**Fog computing for saving energy**

Master of Science (Computer Science)

COMP90044 - Research Methods Assignment C

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**revision statement**

* Specific feedback
* Removed low-quality sources (Online sources like Wikipedia)
* Restructured section 2 – add a brief at the beginning of section 2 to make paragraphs in section2 are at the same level; list future studies after the conclusion part.
* Format problems are fixed – indent problems
* General feedback
* Rewrite the Introduction part – easier for non-specialist to read.
* Conclude and listed the specific areas of future works.
* Double-checked grammar mistakes.
* Didn’t make changes for the fourth feedback since I didn’t produce too many technical details.

1. **Introduction**

In recent years, the development of cloud computing can be described as turbulent. Most of the companies are using cloud-based services for processing user data, such as Google, Amazon, IBM and Microsoft etc. Compared to centralized data centers, cloud computing distributes the data and the computing to a large number of distributed computers (Mahmud, Kotagiri and Buyya, 2017).

However, in 2012, the number of Internet of Things (IoT) devices has increased remarkably. The increase of data stream leads to the demand for fast computing and low latency. In order to solve this problem, a new paradigm called Fog Computing came into being. Typically, Fog computing is an extension of Cloud Computing in data storage, computing and network facilities and it resides closer to IoT devices/sensors. Mobile phones using the 5G technique combined with fog computing can download a blue ray video in seconds and actualize direct device-to-device wireless communication theoretically. That being said, fog computing can improve the network performance in spectrum and energy efficiency (Kitanov & Janevski 2017).

Cloud Computing is more likely focusing on providing resources in core networks. In contrast, Fog Computing provide resources in the distributed edge networks which is closer to the user level (Amendola, Cordeschi & Baccarelli, pp.21-26). This article mainly analyzes how fog computing can save energy.

This paper is structured as follows. Section 2 reviews the works of literature of fog computing. Section 3 summarizes the conclusions of this work. Finally, Section 4 lists some remaining problems and future studies in fogging.

1. **Literature Review**

In this chapter, section 2.1 introduces what is fog computing, section 2.2 lists the methodology writers use and how to improve energy utilization in Fog Computing. Section 2.3 illustrates applications using fog computing which can be improved for saving energy.

* 1. **Introduction to fog computing**

As the development of Internet of Things (IoT) and mobile Internet (e.g. 5G) became rapid, people are increasingly relying on cloud computing. The increasing number of networking devices, intelligent devices and mobile applications become the main way for people to deal with transactions on the internet. The amount of data and the number of data nodes increase with accompanying, therefore, a large number of network bandwidth will be occupied, thus increasing the burden of data centers and the load of data transmission.

Fog computing can be understood as a distributed cloud computing which is nearer to the end of users. In order to minimize the expenses of communication traffic in data centers, fog computing concentrates data, data processing and application on devices at the edge of the network, complements cloud computing by computing from remote data centers to edge devices and distributing network resources (Baccarelli et al. 2017, pp.9882-9910). Unlike cloud computing, fog computing is a distributed model that lies between the cloud computing and personal computing. Since fog computing emphasizes the number of nodes instead of the quality, it computes data with every possible device no matter how weak the single device is.

With the combination of distributed fog computing, techniques such as intelligent routers can form up a data transmission belt between different devices to reduce network traffic while the computing load of data centers is also decreased.

Moreover, fog computing has other attributes such as programmability, scalability, security and real-time features (Baccarelli et al. 2017, pp.9882-9910) that cloud computing doesn’t have or existing defects. With the assistance of distributed fog nodes, data are separated in a large range of distributed servers, so that hackers wouldn’t be able to hack a specific server meanwhile data won’t be lost if the operator had a mistake in coding, for example, Amazon S3 service disruption on 28th February 2018.

* 1. **Energy utilization in fog computing**

By using fog nodes and edge computing, energy costs in signaling overhead can be reduced. For example, authors in the paper (Baccarelli et al. 2017, pp.9882-9910) took 5G technique as an example and explained that the main energy consumption in 5G technique is the energy for signals transferring from densely network edge base station to the base station. Unlike cloud computing, data, data processing and applications are concentrated in devices at the edge of the network, data storage and processing rely more on local devices. These features make mobile devices more convenient and satisfy wider node access.

The ideal capacity of 5G is 1000 times that of 4G and the speed is also faster. That means if we want to increase the capacity and speed at the same time, we need to increase the bandwidth, the spectrum efficiency and the area capacity. First comes to the bandwidth, the high-frequency band is richer in frequency resources. At present, the low-frequency band which is less than 3GHz is basically occupied by 2G/3G/4G, so 5G has to be extended to the high-frequency band of 3.5GHz-30GHz (or even higher). However, the higher the frequency, the stronger the reflectivity leads to the lower penetration ability and the coverage. So, we need a large number of distributed fog nodes to support the requirement.

Another conception proposed by the author in the paper (Baccarelli et al. 2017, pp.9882-9910) is Smart Grid. The Smart Grid model incudes irregular dispersed “consumers” and “producers”. Wireless sensors in buildings that need electricity such as smart homes and intelligent buildings are the consumers. Devices that can produce electrical energy such as wind farm, solar plant and central power plant are the producers. These devices require to support device-to-device communication through Wi-Fi, Bluetooth or other methods. As soon as the energy-producing plant produced electrical energy, the fog layer computes the raw data and manages the energy flow in real-time, in order to ensure power-need devices can get enough electricity from the nearest producer while the producers near low-demand consumers can have a rest. By reducing the energy-loss during energy transmission can improve energy-efficient. (Baccarelli et al. 2017, pp.9882-9910)

Author in the paper (Jalali et al. 2106, pp. 1728-1739) used tiny and distributed computers located in the end-user premises such as Raspberry Pi which been called as nano data centers. Experiments have been made to compare the power consumption rate and the file size downloading from a data center (DC) and from a nano data center (nDC). The results have shown that exchanged bytes during downloading files from a DC are greater than that of a nDC, and the energy consumption of uploading files to a nDC is much smaller than to a DC. More data shows that the best way to save energy is to use distributed small devices that are not frequently accessed, such as video surveillance in users’ house. (Jalali et al. 2016, pp. 1728-1739).

* 1. **Application with fog computing**

Most of the applications using fog computing are aiming to improve the performance of cloud computing. Add sensors and fogging for traffic lights is a good method for managing city traffic. Fog nodes are close to the end of users, transmission between fog layer and internet backbone need less energy. Users can get the data they need from the fog node instead of requesting from the cloud server every time in order to reduce the network transmission overhead, so energy utilization can be improved by putting the computing on the network layer instead of cloud servers. At the same time, the delay between communications can be reduced. Thus, sensors on traffic lights can meet the requirement of low latency below a few tens of milliseconds (Baccarelli et al. 2017, pp.9882-9910), as well as saving energy. It may prevent many severe traffic accidents by adding fog computing. Similar applications are listed as follows. Video surveillance system at the corner of every street can improve police enforcement efficiency. Using a small unmanned aerial vehicle (UAV) to deliver goods etc. These kinds of computing need to be computed at the edge of the fog layer near to the user end, so the low-latency fog computing is also called as “edge computing” (Amendola, Cordeschi & Baccarelli, pp.21-26).

1. **Conclusion**

We have outlined the model of fog computing and the applications with a combine of fogging and cloud computing. All the experiment data and results test by previous researchers are in multiple attempts and simulation. It is clear that by adding a fog layer between the cloud nodes and the end-users can reduce the energy consumption during data transmission. Fog nodes at the edge of the fog layer can compute data and share it between IoT devices, in order to allocate energy resources evenly by figuring out the energy demand of users.

1. **Future studies**

Nowadays, Amazon Web Service Elastic Compute Cloud (EC2) and Simple Storage Service (S3), one of the most popular and advanced cloud server and storage service in the world, do not supply energy-efficient resource or models (Beloglazov, Buyya & Abawajy 2011, pp. 1397-1420). Future studies can focus on how to build a middleware fogging platform based on the remote cloud servers to save data transmission energy resources.

Furthermore, equipping heterogeneous wireless interface cards on IoE devices and then design a platform using the inter-networking of local computing devices (can be a mobile phone, a smart vehicle or any wearable devices), proximate computing entities (e.g. distributed fog nodes) and remote (cloud) servers to allocate all kinds of resources is another considerable issue (Baccarelli et al. 2017, pp.9882-9910).

**References**

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