Faculty of Electrical and Electronic Engineering Technology

FOG-BASED NETWORK DESIGN WITH LOW-LATENCY FOR SMART CITY

SITI HAJAR BINTI ARBAAIN

Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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A project report submitted
in partial fulfilment of the requirements for the degree of
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I declare that this project report entitled "Fog-Based Network with Low-latency for Smart City" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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DEDICATION

I dedicate this to my beloved parents, my father Mr Arbaain bin Bakar, and my beloved mother, Mrs Maryam binti Haji Mat Latir @ Lajim for fully supporting me to finish my final year project. A special appreciation to my supervisor, Ts Dr. Ida Syafiza binti Md Isa for all the knowledge and for always giving her full effort in guiding me patiently throughout this project was done. A big honoured to be under her supervision.

ABSTRACT

A smart city is defined as a platform for using information and communication technologies to improve the quality of urban life while consuming fewer resources at a lower cost. Cloud technology is attractive because it provides infinite storage and computing capacity, flexibility, and benefits from a cost-efficiency model. Since cloud computing deals with many applications that are time-sensitive has burdened the cloud servers to process the services due to high latencies. Therefore, this work proposed fog computing at the access layer to overcome the latency issue. Also, in this work, a Mixed Integer Linear Programming (MILP) model has been developed to optimize number and locations of fog servers to process data from the IoT devices, so that the latency is reduce for smart city application. Twelve Malacca City's tourist attractions spots have been selected as the candidate locations to install the fog servers. The result shows that by increasing the processing capacity of fog server can reduce the number of utilize fog server, besides minimizing the latency. Also, the results shows that high processing demand from user also increase the number of utilize fog at latency.

ABSTRAK

Bandar pintar ditakrifkan sebagai sebuah platform untuk menggunakan teknologi maklumat dan komunikasi untuk meningkatkan kualiti kehidupan bandar sambil menggunakan sumber kos yang lebih rendah. *Cloud* teknologi menarik kerana ia menyediakan tempat penyimpanan dan kapasiti pengkomputeran yang tidak terhingga, fleksibiliti dan faedah daripada kecekapan kos model. Memandangkan *Cloud computing* berurusan dengan banyak aplikasi yang sangat sensitif terhadap masa telah membebankan *Cloud server* untuk memproses perkhidmatan disebabkan kependaman yang tinggi. Oleh itu, kerja ini telah mencadangkan *fog computing* pada lapisan akses untuk mengatasi masalah kependaman. Selain itu, dalam kerja ini, model *Mixed-Integer Linear Programming (MILP)* telah dibangunkan untuk mengoptimumkan bilangan lokasi *fog server* untuk memproses data daripada daripada peranti IoT, supaya isu kependaman dapat dikurangkan bagi aplikasi bandar pintar. Dua belas tempat tarikan pelancong di Bandaraya Melaka telah dipilih sebagai calon lokasi untuk pemasangan *fog server*. Hasil menunjukkan bahawa dengan meningkatan kapasiti pemprosesan *fog server* dapat mengurangkan bilangan penggunaan *fog server*, serta dapat meminimumkan kependaman. Selain itu, keputusan menunjukkan bahawa permintaan pemprosesan yang tinggi daripada pengguna juga dapat meningkatkan bilangan penggunaan kependaman *fog sever*.

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LIST OF SYMBOLS

Σ	-	Sum of (total)
$\forall$	-	For each of
$\in$	-	Refer to
$\neq$	-	Not equal to
α	-	10^8
β	-	Multiply with 100
$\geq$	-	More than or equal to
$\leq$	-	Less than or equal to
μs	-	Microsecond

LIST OF ABBREVIATIONS

MILP	-	Mixed-Integer Linear Programming
AMPL	-	A Mathematical Programming Language
IoT	-	Internet of Things
QoS	-	Quality of Service
GA	-	Genetic Algorithm
VM	-	Virtual Machines
DAOWA	-	Delay-Aware online Workload Allocation and Scheduling
TSD	-	Task Service Delay
VANET	-	Ad-Hox Network
MEC	-	Multi-Access Edge Computing
ITS	-	Intelligent Transportation System
EEFC	-	Energy-Efficient Fog Computing
PS	-	Processing Servers

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CHAPTER 1

INTRODUCTION

1.1 Background

Smart cities help to improve the quality of life of people while maximizing the efficiency of city operations. Cloud technology is attractive because it provides ubiquity, infinite storage and computing capacity, flexibility, and benefits from a cost efficiency model. These characteristics combine to make cloud technology a desirable technology [1]. The cloud services are often used to store and analyze data including servers, databases, networking, and software for applications such as smart city services. However, since cloud computing deals with many applications including healthcare applications that are very time sensitive has burdened the cloud servers to process the services due to high latencies. Therefore, fog computing has been proposed by Cisco [2] to overcome the shortcoming of the cloud computing.

Fog computing was proposed by extending the cloud to the network edge. Fog computing becomes popular to serve applications related to such as Things (IoT) such as smart cities [3]. Fog computing is used to overcome the latency issues that arise with cloud computing. This is because, fog is located near to the users, hence reducing the delay in processing the traffic from the users. In addition, the distributed network architecture of fog computing, compared to a centralized computing paradigm plays a significant role to minimize the information processing and sharing latencies in real-time [4]. This is because the central server will not be overworked, hence cuttings down the processing time while increasing its efficiency.

In this work, a Mixed Integer Linear Programming (MILP) model will be developed to minimize the latency issues in the communication approaches considering the smart cities' application. The model will be used to optimize the number and location of fog servers at the access layer to serve the IoT's applications.

1.2 Problem Statement

The cloud provides a large number of resources as a service, but it has limitations of inconsistent latency, mobility, and location awareness [3]. In cloud computing, the central server handles all of the processing of the data acquired by the node. Hence, there have been several negative effects such as high latencies, network overloading, increased failure risks, and increased security concerns when moving all data and services to the cloud, which is likely to be far from both user and the sensors [1]. This takes a long time because data must be sent from the node to the central server before the server can process the data.

Furthermore, with a significant number of physical devices connected wirelessly, the problem will only get worse as the Internet of Things expands. Generally, cloud services are utilized to process the data but low latency, bandwidth reduction, mobility of IoT devices, and availability needs of IoT applications pose a big challenge to the cloud.

In addition, the work in [5] is concerned with reducing the amount of energy used by the cloud. They implement the MILP model to analyze the impact of various variables, including the popularity of VMs and the traffic between the VM and its users. For instance, this work found that offloading applications to the fog layer can significantly reduce power consumption by 41%.

Most authors are more concerned about energy consumption and Quality of Service (QoS) but there is less work concerned with the latency issues, which is quite significant in smart cities. To deal with such problems, this study intends to focus on minimizing the latency for the communication approaches in smart cities by developing fog computing. Fog computing brings processing, storage, and analysis of data closer to the Internet of Things and end-users, hence reducing latency. Therefore, we develop a system to optimize the number and location of fog servers in the network of smart city applications using Mixed-Integer Linear Programming (MILP) model.

1.3 Project Objective

The aim of this project is to propose a low-latency fog-based network design for smart city applications. Specifically, the objectives of this work are as follows:

1. To develop a mathematical model utilizing a Mixed-Integer Linear Programming (MILP) while minimizing the latency in the network for smart city applications.
2. To evaluate the performance of the proposed fog architecture model in terms of its latency.
3. To evaluate the performance of the proposed fog architecture in terms of latency considering the different processing capacities of the fog server.

1.4 Scope of Project

The scope of the project is defined as follows:

a) A mathematical model will be developed using a Mathematical Programming Language (AMPL) software to optimize the number and location of the fog servers in the network.

b) 12 locations of the famous tourist hotspot in Melaka will be considered in this work to be the candidate location to place fog servers.

c) Wi-Fi will be used as the access point in this work to serve the users.

d) Each Wi-Fi access point will have a coverage of 0.3 km. therefore, the users located within the radius of 0.3 km from the Wi-Fi can be served by the Wi-Fi.

e) The location of fog server is only intended at the access point layer.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the research work that related to this project are presented and discussed. A short description and an overview of related literature are also provided. A few research have concentrated on the design of the MILP model with fog computing for latency and energy efficiency.

2.2 Internet of Things (IoT)

Internet of Things (IoT) is the concept of connecting any devices to the internet to other devices. All devices in the network interact with each other to collect and share data. There is a device that collects data from its surroundings using sensors and actuators and sends this collected data to the internet where the processing of the data can happen. IoT allows an object to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration between the physical world and computer-based system and resulting in improved efficiency, accuracy, and economic benefit. For instance, laptops, phones, watches, washing machines, cars and even the house are one of the devices.

In [6], the concept that be used is IoT as the important key to securing smart city environment. This work proposed a feasible solution for mitigations due to attacks experienced. A smart city is defined as a platform for using information and communication technologies to improve the quality of urban life while consuming fewer resources at the lowest cost. The following parameter can be implemented in the city utility, networking, infrastructure, and sustainable energy.

Authors in [7], proposed collaboration of IoT-fog-cloud system workload allocation strategy to minimizing task service delays (TSD), with the goal of achieving the quality of service (QoS) needs of as many delay-sensitive IoT applications as implementable. This paper developed a new method of allocating work based on the consideration of latency, named delay-aware online workload allocation and scheduling (DAOWA). According to the theoretical analysis and simulation findings, the DAOWA algorithm is capable of reducing the TSD effectively.

In health care monitoring, it is important to have a very efficient monitoring system, especially in the Intensive Care Unit (ICU). The work in [8] observation of a recent study, it's estimated that by 2025, investments in healthcare-based IoT solutions will reach one trillion dollars. This will be accomplished by providing highly customized, easily accessible, and effective healthcare services to all individuals. In [9] proposed an ICU patient monitoring system based on IoT to monitor patients' records and conditions that can be utilized by doctors and hospitals. It was also able to help doctors and hospitals in making prompt choices. They develop a system using IoT devices that gather data from the patient body and communicate it to fog nodes in the hospital. After that, it will analyze the information. Lastly, the report will be uploaded to the cloud in order to be stored there. The finding, the system will let the doctor and ECU staff alert if any abnormalities are noticed.

2.3 Cloud Computing

Cloud technology is attractive because it provides ubiquity, infinite storage and computing capacity, flexibility, and benefits from a cost efficiency model. These characteristics combine to make cloud technology a desirable technology [1]. Cloud computing includes data storage, servers, databases, networking, and software applications. Moreover, cloud computing can also store files on a proprietary hard drive or local storage device; cloud-based storage enables storage in a remote database [10].

The researcher in [1], there have been several negative effects such as high latencies, network overloading, increased failure risks and increased security concerns when moving all data and services to the cloud, which is likely to be far from both user and the sensors. Based on this problem, using fog computing offers a virtualized environment that utilizes resources at the network's edge and is able to bring computing resources closer to end-users. Hence, the computing capacity of fog computing is significantly lower than cloud computing. Also, fog computing enables low delays, the reduction of load at the core network, facilitation of green computing and an improvement in security. To sum it up, fog computing is a better option than cloud computing since it is more appropriate.

Furthermore, authors [11] gives a clear example of the cloud. Transporting data to the cloud, there uses a lot of network resources and causes a lot of traffic, which results in significant delays. Even more importantly, for example, the data gathered by security cameras is very confidential. Using the Internet to transfer them to the cloud raises privacy concerns.

This shows that to solve these issues, an ecosystem for fog computing has been designed and many use cases have been evaluated on it.

2.4 Fog Computing Architecture

This subtopic is to discuss fog computing architecture. The term "fog computing" refers to an extension of cloud computing that incorporates resources located in the cloud and at the edge of the network. It is motivated by the need to fulfil the criteria of Internet of Things applications, which include providing support for mobile devices, location awareness and minimizing latency.

The work in [12], this paper proposed a fog computing service placement for smart cities based on genetic algorithms. This paper aims to provide a formal model for the issue of minimizing the total latency experienced in the system while considering the amount of time essential for data transfer and processing. They evaluate the proposal on a geographic testbed representing the realistic scenario of a Fog architecture located in a small-sized city in Emilia Romagna (Italy).

In [3], the authors conducted a review that focused on IoT-Fog designs proposed by many researchers with the main focus on the minimizing of delay and the management of resources. When contrasted with the cloud, network latency is minimized considerably. The information may be pre-handled on the Fog layer, consequently reducing the data transfer capacity demand and latency and energy consumption. The architecture of Fog computing consists of three layers: the end devices layer, the middle fog layer and the top cloud layer, as shown in Figure 1, which explains the function of each layer. Various architectures have been proposed for