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A Review of Fog Computing in the Domain of IoT: Architecture and Challenges

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Abstract— ***Nowadays with the emergence of IoT applications, several challenges in terms of security, performance, latency and network failure have arisen in the domain of the integrated cloud computing (cc). The exponential growth of IoT applications creates a flood of sensor data which in turn introduces new challenges in data delivery and real time analysis/response. Fortunately, these issues can be addressed to a great extent with the advent of fog computing paradigm which actually brings CC closer to the edge of IoT. More specifically, Fog computing does the trick by storing and processing the IoT data locally in the fog nodes near the IoT devices instead of transmitting the raw data to the integrated CC. This facilitates Fog computing to deliver high quality services while diminishing the response time significantly which makes it an optimal option in delivering services to numerous IoT clients. In this paper, we present an in depth study of integration of Fog architecture with IoT and thoroughly investigate the challenges.***

Index Terms— ***Fog node, IoT, Cloud Computing, response time.***

I. INTRODUCTION

Fog computing [1] has emerged as an extension to Cloud Computing where the processing and storage has been brought closer to the end devices. Day by day the number of sensors is getting increased which in turn produces a large amount of data. Different cloud services like software as a service (SaaS), Platform as a service(PaaS) and Infrastructure as a Service (IaaS) are moving towards Everything as a Service (XaaS). But the traditional cloud computing platform cannot support if the number of devices becomes very large.

On the other hand, delay sensitive applications like video streaming, Augmented Reality etc. require less latency[2]. But, the traditional centralized cloud computing environment cannot reduce the amount of delay as everything needs to be uploaded to the cloud server for processing.[3,4]

Edge computing is another paradigm which supports small scale storage and processing at the end devices instead of sending the data directly to the cloud[5]. It can reduce the latency significantly thus supporting real time applications. However, the main issue comes when bulk amount of data needs to be processed in real time. In that scenario, edge devices become unable to process large scale data and cloud server needs to be communicated, thus the latency gets increased.

Unlike the traditional centralized Cloud Computing, Fog Computing works in a distributed manner and the fog nodes are installed with significant amount of storage and processing capability which can process big data and can respond to the end devices within the time bound[6,7].

This paper focuses on the current architecture of fog computing and integration of IoT with it. Some research challenges are also identified.

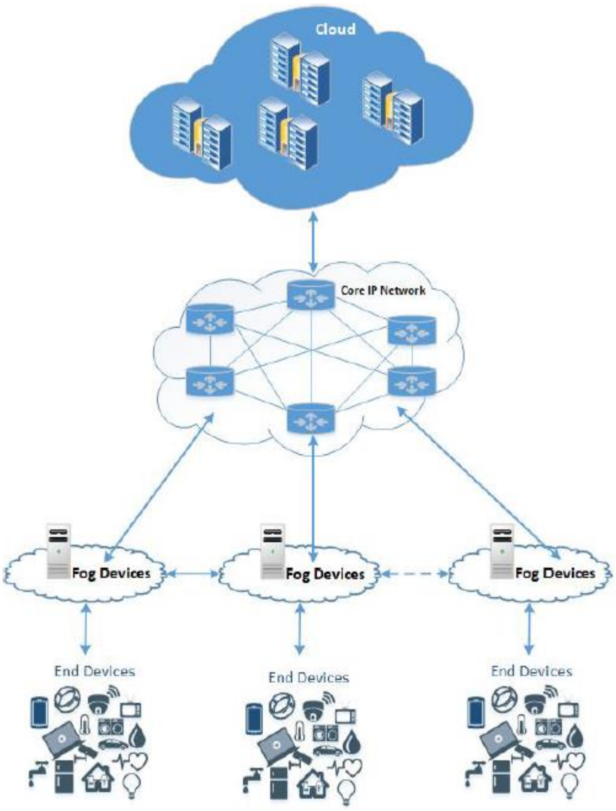

Fig 1: Fog computing brings CC nearer to the edge

II. FOG COMPUTING IN IOT

Fog computing paradigm introduces a virtualized environment which provides computing, storage and network services nearly at the edge of the network[8,9]. Fog nodes are basically edge routers, switches having preinstalled storage and processing power.

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Fig. 2: Overall statistics of connected devices

A. Features of fog computing

Fog computing paradigm introduces several features.

i. Low Latency / Real Time Response – With the increasing demand of short range IoT, several realtime applications are also introduced. In most of these cases the devices require near real-time response for content delivery and actionable information [5].

ii. Dynamic Number of Nodes -- Fig.2 shows the number of connected devices in billions and it is not hard to see that the number of short range and wide range IoT is increasing in an exponential manner. Due to its distributed environment, fog computing can support dynamic number of nodes[6].

iii. Highly Mobile Nodes – A large number of connected devices are wireless and Nodes will be entering and exiting the Fog and the Fog must adapt and continue to perform.

iv. Diverse Set of Failure Modes – Wide range of devices with varying levels of sophistication mean there will be many failure modes that need to be seamlessly handled.

v. Security – Fog computing paradigm controls the Access through a suitable algorithm.

vi. Interoperability- Since fog computing supports heterogeneous network, hence communication between diverse devices and fog nodes become extremely important.

vii. Saving of bandwidth: Most of small scale data processing and big data analytics are done in the fog nodes themselves. Therefore, the cloud server is offloaded significantly and the communication channels are also less utilized. As a result the bandwidth saving is achieved.

III. FOG COMPUTING ARCHITECTURE

Several researchers have proposed different architectures [10,11] for fog computing.

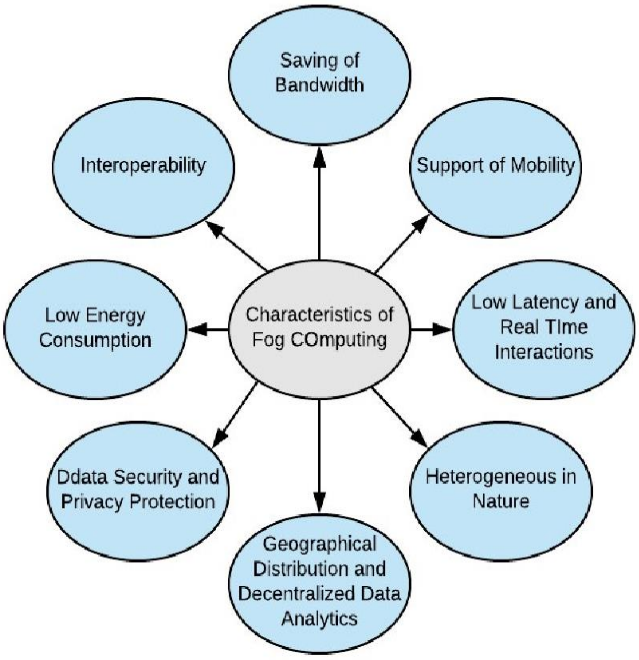

Fig.3: Fog computing characteristics

Basically the researchers have designed the architecture in view of the topologies keeping in mind the user scenarios and services. A layered architecture has been preferred in several researches like Aazam and Huh et al. [12,13], Mukherjee et al. [14], Ranesh et al. [15] and Muntjir et al. [16]. A layered architecture is presented in Fig. 4. The different layers are segregated on the basis of requirement, processing and application. The goalof this layered architecture is to provide the services together while maintain the advantages of modularity.

Layer 1: Physical- Different smart devices like smart vehicles, smart home etc. containing physical and virtual sensors produce data in this layer. After collection, this bulk amount of data is then sent to the upper layers for necessary processing.

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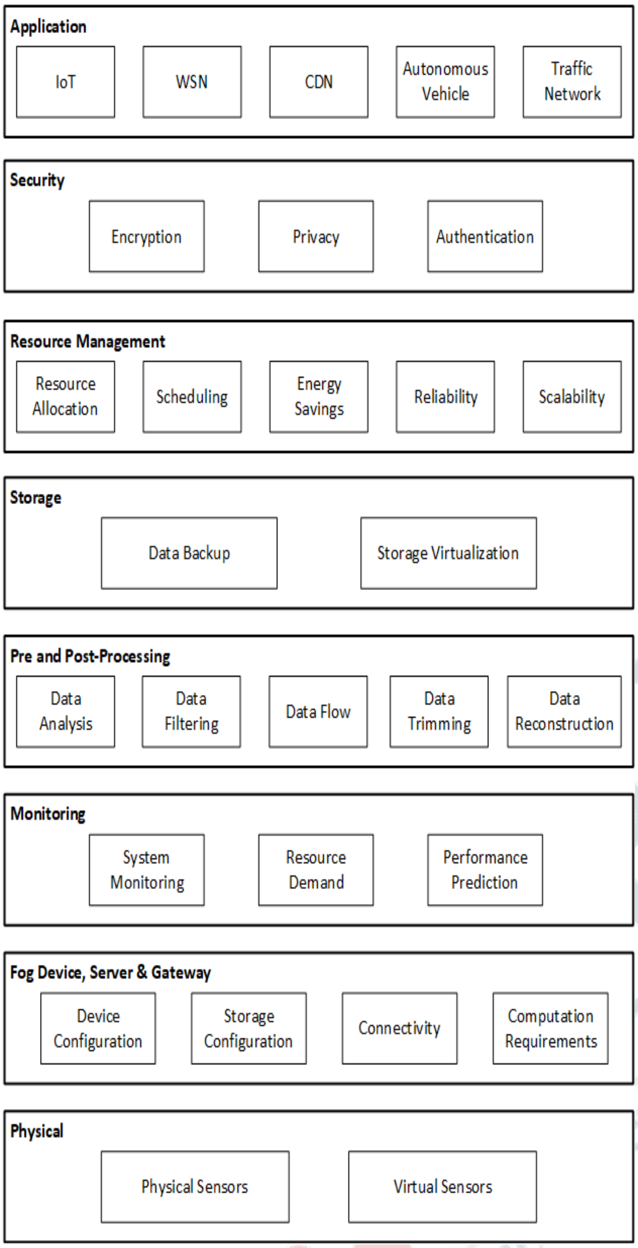

Fig. 4: Layered architecture of fog computing

Layer 2: Fog Devices, Server & Gateway- An independent IoT, device may be a fog server, gateway or a node. It is very important to note that the fog server must have a better configuration compared to any fog device or gateway. It is because; the fog server is the only node which can control the various fog devices and gateways under its control plane.

Layer 3: Monitoring- In this layer, the performance of different IoT nodes are being monitored and a track of the utility, feedback is also kept. Based on the availability of resources, different scenarios are created. These scenarios may exist in the devices as well as in the server side too. The prediction monitor can predict the health of the fog on the basis of the load and resources available.

Layer 4: Pre & post processing- The raw data received from the IoT and smart devices are analyzed in this layer. Since, the fog nodes are equipped with sufficient storage and processing abilities, they can perform Big data analytics to a large extent.

Layer 5: Storage and Resource management- The storage of the processed data is done by the storage module through storage virtualization. The component 'Data Backup' manages the availability of data. It is also responsible for any data loss. However, the storage virtualization comes with a high risk of data loss. Therefore, backing up of data periodically is an important aspect to avoid fog failure. The module name Data backup is responsible for keeping the data backup.

On the other hand, the resource management module performs several crucial tasks like Resource allocation and scheduling. It also takes care of some important parameters like energy savings, reliability and scalability, etc.

Layer 6: Security- This layer is responsible for overall management of security aspects like encryption of user data, protection of information storage. The encryption component looks after the encryption of different communications. The other components like privacy and authentication take care of the confidentiality, integrity and restriction of denial of service attack.

Layer 7: Application- Earlier, fog computing was introduced to support the IoT and Wireless Sensor Networks (WSN). But, gradually, the delay sensitive applications have also started to take the benefits from the fog due to its low latency feature.

IV. RESEARCH CHALLENGES

Fog computing paradigm works in distributed manner which introduces several challenges at the device, network and operational level. Some of the challenges are described below:

A. Challenges due to device heterogeneity

Since, fog computing involves heterogeneous devices, managing the interoperability between different devices stands as a prominent issue.

B. Challenges due to distributed approach

Unlike traditional cloud computing, fog computing follows the distributed approach for storage and offloading. So, there is chance of execution of the same code in different fog nodes within the same edge network.

C. Challenges at computational level

Different devices with varying service request connect to the fog at the same time. Some services are time bound requiring instant response from the fog server, so those services requires processing at the edge. Again, for the services which are not time bound, the fog server sends their data to the cloud for further processing. So, it's tremendously challenging to identify the mode of services in real time.

D. Challenges due to mobility

Few IoT applications like smart vehicle, smart transportation system etc. incorporates highly mobile nodes. So, to provide services to such applications, location awareness becomes an important aspect.

E. Challenges due to fog node failure

Due to the pure distributed nature of the fog computing environment, the chances of fog node failure also increases as these nodes are dispersed, and no central control mechanism is available. A fog node may fail due to user's mis- handling, hardware breakdown or software crash.

F. Challenges in security aspects

Since fog nodes manage, process and store data locally, so chances of attack is higher as compared to the centralized cloud datacenter.

V. CONCLUSION

Due to its low latency feature, the fog computing paradigm has become a growing area of interest for researchers. Though fog computing cannot replace the traditional Cloud computing (CC) but it can serve as an extension to the CC. Especially, the delay sensitive application can take the benefit in a significant manner. Moreover, combining IoT with fog has several advantages. This paper describes the architecture of fog computing in detail. Several research challenges are also identified.

REFERENCES

[1] Z. Wen, R. Yang, P. Garraghan, T. Lin, J. Xu, M. Rovatsos, Fog orchestration for internet of things services, IEEE Internet Comput. 21 (2017) 16–24.

[2] S. Yi, C. Li, Q. Li, A survey of fog computing: Concepts, applications and issues, in: Proc. Workshop Mobile Big Data, 2015, pp. 37-42.

[3] P. Hu, S. Dhelim, H. Ning, T. Qiu, Survey on fog computing:

[4] Architecture, key technologies, applications and open issues, J. Netw. Comput. Appl. 98 (2017) 27–42.

[5] P. Varshney, Y. Simmhan, Demystifying fog computing: Characterizing architectures, applications and abstractions, in: Proc. IEEE 1st Int. Conf. Fog Edge Comput. (ICFEC), 2017, pp. 115–124.

[6] R. Mahmud, R. Kotagiri, R. Buyya, Fog computing: A taxonomy, survey and future directions, in: Internet of Everything, Springer, Singapore, 2018, pp. 103–130.

[7] B. Varghese, N. Wang, S. Barbhuiya, P. Kilpatrick, D.S. Nikolopoulos, Challenges and opportunities in edge computing, in: Proceedings of the IEEE International Conference on Smart Cloud, 2016, pp. 20–26.

[8] G.I. Klas, Fog computing and mobile edge cloud gain momentum open fog consortium, ETSI MEC and cloudlets, 2015, Available at http://yucianga.info/?p=938.

[9] W. Shi, J. Cao, Q. Zhang, Y. Li, L. Xu, Edge computing: Vision and challenges, IEEE Internet Things J. 3 (5) (2016) 637–646.

[10] A. Ahmed, E. Ahmed, A survey on mobile edge computing, in: The Proceedings of the 10th IEEE International Conference on Intelligent Systems and Control (ISCO 2016), Coimbatore, India, 2016.

[11] E. Cau, M. Corici, P. Bellavista, L. Foschini, G. Carella, A. Edmonds, T.M. Bohnert, Efficient exploitation of mobile edge computing for virtualized 5g in epc architectures, in: 2016. 4th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering (MobileCloud), 2016, pp. 100–109.

[12] M. Aazam, E.N. Huh, Fog computing micro datacenter based dynamic resource estimation and pricing model for IoT, in: Proc. Int. Conf. Adv. Inf. Netw. Appl. AINA 2015, 2015, pp. 687–694.

[13] M. Aazam, E.N. Huh, Fog computing and smart gateway based communication for cloud of things, in: Proceedings of the 2014 International Conference on Future Internet of Things Cloud, FiCloud 2014, Barcelona, Spain, 27–29 August 2014, pp. 464–470.

[14] M. Mukherjee, L. Shu, D. Wang, Survey of fog computing: Fundamental, network applications, and research challenges, IEEE Commun. Surv. Tutor. PP (2018).

[15] R.K. Naha, S. Garg, D. Georgakopoulos, P.P. Jayaraman, L. Gao, Y. Xiang, R. Ranjan, Fog computing: Survey of trends, architectures, requirements, and research directions, IEEE Access 6 (2018), 47980–48009.

[16] M. Muntjir, M. Rahul, H.A. Alhumyani, An analysis of internet of things (IoT): Novel architectures, modern applications, security aspects and future scope with latest case studies, Int. J. Eng. Res. Technol. 6(2017) 422–447.