are the use of barcodes (Quick Response codes), the absence of keys, the low cost of renting a bike, and being able to drop them off wherever you want (Ziyu, 2016).

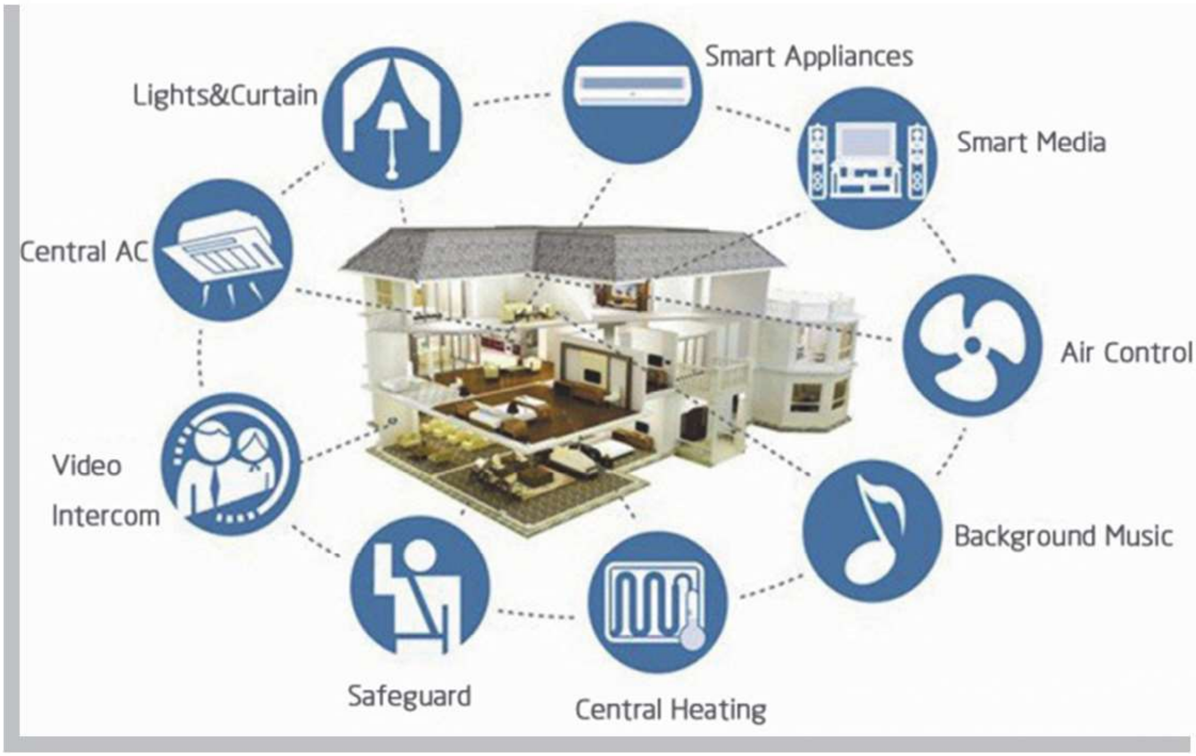
Manufacturing Sector – This sector has been finding different ways to derive value out of this technology. For example, manufacturers are using product tracking mechanisms to ensure accuracy. Parts can be individually tagged and tracked throughout the manufacturing process while on the production line. Parts received from the production plant can be tracked throughout the assembly process. Camera installed along production lines measure the number of components in bins and an inventory management system automatically places supply orders to refill the containers. This would certainly help manufacturers with their carefully scheduled Just-In-Time (JIT) assembly lines (Attaran, 2012). Manufacturers use sensors to improve machines performance, extending their lives, and learn how they could be redesigned to do even more. Tags and sensors containing equipment specifications can be attached to enable easy upgrading. Data captured from sensor devices are used to predict when equipment is wearing down or needs repair. This could reduce maintenance costs by 40 percent and cut unplanned downtime by 50 percent. Today, your car engine could automatically be connected with the manufacturer and in case of breaks down have them direct you to the nearest repair shop, or even send help to you. On a larger scale, the engines in modern airplanes gather thousands of statistics every minute and can relay to the ground or to manufacturer when an issue is beginning to occur reducing the odds of a mechanical failure. Similarly, tags and sensors can be used to keep track of usage, availability, location, and maintenance of material handling equipment. At some of the Land Rover Group Ltd. factories, RFID tags are used to keep track of vehicles as they leave the assembly line for testing and refinement. The technology reduced the labor costs involved in looking for "lost" vehicles, decreased inventory carrying expenses, and assured faster order-to-cash cycles. Furthermore, Land Rover realized a full return on investment within nine months (Rothfeder, 2008).

Energy - The smart grid is one example of the widespread application of IoT. In this application, each component of the electric grid from transformers to power lines to home electric meters has sensors and is capable of two-way communication. Using the smart grid, the electric company can manage distribution more efficiently, be proactive about maintenance and respond to outages faster (Rouse, 2015)

Smart Building - The field of smart building is expanding rapidly. A smart home is equipped with special structured wiring and sensor devices to enable a remote control of an array of automated home electronic devices that provide communications, entertainment, security, and convenience (Figure 6). A homeowner can use a cell phone to arm a home security system, control lighting or temperature gauges, switch appliances on or off, program entertainment system, and perform many other tasks (Rouse, 2005). Today, you don't need to carry house keys. You can buy door locks that open when they have your phone placed near them using Near Field Communication (NFC) technology. Some hotels even use this technology today instead of giving you a room key. Figure-6 highlights IoT application for a smart home.

Smart Cities - On a broader scale, IoT can help creation of "smart cities" where we can improve our quality of life by using urban informatics and technology to reduce waste and improve efficiency for energy use, water consumption, and pollution control. A smart city integrates information and communication technology and IoT solutions in a secure fashion to manage a city's different functions. Those functions include, but are not limited to, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services. The savings gained from Smart Cities is incredible. For example, smart water technology can save $12 billion annually. Sensors installed in individual vehicles can be linked to broader systems that help to manage traffic congestion across the city.

Figure 6 - Use of IoT in Every Aspects of Smart Home



Source: TechPedia, 2015

Several cities around the world have implemented Smart City technologies and programs including Southampton, Amsterdam, Barcelona, Madrid and Stockholm. Smart cities will reach $1.56 trillion investment by 2020 (Libelium, 2016).

Wearable Devices – Wearable devices, such as smart watches and fitness bands, are excellent examples of IoT products that make cool sensors you will wear on your body. The experience of wearing a watch is being transformed entirely by a combination of sensors, connectivity, data aggregation, and analysis. The wearable wrapped around your wrist can track your steps, calculate calories burned, monitor hours of deep asleep at night, monitor your stress level, and a host of other factors. For example, the FitBit Surge tracks everything from exercise type to sleep stage and provides distance, time, and heart rate data to the user. As wearables further shrink in size, they will be used to track employees at work, children at play, and even the elderly in assisted living.

SUMMARY AND CONCLUSION

Perhaps the biggest technology trend that is taking place right now is the Internet of Things. IoT will give us the most disruption as well as the most opportunity over the next five years. IoT is expected to revolutionize and change the world we have come to know and certainly your career and personal life.

This study identified three benefits/success measures associated with IoT: improved productivity, better-quality information, and speedy information retrieval. Each of these three benefits measures a different aspect of success. The most highly regarded benefit of an IoT-enabled strategy is its ability to improve the productivity of its users. If leaders implement proper policy actions to encourage interoperability, ensure security, and protect privacy and property rights, IoT can begin to reach its full potential.

IoT downsides include challenges to personal privacy, over-hyped expectations, and technology complexity. IoT poses the normal risks associated with the increased use of data. It also poses a greater risk of systemic breaches as organizations connect to millions of embedded sensors and communications devices. Malicious hacking and the damage from a break-in can be literally life threatening. Finally, many of the challenges with IoT aren't technology-related or security concerns. Instead, they come from the industry's slow adoption and, often, resistance to change.

IoT will soon become a differentiating factor in competition. To capture the full range of benefits promised by the IoT, company executives must take a systematic approach to address the organizational challenges and risks IoT will create. Notably, they need to overcome the technical, organizational, and regulatory hurdles associated with using the IoT technology. In particular, organizations that use IoT technology will need better tools and methods to extract insights and actionable information from enormous IoT data gathered from customers, equipment, and people.

TABLE 4-1
APPLICATIONS OF IoT IN DIFFERENT INDUSTRIES

Industry	Applications
Healthcare (Internet of Medical Things) (IoMT)	• Telemedicine - remote patient monitoring of people with chronic conditions • Tracking patients medication orders • Wearable devices that can send information to caregivers • Hospital beds with sensors that measure patient's vital signs • Real-time location services with badges that can track patients, staff, and medical devices • RFID tags placed on medical equipment and supplies for inventory tracking • Environmental monitoring-checking the temperature of refrigerators and hand hygiene compliance
Precision Agriculture/Precision Farming	• Precision weather forecasts • Deep thunder and precision agriculture- ensure that crops and soil receive exactly what they need for optimum health and productivity • Enables as-needed farming and site-specific crop management
Retail Industry	• Reliable and accurate order forecast • Better products' position on shelves • Improved counterfeiting identification, theft prediction, and faster recalls • Amazon Go- a convenience store that has no registers, no self-checkout, and no lines • Inventory optimization • Facility layout optimization • Customer-relationship management

Industry	Applications
Transportation	• Driverless car or autonomous vehicle- A robotic vehicle that is designed to travel between destination without a human operator • 250, 00 vehicles will be connected to the Internet by 2020 • Save maintenance costs by predicting when maintenance is needed for vehicles • Mobike-Inexpensive bike rental in Shanghai where you can pick up a smart bike from a location near to you and drop it off when done anywhere in the city
Energy	• Smart grid – all the components of the electric grid are capable of two-way communication using sensing and measurement technologies • Electric companies can manage distribution more efficiently and respond to outages faster

TABLE 4-2
APPLICATIONS OF IoT IN DIFFERENT INDUSTRIES

Industry	Applications
Cities	• City's functions are managed by integrating multiple information, communication technology, and IoT solutions • Individual vehicles with sensors are linked to broader systems to manage traffic congestion • Cities like Amsterdam, Barcelona, Madrid, and Stockholm implemented the technology
Buildings and Homes	• Smart homes enable homeowner to remotely control and program an array of home electronic devices by entering a single command • Temperature monitoring and HVAC control • Safety and security • Home healthcare • Fire and leak detection • Solar panel monitoring and control • Automated meter reading

Industry	Applications
Manufacturing	• Camera installed along production lines measure the number of components in bins and an inventory management system automatically places supply orders to refill the containers • Predict when equipment is wearing down or needs repair. This could reduce maintenance costs by 40% and cut unplanned downtime by 50% • Help to improve machines performance, extending their lives and learn how they could be redesigned to do even more • RFID tags are used to optimize equipment use and inventory • Usage based design and pre-sales analytics • Adds intelligence to manual processes • Enhanced visibility into customer needs • Accurate & timely asset tracking
Mining/ Oil and Gas	• More than 30,000 sensors are used on a typical oil rig for optimization, prediction, and data-driven decision making • Self-driving vehicles promise to raise output by 5% and productivity by 25%. They could also cut safety costs by 20%
Wearables	• Smart watches and fitness bands can track your steps, calculate calories burned, monitor your stress level • They can track employees at work, children at play, and even the elderly in assisted living.

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