Internet of Things (IoT) and Emerging Application

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ABSTRACT

Internet of Things (IoT) provides an environment where everything around us is connected and is uniquely identifiable. This pervasive and ubiquitous environment of connectivity can be very conveniently used for collecting information and enabling intelligent decision-making in many applications that we use daily. Use of appropriate sensors in IoT provides capability of sensing any desired type of information from the surroundings including temperature, light, humidity, seismic vibrations, radiation levels, presence or nature of biological organisms, geological features and more. Recent advancements have made it possible to make things (as in IoT) or objects small in size, powerful in processing, and energy efficient for operational longevity. These aspects of IoT are prompting many emerging applications including in the fields of health, transportation, agriculture, energy, and environment. Hence this evolving field of Internet of Things will be interdisciplinary in nature and will certainly provide a platform for individuals from multiple disciplines to work together. This paper presents an attempt to capture the current state of IoT, its emerging applications, the opportunities it offers, and the challenges it poses.

Keywords: Internet of Things (IoT), ambient technologies, smart systems.

1. INTRODUCTION

The Internet has been rapidly evolving over a period of less than three decades and it has impacted almost all aspects of our life. Other technical advances that have contributed to this unprecedented phenomenon include shrinking size of hardware components packed with manifold processing power, and lower prices. These factors have paved the way for many powerful and beneficial applications that were not possible earlier. Some of the applications such as the number of steps one takes daily, or the number of calories one has burns daily, or commanding household appliances by voice etc. may seem trivial but they are becoming a part of our daily life and our lifestyle. Looking at the bigger picture, the reality seems to be that these applications are popular because they provide ease of use, provide mobile connectivity, provide broader control, and hence are broadly impactful. Based on these factors, an unprecedented number of devices are being connected to the Internet.

Internet of Things (IoT) is a pervasive form of Internet that provides connectivity to almost any object that we can think of, each object is uniquely identifiable, and can communicate with anyone from anywhere and at any time. Each object connected to the Internet of Things is capable of collecting and/or sensing information, processing it, and communicating it. Therefore, each object must have a communication protocol stack to handle its communication needs. The objects include, and are not limited to, common things such as chairs, doors, fans, sprinklers, appliances, cameras, lights, utility meters, etc.

Technically, an object connected to IoT will have an adequate processing power and communication capability. In its rudimentary form, an IoT platform consists of a large number of objects densely deployed for applications such as agriculture, environment, energy, healthcare, transportation, and smart systems. Technological advances continue to make these objects smaller, more powerful, energy efficient, and cost-effective. Based on the information handling capabilities and compact size, IoT objects may soon have the capabilities of adaptation, self-awareness, and self-organization [1,2].

Internet of Things has rapidly evolved over the past decade. Its impact on our daily activities is becoming visible and is expected to continue its extraordinary growth trajectory for the unforeseeable future. The number of devices connected to IoT in 2016 was estimated to be 6.4 Billion. This number is estimated to be 50 Billion by year 2020 and 64 Billion by 2025 This growth trajectory indicates that at this stage about 127 new objects are being connected to IoT every second. More than 80% of senior corporate executives feel that IoT is critical for their businesses. It is estimated that IoT spending will reach $1.2 Trillion by year 2022 [3,4,17].

IoT applications include healthcare, agriculture, energy, environment, transportation, and many more. IoT introduces capabilities where information gathering, and processing, is associated with some decision-making and hence lead to development of smart systems [6]. Due to its pervasive presence and ubiquitous nature, IoT is also considered as a part of ambient technologies. Although, there is no single definition of IoT, one can say that, “Internet of Things refers to a self-organizing, pervasive network of objects, where each object is uniquely identifiable and accessible from anywhere and at any time”.

There are numerous impactful applications of IoT that are emerging. This paper discusses the applications in the following areas:

- Smart healthcare
- Smart transportation
- Smart environment
- Smart energy use
- Smart agriculture
- Smart cities

The paper also discusses the opportunities offered and the challenges posed by the remarkable growth of the Internet of Things. The next section briefly discusses each of the emerging applications listed earlier. Section 3 discusses the opportunities and the challenges. Section 4 presents summary and conclusions of the paper.

2. EMERGING APPLICATIONS OF IOT

The impact of Internet of Things has been growing rapidly and this trend is expected to continue. Undoubtedly, the impact of IoT is being viewed as positive in many areas of our daily life. In this section, the positive impact of IoT in a few key areas is described briefly.

Smart healthcare

Internet of Things offers unprecedented potential for smart healthcare including hospitals, home-based healthcare, remote healthcare, telemedicine, automatic measurement-based medicine dispensing, and more. Some of the possible examples of the existing and emerging applications of IoT in healthcare are discussed here.

Use of IoT in monitoring patients at home and tracking patients (including candidates for organ transplants) can certainly help save lives. This combination can also be used for remote monitoring of patients at home, collecting information (including medical information such as blood pressure, heart rate, temperature, glucose level etc.), analyzing information, and making decisions. The decisions may include dispatching a healthcare team, if needed [9].

As the size of IoT objects shrink, a large number of objects can be embedded in fabric to make "smart garments". Such garments have a large number of applications in monitoring patient conditions and communicating that to nearby healthcare facilities.

In addition, advances in data science and communication technologies are introducing some intelligence possibilities in design of smart homes. Such homes will be able to make some basic decisions that will be particularly beneficial to elderly, physically challenged, and home-bound population. The activities/actions that smart homes can perform include monitoring the movement patterns inside a home, recognize fall of a human being, monitor sleep patterns, monitor medicine consumption etc. It can even recognize an unusual situation and inform a relevant agency so that appropriate help can be provided in a timely manner, if needed [10].

Smart transportation

A rapid growth in the world population combined with the rapid and significant advances in technology, travel (ground, air, and sea) has been steadily increasing. Transportation routes are becoming crowded. There is a strong need for infusing and/or integrating technology to efficiently manage the traffic and reduce its adverse impact. Using the capabilities of the Internet of Things in transportation, is expected to revolutionize the traffic management. Smart transportation is not only a timely idea, it is also efficient and economical [15]. Although their acceptance and common use may take some time, driverless cars are already not too far from being available.

Implementation of smart transportation infrastructure will require roads as well as vehicles to be equipped with objects that provide pervasive IoT connectivity for collecting and sharing information. Monitoring parking lots and guiding vehicles to vacant/available parking spots will certainly be popular in urban environments. Younger generation living in urban areas do not like owning a car but may want to have access on as-needed basis. Having cars with shared ownership may address that lifestyle. In addition, driverless vehicles can reduce the parking hassles because such vehicles can take individuals to their destinations and can then be asked to go and park themselves somewhere.

Using Internet of Things in smart transportation will certainly change the landscape of real-time traffic data gathering, sharing, and management. Vehicles will be expected to monitor traffic conditions, exchange information with each other, and make efficient and safe routing decisions. Smart transportation is expected to maximize the throughput and use of the transportation infrastructure to its safest possible capacity. The traffic information being monitored and collected can be used for future traffic estimations (even at locations that are not being monitored), predicting traffic conditions, and initiating steps to avoid potential hazards [15].

Smart environment

The population of our planet has been growing rapidly. The quality of environment that we live in has become a topic of many scientific studies. Global warming, rise of sea levels, and pollution have become major challenges for our society. Scientists have been monitoring environmental data for years and have been studying it to assess trends and patterns using whatever technologies are available including satellites and remote sensing techniques. Internet of Things will provide significantly enhanced capability to monitor the environment around us.

Environmental monitoring using Internet of Things is expected to revolutionize the field of environmental monitoring and earth sciences. IoT objects can be deployed in remote areas that are generally not easily accessible. The data from these objects can be collected and integrated with the historical data that already exists in environmental databases to assess what future holds. These assessments can lead to timely warnings for environmental hazards such as floods, volcanic eruptions, and earthquakes.

Density and computational power of the IoT objects used for environmental monitoring depend upon the application scenarios. Similar to their use in other smart applications, these objects can collaboratively monitor environmental conditions and can be programmed for gathering specific information such as vibrations, temperature, sound, humidity, pollutants, and other similar parameters [5,8]. Based on the pervasive nature of IoT, these objects can be used to monitor quality of indoor as well as outdoor air and appropriate actions can be taken in a timely manner to ensure safety of the habitants.

Smart energy use

Conservation of energy is another critically important area to be addressed to meet the energy needs for the growing population of the world. Emerging technologies such as Internet of Things can be immensely helpful in this field as well. A smart grid with the use of sensing IoT objects (including smart meters, smart appliances, and better monitoring of flow of energy from generating points to consuming points) promises efficient, adaptable, and reliable transmission and distribution of energy. It is expected to revolutionize the current electric power distribution infrastructure by integrating with communication and information technologies.

With the use of objects connected to the Internet of Things, the smart grid empowers both the utility companies and customers to effectively and efficiently monitor, predict, and manage energy usage. This integration, while necessary and beneficial, creates some challenges as well. One of the strongest challenges is smart grid's vulnerability due to its integration with cyber infrastructure. The size of smart grid and potential intrusion points make its protection and security even more complex [13].

The collaborative and context-aware nature of Internet of Things brings several advantages over traditional monitoring including greater fault tolerance, improved accuracy, larger coverage area, and extraction of localized features. IoT objects can monitor the overall network and communicate with the control center. This can in turn help operators decide appropriate actions [7].

Smart agriculture

The world population has increased significantly over the last few decades and it is estimated to reach 10 Billion by 2050. Such a dramatic growth in world population will need a significant increase in food production. History shows that over the past century technological advances have always been helpful in making farming better and increasing agricultural yields. At the same time, technologies have also witnessed unprecedented leaps and have become much better. Effective use of latest technologies and conservation of precious resources including water is absolutely essential in meeting the intake needs of the world's growing population. In other words, agriculture has to become smarter to sustain our existence and a better future for us.

Internet of Things offers a great potential for use in the field of agriculture. IoT objects can be deployed to monitor the climate (temperature, humidity, irrigation needs etc.) around the farm, and health of the crops/plants [16]. This information can be used to assess the necessary corrective steps/actions for better agricultural health. In larger agricultural fields, frequent and timely collection of information from IoT objects or sensors and its processing may be time-consuming and may be challenging. In such situations, small autonomous aerial vehicles can be flown in a pre-determined pattern to collect information from sensors and transmitted to a processing unit for making decisions about the necessary steps. Such an integration of IoT objects and/or sensors in agriculture can be immensely impactful in improving the health and yield of crops/plants and conserving irrigation water at the same time. The time of irrigation and the amount of water needed for that can be calculated based on the collected data. Similarly, the amount of fertilizer and pesticide can be applied to selective areas rather than to the entire farm. This will not only improve the agricultural health of a farm, but will also conserve resources and improve yield.

Smart cities

A smart city uses pervasive connectivity among its key industry and service sectors to achieve smart governance, smart transportation, smart utilities, smart structures, smart disaster management, and smart waste management. The smart city market is estimated to be hundreds of billions of dollars by 2020. Internet of Things will certainly be a building block for a smart city [12,20].

There are many aspects of smart cities that are important for the city residents and for the city management. One such service is traffic management. Internet of Things can be instrumental in monitoring traffic conditions and managing the traffic based on the real-time data collected. The traffic management may include rerouting the traffic away from congested areas, opening and closing directional lanes, and adjusting the timing of traffic signals.

Similarly, waste management is another aspect that is important for the city residents and for the city management. Integrating Internet of Things in the process will certainly improve the collection process and reduce

the cost. For example, the waste containers can be connected to IoT as objects and can periodically transmit or provide information about the amount of the waste in them. That will enable an efficient routing of the trucks to collect waste. That will eventually reduce the cost and residents will reap an economic benefit.

Structural integrity of building and infrastructure such as bridges is another aspect of a smart city that improves the safety of its residents and visitors. In general, building and bridges etc. are periodically inspected to assess their structural health. However, some of the hidden weak point may not be visible. Embedding some sensors inside the structures and connecting these as IoT objects can help collecting data more frequently enabling deeper and more accurate health assessment of structures. In other words, the smart structure will communicate its health through IoT objects and ask for maintenance, if needed.

Another important aspect of a smart city is smart disaster management. The best approach to addressing a disaster situation is to avoid a disaster situation. Technologies such as Internet of Things can be used for information gathering, identifying patterns, and making decisions to avoid a disaster. However, even with the best of the technologies, disasters (natural or man-made) are not fully avoidable. Unfortunately, disasters such as storms (hurricanes), floods, fires, earthquakes, terrorist attacks continue to disrupt our lives. Such incidents have undetermined outcomes and many unknown situations to deal with. Rescue efforts to minimize the loss of human life are of utmost importance and time is of essence. In an unfortunate situation, if a disaster does happen, technologies can help in dealing with the aftermath of a disaster. Traditional approaches such as using trained dogs, robotic cameras, and sound sensors are slow, time consuming, and less effective. Appropriate use of IoT objects can help in detection of injured/living human beings and their locations. In addition, these can also help in determining what help is needed and where [11].

Embedding IoT objects in buildings, bridges, and other such structures can help detection of structural deficiencies and defects that may be developing. These objects can continue monitoring the health of structures and communicate any weaknesses so that an appropriate corrective action can be taken to avoid a disaster.

There are many more examples such as healthcare, energy etc. where Internet of Things can improve quality of life of residents and visitors of smart cities [20].

3. OPPORTUNITIES AND CHALLENGES

Internet of Things represents the next major step in the field of connectivity where everything is expected to be connected and uniquely identifiable. We, as a society, are already an information-based society and IoT will bring that aspect to the next level by a very wide margin. Similar technologies of recent past have already modified human behavior in terms of communication, social interactions, education, business and many more. IoT will undoubtedly play a major role in impacting our behavior in ways that we cannot even imagine at this stage. As discussed earlier, there are tremendous opportunities that IoT provides in many fields including healthcare, energy, environment, education, transportation, agriculture and many more. Business community is already positioning to play its role and reap benefits [18].

All opportunities come with some challenges and emergence of IoT has its share of challenges as well. A major challenge that IoT poses is the volume of information that IoT devices/objects will generate. Management of that amount of information will not be a trivial task. In addition, pervasive nature of IoT connectivity of everything creates vulnerabilities for malicious attacks. Therefore, security and privacy of IoT objects and user information will be a major challenge in IoT environment [13]. Reliability and resilience of IoT connectivity will be a challenge for IoT governance and a concern among users. With such an impactful communication and connectivity environment as IoT, and high level of anticipated IoT dependency, users must be confident about its reliability and service availability. Another major challenge posed by IoT environment is the source of energy for IoT objects. Battery-powered IoT objects can only operate as long as the battery life is. Operational longevity of IoT objects will be a key aspect for its success. Efficient algorithms, and innovative implementation that use less energy will certainly be preferable. Research efforts are being directed toward finding alternative sources of energy for IoT objects that will eliminate or minimize the battery use [14]. Finally, one of the challenges that deployment of all technologies poses, is education of users and the level of comfort/trust in using Internet of Things. That will certainly come with time. However, efforts can be directed by the business community to achieve that sooner than later [19].

4. SUMMARY AND CONCLUSIONS

Internet of Things (IoT) provides pervasive connectivity for everything (called objects) around us and where each object is uniquely identifiable from anywhere and at any time. It is expected that about 50 Billion objects will be connected by 2020. IoT is expected to create an impactful disruption in many, if not all, aspects of daily life and our lifestyle. The paper has presented some examples of applications where IoT can be used for operational efficiencies and societal benefits. The applications discussed briefly in this paper include smart healthcare, smart transportation, smart environment, smart energy use, smart agriculture, and smart cities. Based on the broad nature of IoT applications, the field is interdisciplinary in nature and will certainly bring individuals from multiple disciplines to work together.

The paper has also discussed opportunities that Internet of Things provides and the challenges it poses. The opportunities that IoT creates are numerous. Business are eager to participate for their as well as societal benefits. There are several challenges that IoT deployment poses. These challenges include management of a massive amount of information that IoT objects will generate, security/privacy of information and IoT users, reliability/resilience of IoT's operational environment, energy sources, and level of users' comfort. Historically, in deployment of many technologies, there have been many challenges and concerns. However, with the passage of time, the societal benefits outweigh the concerns and society becomes comfortable in using the technologies for its good.

References

[1] Ahmed, S., Ilyas, M., and Raja, M.Y.A., "Internet of Things: Application in Smart Healthcare", Proceedings of the 9th International Conference on Society and InformationTechnology (IICSIT 2018), Orlando, Florida, March, 2018, pp. 19-24.

[2] Ahmed, S., Ilyas, M. and Raja, M.Y.A., "Smart Living: Ubiquitous Services Powered by Ambient Intelligence (AmI)", 16th IEEE International Conference on Smart Cities: Improving Quality of Life using ICT, IoT, and AI, Charlotte, North Carolina, October 2019.

[3] Al-Fuqaha, A. Guizani, M., Mohammadi, M., Aledhari, M., and Ayyash, M., "Internet of Things: A survey on Enabling Technologies, Protocols, and Applications", IEEE Communication Surveys and Tutorials, Vol. 17, No. 4, pp. 2347-2376, 2015.

[4] Ahson S. and Ilyas, M., "Location-Based Services Handbook: Applications, techniques, and Security", CRC Press, 2011.

[5] Cook, D., and Das, S., "How Smart Are Our Environments? An Updated Look at the State Of The Art", Pervasive and Mobile Computing, pp. 53-73, 2007.

[6] Gubbi, J., Buyya, R., Marusic, S., and Palaniswamy, M., "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions", Future Generation Computer Systems, Vol. 29, No. 7, pp. 1645-1660, 2013.

[7] Gungor, V., Lu, B., Hancke, G., "Opportunities and Challenges of Wireless Sensor Networks in Smart Grid", IEEE Transactions on Industrial Electronics, Vol. 57, No. 10, pp. 3557-3564, 2012.

[8] Hart, J., and Martinez, K., "Environmental Sensor Networks: A Revolution in the Earth System Science?", Earth-Science Reviews, pp. 177-191, 2006.

[9] Ilyas, M., "Advances in Healthcare Technologies", Fifth International Workshop on Frontiers of Information Technology, Islamabad, Pakistan, 2007.

[10] Islam, S. M. R., Kwak, D., Kabir, M. H., Hossain, M., and Kwak, A. K., "The Internet of Things for Healthcare: A Comprehensive Survey", IEEE Access, Vol. 3, pp. 678-708, 2015.

[11] Ji, Z., Qi, A., "The Application of Internet of Things (IoT) in Emergency Management System in China", Proceedings of 2010 IEEE International Conference on Technologies for Homeland Secuirty (HST), pp. 139-142, 2010.

[12] Kortuem, G., Kawsar, F., Fitton, D., and Sundramoorthy, V., "Smart Objects as Building Blocks for the Internet of Things", IEEE Internet Computing, Vol. 14. No. 1, pp. 44-51, 2010.

[13] Sicari, S., Rizzardi, A., Grieco, L. A., and Coen-Porisini, "Security, Privacy, and Trust in Internet of Things: The Road Ahead", Computer Networks, Vol. 76, pp. 146-164, 2015.

[14] Stankovic, J. A., "Research Directions for the Internet of Things", IEEE Internet of Things Journal, Vol. 1, No. 1, pp. 3-9, 2014.

[15] Tubaishat, M., Zhuang, P., Qi, Q., and Shang, Y., "Wireless Sensor Networks in Intelligent Transportation Systems", Wireless Communications and Mobile Computing, pp. 287-302, 2008.

[16] Wang, N., Zhang, N., and Wang, M., "Wireless Sensors in Agriculture and Food Industry – Recent Development and Future Perspective", Computers and Electronics in Agriculture, pp. 1-14, 2006.

[17] Whitmore, A., Agarwal, A., and Xu, L. D., "The Internet of Things – A Survey of Topics and Trends", Information Systems Frontiers, Vol. 17, pp. 261-274, 2015.

[18] Wortmann, F. and Fluchter, K., "Internet of Things Technology and Value Added", Business and Information Systems Engineering, "Vol 57, No. 3, pp. 221-224, 2015.

[19] Xu, L. D., He, W., and Li, S., "Internet of Things in Industries: A Survey", IEEE Transactions on Industrial Informatics, Vol. 10, No. 4, pp. 2233-2243, 2014.

[20] Zanella, A., Bui, N., Castellani, A., Vangelista, L., and Zorzi, M., "Internet of Things for Smart Cities", IEEE Internet of Things Journal, Vol. 1, No. 1, pp. 22-32, 2014