Journal of Engineering Technology (ISSN 0747-9964)
Volume 6, Special Issue on Technology Innovations and Applications
Oct. 2017, PP. 79-84
ORIGINAL ARTICLE

Cloud of Things: A Review

Muhammad Kashif Hanif, Muhammad Umer Sarwar, Ramzan Talib, Qurat-ul-ain, Muhammad Aftab ur Rehman

Department of Computer Science, Government College University, Faisalabad, Pakistan

Abstract: Introduction: Internet of things is collection of sensor based devices. These devices can generate data but have limitations regarding processing and storage of produced data. Cloud computing is combination of commodity hardware that is connected with each other. Cloud computing provides storage and processing services. These services can be used to process and store data produced by sensor based devices. Integration of cloud and internet of things is referred as "cloud of things". Cloud computing provides software, platform and infrastructure as a service. **Methodology:** This work reviews the literature about applications, protocols and challenges to integrate cloud computing and internet of things. **Results and Conclusion:** Cloud of things provides several advantages like unlimited virtual storage capacity, computation of complex data sets and ease of access. However, security, quality of service, standardization and unnecessary communication of data are major challenges.

Keywords: Internet of things, Constrained Application Protocol, Low power wireless area network, Message Queuing Telemetry Transport.

1. Introduction

Technology has shifted from desktop computer to miniature and embedded devices. These miniature devices have a lot of sensors integrated in them. These sensors can help activities of human life. Sensors have a direct link with daily events. Internet of Things (IOT) is about knowledge of things that have sensors and can be self-configured [1]. The number of connected devices are far more than number of people on earth. Sensor generates a lot of data. This data can be of great value if it is processed and stored. Memory and processors of sensor based devices are generally very limited. They are unable to analyze and get valuable results out of huge data. Moreover, IOT devices need to exchange data with other applications. Web based interface is required to control and access IOT devices anywhere and anytime. Data generated by IOT devices should be processed in real-time to make quick response and decision making. Therefore, scalable IT resources are required for easy and secure data exchange in a cost effective manner [2].

Cloud computing can provide cost effective solution for easy and secure data exchange. Cloud computing is based on utility model. Cloud computing abstracts all type of resource management, operating system issues, load balancing, and storage complexities. It provides new horizons for developing, testing, running, deploying and managing applications on internet. Application developers and users both can utilize cloud computing services over internet. Cost of cloud computing services will be paid according to the time and services used. This facilitates the developer to focus only on development and monitoring of application rather than maintenance and management of resources required.

Cloud computing belongs to the category of distributed computing having pool of shared resources that can be configured according to the requirement. At the basic level, cloud computing provides three services, i.e., infrastructure, software, and platform. Internet connectivity is needed to access services provided by

cloud computing. User does not need to install, maintain, and store application. Similarly, application developers can use platform as a service. All required tool kits and resources are provided to developer by cloud computing. Infrastructure as service gives storage and computational services. User only needs to pay for these services according to the use [1].

Both IOT and cloud computing are separately mature fields. A lot of research has been conducted in the field of cloud computing and IOT separately. IOT have storage and processing constraints. These constraints can be compensated by integrating it with cloud. Section 2 presents review on integration of cloud computing and IOT. Section 3 discusses the frameworks and protocols for cloud of things. Sections 4 and 5 present different applications and challenges of cloud of things domain, respectively. Finally, section 6 gives conclusion.

2. Integration of cloud computing and IOT

Cloud computing and IOT are hot topics in internet application domain. IOT have limited processing and storage capacity. Cloud computing can help to overcome these constraints. Cloud computing permits data to be stored and used intelligently. Cloud computing and IOT are complementary technologies that can expand horizons of internet [3].

Integration of cloud computing and IOT technologies can provide several benefits. Cloud of things can be used for smart monitoring and automated decision making (Figure 1). Cloud of things has three tier architecture, i.e., sensing nodes, cloud computing, and applications. Every device that has embedded sensors acts as a node. These nodes gather and transfer the data to cloud computing. Cloud computing can acts as intermediate layer between the IOT devices and the applications. Cloud computing is responsible to process and store data. Cloud computing layer hides all functionality and complexities that are required to produce Cloud of things. Application layer is used to extract value out of processed data [4]. With Cloud-based tools, the user can program from anywhere with internet connection [2]. Analytical developer provides analytical tools. Artificial intelligence experts provide data mining and machine learning tools [1].

Figure. 1. Cloud of Things [5].

Integration of IOT and cloud computing provides numerous benefits.

- New services: Cloud of things provides new horizons for sensing applications and users. It provides sensing as a service, video surveillance as a service, sensor events as a service, identity and policy management as a service, database as a service, Ethernet as a service, and data as a service [3].

- Unlimited virtual storage: Cloud computing has several commodity nodes that are connected through network and internet. Cloud computing can be used to store and process huge amount of data. IOT nodes do not have storage capacity. This limitation can be removed by integrating IOT with cloud [3].
- Computation of complex data: IOT does not have capability to process data on-site. Cloud computing have unlimited computation capacity. Cloud computing and IOT are combined to get low cost data analysis that ends up in increased revenues and reduced risks [3].
- Inter-communication: IOT nodes have dedicated hardware which is used to communicate with each other. High speed cloud can keep track of all nodes so communication becomes easy. Real time access to data and co-ordination among nodes is required [3].
- Ease of access: Cloud computing provides reduced deployment cost to IOT applications. Moreover, data can be accessed any time and from any location [3].

3. Frameworks and protocols

Different frameworks are available for Cloud of things. COSM framework provides data management and infrastructure as a service for sensor based devices. It provides a platform for developers to manage sensor data using online database services. COSM provide services to millions of things per day. It provides service to embed real time graphs and can manage real time alterations of sensor based data [2]. Nimbits is an open source platform that provides data logging services using cloud computing. It can be used to share and manage data produced by sensors. Users can create data points. It can save all forms of data in data points. Nimbits gives a mechanism for data compression and alert management method. It can relay data to spreadsheets and even to websites [2].

ThingSpeak is also an open source framework which provides API to store data. It is specifically for HTTP enabled and LAN based devices. This framework enables user to track the location and process only numeric data. User can update status of sensor enabled devices using social networking websites. Applications only support JSON and XML formats [2]. Paraimpu is a framework that allows developers to make personalized applications for sensor enabled things. User can create applications to integrate motors, sensors, lights, domestic appliances as well as micro-controllers. Devices can communicate with the web using Paraimpu. Paraimpu permits user to compose, interconnect, and mash-up things to react with events, environmental sensors, and social activities [2]. iDigi device cloud provides remote access of things to user via online web application. It can manage home appliances remotely. It is platform as a service for machine to machine communication irrespective of location and network. It provides software as a service, on demand cache storage, and permanent storage option [2].

Cloud of thing contains billions of tiny internet nodes. These nodes need to communicate with dedicated devices and cloud using rule set. These rule sets are known as protocols [4]. Constrained application protocol works on request-response model like HTTP. It is based on client-server architecture. It exchanges messages using UDP. This protocol provides high level of communication security with less complexity [4]. Low power wireless area network is based on IPV6 technology. It provides IP addresses to a wide range of network devices at low cost. It can be used in low power loose network [4]. Message queuing telemetry transport is a light weight protocol for low bandwidth network. It is used in combination with TCP. It provides reliable, ordered and error checked message delivery [6].

Journal of Engineering Technology (ISSN 0747-9964)
Volume 6, Special Issue on Technology Innovations and Applications
Oct. 2017, PP. 79-84
ORIGINAL ARTICLE

4. Applications

Cloud of things can be used for applications in domain of healthcare, telemedicine, better product-line management, criminal investigation, crowd management, smart home, smart city, smart metering and many more [7]. Figure 2 shows some of the IOT applications.

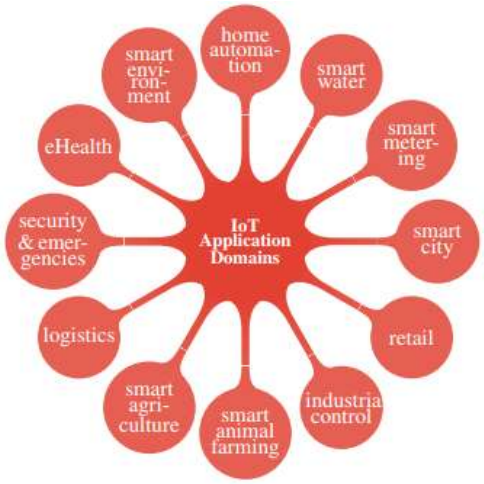

Figure. 2. IOT Applications [8].

- Health care: Healthcare applications generate a vast amount of sensor data that needs to be managed properly for further analysis and processing [9]. These applications lack security, quality of service, interoperability and drastically increasing storage requirements [9].
- TweetOT: It is possible to create an application in which every home appliance is connected to LAN. It tweets periodically to update the status.
- Video surveillance: Now-a-days security is a real threat due to terrorism. Video surveillance is requirement of the day. Sensors are used to get footage while cloud computing processes and stores the data. Cloud computing provides quick and easy access to user devices [3].
- Smart Home: Integration of cloud computing and IOT leads to smart home where every device is automated. Several smart-home applications exists which can recognize intelligent management of energy consumption, lighting, heating, and air conditioning [3].
- Traffic management: Efficient traffic management can be done with cloudIOT. Sensors can get the data and provides it to cloud computing. In return, cloud computing will analyze and provide information about congestion on a particular road. Load of traffic can be balanced in rushing areas.
- Smart city: Smart city is a city in which every asset of city is managed through the use of IOT and cloud computing. Sensors are used to get data and cloud computing is used to process and store the data [3].
- Crowd management: Crowd management means to organize and manage group of people present in particular event. This can also be done using cloud and sensor enabled devices.

- Smart Energy: IOT and cloud computing can be effectively merged to provide intelligent management of energy distribution and consumption in both local and wide area heterogeneous environments. The integration of cloud computing platforms in this IOT scenario increases the concerns about security and privacy issues for smart grid software deployment for utilities [9].
- Smart transport: A data cloud for management of IOT-based vehicles can be developed. The deployment of smart transport can lead to business profits, traffic management, and increased road safety. There may be some concerns regarding security and privacy due to lack of established infrastructure for authentication and authorization.
- Smart logistic: Logistic refers to the management of supply chain process. It can facilitate both suppliers and consumers. Cloud of thing can help to manage short shipping routes for efficient shipping.

5. Challenges

Major challenges for cloud of things are [10]:

- Standardization: Cloud of things is an emerging field. A lot of platforms and APIs are developed but still there is a room for standardization of protocols, platforms and APIs [3].
- Unnecessary communication of data: Data uploading is not required all the time. Nodes should be intelligent enough to stop generating data when uploading is not required. Gateways should be smart enough to stop transferring data to cloud to avoid unnecessary communication. This can lead to efficient resource and power utilization [10].
- Security and privacy: Encryption of data can provide confidentiality, integrity and authenticity. Encryption cannot provide security from spoofing and insider attacks.
- Energy efficiency: Data transfer among cloud computing and IOT devices require lot of power. Decoding is more power consuming as compared to encoding. This requires a permanent power supply [4]. Energy intensive tasks should be performed on cloud to gain energy efficiency [10].
- Resource allocation: Resource requirement of every sensor is different from other IOT sensors. It is difficult to guess type of resources required by IOT devices. This decision is dependent upon sensor type, purpose of IOT, frequency of data generation, and amount of data [4]. Sending a sample packet from the newly added node can also be useful [10].
- ID management: A lot of devices interconnect with each other. In-order to support full communication among devices and cloud, a unique id is required for every device [4]. Communication devices works on IPv-4. However, cloud works on IPV-6. Therefore, a standard is required so IPv4-IPv6 transition is smooth.
- Node discovery: All the nodes are inter-connected via cloud so it is compulsory to keep track of every node. New nodes are added to the system which requires node management [4].

- Quality of service: Cloud and IOT should ensure task duplication in order to maintain quality of service. Data duplication is required to ensure reliability and failure management. Bandwidth, service delay, jitter, and packet loss ratio are parameters to measure quality of service [10].

- Location of data storage: Time sensitive data should be stored in nodes that are near to user. The reason is latency can be major issue [4]. For time sensitive data, Fog computing is best option. Fog computing is a classical extension of cloud computing in which data is saved near the ground (user).

6. Conclusion

This paper reviews integration of cloud computing and IOT. Cloud computing compensates technological constraints of IOT that are storage and processing. Both open and closed source frameworks are present for cloud of things. Cloud of things has several applications in almost every domain of life like smart homes, smart metering, smart transportation, crowd management and logistics management, etc. Cloud of things provides many advantages like ease of access, unlimited storage capacity and complex computation etc. Cloud of things faces many issues like security, quality of service, data communication, node discovery and resource allocation etc. Cloud of things is a vast area and has future research scope.

References

[1]. Tiwari. V. K, Singh. V, "Study of Internet of things (IoT): a vision, architectural elements, and future directions," International Journal of Advanced Research in Computer Science 2016; 7(7).

[2]. Zhou. J, Leppanen. T, Harjula. E, Ylianttila. M, Ojala. T, Yu. C, Jin. H, Yang. L. T, "Cloudthings: A common architecture for integrating the internet of things with cloud computing", in IEEE 17th International Conference on Computer Supported Cooperative Work in Design (CSCWD), 2013; 651–657.

[3]. Botta. A, Donato. W. D, Persico. V, Pescapé. A, "On the integration of cloud computing and internet of things", in IEEE International Conference on Future Internet of Things and Cloud (FiCloud), 2014; 23–30.

[4]. Lakshmi. K. K, Girija. N. C, Persya. A. C, "Integration of Cloud Computing for IoT," International Journal of Emerging Research in Management &Technology, 2015; 4(5):371-375.

[5]. Petrolo. R, Loscrì. V, Mitton. N, "Towards a smart city based on cloud of things," In Proceedings of the 2014 ACM international workshop on Wireless and mobile technologies for smart cities, 2014; 62-64.

[6]. Caro. N. D, Colitti. W, Steenhaut. K, Mangino. G, Reali. G, "Comparison of two lightweight protocols for smartphone-based sensing," in IEEE 20th Symposium on Communications and Vehicular Technology in the Benelux (SCVT), 2013; 1–6.

[7]. Yang. C, Huang. Q, Li. Z, Liu. K, Hu. F, "Big Data and cloud computing: innovation opportunities and challenges," International Journal of Digital Earth 2017;10(1):13-53.

[8]. Asin. A, Gascon. D, "50 sensor applications for a smarter world," Libelium Comunicaciones Distribuidas, Technical Report 2012.

[9]. Manea. G, Popa. S, "Integration of Sensor Networks in Cloud Computing," University Politehnica Of Bucharest Scientific Bulletin Series C-Electrical Engineering And Computer Science 2016; 78(2):13-22.

[10]. Aazam. M, Khan. I, Alsaffar. A. A, Huh. EN, "Cloud of Things: Integrating Internet of Things and cloud computing and the issues involved," in IEEE 11th International Bhurban Conference on Applied Sciences and Technology (IBCAST), 2014; 414-419.