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Fog Computing Quality of Experience: Review and Open Challenges

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ABSTRACT

Since its inception in 2012, fog computing has played a dominant role in addressing the quality of service (QoS). However, with the emergence of the internet of things and artificial intelligence technologies, which create a "smart world" where everything is automated, offering quality of service alone is no longer sufficient as it does not offer a satisfactory user experience. Quality of experience (QoE), which satisfies user experience and improves user performance, becomes vital and fog computing remains a key technology. To understand QoE, there was a need to distinguish it from QoS based on stance, scope, perspective, focus, and methods. A systematic literature review was done looking at works that use fog computing to maintain or improve QoE with the focus being on problems being addressed in a paper and how the results contributed to improving QoE. Critical analysis of the review showed that even though strides have been made to improve QoE, open research challenges still exist that require intervention to improve or maintain acceptable QoE in fog computing to satisfy user needs.

KEYWORDS

Fog Computing, Quality of Experience (QoE), Quality of Service (QoS), User Experience

INTRODUCTION

With the dawn of the Internet of Things (IoT) technology made up of distributed sensors and intelligent terminals that generate much data that traverse the internet to the cloud where it should be saved, several challenges have also risen (Laghari et al., 2021). These challenges include but are not limited to high latency, congestion of network, loss of reliability, poor Quality of Service (QoS) and Quality of Experience (QoE), among other challenges (Michaela et al., 2018). The challenges mentioned above are caused by the geographical distance between cloud computing servers and IoT devices. Fog computing was introduced to bridge the geo-graphical distance and address some of the aforementioned challenges (Michaela et al., 2018) . Ever since fog computing inception by Cisco in 2012, much research has been done in academics and industries. Fog computing has been implemented in different platforms and application areas such as smart homes, smart grids, smart vehicles, and

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health data management (Laghari et al., 2021) . Moreover, the survey findings by Laghari et al., (2021), Babu et al., (2018) and Vambe et al., (2019) showed that fog computing provides improved QoS in different application areas where it was implemented.

However, due to the ever increase of IoT devices' use, users' need to get a guaranteed user experience. Quality of Service alone is no longer good enough to meet end-user requirements. As such, there is a need to improve fog computing to offer improved QoE since end-users are the ones who are supposed to benefit much from IoT devices. Quality of Experience is not only good for end-users, but network operators can also benefit if and only if they can have the ability to measure it (Nobre, 2018). Network operators' ability to measure QoE will contribute to the overall user's satisfaction regarding reliability, availability, scalability, speed, accuracy, and efficiency (Dr. Jens Berger, 2019)(Krasula et al., 2020). Many networks and other researchers now focus on improving QoE in fog computing to ensure that the user's needs are satisfied with minimum network resources. Thus, guaranteeing QoE to end-users. Therefore, this survey paper seeks to establish the following:

1. What are the similarities and or differences between QoS and QoE in general?
2. What are the QoE application areas, factors, measurements and management techniques?
3. How fog computing has been used to improve QoE in existing systems/applications?
4. What has been done to maintain and improve QoE in fog computing?
5. What are the open research gaps that need attention in fog computing to maintain and or improve QoE?

This paper starts by highlighting the methodology adopted in section 2. Section 3 gives a clear distinction and or similarities, if any, between QoS and QoE to understand QoE. Moreover, a synopsis of QoE application areas and factors are discussed. Followed by a brief discussion of QoE measurements and management techniques, respectively. Section 4 will give an in-depth systematic scrutiny of literature, looking specifically at works whose motive was to improve QoE in fog computing. Open research challenges are pinpointed and discussed in section 5. These open research gaps will act as future research areas in fog computing that need to be addressed to guarantee satisfactory QoE for users. In section 6, the summary of the whole paper is then given as a conclusion.

METHODOLOGY

Systematic literature review methodology (Cruz-Benito, 2016),(Tikito and Souissi, 2019) was adopted for this work to establish how fog computing was used to bring about improved QoE in existing systems by collecting and critically analyzing multiple fog computing research articles through a systematic process. Moreover, we looked at work that showed progress to further maintain or improve QoE in fog computing. Briefly, we searched Scopus with the search key term *"quality of experience (QoE)"* in combination with *"fog computing"; "edge computing"*. All the article titles and abstracts that were mostly from 2012 to 2022 (within 10-year range) and relevant were reviewed. Specifically, articles which had solutions clearly tested either in a simulated environment, experimental or real-world setup with clear development protocol with the intention to maintain or improve QoE in fog computing were considered and reviewed in full.

The reason for choosing works within the 10-year range is because, fog computing was officially implemented in 2012. Moreover, a lot would have changed in the field of technology if we looked for works that is more than 10 years, which makes it irrelevant to consider such works.

We excluded all articles that were not fully tested but being proposals and those that were older than 10 years.

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