A Survey of the Evolution and Application of Mobile Edge Computing

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ABSTRACT— It is difficult to estimate the number of devices connected to the internet. Informed estimates range from 20billion to 50billion by the year 2020. The implication of this is that the sheer number of smart devices trying to communicate on the internet would render the model upon which the concept of Cloud Computing is built, ineffective. The proliferation of Real-time and other resource-intensive applications owing to the advent of Internet of Things and Big Data, as well as the constraints of mobile devices in terms of processing capability and battery life has made computational offloading necessary if Quality of Service and Quality of Experience are to be met. Offloading to Data Centers at the core of the network would reduce but not eliminate delays as latency would still be significantly high. Mobile Edge Computing is a technology that provides a solution to this problem by relocating computational power from the core of the network to the edge. This reduces the distance between mobile equipment and data centers because in most instances user equipment is just a hop away from datacenters. Hence reducing latency significantly and improving both QoS and QoE. This paper surveys the evolution of Mobile Edge Computing and looks at some application areas.

KEYWORDS—Mobile Edge Computing, Cloudlets, Cloud Computing, Fog Computing, IoT

INTRODUCTION

There are over two billion smartphones in the world today and the advent of the Internet of Things would see to the addition of many more billions of smart devices into the communication ecosystem. By some estimates smart devices would number up to 20 billion by the year 2020 [1]. The direct consequence of this proliferation of smart devices is the overstretching of mobile networks and the internet backbone itself. This becomes even more pertinent with Big Data and the computation intensive applications that handle such data because mobile devices have major limitations in terms of computational capacity, battery life, and storage space. Because of these constraints, smart devices make extensive use of the Cloud to offload computation-intensive tasks.

In spite of the apparent advantages of offloading onto the Cloud, there is an associated cost in terms of latency and Quality of Service. The time it takes for data to travel to the core of the network where Cloud servers are located and back is usually too long to make the execution of real-time applications feasible [2]. This forms the core of the argument for shifting computational power from the core of the network to the edge. Hence the birth of Edge Computing.

I. EVOLUTION OF MOBILE EDGE TECHNOLOGY

The widening gap between the demand for complex applications that require high computational capacity and huge storage space such as video processing, object recognition, or 3D navigation systems, and the availability of these resources in mobile devices have created a niche for Mobile Cloud Computing. Mobile Cloud Computing is a technology that is based on the idea of Offloading complex applications that demand huge resources (in terms of computation and storage) to Cloud servers that have an abundance of these resources.

Offloading, as argued by [3], is different from other similar computing architectures like Client/Server or Grid computing. In both Client/Server and Grid Computing process migration occurs typically within the same computing environment – the Grid for Grid computing and the Local Area Network for Client/Server. Computational Offloading on the other hand involves migrating programs to servers outside of the immediate computing environment.

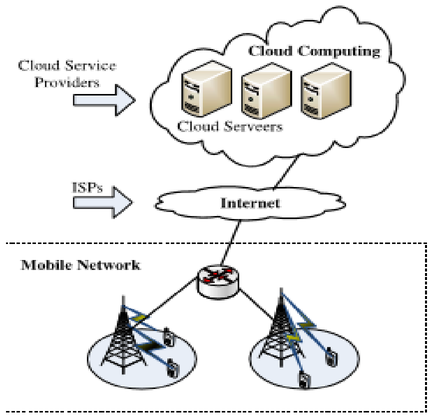

FIGURE 1. Architecture of mobile cloud computing.

The figure above shows the typical architecture of Mobile Cloud Computing. Mobile user equipment connectto the Mobile network via base stations and subsequently use the internet infrastructure to connect to Cloud Servers through Cloud Service Providers.

This architecture however has a lot of latency inherent in it. This is largely due to the fact that it is WAN dependent and delay and jitter are parameters that are difficult to control in WANs [4]. An early solution to the issue of latency in Mobile Cloud Computing is the concept of Cloudlets.

A. Cloudlets

Cloudlets are viewed as an implementation of Mobile Cloud Computing but conceptually they are more similar to Mobile Edge Computing (MEC). The difference being that in MEC servers are owned and managed by mobile infrastructure providers while Cloudlets are owned and managed by end-users. [5].

Cloudlets are perhaps the first step in the evolution towards Mobile Edge Computing. Basically, a Cloudlet is just a high capacity computer (or cluster of computers) that is deployed within the vicinity of mobile devices in order to provide computation and storage services to mobile user equipment [4]. The Cloudlet is usually a single hop away from User Equipment and resource demanding applications can be offloaded and results sent back at incredibly low latencies.

The design architecture of Cloudlets is such that mobile devices switch from mobile networks to WIFI in order to access the Cloudlet services [5].

The major improvement that Cloudlets brought over the concept of Mobile Cloud Computing is in the reduction of latency. Latency hurts usability by degrading the crispness of crispness of system response thereby making deeply immersive and computation intensive tasks jerky to the point of distraction [6].

A cloudlet typically has a 3-layered architecture; the component level, the node level and the cloudlet level [7]. They also classified Cloudlets as adhoc and elastic. With adhoc Cloudlets, nodes are discovered dynamically as opposed to elastic Cloudlets whose entire infrastructure is visualized using a virtual machine.

B. *Fog Computing*

In spite of the apparent advantages of MCC and Cloudlets, they still do not meet the needs of some mobile devices especially IoT. This is due to the fact that IoT applications usually require in addition to low latency, mobility support, geo-distribution, and location-awareness [8].

Fog computing is proposed to enable computing directly at the edge of the network, those devices that provide these services are called Fog nodes [8]. Unlike in Cloudlets, Fog nodes do not have to be resource rich [9] because conceptually, fog nodes are a huge number of heterogeneous (wireless and sometimes autonomous) ubiquitous and decentralised devices communicate and potentially cooperate among them and with the network to perform storage and processing tasks without the intervention of third parties [8].

C. *Mobile Edge Computing*

In the article “Challenges and Opportunities in Edge Computing” [10] explored the research space in Edge Computing. Interestingly they didn’t identify any difference between Edge Computing, Fog Computing, and Cloudlets. They identified them as terms used to describe the same phenomenon.

Their paper discussed the motivations, the opportunities, and the challenges in Edge Computing. Figure 2 summarizes their findings.

Basically, Mobile Edge Computing (MEC) is a computing paradigm in which the vast amounts of idle computation power and storage space distributed at network edges is harnessed in such a way that resource-constrained mobile devices can perform computation-intensive and latency-critical tasks [11].

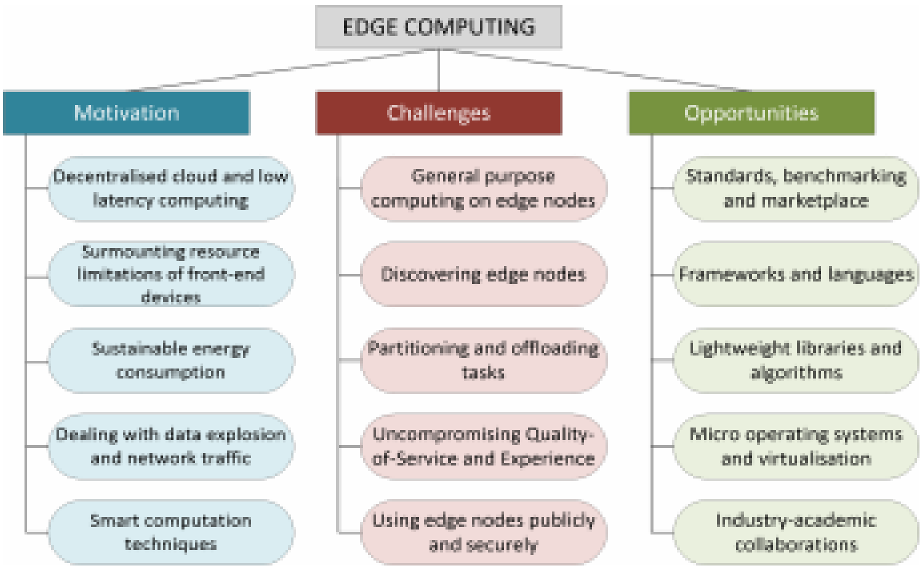

Fig. 2. Motivation, challenges and opportunities in edge computing

APPLICATIONS OF MOBILE EDGE COMPUTING

The proliferation of mobile devices and the exponential growth we are currently witnessing in the number of the active mobile devices that are being coopted into the communication ecosystem has seen to the unprecedented success of Cloud and Cloud-related services. Amazon and Dropbox readily come to mind [11].

Edge Computing is still at its very infancy yet a lot of research has been done to highlight some of its key areas of application.

When mobile networks supporting high data rates and low latency computation are deployed, new application areas emerge [12]. Augmented Reality which is an interaction paradigm that superimposes a computer-generated environment to a real-life environment, is one such application area.

Other areas highlighted by [12] are Intelligent Video Acceleration, connected cars, and Internet of Things.

Big Data analytics is also an application area of immense importance. A significant proportion of the devices that make up the Internet of Things are video cameras or camera-enabled sensors [13]. Analytics of the massive video content being generated at the Edge of networks is an area with a lot of applications in smart cities, surveillance, and in fighting crime.

RESEARCH AREAS

As with any emerging field, Standardization and Benchmarking is needed in order for the technology to become established and ultimately become ubiquitous as is the target with Mobile Edge Computing.

Currently, organizations such as National Institutes of Standards and Technology (NIST), IEEE Standards Association, International Standards Organisation (ISO), Cloud Standards Customer Council (CSCC) and the International Telecommunication Union (ITU) are actively engaged in research about standards and benchmarking [10].

Another area of research is in software mechanisms and algorithms needed for the collective control and sharing of cloudlets and in computational offloading [14].

The work of [11] categorizes the research areas in Mobile Edge Computing into five as depicted in figure 3.

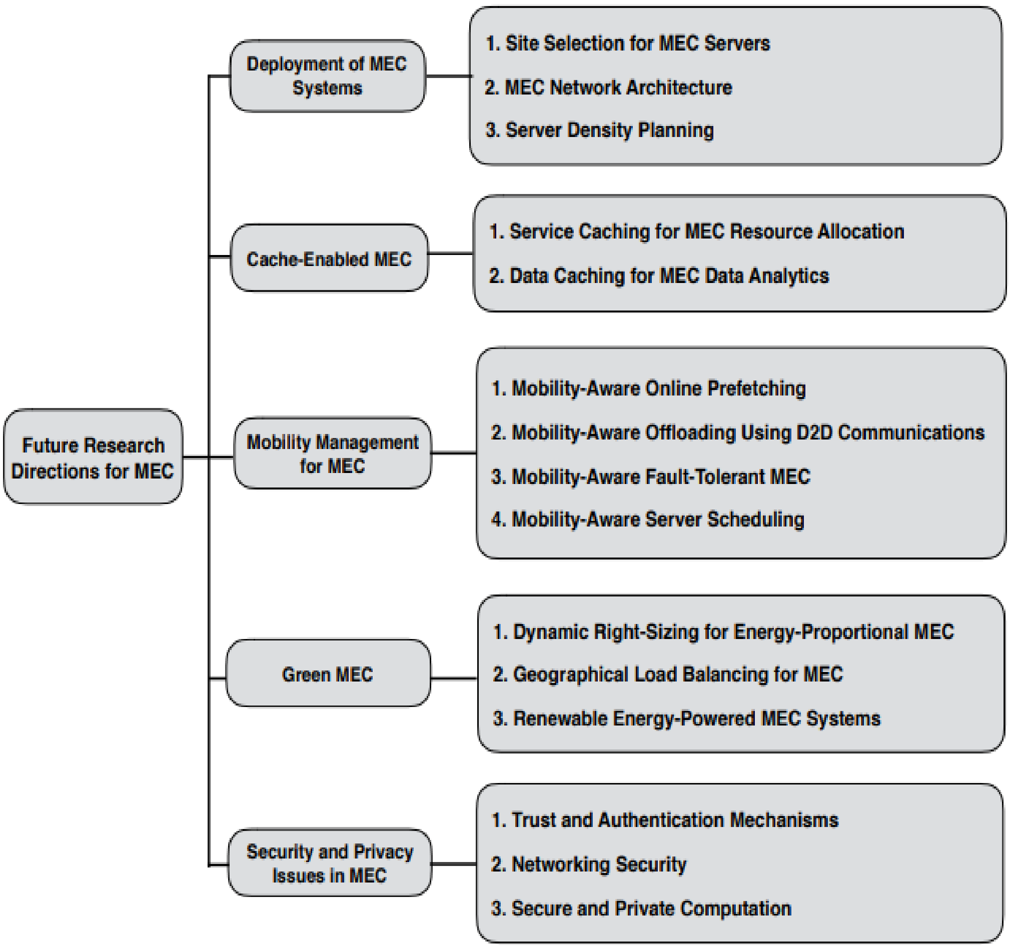

Figure 3: Research Areas in Mobile Edge Computing

CONCLUSION

The speed with which the sizes of data sets are growing and the accompanying high computation capacities required to process these big data sets is not matched by advances in speeds of processors of mobile devices and battery life. Mobile Edge Computing bridges that gap. Smart phones have made the dream of ubiquitous computing a reality and the Internet of Things would further entrench this reality in the years to come. Mobile Edge Computing is the glue that holds all of that together. The field is at its infancy but already has numerous areas of application. Its numerous active research areas would only just further widen this area of application.

REFERENCES

[1] Gubbi, J., Buyya, R., Marusi, S., & Palaniswami, M. (2013). Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. *Future Generation Computer Systems, 29(7),* 1645-1660.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Pavel, M., & Zdenic, B. (2017). Mobile Edge Computing: A Survey on Architecture and Computation Offloading. *arXiv preprint arXiv:1702.05309*.

[3] Kumar, K., Liu, J., Lu, Y.-H., & Bhargava, B. (2012). A Survey of Computation Offloading for Mobile Systems.

[4] Pavel, M., & Zdenic, B. (2017). Mobile Edge Computing: A Survey on Architecture and Computation Offloading. *arXiv preprint arXiv:1702.05309*.

[5] Beck, M. T., Werner, M., Feld, S., & Schimper , T. (2014). MobileEdgeComputing: A Taxonomy. *The Sixth International Conference on Advances in Future Internet.* Munich.

[6] Satyanarayanan, M., Bahl, P., Caceres, R., & Davies, N. (2009). The Case for VM-based Cloudlets in Mobile Computing. *IEEE Pervasive Computing*.

[7] Verbelen, T., Simoens, P., De Turck, F., & Dhoedt, B. (2012). Cloudlets: Bringing the cloud to the mobile user. *Verbelen, Tim, et al. "Cloudlets: Bringing the clouProceedings of the third ACM workshop on Mobile cloud computing and services.* (pp. 29-36). ACM.

[8] Yi, S., Li, C., & Li, Q. (2015). A Survey of Fog Computing: Concepts, Applications, and Issues. *Proceedings of the 2015 workshop on mobile big data* (pp. 37-42). ACM.

[9] Willis, D., Arkodeb, D., & Suman, B. (2014). ParaDrop: a multi-tenant platform to dynamically install third party services on wireless gateways. *Proceedings of the 9th ACM workshop on Mobility in the evolving internet architecture* (pp. 43-48). ACM.

[10] Varghese, B., Wang, N., Barbhuiya, S., Kilpatrick, P., & Nikolopoulos, D. (2016). Challenges and Opportunities in Edge Computing. *arXiv preprint arXiv:1609.01967*.

[11] Mao, Y., You, C., Zhang, J., Huang, K., & Letaief, K. (2017). *A Survey on Mobile Edge Computing: The Communication Perspective.* IEEE.

[12] Hu, Y. C., Patel, M., Sabella, D., Sprecher, N., & Young, V. (2015). *Mobile Edge Computing A key technology towards 5G.* Sophia Antipolis: European Telecommunications Standards Institute.

[13] Satyanarayanan, M., Simoens, P., Xiao, Y., Pillai, P., Chen, Z., Ha, K., . . . Amos, B. (2015). Edge Analytics in the Internet of Things. *IEEE Pervasive Computing*, 24-31.

Satyanarayanan, M. (2017). *The Emergence of Edge Computing.* IEEE Computer Society.