Landscape of IoT: Architecture, Challenges, and Applications

Punit Sharma
Assistant Professor
PG Department of Computer Science and IT
DAV College, Amritsar

Abstract: IoT evolving as the next subsequent phase of the internet, it becomes quite obvious to have the check on the architecture, protocols used and applicability domains of the IoT. With the IoT a new era of the pervasive connectivity is beginning where not only machines but any object we can think of will be connected and communicating with each other. Consequently IoT is paving and exploring the new ways and areas for the research purpose. This paper represents the development and the potential domains of IoT. There are diverse set of domains ranging from health care, smart cities, agriculture, fitness and entertainment etc., where the IoT have developed intelligent applications

Keywords: Internet of Things; IoT, protocols, smart-cities.

1. **Introduction:** The Internet of Things is community of all forms of bodily gadgets officially describing them as "things" ready with sensors, actuators, software program and different technology so as to let these objects to be connected with each other and communicate to serve a meaningful purpose using the internet. IoT is a prototype of the physical things those are addressable using the internet protocols having unrivalled sensing powers, different processing speeds and divergent actuation capabilities[1].The primary cause of the IoT is to interconnect any sort of the possible gadgets at anytime and anywhere with the usage of the internet. Vermesen et al. [2] defines the Internet of things as reciprocity between the digital and physical worlds. This reciprocity necessitates the usage of the sensors and actuators to provide the high degree of intelligence.

   IoT is not just a single technology but is an aggregation of the stack of divergent technologies working in tandem. The revolution in the smart phones have paved the foundation for all other things to act smartly and exchanging the information using the embedded sensors and actuators [3]. The interaction with the physical environment is carried out using the digital devices called sensors and actuators. The data sensed by the sensors is stored and then is processed intelligently so as to draw meaningful information from the data captured[14]. The conversion of the energy into motion is done using actuators. These actuators are present almost in all the machines or the devices. The data after captured can be stored on the remote servers or in some cases on the edge of the network. As the IoT objects are energy harvesting and have the limited computational capabilities so the data is sent to the remote servers for the processing. If some pre-processing is possible then it can be carried out at the servers' levels. The communication between the IoT devices is wireless because the devices are geographically dispersed. Some decisions or actions are to be taken after the processing of the data of the data captured by the sensors[16]. The actuators can be of any kind either changing the statistics of the environment or directing the other smart devices to perform an action based on the inferences of the data. The core infrastructure of the IoT includes sensors, actuators, communication and the servers.

2. **Sensors and Actuators:** To fetch the data from the external environment, all the IoT based applications must to have sophisticated sensors which are the essential components of the smart objects. These sensors being small in size are low cost and consume very less energy. Schmidt and Van Loerhoven[13] provide the overview of the different types of sensors that are used for the building of smart applications.

   2.1 Mobile Phone based Sensors: Mobile-based sensors are becoming increasingly sophisticated and are being used for a wide range of applications, from fitness tracking to environmental monitoring. Mobile-based sensors are sensors that are integrated into mobile devices such as smart phones and tablets[17]. These sensors are used to detect and measure various physical parameters such as light, sound, temperature, humidity, and motion.To list some of them are accelerometer, gyroscope, GPS, proximity sensors and barometer etc.

FIGURE 1: Mobile device sensor

2.2 Medical Sensors: Medical sensors are devices that are used to monitor various physiological parameters of the human body, such as heart rate, blood pressure, glucose level, oxygen saturation, and body temperature. These sensors are widely used in healthcare for the diagnosis, treatment, and management of various medical conditions[18]. Some examples of medical sensors include ECG, blood pressure, glucose sensors and pulse oxymeter etc. Medical sensors can be invasive or non-invasive, and may be worn on the body, implanted in the body, or used externally. They are used in a variety of healthcare settings, from hospitals and clinics to home-based monitoring.

FIGURE 2: Blood oxygen sensor

2.3 Actuators: Actuators are used in a wide variety of applications, from industrial machinery and robotics to home automation and automotive systems. An actuator is a device which can effect a change in any mode of operational effect by converting one form of energy into another form. These can be categorised into three types namely electrical, hydraulic and pneumatic[20]. A good example of an actuator is the digital finger which can turn switch on/off.

In many applications, sensors and actuators work together to form a closed-loop control system. The sensor detects a physical quantity, the control system processes the signal and generates an output, and the actuator produces a physical action in response to the output signal.

3. **Architecture and Design of IoT:** The architecture of IoT can be divided into five layers, as described by Atzori, Iera, and Morabito in their paper "The Internet of Things: A survey" published in the IEEE Communications Surveys & Tutorials journal[12] :i*) Perception Layer:* This layer comprises the physical devices or sensors that are connected to the internet. These devices can be sensors, actuators, or any other type of embedded system that can collect or manipulate data. They are equipped with sensors, processors, and communication modules that enable them to interact with the network.*ii)Network Layer:* This layer is responsible for connecting the devices to the internet and providing them with access to other devices and services. It includes wireless and wired networks such as Wi-Fi, Bluetooth, cellular networks, and others. The network layer also includes gateways that enable communication between devices that use different protocols.*iii)Middleware Layer:* This layer is responsible for managing the communication between the devices and the cloud. It includes protocols, gateways, and software platforms that enable communication, data management, and security. *iv)Application Layer:* This layer is responsible for providing services and applications that utilize the data generated by the devices. These applications can be used for various purposes such as monitoring, control, automation, and optimization.*v) Business Layer:* This layer is responsible for managing the business aspects of IoT, such as pricing, billing, and customer support.

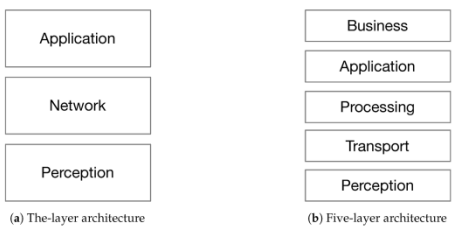

FIGURE 3: Architecture of IoT

Designing an IoT system requires a multidisciplinary approach that involves expertise in sensors, connectivity, data processing, user interface design, and security. The followings are some of the design issues required for the designing the IoT system[21][22]:) identify *the problem or use case:* The first step in designing an IoT system is to identify the problem or use case that the system is meant to address. This could be anything from monitoring the temperature in a building to tracking the location of a fleet of vehicles.*ii)Select the sensors and devices:* Once the use case has been identified, the next step is to select the sensors and devices that will be used in the system. This could include things like temperature sensors, motion detectors, or GPS trackers.*iii)Choose the connectivity technology:* The sensors and devices in an IoT system need to be able to communicate with each other and with the cloud or other central system. This could be done using Wi-Fi, Bluetooth, cellular networks, or other wireless communication technologies. *iv)Develop the data processing and storage infrastructure:* IoT systems generate a lot of data, and this data needs to be processed and stored somewhere. This could be done using cloud computing services or on-premises data centers. *v)Create the user interface:* The user interface is the way that users interact with the IoT system. This could be a dashboard or mobile app that displays data and allows users to control devices.*vi)Implement security measures:* IoT systems can be vulnerable to cyber attacks, so it's important to implement security measures to protect the system and its users.*vii)Test and iterate:* Once the IoT system has been designed and implemented, it's important to test it thoroughly and iterate on it based on feedback from users and performance metrics.

4. Challenges: The Internet of Things (IoT) presents a range of challenges that must be addressed for its successful implementation. Some of the major challenges in IoT include: i) Security: With billions of devices being connected to the internet, security is a critical challenge. IoT devices are often deployed in insecure environments and can be vulnerable to hacking, malware attacks, and other security threats. *ii) Interoperability:* IoT devices often come from different manufacturers and may use different protocols and standards. Ensuring interoperability between these devices can be a significant challenge.*iii) Scalability:* As the number of IoT devices grows, so too does the amount of data generated. Managing and processing this data can be a challenge, particularly when it comes to scaling up to handle large volumes of data. *iv) Power Consumption:* Many IoT devices are battery- powered and may need to operate for extended periods without recharging. Managing power consumption is a significant challenge, particularly for devices that need to transmit data over long distances.*v) Privacy:* IoT devices collect large amounts of data about users, including their location, behavior, and preferences. Ensuring the privacy of this data is a critical challenge, particularly in industries such as healthcare and finance.*vi) Cost:* IoT devices can be expensive, particularly when deployed at scale. Ensuring that the cost of IoT devices is reasonable and justifiable is a significant challenge for organizations[23].

Addressing these challenges requires a comprehensive approach that involves careful planning, robust security measures, and the development of industry-wide standards and best practices.

5. Applications of IoT: there are numerous intelligent applications where the IoT plays its vital role and there is wide range of such areas. Some of the potential uses of IoT includes smart homes, smart cities, healthcare, intelligent parking management, accident detection applications, smart traffic lights social life and entertainment etc.

5.1 Home Automation: There are two major reasons which make smart homes so popular. First being the maturity of the sensor and actuation technologies and second being the dependency of the people on the technology to meet their concerns over the quality of the life and security of their homes[6]. IoT devices can be used to control and automate various aspects of a home, such as lighting, heating, security systems, and entertainment systems[8]. These smart home applications are very beneficial for the elderly and physically disabled persons. There health is constantly monitored and the relatives are immediately informed in case of any emergencies, even the floors are equipped with the pressure sensors and the fall of any object is detected. There are many security issues associated with these benefits and the major one is security as all the happenings taking place at home are being recorded and can be compromised any time. Reliability is another issue since there is no central system administrator to manage and monitor the whole system[11].

FIGURE 4:Home automation

5.2 City Automation: Using the intelligent processing systems and the sensors, the traffic of the cities can be easily managed. The intelligent processing can cause to reduce the traffic congestion, hastle free parking and avoidance of the accidents. There are applications which make the drivers more safe drivers as these applications observe the behaviours of the drivers like when they are drunk, when they feel drowsy or tired etc[7]. IoT technology can be used to improve the efficiency and quality of city services, such as traffic management, waste management, and public safety[10].

5.3 Healthcare: IoT applications and their appliances are really very beneficial in the healthcare domain. The smart health applications make the independent life possible [9]. These applications constantly monitor the health conditions. If the observed health conditions are very serious then immediate help line is called for the medical assistance and if it is minor then the prescription is suggested to the patient. Some applications can even detect the stress level of the students and can monitor the physical activities of them. Hence IoT devices can be used to monitor patient health and provide real-time medical data to doctors and healthcare providers.

FIGURE 5: IoT in healthcare

5.4 Agriculture: The good production in the agriculture depends on the environmental parameters such as humidity and the temperature. These parameters are recorded in real time, are analysed and then used for the good quality and the bumper yield. IoT devices can be used to monitor crops and soil conditions, enabling farmers to optimize yields and reduce waste[15]. The biosensors are used to detect the pesticides residues. The major concern of the air pollution can also be addressed with the help of the IoT applications. These applications can monitor the vehicles which cause the undue amount of the air pollution. The RFID tags are used to detect such vehicles and appropriate actions can be taken against those polluting vehicles[19].

6. Conclusion: In this paper the current technologies used in the IoT domain were discussed. oT has the potential to revolutionize the way we live and work, from smart homes and cities to industrial automation and healthcare. It offers numerous benefits such as increased efficiency, reduced costs, improved safety, and enhanced quality of life. However, IoT also poses significant challenges such as privacy and security risks, data management and analysis, and interoperability between different devices and platforms. As the technology continues to evolve, it will be important to address these challenges and ensure that IoT is developed and implemented in a way that maximizes its benefits while minimizing its risks.

References

[1]. AbdelRahman H. Hussein, “Internet of Things (IOT): Research Challenges and Future Applications,” Vol. 10, No. 6, pp. 77–82, 2009.
[2] O. Vermesan, P. Friess, P. Guillemin et al., “Internet of things strategic research roadmap,” in Internet of Things: Global Technological and Societal Trends, vol. 1, pp. 9–52, 2011.
[3] Atzori, L., Iera, A., & Morabito, G. “The internet of things: A survey. Computer Networks”, 54(15), pp.2787-2805,2010.
[4] Jara, A.J., et al., "The Internet of Things: A Survey." In: Computer Networks ; 10: 2787-2805. pp.2794-2796,2014.
[5] Kumar, N. and Lee, S. "Security in the Internet of Things: A Review." In: Journal of Information Processing Systems 12(4): 707-721. : pp.711-713,2016.
[6] R.J.Robes .,et.al.,”A Review on security in smart home development,”In:Journal of advanced Science and technology,vol 15,2010.
[7] Y.-S. Chen .,et al., “An automatic traffic surveillance system for vehicle tracking and classification ,” In Image Analysis,pp.379-386,Spronger,2003.
[8] H.Lim.,et al.,”Design and implementation of smart home energy management system ,”IEEE Transactions on Information Technology in biomedicine,vol 16,pp.1274-1286,2012.
[9] S.M.Naqvi .,et al.,”A posture recognition-based fall detection system for monitoring an elderly person ,“ ,”IEEE Transactions on Information Technology in biomedicine,vol 11,pp.1086-1098,2013.

[10] G.Chen.,et al.,"Detecting traffic congestion using cell phone accelerometer In"proceedings of International Joint conference on Pervasive and Ubiquitto Computing .pp.107-110 ,September 2014.
[11] S.Das,et al.,"Design and implementation of smart home energy management system ,"IEEE Transactions on Information Technology in biomedicine,vol 16,pp.1255-1265,2012.
[12] L.Atzori,et al.,"SIoT:giving a social structure to the IoT,"IEEE communication Letters vol. 15 pp.1193-1195,2011.
[13] A. Schmidst and K.Van Laerhoven ,"How to builg smart appliances?"IEEE Personal Communication ,vol 8,pp.66-71,2001.
[14] Samizadeh Nikoui, Tina, et al. "Internet of Things architecture challenges: A systematic review." International Journal of Communication Systems 34.4,2018.
[15] Lakhwani, Kamlesh, et al. "Development of IoT for smart agriculture a review." Emerging Trends in Expert Applications and Security: Proceedings of ICETEAS 2018. Springer Singapore, 2017.
[16] Usak, Muhammet, et al. "Health care service delivery based on the Internet of things: A systematic and comprehensive study." International Journal of Communication Systems 33.2,2016.
[17] L.Peri,R.Guinness et al.,"Human behaviour congestion using smart phone sensors"vol 13,pp.1402-1424 ,2013.
[18] M.J.McGrath and C.N.Scanaill,"Body-worn ambient and consumer sensing for health applications ,"in sensor Technologies ,pp.181-216,Springer,2013.
[19] R.Want ,"An introduction to RFID technology,"IEEE Pervasive Computing ,vol.5 pp.25- 33,2006.
[20] Accelerometers,Chris ,woodford , http:www.explainthatstuff.comaccelerometers.html.
[21] Burhan, Muhammad, et al. "IoT elements, layered architectures and security issues: A comprehensive survey." sensors 18.9 ,2018.
[22] M.Weyrich and C.Ebert"Reference architecture for the internet of things,"IEEE software ,vol 33,pp.112-116,2016.
[23] Sedrati, Anass, and Abdellatif Mezrioui. "A survey of security challenges in internet of things." Advances in Science, Technology and Engineering Systems Journal 3.1,pp.204- 218,2018.
[24] Zhou, Wei, et al. "The effect of iot new features on security and privacy: New threats, existing solutions, and challenges yet to be solved." IEEE Internet of things Journal 6.2,pp.1606-1616,2018.
[25] D.Zeng and Z.Cheng,"The web of things: A survey, "journal of communication ,vol 6,pp.424- 438,2011.